WBGU

German Advisory Council on Global Change

Flagship Report

Towards Our Common Digital Future

WBGU

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- monitors and assesses national and international policies for sustainable development,
- elaborates recommendations for action,
- raises public awareness and heightens the media profile of global change issues.

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Towards Our Common Digital Future

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Copy deadline: 12.04.2019

Recommended citation: WBGU – German Advisory Council on Global Change (2019): Towards Our Common Digital Future. Flagship Report. Berlin: WBGU.

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Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

ISBN 978-3-946830-03-0

Translation: Bob Culverhouse & Margaret Helliwell, Berlin

The R&D project that generated this report was conducted on behalf of the German Federal Ministry of Education and Research and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety under grant number 01RIO708A4. Responsibility for the content of this publication rests with the author.

Design: WERNERWERKE GbR, Berlin
Cover photos: ©gettyimages: Marcia Straub „An Abstract Image of the Woods“ and Flashpop „Group of children wearing virtual reality headsets“

Production: WBGU
Typesetting: WBGU
Printing and binding: Ruksaldruck, Berlin

FSC www.fsc.org MIX Paper from responsible sources FSC® C104247

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Acknowledgments

The WBGU would like to thank all external experts for their input and valuable assistance. Specifically, the following expert reports and statements, which are available on the WBGU website, were integrated into this report:

- Prof Dr Wolfram Burgard (Faculty of Engineering, Autonomous Intelligent Systems, University of Freiburg): Künstliche Intelligenz, 2018.
- Prof Dr Dr hc mult Niels Birbaumer (Institute of Medical Psychology and Behavioural Neurobiology, University of Tübingen): Technologien und Visionen der Mensch-Maschine-Entgrenzung, 2018.
- Prof Dr Jeanette Hofmann (Berlin Social Science Center – WZB): Internet Governance, 2018.
- Dr A. R. Köhler, Jens Gröger and Ran Liu (The Oeko-Institut): Kurzgutachten Energie- und Ressourcenverbräuche der Digitalisierung, 2018.
- Prof em Dr.-Ing. Dr hc mult Paul J. Kühn (University Stuttgart, Institute of Communication Networks and Computer Engineering – IKR): Informationstechnische Gestaltung einer nachhaltigen Digitalisierung, 2018.
- Constanze Kurz and Frank Rieger (Chaos Computer Club – CCC): Netzpolitische Handlungsoptionen für eine nachhaltige Digitalisierung, 2018.

The WBGU received valuable suggestions from hearings of experts during its internal conference held in Nauen in May 2018 and during its regular internal meetings: Prof Dr Jeanette Hofmann (Berlin Social Science Center – WZB); Prof Dr Nick Bostrom (University of Oxford, Future of Humanity Institute); Prof Dr Sabine Trepte (University of Hohenheim, Media Psychology Department).

During the hearing of experts on the 'Relationship between Humans and Machine' ('Verhältnis Mensch–Maschine') held on 18 October 2018, the WBGU had the opportunity to exchange views with: Dr Aljoscha Burchardt (German Research Center for Artificial Intelligence – DFKI, Member of the Enquete-Commission on Artificial Intelligence of the German Parliament) and Dr Jan Alexandersson (German Research Center for Artificial Intelligence – DFKI, CEO Startup 'ki elements').

The topic of this flagship report was examined in greater depth during the expert discussion on 'Digitalization' with representatives of the research community that was held on 14 December 2017 in Berlin: Dr Christian Anton (Leopoldina); Dr Stefan Brandt (Futurium); Prof Dr Martin Grötschel (Berlin-Brandenburg Academy of Sciences and Humanities – BBAW); Dr Rüdiger Haum (Futurium); Dr Karl Eugen Huthmacher (BMBF); Dr Susanne Kadner (acatech); Prof Dr Paul J. Kühn (University of Stuttgart); Dr Ulf Lange (BMBF); Prof Dr Armin Reller (University of Augsburg); Dr Christoph Revermann (Office of Technology Assessment at the German Bundestag – TAB); Prof Dr Jürgen Roßmann (RWTH Aachen); Dr Stefan Schneider (BMBF).

The event entitled 'WBGU Discussions: the Good Digital Life – the Environmental Perspective' ('WBGU im Gespräch: Gut Leben Digital – die Umweltperspektive') on 16 March 2018 also served to gain a more profound understanding of the topic: Dr Harald Bajorat (BMU); Dr Stefan Bergheim (Center for Societal Progress); Hubertus Drinkuth (Systain Consulting); Vivian Frick, MSc (Institute for Ecological Economy Research – IÖW); Walter Kahlenborn (adelphi); Kai Kallweit (Bitkom); Michael Marten (BMU); Dr Carsten Neßhöver (German Advisory Council on the Environment – SRU); Nilgün Parker (BMU); Vera Scholz (German Society for International Cooperation – GIZ); Philipp Sommer (Environmental Action Germany); Max Thinius (Futurologist); Charlotte von Möllendorff (NABU); Dr Ulf Lange (BMBF).

Thanks are also due to the panellists of the WBGU panel discussion on 'Digitalization and sustainability – What kind of future do we want?' ('Digitalisierung und Nachhaltigkeit – Welche Zukunft wollen wir gestalten?') on 20 June 2018: Markus Beckedahl (netzpolitik.org); Joana Breidenbach (betterplace.org); Christian Kulick (Bitkom); Prof Dr Judith Simon (University of Hamburg).

Sascha Wolff and Susanne Mira chaired the World Café on 'The Digitalized Anthropocene' ('Das digitalisierte Anthropozän') on 20 June 2018, sharing reflections and insights on digitalization with their guests: Klaus Milke (Germanwatch); Prof Dr Sabine Trepte (University of Hohenheim, Department of Media Psychology); Prof Dr Katharina Zweig (Technical University of Kaiserslautern, Algorithm Accountability Lab).

We would also like to thank the participants in the WBGU's Panel on 'Digitalization as a lever for the vision of a sustainable EU' ('Digitalisierung als Hebel für die Vision einer nachhaltigen EU'), which was held on 11 October 2018 as part of the 26th Annual Conference of the network of European Environment and Sustainable Development Advisory Councils (EEAC): Dieter Janecek (MdB, German Bundestag); Dr Harry Lehmann (German Environment Agency – UBA); Max Thinius (Futurologist).

The colloquium 'Fragility and autonomy of technical systems' ('Fragilität und Autonomie technischer Systeme') held on 19 October 2018, organized by the WBGU together with INFRANEU, also provided valuable results and food for thought: Staatssekretär a.D. Ulrich Arndt (INFRANEU-Hauptverband); Arslan Brömme (Vattenfall); Rudolf Gurland (T-Systems International, Telekom Security); Oliver Haase (Berliner Stadtreinigung – BSR); Hermann Kühne (Berliner Wasserbetriebe – BWB); Friedrich-Wilhelm Menge (Berliner Verkehrsbetriebe – BVG); Andrea Pieper (GASAG); Ingo Schwarzer (Deutsche Bahn, DB Systel); Jens Wiesner (Federal Office for Information Security – BSI).

Furthermore, the WBGU wishes to thank all those who provided valuable support through discussions, comments contributions, advice, research, and peer reviews of individual parts of this report: Dipl.-Math. Thilo Ernst, Dipl.-Ing. Karsten Isakovic, M. Sc. Fabian Kirstein, Dipl.-Inf. Nadja Menz, Prof Dr rer nat Adrian Paschke, Dipl.-Inf. Jaroslav Svacina, Dipl.-Ing. Jens Tiemann and Dipl.-Phys. Stephan Waßerroth (Fraunhofer Institute for Open Communication Systems – FOKUS); Dr Benjamin Stephan (Greenpeace Germany); Dr Mandy Singer-Brodowski (Institut Futur); Adrian Heilmann, Dr Frank Hellmann, Claudia Köhler, Aylin Mengi, Julia Stanoeva and Amelie Thürmer (Potsdam Institute for Climate Impact Research – PIK); Dr Daniel Voelsen (German Institute for International and Security Affairs – SWP); Dr Diana Serbanescu and Dr Stefan Ullrich (Weizenbaum Institute for the Networked Society); Dr Holger Berg and Dr Henning Wilts (Wuppertal Institute for Climate, Environment and Energy; Division 'Circular Economy').

Contents

Boxes

Tables

Figures

Acronyms and Abbreviations

acatech	Deutsche Akademie der Technikwissenschaften *German National Academy of Science and Engineering*
ACM	Association for Computing Machinery
ADM	Algorithmic Decision Making
AGI	Artificial General Intelligence
AI	Artificial Intelligence
AIIB	Asian Infrastructure Investment Bank
APC	Association for Progressive Communications
AR	Augmented Reality
ASIC	Application-Specific Integrated Circuit
B2B	Business-to-Business
B2C	Business-to-Consumer
BCI	Brain Computer Interface
BECCS	Bioenergy with Carbon Capture and Storage
BGBl	Bundesgesetzblatt
BMBF	Bundesministerium für Bildung und Forschung *German Federal Ministry of Education and Research*
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit *German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety*
BMWi	Bundesministerium für Wirtschaft und Energie *German Federal Ministry for Economic Affairs and Energy*
BNE	Bildung für nachhaltige Entwicklung
BRICS	Association of five major emerging national economies: Brazil, Russia, India, China and South Africa
BSI	Bundesamt für Sicherheit in der Informationstechnik *German Federal Office for Information Security*
C2C	Consumer-to-Consumer
CA	Capability Approach
CAPS	Collective Awareness Platforms for Sustainability and Collective Action (EU Project)
CAVs	Connected Autonomous Vehicles
CBD	Convention on Biological Diversity
CDP	Carbon Disclosure Project
CFR	Charter of Fundamental Rights of the European Union
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO_2	Carbon dioxide
CPU	Central Processing Unit
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSER	Corporate Socio-Environmental Responsibility
DAC	Direct Air Capture
DART 2020	Deutsche Antibiotika-Resistenzstrategie
DC	Development Cooperation
DNS	Domain Name System

DRM	Digital Rights Management
DSI	Digital Sequence Information
EBV	Essential Biodiversity Variables
ECOSOC	Economic and Social Council (UN)
EEG	Electroencephalography
EITI	Extractive Industries Transparency Initiative
EMAS	Eco-Management and Audit Scheme
EOSC	European Open Science Cloud (European Commission)
EPOS	European Public Open Spaces
EU	European Union
FabLab	Fabrication Laboratory
FAIR	Findable, Accessible, Interoperable and thus Reusable (GO FAIR Initiative)
FAO	Food and Agriculture Organization (UN)
FIfF	Forum InformatikerInnen für Frieden und gesellschaftliche Verantwortung *Forum of Computer Scientists and IT Professionals for Peace and Social Responsibility*
FONA	Rahmenprogramm Forschung für nachhaltige Entwicklung (BMBF) *Framework Programme 'Research for Sustainable Development'*
FSC	Forest Stewardship Council
GAFAM	Google, Amazon, Facebook, Apple and Microsoft
GDPR	General Data Protection Regulation (EU)
GEO BON	Group on Earth Observations Biodiversity Observation Networks
GG	Grundgesetz *Basic Law for the Federal Republic of Germany*
GPU	Graphics Processing Unit
HLPF	High-level Political Forum (ECOSOC)
HOCH^{N}	Nachhaltigkeit an Hochschulen (BMBF)
HTTP	Hypertext Transfer Protocol
ICANN	Internet Corporation for Assigned Names and Numbers
ICT	Information and Communications Technology
IDM	Information Delivery Manual
IDS	Intrusion Detection System
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IGF	Internet Governance Forum (UN)
INDC	Intended Nationally Determined Contributions
IoT	Internet of Things
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (UNEP, UNESCO, FAO and UNDP)
IPCC	Intergovernmental Panel on Climate Change (WMO, UNEP)
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
ISSC	International Social Science Council (UNESCO)
IT	Information Technology
ITU	International Telecommunication Union
LDCs	Least Developed Countries
MaaS	Mobility as a Service
NAZCA	Non-state Actor Zone for Climate Action (UN)
NDB	New Development Bank (BRICS)
NetzDG	Netzwerkdurchsetzungsgesetz *German Network Enforcement Act*
NFC	Near-Field Communication
NGO	Non-governmental Organization
NNMI	National Network for Manufacturing Innovation
OECD	Organisation for Economic Co-operation and Development

OER	Open Educational Resources
OZG	Onlinezugangsgesetz *Online Access Act (Germany)*
PAN	Personal Area Networks
R&D	Research and Development
REDD+	Reducing Emissions from Deforestation and Forest Degradation (UNFCCC)
RFID	Radiofrequency Identification
RGGI	Regional Greenhouse Gas Initiative (USA)
RRI	Responsible Research and Innovation
SDGs	Sustainable Development Goals (UN)
SHS	Solar Home Systems
SMEs	Small and Medium-sized Enterprises
STEM	Science, Technology, Engineering and Mathematics
TCP/IP	Transmission Control Protocol/Internet Protocol
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicles
UDP	User Datagram Protocol
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGIS	United Nations Group on the Information Society
UNICEF	United Nations Children's Fund
VPN	Virtual Private Network
VR	Virtual Reality
W-LAN	Wireless Local Area Network
WAN	Wide Area Networks
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen *German Advisory Council on Global Change*
WCMC	World Conservation Monitoring Centre (UNEP)
WHO	World Health Organization
WTO	World Trade Organization
WSIS	World Summit on the Information Society
WWW	World Wide Web

Summary

'Digitalization' is often described as a huge upheaval facing our societies to which we must adapt. The WBGU opposes this interpretation, saying that digitalization must be shaped in such a way that it can serve as a lever and support for the Great Transformation towards Sustainability, and can be synchronized with it. The WBGU understands digitalization broadly as the development and application of digital and digitalized technologies that augment and dovetail with all other technologies and methods. It has a profound effect on all economic, social and societal systems and is developing an ever greater transformative force. This in turn is increasingly having a fundamental impact on people, societies and the planet itself and must therefore be managed accordingly. Just as in 1987 the Brundtland Report entitled 'Our Common Future' outlined the concept of Sustainable Development, the WBGU's report entitled 'Towards Our Common Digital Future' sketches the concept of a *digitalized sustainability society*.

This report represents the greatest challenge the WBGU has taken on since it was founded in the Rio year 1992 – intellectually, politically and ethically. The WBGU is expanding the scope of its analysis beyond its core area of expertise, because the future fate of the planetary environment will depend massively on the progress of the digital revolution. The WBGU is getting involved in a societal discourse that is becoming increasingly hectic because it is about global innovation leadership in the 21st century. The WBGU is also trying to find answers to core questions – questions about the medium-term future, indeed even about the sheer survival of the *Anthropos* on Earth. Sustainability transformation can only succeed if the digital upheavals can be successfully geared towards sustainability. Otherwise, digitalization threatens to act as a 'fire accelerant', exacerbating growth patterns that breach the planetary guard rails. Sustainability pioneers must seize the opportunities offered by digitalization and, at the same time, contain its risks. If those who are attempting to advance sustainability transformations ignore or neglect the dynamics of digitalization, the Great Transformation towards Sustainability will fall by the wayside. The WBGU therefore advocates the continuation and acceleration of the Great Transformation by digital means. In addition, it is becoming clear that digitalization is going to change our societies so profoundly that our understanding of sustainability will also have to evolve in radical, new directions. The WBGU reveals possible directions for the next generation of sustainability paradigms and goes far beyond the perspectives of the 2030 Agenda.

Putting such an epochal watershed in the history of humankind into perspective, while at the same time providing practical advice for policy-makers, is ambitious and fraught with tension. Yet even if some assessments of these fundamental changes should be mistaken, this can still be useful in throwing some light on the paths that should now be quickly pursued by more knowledgeable people.

In a sense this is a warning: this WBGU report attempts to take *a holistic approach to digitalization in the context of the sustainable development of our civilization, which is under threat from many sides – an approach that has been missing up to now*. Such a huge aspiration can only be realized – if at all – with weaknesses, generalizations and omissions. This report should be read accordingly.

However, in order to facilitate a favourable and productive reception, the structure of this WBGU report also deviates from the norm: this time, the actual summary is preceded by a narrative essay, which attempts not only to sketch out the report's train of thought, but also to indicate the immense thematic landscape, which, in addition to balmy lowlands and emerging new realms of possibility for sustainability reforms, also includes some deep abysses. On this terrain, the narrative deals with the digital possibilities for, and risks to, preserving what evolution had yielded until the Earth's entry into the Anthropocene period, and with the conceivable creation of new digital entities or even the possible substitution of human intelligence by machine intelligence. This is followed by a summary of the report's key messages, the individual chapters and recommendations for action and research.

Conservation and creation in the Digital Age

Albert Einstein revolutionized physics in the early 20th century – this is a well-known fact. He also possessed the rare gift of being able to express complex facts both within and beyond science in a single sentence. Not least, he is credited with the following famous statement:

Problems cannot be solved with the same way of thinking that created them!

Of course, this is an aphoristic simplification of critical aspects of societal reality. Nonetheless, it is an ideal starting point for a combined approach to what are perhaps the two most important developments of the recent modern age: on the one hand the growing threat to humanity's natural life-support systems, and on the other the explosive advances in the field of information and communication technologies.

In a sense, the first development is the source of the WBGU's raison d'être since its foundation by the German Federal Government in 1992. The analysis of the damage caused by civilization to the natural life-support systems and the resulting self-threat to humankind centres on the climate crisis, which is constantly intensifying and whose all-encompassing dimension has been revealed by research in recent years. The rapid pollution and acidification of the oceans, the progressive loss of biological diversity, and the degradation of fertile soils are also being documented in ever greater detail and increasingly understood in context.

The Special Report of the Intergovernmental Panel on Climate Change (IPCC) on the feasibility of limiting anthropogenic global warming to 1.5°C (IPCC, 2018) convincingly argues that this limitation could avert serious damage to nature and culture in many parts of the world. At the same time, however, it also confirms that this success – if at all – can only be achieved with a rapid and far-reaching transformation of an economy still dominated by fossil fuels. A recently published meta-study by an international research group (Steffen et al., 2018) points out that it might not even be possible to stably 'park' the climate system near the 2°C guardrail. Self-reinforcing processes (such as the release of greenhouse gases from thawing permafrost soils in Siberia and Alaska) could cause the system to slide uncontrollably towards an irreversible 'Hothouse Earth' state. The implications would be the same as shifting the global environment 15 million years back in geological time – involving a 5–6°C increase in the Earth's temperature and a rise in sea levels of up to 60 metres. Similar tipping processes could probably also be triggered by anthropogenic disturbances in the biosphere and pedosphere.

These and other recent publications make it clear that the implementation of the Paris Agreement on climate change, the Aichi Biodiversity Targets, and soil regeneration are *minimum measures* for preserving the natural human life-support systems.

Yet the acute environmental crisis is only one of the many sustainability challenges that have been created by the modern industrial age. Strategies for dealing with them are inextricably linked with questions of social justice and societal cohesion. The United Nations' Sustainable Development Goals (SDGs) represent a reasonably suitable set of objectives for this complex of challenges. In addition to critical environmental and resource-related aspects, they also take into account numerous socio-economic dimensions, the sustainable restructuring of our industries and cities, the fight against poverty, the reduction of inequality and conflicts, and, not least, equal opportunities for all people to lead a fulfilled, good life – regardless of gender, age, physical health or origin (UN, 2018).

In this context, the WBGU has developed a much simpler orientation system ('normative compass': WBGU, 2016a, b), which so far includes the concepts of 'Inclusion', *'Eigenart'* (a German word meaning 'character') and 'Sustaining the natural life-support systems'. It is explicitly supplemented in this report by the indispensable category of 'Dignity' (Fig 1). Unfortunately, despite progress on some sub-targets, global society as a whole is currently failing to take the right course, regardless of which navigation system is consulted.

The rather nebulous term 'digitalization' is used to denote the second development mentioned above, even though it represents nothing less than a civilizational revolution. It is now common knowledge that a new era began with the introduction of electronic data processing in the 1950s, but what is going to happen, when and how in this age is the subject of sometimes naive fantasies of progress, bitter controversies and increasingly fear-laden scenarios. Controversies are ignited particularly by the mass collection of private data, the manipulation of communicative spaces, and discrimination by algorithmically controlled systems. The imagined free, equal, worldwide network has in reality become a software-based cybersphere driven by economic and geopolitical interests. Popular dystopias are particularly concerned with the technical creation of different forms of 'artificial intelligence' (AI), although there is already considerable controversy over this term. Even so, it is a fact that in strategic games such as chess or Go, self-learning machine systems based on neural networks now effortlessly beat the world's best human opponents. And that is only the tip of the digital iceberg, as this report will explain.

First, however, we consider it important to put this

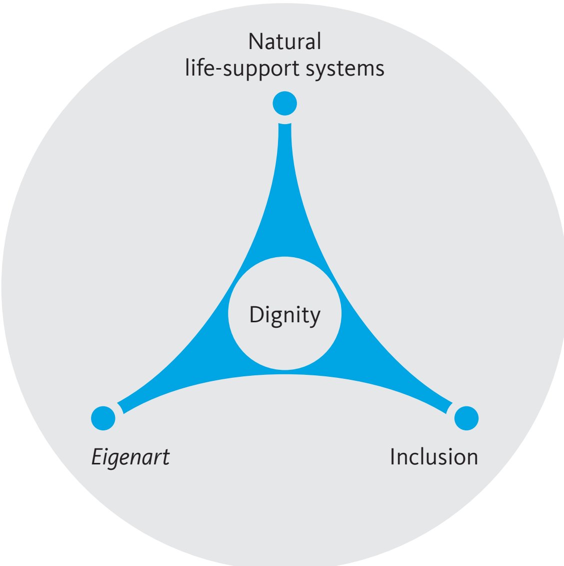


Figure 1
Normative compass for the Great Transformation towards Sustainability in a digitalized society. The transformation can be achieved by interaction and a balance between the following three dimensions:

- 'Sustaining the natural life-support systems' (N): Comply with planetary guard rails and avoid or solve local environmental problems.
- 'Inclusion' (I): Ensure universal minimum standards for substantive, political and economic inclusion.
- *'Eigenart'* (E): Recognize the value of diversity as a resource for successful transformation and as a condition for well-being and quality of life (*Eigenart* is a German word meaning 'character').

Up to now, human dignity has been the WBGU's implicit normative starting point. It cannot be realized without the three compass dimensions, but it is becoming an increasingly sensitive issue in the Digital Age due to numerous challenges. For this reason, the WBGU explicitly names the inviolability, respect for and protection of *Dignity* as guidance in the sense of the Transformation towards Sustainability.
Source: WBGU; diagram: Wernerwerke, Berlin

breathtaking dynamic into the larger planetary context. The history of human civilization is marked by two steep steps, one of which was climbed in the millennia following the last Ice Age (i.e. from 11,000 years ago), the other 150 years before the First World War (i.e. from the year 1760 CE). In the first case, known as the Neolithic Revolution, *Homo sapiens´* metabolic-physiological potential soared as a result of plant management and animal husbandry. In the second case, the Industrial Revolution, humankind's manual skills were increased a hundredfold through mechanization and fossil fuels. With the digital revolution that is now taking place, certain cognitive achievements of our species – the only one of many millions of species on Earth with technical intelligence – will eventually be replaced or far surpassed.

Is the stage thus set for an act of creation with no geological or religious template? Could this act bring together 'supernatural' physiological, manual and cognitive abilities in a novel way and thus transcend the essence of what is human? This could set in motion a whole new epoch of evolution on our planet. However bizarre the idea may sound to many, it is already being discussed seriously in certain circles. The WBGU looks into it in Chapters 6 and 7 of this report – for the first time explicitly discussing the significance of this utopia/dystopia for the great issues of sustainability.

Before doing so, however, it is necessary to carefully explore the prospects opened up by the digital revolution for the timely resolution of the acute global environmental crisis, which could soon put an end to our civilization and thus also to all speculation on 'human enhancement'. After all, in the sense of Einstein's above-mentioned quote, one can say that cybernetics and information and communication technology mark the birth of a new way of thinking that is systemic and networked. It could help solve the problems created by the 'old' industrial way of thinking – alongside all the great achievements of the modern age. This old way of thinking has now practically congealed into a dogma, insisting on specialization, separation and linearization. However, what is needed is a holistic approach in order to avoid 'not seeing the wood for the trees', to recognize side effects, and to close loops. The very paradigm on which progressive digital concepts and applications are based can create the necessary conditions for this, especially since it emerged in close interaction with the complexity sciences.

However, if we now add a logical step to Einstein's statement, then the 'new' way of thinking should not only provide a better explanation of the world, but also help solve the real problems that have been piled up by the conventional model, which has reached its limits. In today's prevailing digitalization euphoria, which is seizing even the most peripheral corners of the planet, AI's arsenal of methods is believed to be capable of every conceivable – and inconceivable – miraculous achievement. And indeed, they really are perhaps the most powerful tools ever created by our civilization.

So what could be more obvious than to apply these tools on a grand scale as quickly as possible to the most pressing challenges this civilization has ever faced: particularly to anthropogenic global warming, which sets the framework for all other current environmental crises? Shouldn't machine intelligence help us where human intelligence obviously fails?

In its report, the WBGU has examined these questions and reaches a double conclusion. On the one hand, it must be plainly stated that the digitalization of business and everyday life has so far been only marginally oriented towards sustainability aspects. There is no lack of rhetorical references, especially by applying the term 'smart' to every subsystem of industrial society that needs to be transformed in a climate-friendly way: smart grids, smart cities, climate-smart agriculture, etc. However, up to now, digital resources and projects have been mainly used for conventional growth in established markets characterized by international competition. Sustainability is not the primary purpose of digital progress in these contexts; the dominant aspects are entertainment, convenience, security and, not least, short-term financial gain. Overall, digitalization processes today tend to act as 'fire accelerants', exacerbating existing non-sustainable trends such as the overuse of natural resources and growing social inequality in many countries.

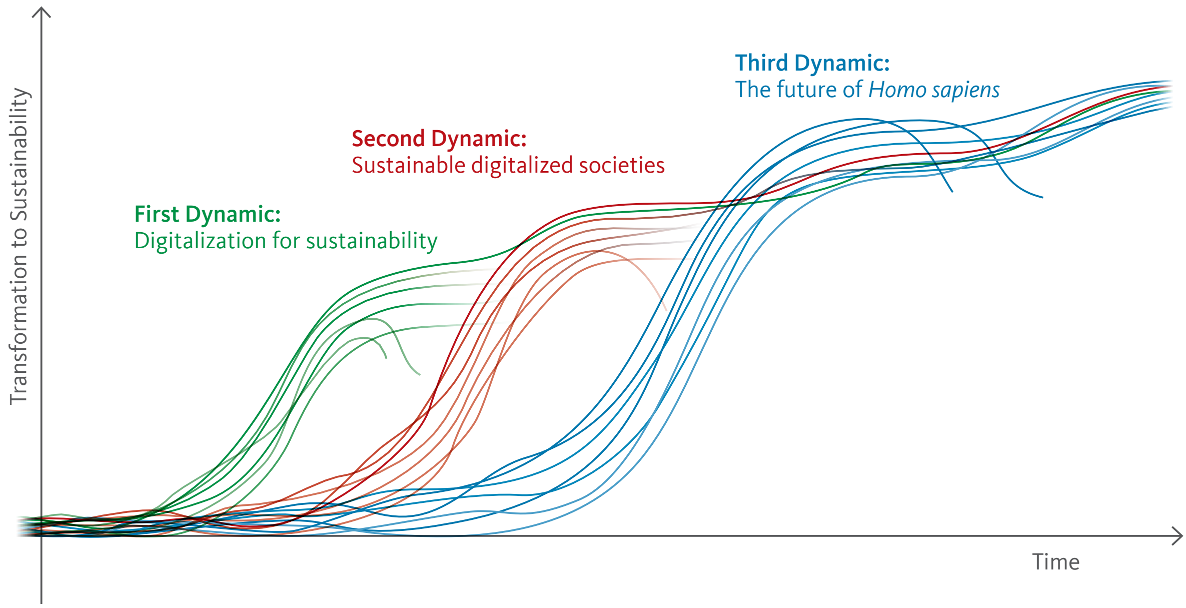
On the other hand, what is not yet possible can – and must – become possible. After all, digitalization offers an enormous range of possibilities for supporting the Great Transformation towards Sustainability (WBGU, 2011) – from sensor systems to self-organized system optimization. The WBGU has defined three Dynamics (Figure 2) to illustrate the huge spectrum of potential benefits and risks in the context of digitalization and sustainability. In the First Dynamic, 'Digitalization for sustainability', attention is focused on the implementation of the 2030 Agenda and the SDGs. This can only be a provisional overall assessment, as the scientific literature on the subject is astonishingly sparse and unspecific. There are many general assumptions and expectations, albeit few specific and quantitative analyses. It is evident that 'digitalization' can have numerous effects that are harmful to sustainability as well as effects benefiting sustainability. The first category includes, of course, information and communication technologies' enormous thirst for energy, unless this thirst is quenched from renewable sources. The second category includes the rapid emergence of immersive virtual reality that could probably make the majority of business trips by plane unnecessary.

It is also evident, however, that there is no systematic analysis of the relevant opportunities and risks, either for Germany or worldwide. In this respect, the WBGU identifies not only major shortcomings, but also a glaring gap in research. The WBGU demands that the two cardinal challenges – i.e. 'sustaining the natural life-support systems' and the 'digital revolution' – are finally studied holistically. This will require the creation of effective political incentives and processes.

If we now go one step further from the opening quotation, the question immediately arises as to what *new* problems are created by the way of thinking that perhaps solves the *old* problems. This analytical twist is more than justified, as shown by the chronicle of innovations and their consequences. No one will deny that the invention of movable-type printing at the beginning of the modern age (i.e. around 1450 CE) created the basis for the later Enlightenment and the democratization of knowledge. However, in addition to printing Bibles, leaflets were produced predominantly to sow hatred, paving the way for the terrible religious wars in Germany. What is taking place today in the internet-based 'social media' seems like a repetition of history, albeit at an incomparably higher technical level. The mechanized use of fossil fuels has produced industrial mass production and thus created a great deal of prosperity; but it has also made mechanized killing possible in countless regional conflicts and two world wars.

Thus, it might be inferred from the history of innovation that there is such a thing as a 'retarding moment', i.e. that disruptive technological innovations are initially more of a curse than a blessing for society as a whole. It would be naive to think that everything will be different this time, especially since the digital revolution will probably eclipse all earlier phases of technical progress in terms of reach, range and speed. Instead of hoping for voluntary self-restraint on the part of technology developers and political-economic interests, common-good-oriented democratic states must not only build up a strong anticipatory capacity, but also create a strategic bundle of institutions, laws and measures. Only in this way can digital forces be harnessed and simultaneously contained. The WBGU's Second Dynamic, 'Sustainable digitalized societies', looks at this challenge of shaping the Digital Age itself in the sense of a humanistic, sustainable world society.

Relevant topics range from dealing with the now widely discussed changes in the global labour markets to necessary reforms in the education system, the protection of individual privacy and the digital public sphere, to the mammoth task of gearing the shifts of power in the AI age towards a pluralistic, mature society. Another important task is the need to restrict the rapidly rising consumption of energy and resources by hardware and software. The lack of transnational political architecture ('global governance') remains the elephant in the digital room for solving both old and newly emerging problems. The key challenge for the international community is to develop a common vision of a sustainable, digitally supported future – despite faltering multilateralism – and, with this in mind, to affirm and establish collective principles, regulatory framework conditions and ethically justified boundaries. The WBGU develops far-reaching recommendations for action in these thematic areas based on the normative principles of guaranteeing the natural life-support system, societal inclusion, *Eigenart* and inviolability of human dignity.



↑ Digitally support sustainability

- Comply with planetary guard rails (climate, nature, soils, oceans)
- Secure social cohesion (against hunger, poverty, inequality; for access to water, health, education, energy)

↓ Ecological and societal disruption

- More emissions and resource use
- More inequality
- Greater concentration of power
- Erosion of civil rights and privacy
- Erosion of the state's governance

↑ New humanism

- Networked world society as a further advancement of Enlightenment and humanism
- Development of global (environmental) awareness
- Culture of cooperation, empathy, global solidarity

↓ Digitally empowered totalitarianism

- Hollowed-out democracies and digitally empowered autocracies
- Massive inequality, domination by elites, total surveillance and loss of freedom
- Environmental destruction and loss of social cohesion

↑ Strengthen *Homo sapiens*' self-confidence

- Preservation of the biological human in its natural environment
- Ethically reflected advancement of humanity
- Design human-machine collaboration

↓ Blurring of borderlines between humans and machines

- Abuse of human-machine relationship
- Superintelligence
- Artificial human evolution

Figure 2
Three Dynamics of the Digital Age.
The chart shows the positive case of the Dynamics being successfully contained through goals and governance. All three Dynamics are already emerging in parallel today, albeit with different levels of intensity, so there is no strict chronological sequence involved. Each Dynamic consists of different subpaths following different trajectories. The name given to each Dynamic reflects the priorities for action required in each case.
The texts beneath the figure give keywords on the potential (↑: upper row) and risks (↓: lower row) of the three Dynamics.
Source: WBGU; diagram: Wernerwerke, Berlin

As an interim summary, it can be stated that a proactive state has at least two major challenges in the Digital Age: on the one hand, to tap the enormous potential of novel information and communication technologies for the purpose of sustainability transformation ('old problems') and, on the other hand, to prevent possible, indeed probable, negative spin-offs from the surge of innovations ('new problems'). These two tasks involve quite different philosophies of public action or inaction. The contemporary 'American model' largely refrains from regulatory intervention and relies on market forces to ultimately guarantee the maximization of the common good. By contrast, the contemporary 'Chinese model' relies on hierarchical planning and a command economy, at least in areas of strategic national importance. The WBGU is firmly convinced that neither political philosophy can do justice to the dual responsibility described above. It is a third, civil-society path in the tradition of the Enlightenment and humanism that seems appropriate. A Europe acting jointly could introduce this into the global negotiations and set an example together with like-minded states.

This brings us to the last step outlined in the Einstein quote. Whenever there is a sweeping reference to 'problems', then it must be made clear that these are defined by *passive-active relationships*: not only is it necessary to ask which problem arises for which subject via which agent, but also how this problem is perceived and assessed. It follows, among other things, that a problem can be changed or eliminated by changing the physical or psychological state of the subject, even if the agent remains the same. This sounds like superfluous hair-splitting; it is, however, anything but:

After all, human beings themselves will be changed by the digital revolution, and the WBGU considers this development in the Third Dynamic, 'The future of *Homo sapiens*'. In evolutionary terms, *Homo sapiens* is a creature of the Ice Age, an epoch in geological history when environmental conditions were characterized by rapid and massive change. Accordingly, the people of that time had to organize themselves as opportunistic hunters and gatherers in small, highly mobile groups. The comparative advantage of this particular species lay not in the shaping of its living conditions, but in its perfect adaptation to the given circumstances. This advantage was partially eliminated by the transition to settled agriculture, and this change in lifestyle was even accompanied by retrograde physiological and cognitive steps. Individually, Neolithic humans were probably weaker and more susceptible to disease than their early ancestors. However, these disadvantages were offset at the level of the overall population by new opportunities (such as stockpiling), so that the population was able to grow markedly. A similar process took place in the course of the Industrial Revolution, which ultimately brought about the 'Great Acceleration' (Steffen et al., 2015) of societal metabolism and population dynamics in the 20th century.

There is much to suggest that the digital innovations that are just beginning to unfold will most likely transform people's qualities and the structures of people's coexistence even more radically – depending, of course, on how these innovations are accompanied, guided, restricted or even prevented. Here lies the most profound question of the Digital Age. As indicated above, all attempts at an answer must take their orientation from the key category of 'Dignity', which complements the WBGU's previous compass of values.

The current debates on topics such as 'artificial intelligence' and 'human-machine interactions' are taking place amid increasing tensions between hope, horror and hype and largely ignore the embedding of the emerging conglomerates in the natural environment. However, science cannot simply withdraw from this field, but must – in terms of an extended concept of sustainability that includes the human being – deal with the dominant utopian and/or dystopian discourses and their drivers. For the WBGU, this debate explicitly belongs to the science-based deliberation culture of an open democratic society that remains a fundamental guideline for the European Union.

Fully aware of the speculative nature of the following thoughts, the WBGU would like to introduce three hope-oriented mind games into the corresponding discourse:

1. Humankind finds itself

It is uncertain whether and when the development of *universal* AI will succeed. Nevertheless, it is already clear that in some areas AI far surpasses the cognitive performance of our species. However, the corresponding abilities by no means make up the entire human being. If nothing else, the achievements of information and communication technology could draw our attention and appreciation to capacities that are not directly cognitive; these are often referred to collectively as emotional and social intelligence. Most likely these were at least as important in civilization building as the achievements of measuring, calculating and documenting. AI would possibly grant us a certain amount of emancipation from the latter and allow us to focus more on skills such as empathy, care and solidarity. In contrast to the 'hard' clichés of the superhuman with the computer brain in a world of steel, this would delineate a 'soft' vision of societal progress.

2. Humans create companions for themselves

The more advances AI makes in ever broader application areas, the more diverse and intimate will be the points of contact, interfaces and hinges between technology and people. This can lead to symbiotic connections, which, however, may turn out differently than imagined in the popular 'cyborg' dreams. It is also possible that AI-enabled entities emerge that will become well-integrated, loyal companions of humans in societies that are more liveable than those of today. For example, in the medium term, digital assistants could liberate us more and more from monotonous activities (e.g. by taking on logistical tasks), support us in learning and understanding (e.g. by synthesizing and interpreting the overwhelming wealth of information), and ultimately help us to value ourselves and our environment more highly (e.g. through diagnostics and mirroring). Such a prospect encounters far less scepticism in the East Asian cultural sphere than in Western societies, for example, and promotes a world view that does not categorically isolate humans from nature and technology.

3. Humans invent their masters

Speculation about the future progress of AI-relevant technologies diverges widely: Ideas on what *ontological quality* these could produce remain highly controversial. Especially in the debate on 'Artificial General Intelligence' or even 'Super Intelligence', (human) opinions differ greatly. However, the emergence of *conscious* AI systems has been discussed for some time. Assuming this possibility, it would be only logical to ask whether *animate* artificial entities with independent decision-making and reproductive capabilities could be formed in a later phase of the digital revolution.

The WBGU has also examined this mind game – which, from today's perspective, appears absurd to many experts outside of Silicon Valley – and looked for possible societal options for action. The intuitively 'reasonable' option would be a general moratorium that would fundamentally prohibit R&D efforts to create conscious and therefore sentient systems. The current controversies about certain procedures in reproductive medicine and synthetic biology can provide valuable pointers here.

But is such a complete and, above all, global moratorium even feasible? While this text is being written, an attempt is perhaps being made in a well-guarded research laboratory somewhere in the world to equip an AI system with 'feelings'. In this respect, the WBGU has decided to recommend at least a discourse on an alternative option:

If the development of civilization since the Neolithic Age has evidently been self-organized and directed toward substituting and transcending human (physiological, manual and cognitive) capabilities, can the creation of a new entity *by humans* not be seen as the next, perhaps inevitable leap in planetary evolution? Such reflections generate horror or enthusiasm, depending on the circles in which they are presented.

Yet although the protection of human dignity remains a quintessential challenge, it is equally important to understand the genus *Homo* as a product of the fundamentally open 'life' process. Seen from an optimistic point of view, could the combination of humankind's social and emotional intelligence with the superior cognitive abilities of machines make a form of co-evolution possible whose creatures possess even *more humanity* than we ourselves do?

So much for mind games. In this flagship report, the WBGU explicitly recommends that the current challenges of digitalization be contained by regulation and placed at the service of the Great Transformation towards Sustainability. At the same time, however, we must start thinking today about the future of humankind in the post-industrial age in a democratic way that is oriented towards the common good. Particular care should be taken, especially in the areas of research and development and in multilateral policy, to ensure that no irreversible decisions are taken and that as much scope as possible remains for society to shape the future.

In Einstein's sense, we are faced with the Herculean task of mastering the present-day ecological and social challenges – both generally and with the help of digital means – while anticipating and largely avoiding the problems associated with these new tools. The protection of human dignity is the ultimate challenge in this context.

The tasks ahead: the Great Transformation towards Sustainability in the shadow of digital upheaval

The WBGU's aim with its work on the Great Transformation towards Sustainability is to put forward for discussion development paths to sustainable societies that keep within the planetary guard rails and can offer all people, including future generations, a good life in dignity and a long-term future (WBGU, 2011). This transformation includes profound changes to infrastructures, production processes, investments, regulatory systems and lifestyles, and a new form of interaction between politics, society, science, business and individuals. International agreements that call for transformations towards sustainability now exist due to the adoption of the 2030 Agenda with its 17 SDGs (2015), the Paris Climate Agreement (2015) and the Aichi targets for biodiversity (2010). Nevertheless, the change in direction towards sustainability is proceeding much too slowly. Our economies and societies are still on a collision course with the Earth system. Moreover, social centrifugal forces are undermining cohesion and stability in many societies. So far, there has been too little research on how digital change can make sustainability transformations easier – or more difficult – or how it might lead to completely new demands on sustainable societies or to changes in people's understanding of sustainability. In this respect, the WBGU's report identifies not only massive deficits in action, but also blatant gaps in research, and emphasizes key messages.

Combine digitalization and sustainability research (p. 23)

Using digitalization to implement the 2030 Agenda

The WBGU's analyses show that digitalization dynamics have a massive impact on all 17 SDGs of the 2030 Agenda. The debate on the implementation of the SDGs can no longer be conducted without an adequate understanding of the potential benefits and risks of digitalization for the entire 2030 Agenda.

A double course correction is needed

The first course correction requires a profound change in the discussion on the Great Transformation towards Sustainability, since, up to now, it has hardly taken into account the fundamental dynamics of digitalization, e.g. the opportunities and risks of algorithm-based decision-making processes, or the interlinkage between our physical world and virtual spaces. These topics cannot be found in either the 2030 Agenda adopted by the UN in 2015, Germany's 2017 sustainability strategy, or the WBGU report on the Great Transformation published in 2011.

Sustain natural life-support systems (p. 17)

The second course correction must be made by the economic, societal and political digital pioneers and by digitalization research, because up to now digitalization has hardly been linked with the great sustainability challenges of the Anthropocene. Digitalization should be made sustainable and used as a powerful tool to achieve the sustainability goals! The actors of sustainability and digitalization need to make a powerful joint effort to initiate a trend reversal towards a digitalized sustainable society.

Action needs to be taken quickly – combine digitalization, planetary guard rails and social cohesion

The report shows that digitalization can help us comply with the planetary guard rails. Decarbonization, a circular economy, more environmentally friendly agriculture, resource efficiency and emissions reductions, and the monitoring and protection of ecosystems could be achieved more easily and quickly with digital innovations than without them. It is therefore imperative that these possibilities of a digitally driven sustainability transformation are rapidly and comprehensively mobilized. Furthermore, digitalization can tap potential for societal modernization. Globe-spanning knowledge, globe-spanning communication, and global societal networking in virtual and hybrid spaces can accelerate sustainability transformations, improve human inclusion, strengthen global environmental awareness, and create a transnationally networked society in which global cooperation cultures develop.

However, the WBGU also shows that there is no technological determination *per se* for the major challenges facing humankind. The digitalization of the past decades – the internet, the many different terminal devices, the increase in production automation and product networking – has been accompanied by ever increasing energy and resource consumption, as well as global production and consumption patterns that place an even greater burden on ecosystems. Technical innovation surges do not automatically translate into sustainability transformations, but must be closely coupled with sustainability guidelines and policies.

Promote poverty reduction and inclusive development (p. 18)

Nor is the societal innovation potential of the digital transformation automatic. At present, our societies seem to be overwhelmed by the speed and extent of technological upheavals and their use by powerful actors – mainly from the private sector, although there are state actors, too. Fake news, social credit scores, the erosion of civilization standards on the internet, the loss of confidence in data-driven services, governments' problems in properly taxing companies operating in the digital sphere, politicians who seem overtaxed by the demands of accelerated digitalization – all these are just some of the pathological effects of unchecked developments.

Digitalization to support sustainability transformations – an enormous (inter)national task

Up to now, digital expertise has been severely underdeveloped in ministries, parliaments, municipal administrations, non-governmental organizations, sustainability research institutes, the media and international organizations. Creating the sheer ability to shape and plan requires a push for modernization in all the areas mentioned, in order to create digital expertise and bring it into line with the requirements of the sustainability transformation. If this does not succeed, technology-oriented and short-term self-dynamics will prevail; then it will no longer be possible to link the digital transformation with the sustainability transformation. Public institutions need to make comprehensive modernization efforts, like those carried out in the early 1970s, supported and accompanied by extensive scientific research programmes (Scharpf, 1972; Mayntz et al., 1978). Back then, the aim was to prepare public institutions to dovetail economic, technological, social and environmental developments and to expand societal inclusion; today, the aim is to create comprehensive digitalization expertise and to combine this with sustainability transformations.

The Digital Age is emerging as a new societal formation – imagining the Great Transformation towards Sustainability beyond 2030

The WBGU identifies five core characteristics of the Digital Age that make it possible to understand development trends and the direction of change. It becomes clear that using digital instruments to implement the sustainability goals is not enough. The digital upheavals are fundamentally changing the playing field of societal development. The Great Transformation towards Sustainability can only take place under these changing conditions of the Digital Age, which were hardly taken into consideration by the architects of the 2030 Agenda.

- *Interconnectedness:* Technical systems, as well as people, things, processes and organizations, are becoming more and more omnipresently interconnected at different levels of action. This development can multiply exchange relationships, cooperation and learning opportunities, and creates qualitatively novel, often transboundary economic, social, cultural, institutional and political networking structures. Networking can increase the vulnerability of interdependent infrastructures and processes.
- *Cognition*: Universal intelligence is humankind's unique selling point in the world as we know it. The Internet of Things and methods from big data and AI are increasingly creating technical systems that can use computers to perceive, learn, analyse, evaluate and in this way, for example, create art and texts or recognize and imitate language and faces. Silicon Valley expects original achievements by AI systems to be good enough to win Nobel prizes in 5–15 years' time. Such systems could fundamentally change many things: our view of what it means to be human, the economy, labour markets, learning processes, our knowledge, our dealings with technology, society and nature.
- *Autonomy:* Autonomous technical systems that make independent decisions based on data are already being used in industry to control production processes, in public environments to improve public safety, and (already in many contexts) to predict and monitor human behaviour. In the future, such autonomous technical systems will be used in many different ways: in transport (autonomous driving), the banking system, the social sector, the judicial system, and political negotiation processes. They can recognize patterns that are hidden from human beings because of their complexity or the large amount of data involved. They can help to make better-informed economic, political and social decisions, but they can also lead to a loss of societal control, the abuse of power or an undermining of privacy and freedom.
- *Virtuality*: The virtual world is creating new spaces for human societies. People can meet in virtual spaces regardless of their physical location, and access and change distant objects. Avatars and social bots can become people's companions. In this way, the Earth system, ecosystems and distant cultures can be experienced directly. At the same time, designing these virtual and hybrid spaces is a great challenge. This is already illustrated by the dystopian example of people sinking into virtual (game) worlds which only suggest a connection to nature, while real nature is increasingly degenerating.
- *Knowledge explosion*: Digital methods are modernizing all kinds of quantitative and qualitative research. Almost every traditional scientific discipline already has a digital manifestation called eSciences, digital humanities, etc. Data acquisition and processing, as well as modelling, simulation and visualization, offer new approaches to understanding and shaping our natural and societal realities. In addition, digital methods offer novel approaches to knowledge, education and global exchange.

These five characteristics will change not only our economies and technical infrastructures, but also *Homo sapiens* itself. The Anthropocene – the human age – hitherto a term that emphasizes that humans have become the greatest force for change in the Earth system, is gaining an extended meaning: in the *digital Anthropocene*, humans create tools with which they can now fundamentally transform themselves through ever closer human-machine cooperation using digitalized technology and an ever closer interaction with AI, right up to the technological dystopias of 'human enhancement', a technologically supported optimization of the human being.

At the same time, developments that are of great importance are conceivable and possible, specifically from the point of view of sustainability transformations: globally networked civil societies, the emergence of a global (environmental) awareness, a circular economy supported by digitalization, universal access to exploding knowledge, or new opportunities for developing countries and emerging economies to quickly embrace new digitalized infrastructures. In the 21st century, therefore, digitalization will change the deep structures of our societies just as fundamentally as the drivers of the Industrial Revolution led to the fundamental transformation of the world in the 19th century. Adam Smith, who was not only an economist but also a moral philosopher – a fact that is often forgotten – argued in his 'Wealth of Nations' (1776) that markets and radical change could only function without destabilizing societies if the autonomy of market dynamics were constrained by the norms and values of societies. This is all the more true for digital upheavals. Unless digital change is embedded in strong systems of standards and values, the dystopian potential of the digital society will prevail.

Set framework conditions and limits to the sustainability of digitalization (p. 17)

Karl Polanyi, Émile Durkheim and Max Weber also teach us that standards and values can ultimately only be anchored in societies and protected from the interests of the most powerful actors if institutions are created that can deal with the changes and steer individual and collective actions into channels agreed on by society. Against this background, the WBGU discusses digitalization not only as a process of technological change, but in particular from a normative perspective and as a societal task for managing the processes involved.

Avoiding systemic risks in the Digital Age

In order to be able to exploit the potential of digitalization, we must be aware of the possible systemic risks in the Digital Age. Digital systemic risks are conceivable, large-scale changes in our societies, each of which could in itself trigger destabilization in those societies. Domino and cumulative amplifying effects would multiply accordingly and have a broad-based impact.

Shape the work in the future and promote the reduction of inequality (p. 19)

Some of these threats are undisputed (e.g. labour-market disruptions), but the magnitude of the changes is uncertain. The probability of other systemic risks occurring is significant (e.g. breaching of planetary guard rails, digital authoritarianism, further power gains by large digital corporations), while the probability of other risks occurring is relatively low from today's perspective (e.g. acceptance of human enhancement to create an optimized *Homo sapiens*). However, even the latter systemic risks should not be neglected because, in a worst-case scenario, they would have a major impact on the future of civilization. The WBGU identifies systemic risks in the Digital Age, which include the following:

- exceeding planetary guard rails as a result of digitally driven, resource- and emissions-intensive growth patterns,
- disempowerment of the individual, threats to privacy and an undermining of the digitalized public sphere through digitally empowered authoritarianism or totalitarianism,
- an undermining of democracy and deliberation by normatively and institutionally non-embedded, automated decision-making or decision-making support,
- dominance by companies that can elude government control, driven by further data-based power concentration,
- disruption of labour markets by the comprehensive automation of data-driven activities and the danger that human labour will become 'increasingly irrelevant' to the economy,
- a deeper division of the global society because access to, and use of, digital potential is mainly limited to the wealthy minorities in world society,
- abuse of the technologization of human beings based on human-enhancement philosophies and methods.

It is also important to bear in mind that the digital upheavals are being experienced by societies that are already unsettled by globalization, the rise of new powers, by forms of authoritarian populism and the flow of refugees. The bow waves of digitalization are colliding with the current crisis in Europe and the West and with frontal attacks on a multilateral world order based on cooperation and rules. The systemic risks of the Digital Age could overlap with and reinforce the centrifugal forces that already exist in many societies.

Setting the course for a European road to a digitalized sustainable society

The European Union (EU) should lead the way in integrating sustainability and digitalization.

Establish the EU as a pioneer of a digitalized sustainability society (p. 21)

It is precisely by strengthening technological innovations and systematically linking them to sustainability-oriented social, cultural and institutional innovations that the EU could add something special to the global technology race and make a real impact on the search for roads to the digitalized sustainability society. The EU is already a pioneer in some areas of digitalization regulation. In the field of data protection and the protection of privacy, the General Data Protection Regulation (EU, 2016) is so far unique in the world.

Protect privacy (p. 20)

It embodies a Europe that defends fundamental rights against commercial and state data-collection frenzy. Furthermore, the EU is working on a European data space aimed at providing citizens and businesses with a highly developed, well-functioning, transparent system of public data, information, services and standards. This system would also help combine competitiveness with data protection in order, hopefully, to create competitive advantages for EU companies, e.g. in competition with China and the USA. The EU is also at the forefront of sustainability policy (e.g. environmental protection is enshrined as an EU objective in the Charter of Fundamental Rights, and the EU is currently working on a new Environmental Action Programme as well as a decarbonization strategy as a contribution to the Paris Agreement). However, the EU is not (yet) a pioneer when it comes to the urgently needed, implementation-oriented dovetailing of sustainability and digitalization. Ideas on how ethical principles for AI could be developed, or how digital change should be used to implement the SDGs, are still in their early stages.

The WBGU proposes fundamental decisions to be taken on five different stages for a *European road to digitalized sustainability societies*, in order to master the profound and radical changes towards sustainability in the Digital Age. Taking this road can only succeed if the fundamental decisions made on the five stages are intermeshed.

1. *New humanism for the Digital Age – renew the normative foundations of our societies:* The WBGU is developing some basic features of a new humanism for the Digital Age with the aim of defending the fundamental, albeit endangered achievements of humanism and enlightenment over the past two centuries and, at the same time, creating attractive future prospects for a digitalized sustainability society. Our hope is that Europe will be able to make such an effort for civilization.

Begin societal discourse on new normative issues (p. 21)

2. *Charter for the transition to a digitalized sustainability society:* Societal discourses for a new humanism need a starting point. On the basis of its analyses and discussions, the WBGU has condensed some key principles and guidelines for the digitalized sustainability society into a Charter. They include the protection of the planet and the preservation of human integrity and dignity. The Charter also encompasses support for local and global fairness, justice and solidarity under the conditions of a digital revolution. Finally, the Charter includes strengthening global (environmental) awareness and the cultures and systems of global cooperation by using digital opportunities, and also strengthening an advancement of AI that furthers human development opportunities, societal learning and social cohesion. The Charter can become the starting point for the renewal of sustainability paradigms and place our common digital future at the centre of efforts at the national, European and global level. The Charter follows on from the 2030 Agenda and, at the same time, goes beyond it to denote the normative foundations of our societies in the Digital Age.
3. *Building blocks of a responsible society capable of taking action:* Science and education are fundamental for freedom, inclusion and the *Eigenart* of the individual in the sense of future-oriented and creative, inclusive societies. The demands placed on our societies cannot be 'solved' solely by individual policy instruments (such as a CO_2 tax, resource

pricing or a new global competition regime). Rather, responsible societies capable of taking action must be developed and strengthened, so that the upheavals outlined can be mastered and managed.

Promote future-proof education and digital literacy (p. 19)

The WBGU sees the following central building blocks in this context, which – in their entirety and if they are cleverly combined – result in the architecture of feasible, responsible societies. The WBGU proposes concrete reform packages for all these basic elements of a responsible society capable of taking action:

- People must be enabled to understand and help shape the upcoming upheavals. Comprehensive education for sustainable development in the Digital Age is the key to this.
- Science should generate knowledge about the future to shape digitalized sustainability and sustainable digitalization. Just as, four decades ago, the Herculean task was accomplished of bringing together climate and Earth-system research with social science and economic disciplines to form the sustainability sciences that are established today, it is now necessary to quickly and closely interlink these with digitalization research.
- States must be capable of shaping processes themselves: states and public institutions need to invest in their own capabilities in order to establish and consolidate digital literacy for the transition to a sustainability society.
- The creation of arenas for experimentation and discourse in Germany and Europe would make it possible to prepare and accelerate innovations, to think ahead and to develop examples for shaping the future.

Regulate shifts of economic and political power (p. 20)

- The new power constellations must be contained in order to secure democratic inclusion. Important examples in view of the high global mobility of the digital economy are the international harmonization of competition law and corporate taxation, as well as non-discriminatory, clearly regulated cross-border exchange processes in virtual spaces that are standardized in the sense of interoperability.
- Digital changes always have a global impact, so that global, rule- and fairness-based regulatory models are needed that enable a combination of digital and sustainability transformations as proposed in the WBGU Charter. Only if the EU develops a common policy in this direction will European societies be able to influence the global restructuring of the future.
- Digitalization will fundamentally change the opportunities available to societies in developing countries and emerging economies – for better or for worse. International cooperation for sustainable development, and Germany's and the EU's cooperation with the United Nations and other multilateral actors, must therefore be urgently expanded in this direction.

4. *Technological game changers can accelerate sustainability transformations:* Digitalization offers an enormous toolbox of instruments and methods that must be used effectively and efficiently to achieve the sustainability goals. Here are some examples of technology-led game changers that the EU should rapidly promote in order to trigger change processes in European societies and in the world economy in cooperation and competition with other states and the United Nations:
   - The extended possibilities of digitalized remote and near-Earth observation, and the sensors, equipment and infrastructure required for this purpose, should be expanded worldwide and upgraded for the comprehensive and real-time monitoring of the natural Earth systems, their condition and development. The resulting international digital commons should be used as a starting point for the establishment and realization of services and applications for global (environmental) awareness.
   - Building on this, the nation states should, in the context of the UN, develop a globally coordinated and interoperable system of digital SDG indicators to improve the topicality, transparency, comparability and verifiability of digitalized national and international SDG reports.

Establish and secure digital commons (p. 21)

- In parallel, the sustainability and environmental data collected for SDG indicators and Earth observation should be made available as digital commons.

Provide public-service ICT (p. 21)

- Also, ICT infrastructures should be made available on a non-discriminatory basis as part of basic public services, thus fostering inclusion and the emergence of 'quality media' also in the digital sphere.
- The use of digital technologies, processes and infrastructures that make it possible to map the emission and resource footprints of both traditional industries and the digital economy across the entire value chain should be globally established.
- The diverse potential of AI should be used in sustainability issues, for example, to improve understanding of material cycles, production processes, supply chains, usage contexts and consumption patterns, to determine key triggers and patterns, and to identify and implement optimization potential.
- The use of digitalization to determine ecological parameters and correlations (e.g. reaching SDGs, footprints, material cycles) creates the information base for an efficient regulation of environmental resource consumption. Especially for the central goal of decarbonization, digitalization can make the difference, as it not only plays a key role in the realization of renewable energy supplies, but also makes specific production- and consumption-oriented regulations possible. In combination with economic policies on decarbonization, these can have a real impact.

Consider the fragility and autonomy of technical systems (p. 20)

- However, none of these digitalization-related levers will become effective without comprehensive guarantees of the resilience, cyber-security and trustworthiness of digitalized infrastructures, their longevity and robustness, and human decision-making sovereignty in the case of societally relevant automatic systems involving AI.

5. *Strengthen the sustainability and resilience of the economy:* Digitalization processes not only open up opportunities to advance a green economy, but also to strengthen the diversity and resilience of economic structures by supplementing the private sector with other economic forms. Digitalization is also used by cooperative, public and common-good-oriented enterprises to create new business models. This emerging diversity again ties in with the old strengths of post-war European economies: a strong private sector, a diversity of business forms, and markets embedded in institutions and normative systems. In order to exploit the potential benefits of digitalization, it is important to find a new balance between entrepreneurial competition, national legal frameworks, societal responsibility and orientation towards the common good. The guard rails and values set out by the Paris Agreement on Climate Change, the 2030 Agenda and the WBGU's Charter for a Digitalized Sustainability Society could thus become guidelines for the renewal of Europe.

Gear digitalization towards the common good (p. 17)

Immanuel Kant analysed the essence of the Enlightenment as a 'change in the way people think'. Having arrived at a new level of civilization in the Digital Age, we face a similar challenge in the struggle for sustainable, globally and virtually networked digitalized societies and in the search for a new humanism: *the further development of our civilization on a finite planet in the digital Anthropocene.*

An overview of the report

This Section provides an overview of the report's individual chapters and the main issues covered.

Sustainability in the age of digitalization

After *Chapter 1*, the 'Introduction', *Chapter 2,* 'Sustainability in the age of digitalization', embeds the report's theme into the WBGU's sustainability perspective and presents the WBGU's normative basis in the form of a 'normative compass'. This compass is explicitly based on the bedrock of the Enlightenment and on respect for human dignity, with the aim of meeting the related challenges posed by digitalization. As a first step, the report creates the link between digitalization and the

Box 1

Arenas of digital change

The 'arenas of digital change' are intended as examples to give a multifaceted impression of how digitalization can be placed at the service of the Transformation towards Sustainability. The report briefly presents and analyses concrete topics and extrapolates recommendations for action and research.

Industrial metabolism

Digitalization changes the energy- and material-exchange relationships (metabolism) within companies and value chains. In the case of digital devices, the main issue is currently environmental risks (e.g. electronic waste). In production, digitalized manufacturing processes that are coordinated in the sense of Industry 4.0 offer potential for higher resource efficiency. Digital platforms could enable a close linkage of material flows between companies. The global sustainability implications and the contribution to the circular economy are ambivalent and require in-depth analyses.

New forms of digital economy

Digital technologies enable new, collectively organized economic systems that are oriented towards the common good. These include new business models (sustainable digital entrepreneurship, green digital start-ups) and corporate forms (platform cooperatives), alternative forms of production (prosumer, commons-based peer production), and participatory value creation (sharing economy). Unlocking the related potential requires a suitable legal framework, a corresponding promotion of economic development, and the development of infrastructure.

Sustainable consumer behaviour

Digital technologies can be used to help people to consume in a sustainable manner (e.g. by buying only what they need, and through resource-sparing use, reuse, repairing and sharing). The focus is on consumer decisions about the type, quantity and use of products. It presents sustainability-relevant forms of 'digitalized consumption' and identifies the challenges and potential of digitalized consumption for sustaining natural life-support systems.

Online commerce

Online commerce is growing rapidly. This involves both negative environmental effects – from delivery services, packaging waste and returned goods – and positive effects from fewer private journeys and optimized logistics. Most of the turnover in online commerce is currently concentrated on a small number of companies that are displacing bricks-and-mortar retailing outlets. Opportunities for monitoring compliance with environmental and social standards at the place of origin are diminishing. Municipalities and cities should develop strategies to react to the displacement of the local retail trade.

Electronic waste and the circular economy

Digitalization is a driver of resource extraction and rapidly growing amounts of electronic and toxic waste. In order to reverse this trend, aims of the circular economy – e.g. resource conservation, durability, ease of repair, recycling – must already be integrated into business models and product designs. Clear regulations and incentives, societal embedding and a research offensive are levers for unlocking the potential of digital technology along the entire product life cycle.

Digitalization for climate-change mitigation and the energy transformation

Digital solutions support the integration of fluctuating renewable energies into energy systems and can promote access to modern energy in off-grid regions. Increases in energy demand triggered directly and indirectly by digitalization can be problematic. Long-term targets must be clear and reliable to ensure that investment and innovation are used for climate-change mitigation. The reliability and security of the increasingly complex energy systems and data protection should be taken into account from the outset.

'Smart City' and sustainable urban development

Sustainable urban development using digital technologies presupposes that municipalities and urban societies retain their governance sovereignty vis-à-vis the digital economy and develop their own technological sovereignty. A growing number of cities are actively investing in decentralized digital urban platforms, open architecture and an orientation towards the common good. If this trend prevails, there is justified hope that the digital transformation can be used for inclusive, sustainable urban development.

Sustainable urban mobility

Digitally supported innovations in the transport sector are currently being tested in many cities and give us an idea of future disruptive changes. In many cases, it is not clear how data and liability issues will be handled. However, solutions to key problems of urban transport systems (e.g. high CO_2 and air-pollutant emissions, land consumption, noise pollution, increasing travel and transport times and accident risks) are not a purely technological matter; rather, they will be decided by how digital solutions are embedded into comprehensive concepts of sustainable urban mobility.

Precision farming

Land use is a key sustainability issue for food security and nature conservation. Digitalization must not reinforce the trends towards industrial agriculture. It should be used to reduce environmental damage caused by the use of fertilizers and pesticides and to promote the diversity of cultivation methods and landscapes. Trustworthy data systems, a focus on data sovereignty, Open Data and Open Source can all help prevent farmers from increasingly losing control and becoming dependent on agricultural corporations.

Agriculture in developing countries

Most of the world's agricultural land is farmed by smallholders. Precision agriculture is highly capital-intensive and therefore less suitable for smallholder agriculture in developing countries. Even so, digitalization can increase the efficiency, productivity and sustainability of small farms by improving access to information, advice and education. Mobile connectivity and organizing small farms in cooperatives play a key role here.

Monitoring ecosystems and biodiversity

Digitalization is changing nature conservation in fundamental and transformative ways. Digitally enhanced ecosystem monitoring cannot directly influence the drivers of the biodiversity crisis, but it is a source of valuable knowledge and opens up new opportunities for monitoring compliance with management rules and bans that are aimed at preventing the overexploitation of biological resources. The vision of a global system for monitoring biodiversity with semi-automated inventories of species and ecosystem services is becoming more realistic.

Collective global awareness

Individuals can be motivated to act in a way that preserves the Earth system by creating a corresponding awareness of the problem and specific knowledge of how best to act. New digital possibilities, such as interactivity, gaming, virtual experiences of nature and citizen-science projects offer new opportunities for promoting environmental awareness. In the longer term, this will lead to a new willingness for global cooperation and a strong sense of global citizenship.

Public discourse

Digital technologies are changing how we communicate, how we perceive societal debates, and how we can take part in them. New forms of participation, algorithmic pre-structuring of media content, the use of social media, and new forms of content editing are restructuring public discourse. New skills and suitable legal and institutional framework conditions are required to ensure that the foundations of democratic opinion-forming and journalistic quality are preserved in the long term.

Scoring society

Scoring procedures map human behaviour using numbers. They are being used in more and more core areas of society (e.g. health care, law enforcement) as a basis for decision-making, often without the knowledge of those affected. The potential for more objective decision-making is being undermined by a lack of transparency concerning areas of application, methods and data, as well as a lack of supervision. Individuals should be given a right to have decisions justified by rational reasons. The way in which scoring influences societal norms and moral standards should be a central research topic.

Future-proof education

Up to now, digitalization has not been systematically incorporated into educational programmes. The planned promotion of digital skills and infrastructure (e.g. in the German 'Digital-Pact for Schools') seems necessary, but it is not enough. The conceptual combination of digitalization and sustainability requires a variety of initiatives in the education context. The WBGU shows how education could be 'future-proofed', which risks (e.g. 'fake news') should be countered, and where there is potential for more solidarity-based quality of life.

Public-service ICT

Information and communication technologies (ICT) have become a lot more important in society and are increasingly influencing citizens' lives. The public sector has a responsibility for the operation and content of public-service ICT. This is an important prerequisite for equal inclusion in societal life, for the provision of, and access to, digital commons, and as a locational factor for innovation, competition, employment and sustainable economic growth.

Digital technology as a gender bender?

Despite growing political attention, gender equality has not been achieved in any country in the world. Existing gender inequalities and stereotypes are reproduced in socio-technical systems such as the internet, and this can lead to new discrimination. Equal-opportunity measures are still necessary, and not only in the context of a two-gender understanding of the issue. Digital technology offers emancipatory potential by providing access to information and networking, exposing discrimination, and raising awareness in digital arenas for experimentation.

Digital self-tracking

Digital self-tracking apps supply people with information about their own bodies and offer comparisons with others. The WBGU uses this example to reveal the implications of healthcare-system digitalization and universal data collection and availability. The potentially better information base for users is partly offset by major quality deficits in data protection, data quality, collection and processing. In addition, users' privacy, personal freedom and self-determination could be restricted.

International division of labour

The ongoing digital structural transformation in the international division of labour will lead to a readjustment of the role of developing countries and emerging economies. Unequivocal conclusions on the impact of digitalization on the international organization of value chains are currently limited. On the one hand, there are large potential job losses due to digitally supported automation and production relocation processes; on the other, new markets are accessible, primarily via digital platforms.

Working environments of the future

Digitalization and sustainability transformation are radically transforming labour markets. People will continue to work in the future, but it remains to be seen how this can be embedded into society and organized in such a way that the functions of gainful employment as we know them today – securing livelihoods, social participation, the basis of self-esteem – can be guaranteed in the future. However, digital change and sustainability transformation offer opportunities to develop and establish new models for more sustainable working environments.

Digital commons

Based on common goods in general, digital commons are data, pieces of information, educational and knowledge artefacts in the public interest that are available to the public barrier-free. They must be protected from exclusionary use for profit maximization and from abuse. To this purpose, fundamental organizational, regulatory and financial decisions, e.g. obligations to provide information, are necessary to develop a public-welfare orientation using digital common goods.

Great Transformation towards Sustainability. This is followed by an explanation of the three dimensions of the WBGU's normative compass – *Sustaining natural life-support systems*, *Inclusion* and *Eigenart*. Human *Dignity* is both the explicit starting point and the target vision of the normative compass, since it is particularly significant in the Digital Age, and protecting it is a key priority in shaping digitalization.

Understanding the Digital Age

Chapter 3, 'Understanding the Digital Age', provides basic knowledge and develops a conceptual angle on the facets of the Digital Age. In order for digital change to be placed at the service of the Great Transformation towards Sustainability, the potential benefits and risks of digital technologies and solutions must be understood and globally oriented towards the SDGs. The Chapter analyses the historical development towards the Digital Age, its basic functions, key technologies and essential characteristics, as well as foreseeable changes to key areas of human civilization, i.e. to the environment, to human beings, society, the economy and technology. It becomes clear that the dynamics of digitalization are profoundly changing the conditions under which the Transformation towards Sustainability must take place. An evaluation of recent reports by international organizations shows that shaping the Digital Age to make it sustainable involves a lot of uncertainty, so that flexible governance is required. Charters for the Digital Age that have been proposed to date indicate the beginnings of a corresponding framework for action; however, they neglect the specific connection between digitalization and sustainability.

Actor constellations in the digital transformation

Chapter 4, 'Actor constellations in the digital transformation', raises the question of who will shape the Digital Age. An introduction to the theoretical principles of how a Transformation towards Sustainability can be shaped is followed by an analysis: assuming that digital change and the Transformation towards Sustainability would cause changes in humanity's leeway for creative action, would these shifts be to the benefit or detriment of individual actor groups? In addition to individuals, business (especially digital companies) and civil society, the WBGU focuses on tech communities, which it believes play a prominent role in the Digital Age. The WBGU identifies considerable shifts of power within the multi-level system of cities and municipalities, nation-states and international organizations, as well as among transnational actor groups operating across these levels. In some cases, they lead to blockades and unsustainable path dependencies, especially due to the lack of control and governance by nation-states and the international community. At the same time, new players, e.g. digital companies and tech communities, are opening up potential avenues of sustainability transformation that have hitherto not been seen among traditional companies.

Arenas of digital change

In view of the broad scope of the two topics of digitalization and sustainability, the WBGU uses a selected range of examples in its approach to *Chapter 5,* 'Arenas of digital change' (Box 1). The Chapter gives concrete examples to illustrate the status, prospects and challenges of digitalization in the face of the necessary global Transformation towards Sustainability. The arenas reflect the scientific state of the art; they are directly related to the issue of sustainability and are particularly important for the Transformation towards Sustainability. They thus provide a multifaceted impression of how digitalization can be shaped in the service of sustainability transformation. Some of the arenas are at the direct interface between the environment and digitalization, dealing, for example, with energy and resource consumption and land use. Others throw light on the interaction between digitalization and key social and economic dimensions of sustainability (e.g. the work in the future, international division of labour, digitally supported mobility). Finally, topics are addressed which, although already the subject of debate today, will only impact on society in the longer term (e.g. the development of collective global awareness). These thematic 'deep drillings' not only generate concrete material leading to recommendations for action and research; they are also one of the main sources informing the WBGU's perspective and messages.

Drafts for the future and visions on digitalization and sustainability

Chapter 6, 'Drafts for the future and visions on digitalization and sustainability', visualizes various different realms of discourse and possibility in a concise, narrative form. The Chapter merges selected elements from scientific and popular-science sources to form utopian and dystopian narratives. These narratives extrapolate trends into the future that are already incipient today, illustrating them and making them tangible. The distinction between utopian and dystopian aspects is not always clear-cut, and any classification is dependent on subjective assessments and cultural preferences. However, the dystopian visions reveal possible breaches of guard rails, such as the authoritarian total surveillance of people by digitally upgraded state institutions.

Preparations must already be made today to anticipate these breaches, in order to be able to recognize and contain at an early stage the threat they pose to sustainability goals.

Synthesis

Chapter 7, 'Synthesis', develops the connection between digital change and the Transformation towards Sustainability with its fundamental questions for the future. The following three 'Dynamics of the Digital Age' are presented to illustrate different, but acute areas where action is needed.

- *First Dynamic: 'Digitalization for sustainability' – using digitalization to protect the Earth system and ensure social cohesion:* Here, the focus is on the 2030 Agenda and its SDGs. On the one hand, the aim is for digitalization to make valuable contributions towards improving and accelerating solutions to global environmental and development problems. On the other hand, digitalization can also massively exacerbate existing sustainability problems and lead to severe societal distortions if no countermeasures are taken.
- *Second Dynamic: 'Sustainable digitalized societies' – realizing a new humanism and preventing digital totalitarianism:* This idea focuses on dealing with the fundamental societal upheavals triggered by digital change. Positive and negative development opportunities with corresponding challenges on how to deal with them are also apparent here. In the positive scenario, there is hope that digitalization will bring us closer to a humanist vision of a sustainable world society in the Digital Age. In the negative scenario, however, digitalization entails the risk that hollowed-out democracies and digitally empowered autocracies will destroy any previous sustainability achievements.
- *Third Dynamic: 'The future of Homo sapiens – discourses on drawing boundaries:* This Dynamic deals with the most fundamental of all sustainability issues: the future viability and identity of the human being itself, embedded in society and in the environment it has transformed. Here, the WBGU asks questions that sound futuristic, but are already highly topical today.

The key challenge for the world community is to develop a common vision for a sustainable, digitally supported future.

Global governance

Chapter 8, 'Global governance for the global Transformation towards Sustainability in the Digital Age', contains initial proposals on how the international community might agree on common guidelines, principles, regulatory and institutional frameworks, and ethically justified limits. The EU has a special role to play here: on the one hand in developing its own sustainable, digitally supported model for the future that differs from the existing models in China and the USA; on the other as a player on the international stage working towards a shared understanding in a multilateral network. The WBGU makes an initial, tentative assessment of the potential benefits and impacts digital technologies can have on sustainability and the SDGs, suggests a further development of the current understanding of sustainability, and presents a charter for 'Our Common Digital Future' as a stimulus for global processes.

The report closes with *Chapter 9,* 'Recommendations for action', and *Chapter 10*, 'Recommendations for research', which are summarized in the following.

Recommendations for action

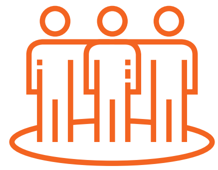
The Digital Age brings with it new challenges when it comes to the protection of fundamental and human rights. In the digital domain, the areas of protection and the options for exercising these rights are changing, so that new assurances are required here. Human dignity is the focal, unchangeable point of reference in this context. In this report, the inviolability of human dignity explicitly serves as a reference point for making digitalization sustainable. Closely linked to this is the need to ensure that the digital revolution is oriented towards the common good and embedded in a strategy of sustainable development. This requires creating appropriate frameworks and demarcations. Unless it is actively shaped, global digital change furthermore risks further increasing the threat to humankind's natural life-support systems. In its stirring paper entitled 'Digitalization: What we need to talk about', the WBGU (2018) formulated subject areas that are taken up in the following recommendations for action.

Sustaining the natural life-support systems

At present, digitalization is perpetuating existing trends towards rising emissions, increasing resource consumption, soil degradation and the destruction of ecosystems, and leading to the production of more and more electronic waste. There are no signs of the necessary trend reversal in which digitalization is completely decoupled from emissions and the pressure on ecosystems, although numerous international agreements are already formulating targets for sustaining natural life-support systems. These must be consistently underpinned by concrete policies and instruments at the national level and beyond. The WBGU recommends:

- *Use digitalization for the comprehensive pricing of environmental goods:* The manifold potential of digitalization for monitoring should be used to make all consumption of resources and all damage to natural life-support systems liable to taxes and charges, to decouple economic development and environmental damage, and to simultaneously avoid undesirable rebound effects from environmental policies.
- *Use digitalization for decarbonization and climate-change mitigation in the energy sector:* The potential of digital technologies should be used to switch to renewable energy systems. Energy and resource efficiency should be made explicit innovation targets for digital technologies and applications.
- *Circular economy, use of resources, toxic substances:* In the spirit of the circular economy, forward-looking product design in the field of electronic appliances should include longevity and ease of repair, and avoid using resources in ways that are harmful to the environment or to health. Electronic waste should be effectively recycled and illegal exports prevented.
- *Ensure sustainable land use and ecosystem protection:* In agriculture, digitalization should be utilized, among other things, to reduce the use of fertilizers and pesticides and to diversify cultivation methods and landscape design. Digitally supported monitoring helps protect ecosystems.
- *Support global (environmental) awareness and sustainable consumption through digitalization:* An obligation to provide digital information on the external effects of products should be introduced; this information should be made easily accessible to consumers (e.g. using footprints). Common-good-oriented platforms with a focus on sustainability should be funded, and the opportunities offered by virtual spaces and global communication networks used to promote transnational networking. Universities and municipalities could create arenas for experimentation to enable people to experience global environmental awareness in virtual spaces.
- *Actively involve companies in designing a digitalized, sustainable future economy:* Incentives should be created to encourage transparent value chains (e.g. certificates and product labels). Public procurement should be correspondingly geared towards sustainability targets.

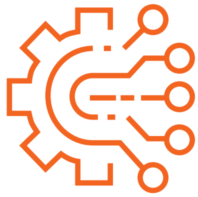
Poverty reduction and inclusive development



The use of digital technologies to combat poverty and promote inclusive development can only succeed if the necessary analogue foundation is in place and the use of technology is integrated into a strategy for a digitalized sustainability society. Digitalization influences the implementation of all 17 SDGs. It should therefore become a cross-cutting task of development policy, and this means developing corresponding skills. In particular, comprehensive use should be made of digital possibilities for resource protection and the mitigation of climate change. Cooperation with emerging economies should focus more on dialogue, scientific cooperation and global governance. Against this background, the WBGU concentrates on examples in the areas of infrastructure and education, urban development and mobility, and improved data applications in development cooperation. The WBGU recommends:

- *Consolidate the analogue foundation, e.g. infrastructures and education:* The use of digital technologies to combat poverty first of all requires bridging the digital divide by developing infrastructures, creating affordable access and promoting digital literacy.
- *Use digitalization to improve development cooperation:* The integration of data-based applications into development cooperation could potentially lead to the development of new solutions. Examples include coordinating humanitarian aid after an epidemic outbreak, supervising compliance with fishing quotas, and monitoring systems for measuring advances in development.
- *Gear the digitalization of cities towards sustainability criteria and inclusiveness:* If the use of digital technologies in urban development in the interests of the common good is to succeed, municipalities and urban societies must retain creative sovereignty and develop into inclusive platform providers.
- *Embed the use of digital technologies into sustainable and inclusive mobility strategies:* Cities should develop models of digitally supported, sustainable urban mobility that focus on health and quality of life. Digital solutions should be used to avoid individual motorized traffic, to improve access to emission-free public mobility, and to make cycling and walking safer.

Work in the future and reducing inequality



Labour markets, gainful employment and the international division of labour in its present form are currently undergoing profound changes. However, people will continue to work in the future. Joint research into digital change and the Transformation towards Sustainability offers opportunities to establish models for sustainable work in the future. The WBGU recommends:

- *Reform tax and contribution systems:* Tax and contribution systems should be used as a central lever for shaping the two processes of societal change. Consistently pricing environmental goods as part of a comprehensive social-ecological tax reform would make it possible to reduce tax burdens on earned income without restricting the state's financial leeway.
- *Secure and promote social standards for occupational health and safety:* Following on from the International Labour Organization's global dialogue process entitled 'The Future of Work We Want', an international initiative should be promoted to seek agreement on (minimum) standards in occupational health and safety and social security, and to negotiate a suitable representation of interests also for people in digital employment relationships.
- *Develop new distribution mechanisms:* New distribution and alternative participation concepts such as an (unconditional) basic income or more direct participation in company profits should be comprehensively scrutinized to determine their individual and societal incentive value. Work carried out in this context should be interdisciplinary and take into account the systemic implications, such as necessary reform steps for financing such mechanisms.
- *Establish a broader concept of work and new guiding principles:* There should be a conscious upgrading of activities and skills that contribute to sustaining the natural life-support systems (e.g. voluntary work) or make better coexistence possible by promoting *Eigenart* and societal inclusion (Figure 1). This can be done by creating free time or financial leeway and incentives, or by integrating these activities into formal labour markets.
- *International division of labour – press ahead with technology transfer:* Ongoing structural change will lead to a readjustment of the role of developing countries and emerging economies. In order to preserve jobs in developing countries and emerging economies, technology transfer should be pursued systematically.

Future-proofing education

Education enables people to carry out productive activities and to think up and implement societal innovations and transformations. To this end, educational content and formats must be in line with the key challenges facing society and promote digital literacy. Further pivotal factors here are equitable inclusion in high-quality formal education and providing educational opportunities in sectors and locations with intensive change processes. The use of digital possibilities can significantly improve access and provision; at the same time, direct experience remains indispensable. The WBGU recommends:

- *Set up an education pact to provide for periods of profound upheaval and digital dissemination in societies:* A new education pact for the 21st century should merge the broad content and personal competence concepts of Education for Sustainable Development and Global Citizenship with online media education, digital intelligence and an understanding of technology. This is equally in line with the kind of qualifications required for increasingly digital, agile and complex work environments.
- *Take education seriously as an investment in the future:* The German National Platform and the expert forums of the Global Action Programme on Education for Sustainable Development have set up structures that make it possible to negotiate an expansion of both the canon of content and strategic measures and projects. Necessary qualification measures and investments should now be defined in close cooperation with pioneers from real life and laid down in a roadmap over a period of, say, 10 years. To achieve this, significantly more funds than in the German 'DigitalPact for Schools' must be mobilized, and corresponding evaluation formats must ensure an upward spiral of ambition.
- *Provide prominent support for a continuation of the Global Action Programme on Education for Sustainable Development:* After the 2019 High Level Political Forum review of SDG 4, 'Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all', the focus in international cooperation should shift from monitoring to implementation barriers and to institutional and financial support for achieving the goals.
- *Strengthen an orientation towards the future in decision-making processes:* Societal understanding of plausible, possible and desirable futures and their political and technological design requires a reflective

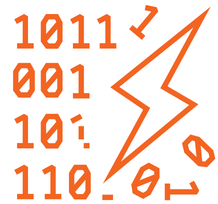
approach to trends and challenges. Anticipation and 'futures literacy' should be specifically promoted as new research and education subjects and consolidated in existing bodies; or else suitable future bodies should be created for the purpose.

Big data and privacy

In the age of big data, both the potential for the common-good-oriented use of data and the technical prerequisites for a totalitarian dictatorship are at a level which, historically, is probably the highest ever. In order to defend and preserve the foundations of free, democratic, peaceful and permanently sovereign societies in the longer term, it is essential to promote data protection, freedom from manipulation and informational self-determination, both nationally and globally. The WBGU recommends:

- *Focus more on sustainability in the use of data:* Sustainability aspects should be consistently taken into account when formulating national or corporate strategies relating to the handling of data.
- *Negotiate a United Nations Privacy Convention:* A United Nations Privacy Convention should be negotiated covering the global human right to privacy (Article 12 of the Universal Declaration of Human Rights; Article 17 of the International Covenant on Civil and Political Rights). Effective privacy protection should be integrated as a cross-cutting issue in all areas.
- *Sustainably protect individual privacy and the digital public sphere – prevent digital totalitarianism*: (Mass) surveillance that is not democratically controlled should be rejected, as it threatens the foundations of democracy. Data protection and data security should be guaranteed technically and organizationally, for example by the strict implementation of data security and data protection by design and by default.
- *Shape the digital structural transformation of the public sphere in a way that is innovative and oriented to the common good:* Informational self-determination should be guaranteed for society as a whole. Furthermore, a broader European or even global public sphere must be strengthened in the service of the common good.

Fragility and autonomy of technical systems



Digital technologies are taking on increasingly complex monitoring and control tasks, and societies and individuals are dependent on their reliability. It is therefore of the utmost importance to focus on protecting the systems from criminal activities, manipulation and espionage, but also from organizational and technical deficiencies and failures. Any transfer of decisions to automated systems in core societal areas should only be carried out in a way that is methodically and democratically safeguarded, and understandable for all those affected. The WBGU recommends:

- *Regard the security of digitalization as a prerequisite for the Transformation towards Sustainability:* Security requirements should always already be taken into consideration during the development of software and hardware (security by design). A European register of technical systems, their outages and damage should be built up.
- *Big data and algorithmic decision-making – create legally enforceable rights:* Lack of transparency and methodological weaknesses can lead to distorted algorithmic decisions. Decision support and decision-making must therefore be verifiable even if a decision is only partially automated. In order to increase enforceability, such decisions should be subject to judicial review by the people affected.
- *Regulate algorithmic decision-making:* There is a need for more transparency about procedures, the participation of civil society, better information for the people affected, and state supervision of algorithmic decision-making. Obligations relating to information and labelling for those responsible for decision-making, preventive monitoring of technical systems in critical areas of application under which the supervisory authority reserves the right to grant authorization, and liability rules should be discussed and established.

Economic and political power shifts

Digital technologies are shifting power and influence between states, companies and citizens. As a result of strong network effects and economies of scale, digitalization today is largely being shaped by a few, mostly private-sector stakeholders. Individual countries, too, are already making intensive use of digital technology to increase their state power. Digitalization will exacerbate existing social inequalities unless all people are equally given the opportunity to share in its potential. The WBGU recommends:

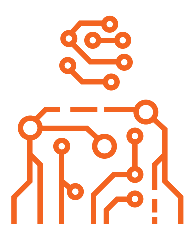
- *Create public-service ICT and digital commons:* All people should have non-discriminatory and barrier-free access to ICT infrastructures, to reliable and high quality data, information, services, knowledge and digital commons as a public service. Net neutrality and a reduction in discrimination should be ensured.
- *Strengthen competition on digitalized markets:* Competition-law regulations and procedures for determining market power and its abuse should be further developed and coordinated internationally. The role of data in the concentration of economic power should be addressed.
- *Contain state concentration of power with regard to the analysis of large amounts of data:* The example of China shows the dangers of a concentration of power that arise when state and economic power are interlinked with digital tools. Citizens of Western countries, too, are at risk from data-based surveillance and abuse of power by both private and state actors. Civil-society initiatives should be strengthened at all levels of governance to actively insist on the observance of human and civil rights.

Global governance for a sustainable Digital Age

The issue of 'digitalization and sustainability' is not robustly anchored in global governance architecture, nor is there agreement among the international community of states on a common framework for action. Furthermore, no suitable global governance has yet developed for the globally operating and dynamically developing international digital economy. The EU should play a leading role by developing and implementing a forward-looking vision and strategy for a digitally supported sustainable society. The WBGU recommends:

- *Call a UN summit on sustainability in the Digital Age with the aim of adopting a charter:* 30 years after the UN Conference on Environment and Development, Germany and the EU should support a 'UN Conference for a Sustainable Digital Age' in 2022. A key outcome of the UN summit could be the adoption of a charter by the international community on 'Our Common Digital Future'. In preparation for the UN Summit, a 'World Commission on Sustainability in the Digital Age' should be appointed, modelled on the 'Brundtland Commission'.
- *Ensure that the issue of digitalization is strongly anchored in the UN's institutional system:* In order to embed the issue of digitalization in work and strategy-building processes, consideration could be given to a UN mechanism for system-wide coordination ('UN Digitalization'). The most complex option from a negotiating standpoint, but potentially the most enforceable, would be a 'UN Framework Convention on Digital Sustainability and Sustainable Digitalization'. In addition, the state of scientific knowledge on all sustainability-relevant aspects of the digital transformation should be reviewed in regular assessment reports. A body similar to the IPCC or the IPBES should be set up for this purpose.
- *Create competitive advantages through an 'EU strategy for sustainability in the Digital Age':* Having its own model of a digitalized sustainability society would give the EU an opportunity to make an international name for itself as a sustainable environment in which to live and work. Guaranteeing data protection and merging digitalization and sustainability to form a model of the 'digitalized sustainability society' can be perceived by businesses and citizens as a basis for future locational advantages. Effective European data-protection instruments should be designed in such a way that they can be used as international standards to facilitate necessary adaptation beyond European borders. In view of the many unpredictable and rapid technological developments, 'European real laboratories for a sustainable and digital future' should also be established.

New normative questions – the future of *Homo sapiens*



Man-made digital technologies irreversibly influence and change not only the planet, but also human beings and prevalent ideas on what it means to be human. The relationship between humans, machines and the environment is dynamic because all three components can be changed by humans via technology. This raises fundamental ethical questions that must be discussed by society as a whole. The WBGU recommends:

- *Anchor research ethics, data protection and a shutdown option within brain-computer interfaces and* *brain-controlled neuroprostheses:* There is an urgent need for action here regardless of the stage of development, as digitally controllable prostheses and implants are already being used for curative purposes today. Contrary to today's common practice, compulsory encryption or shutdown functions should be included.

- *Approval standards and 'early warning systems' for products and services in the field of human-machine interaction:* A labelling obligation should be established for communication with a machine 'counterpart'. Moreover, due to the potentially far-reaching consequences for psychological integrity, corresponding licensing standards should be established for all socio-technological innovations, i.e. products and services related to human-machine interaction. Furthermore, a new, more anticipatory technology-impact assessment and early warning systems should be developed with regard to particularly vulnerable target groups.
- *Continuously adapt our understanding of the 'man – machine – environment' relationship.* Continuous monitoring of technical developments is necessary, especially with regard to human-machine interactions and interfaces, as a prerequisite for the transparency of the state of technical development, its potential and risks. Furthermore, a broader understanding of the future than a one-sidedly technology-oriented understanding is required for the critical and responsible anticipation of the future potential and risks of technological developments. In addition to expanding education to promote digital literacy, the foundations should also be further developed in science itself in the sense of research into the future, prognosis and technological change.
- *Create effective and inclusive discourse arenas:* 'Discourse arenas' should be set up to discuss digital-ethical topics in the context of a broad understanding of sustainability. These should include science, politics, business and potential users.

Research recommendations

Both the structure and the programmes of the German science system should be further developed in order to create and disseminate the knowledge required for digitalized sustainability societies, and to strengthen the role of science as a space for discourse and reflection. 'Transformation research' aimed at better understanding the importance of digitalization for fundamental societal change processes plays an important role here, as does 'transformative research', which, with its research findings, initiates and catalyses transformation processes towards sustainable development (WBGU, 2011:22f.). The contribution of science lies not only in stimulating relevant discourses and providing technically sound foundations for them, but also in developing new technologies for digitalized sustainability and preparing them for application. Table 1 provides an overview of the ideas that the WBGU proposes for the further development of fundamental and applied research, existing research programmes, and sustainable digitalization in industry. These are explained in more detail below.

Ideas for the further development of basic research

Since both digitalization and sustainability are cross-sectional topics, both should be put on the agenda and disseminated by the key actors in the science system (ideas for fundamentally oriented transformation research for digitalized sustainability societies). The WBGU's objective is thus to achieve a powerful inter- and transdisciplinary mainstreaming of these topics in all relevant areas of science itself, as well as in the exchange of ideas with business and society. The aim is to firmly establish, and then successively expand, both a broad understanding of sustainability in the spirit of the SDGs and a sustainable design of research linked to digitalization.

- *Found research institutes on the fundamental issues of digitalized sustainability:* The WBGU supports the initiative for a new Max Planck Institute in the field of 'Geo-Anthropology' (Rosol et al., 2018). In addition, because of the complexity of the fundamental issues involved in digitalized sustainability, the WBGU proposes the establishment of further research institutes – for instance under the umbrella of the Max Planck Society, the Leibniz Association, the Helmholtz Association or the Fraunhofer-Gesellschaft, or as federal or state government institutes – in order to be able to conduct research into the various facets of key questions of a digitalized sustainability society in a way that is free from economic and political constraints.
- *Set up a permanent DFG Senate Commission on Sustainability in Digitalization Research:* The WBGU recommends that the DFG establishes a permanent Senate Commission on Sustainability in Digitalization Research. The Senate Commission should draw attention to digital developments that raise scientific, ethical, legal or social questions and conflict with the conservation of natural life-support systems. It should also point out gaps in research-political and public discourses.
- *Formulate and further develop guidelines on sustainability and digitalization in universities and colleges:*

Table 1
Further development of the German research system showing the challenges of digital transformation in the Anthropocene. Source: WBGU

Strengthening of transformation research	Strengthening of transformative research
Fundamental research on transformation processes in the Digital Age	**Transdisciplinary and application-oriented research for digital change**
Set up research institutes on the fundamental issues of digitalized sustainability Ideas for the further development of fundamental research: › set up a German Research Foundation (DFG) Senate Commission on 'Sustainability in Digitalization Research' › guidelines for universities and R&D	Reciprocally extend research programmes for sustainability and/or digitalization and develop them further in a transdisciplinary way: › Horizon Europe › Future Earth › High-Tech Strategy 2025 › BMBF's Research for Sustainable Development (FONA) › Energy research programme Stimuli for sustainable digitalization in industrial research: › Sustainability lines for R&D › Sustainability-oriented target indicators

Universities and colleges should create, or enhance and implement, guidelines for their own practice on the sustainable use of digital methods and tools in university and college activities. For this purpose, they should seek ways to share and exchange know-how with faculties engaged in research on digitalization. The topic of digitalization should form an additional part of the BMBF project 'Sustainability at Universities' (HOCH^{N}).

Reciprocally intertwine research programmes on sustainability and digitalization and develop them further in a transdisciplinary way

The WBGU is in favour of a reciprocal reorientation of the current research priorities: on the one hand, research on digitalization should consistently incorporate sustainability aspects; on the other hand, sustainability research should be further developed in relation to digitalization and given a transdisciplinary orientation by incorporating real-world laboratories and arenas for experimentation. This can fill existing gaps in knowledge and generate more insights into the potential benefits and risks of digitalization for the transformation towards a sustainable structure of the economy and society.

- *Horizon Europe – embed digital sustainability in Europe:* In view of its great societal relevance, the paradigm of 'responsible research and innovation' should be implemented as a standard for research on digitalization and sustainability. Furthermore, the WBGU recommends structurally incorporating research on fundamental global challenges ('grand challenges') into the future framework programme on research, and focusing it more strongly on issues of sustainable development, digitalization and digitalized sustainability. In addition, the WBGU proposes the establishment of a 'Digital Sustainability Knowledge and Innovation Community' (KIC) at the planned European Institute of Innovation and Technology as a cooperative knowledge and innovation community together with industry.
- *Future Earth – extend sustainability research in the direction of digitalization:* Digitalization issues should be integrated into Future Earth as an important component, a global project on 'eSustainability' should be launched and a knowledge action network called 'Digitalization' created.
- *High-Tech Strategy 2025 – combine thinking on digitalization and sustainability more closely:* Sustainability should be embedded as a cross-cutting topic in the High-Tech Strategy and consistently considered alongside digitalization. As a new global development paradigm, the concept of welfare and the SDGs should be at the forefront of the High-Tech Strategy, and the focus should not be primarily on the concept of growth and international competitiveness. Social, ecological and cultural dimensions of innovations should be reinforced as strategic elements for achieving welfare. Sustainable digitalization, in the sense of its safe, resource-saving and energy-efficient design, should be manifested for every digitally supported implementation project. Digitalization for sustainability, in the sense of developing digitally supported solutions oriented towards the SDGs, should become an additional concrete mission of the High-Tech Strategy.

- *Link FONA[4] with digitalization:* The BMBF's Fourth Framework Programme, 'Research for Sustainable Development' (FONA[4]), should be used to strengthen and further develop the topic of digitalization within the goals of sustainability research. To achieve this, (1) the connection between digitalization and the 2030 Agenda should be made a topic for research, (2) digitalization should be taken into account to ensure the effective implementation of the SDGs, and discussions on values should be intensified, (3) the discussion should also include the issue that digitalization triggers fundamental societal changes. The Transformation towards Sustainability must therefore be re-considered.
- *The concept of the Federal Government's energy research programme should be broadened:* Not only market potential but also societal and environmental sustainability effects should be considered within the framework of R&D projects on energy technologies and systems. Societal and structural prerequisites in developing countries and emerging economies for designing sustainable energy systems should be given greater consideration in research funding, both in the development of new energy technologies and in the investigation of the necessary framework conditions.

Stimuli for sustainable digitalization in industrial research

Two thirds of annual R&D expenditure in Germany comes from the private sector. It is primarily concentrated on high-value technology sectors (BMBF, 2018). Companies are therefore important players in working towards sustainable digitalization.

- *Integrate ethics and sustainability aspects into in-house corporate research:* In order to encourage responsible innovation, the WBGU recommends that the dimensions of ethics and sustainability should be systematically taken into account in private-sector high-tech development – in the sense of responsible research and innovation (RRI). For this purpose, companies should, on the one hand, develop guidelines that consistently integrate ethics and sustainability aspects into their internal research. On the other hand, they should offer appropriate training and further-education programmes to empower developers to critically engage with conscious (e.g. privacy by design) and unconscious (e.g. gender stereotypes) assignments of values in technologies. In parallel, research on linking design ethics with professional ethics (such as the IEEE initiative on 'Ethically Aligned Design') should also be supported. Research funding should offer companies corresponding incentives.
- *Sustainability-oriented target indicators:* The range of instruments offered by digitalization makes it possible for companies to conduct a wide range of observational and analytical tasks. In order to be able to integrate sustainability goals more efficiently into production processes, companies should develop a set of sustainability-oriented target indicators. Companies could make targeted use of data on resource flows and energy consumption for this purpose. They should also forge ahead with the development of monitoring, warning and forecasting systems to ensure compliance with existing limit values.

Recommendations on the content of research on sustainable digital transformation

Compared to the speed and breadth of digital development, there is still not enough reliable knowledge about the impact of digital technologies on the Earth system, societies and people. As a result, socio-political discourses on the effects of digitalization – for example with regard to work in the future or energy and resource consumption – are characterized by contradictory assessments and a lot of uncertainty. Equally, there are only initial research results on digitalization's potential for achieving the SDGs and the question of how digitally supported educational measures can promote knowledge and action for the Great Transformation towards Sustainability. The WBGU proposes the following superordinate lines of research to create more knowledge for a digital sustainable transformation:

- *Research on digitalization for sustainability (First Dynamic):* How can digital technologies, digitalized infrastructures, as well as digitalized systems and end devices be made sustainable, especially with regard to their energy and resource consumption and the establishment of a circular economy? How can digitalization be used as an instrument to implement the SDGs and for decarbonizing today's economic and societal system?
- *Research for sustainable digitalized societies (Second Dynamic):* How can societies be preserved that are both capable of taking action and able to assess the system-changing impact and related uncertainties of digitalization, and can also proactively and sustainably shape that impact and successfully counter any unintended consequences? Important tasks for research include studying systemic risks and potential, developing new forms of inclusion in the context of work in the future, shaping human-machine interactions, and empowering the individual in digitalized sustainability societies. Research funding on the impact of AI on the digitalized sustainability society should be significantly increased.

- *Research on the future of Homo sapiens (Third Dynamic):* As a result of the transformation, being human is itself becoming a topic of sustainable development. To what extent should old and new human images be questioned in the light of possible interlinkages between humans and technology and the increasing cooperation between humans and machines? How can the preservation of human dignity be ensured?

Timely implementation of the recommendations for action and research will make it possible to exploit the potential of digital change for the Great Transformation towards Sustainability and to contain its risks. This WBGU report is therefore intended as a stimulus for long pending discussions and initiatives on all levels and with all actor groups.

1 Introduction

Digital change is epochal and opens the door to a new era of human development. Big data, artificial intelligence, the Internet of Things, cybersecurity and other digital applications will profoundly change systems of societal standards and values. They will also open up new opportunities and entail risks – in similar ways to the previous development of complex human language (about 70,000 years ago), the Neolithic revolution (about 11,000 years ago), the emergence of cities (about 5,000 years ago), the invention of the printing press (550 years ago), and the technological and societal upheavals since the beginning of the Industrial Revolution. Through new globally active actors, digitalization fundamentally changes living and working conditions, production patterns and the international division of labour, communication and information dissemination (and the possibilities for manipulation that this involves), international cooperation and, last but not least, international power constellations. But it is also a significant accelerator when it comes to the consumption of energy and resources. It is an open question whether it will be possible to make use of the new technological possibilities for globally sustainable development; it is also *the* political challenge of the coming decades: how can digital technologies be placed at the service of global sustainability?

This perspective, together with its long-term view well beyond the year 2030 (the target year of the Sustainable Development Goals – SDGs), sets the WBGU's report apart from most existing global studies on the topic of 'Digitalization and Sustainability', which see digital technologies only as an instrument, while their more far-reaching significance for the reorganization of societies and for shaping the future beyond 2030 is hardly discussed. The same applies to the question of which digital development trends should be avoided in order to sustain the natural life-support systems and social cohesion in our societies. Against this background, the present report reformulates the key issues of global sustainability policy in the context of digital change: How can a good life be provided within the limits of the Earth system for a global population that will soon reach 10 billion? Which economic, technological, institutional, social, cultural and normative innovations are necessary locally and globally to make prosperity, human well-being, democracy and security possible within the boundaries of the Earth system? How can local and global ecosystems be stabilized? How can welfare gains in industrialized countries, emerging economies and developing countries be systematically decoupled from resource consumption and the pressure on ecosystems, so as to avoid tipping points in the Earth system? How can a comprehensive decarbonization of the global economy be achieved by the middle of the century in order to stabilize global warming well below 2°C? How can such comprehensive transformations towards sustainability succeed at all within such a narrow time frame? How might such a change be shaped locally, nationally, regionally and globally?

In order to answer these questions and develop solutions, a bridge needs to be built between the networks of digitalization and sustainability – in science, business and politics. These networks have hardly been connected to each other up to now, but they will have to be interdependent in the future if a transition to sustainability is to succeed under the conditions of digital change. Digitalization research, which is highly technology-oriented, is an important driver of fundamental societal and economic change. However, as the WBGU's comprehensive literature analysis shows, it has so far dealt only marginally with the key issues of sustainability research. Similarly, the manifold effects of digital technologies on the Transformation towards Sustainability is a topic that has hitherto received little attention from sustainability research. What potential do digital technologies have for the Transformation towards Sustainability, especially for sustainable mobility, the demand for resources and raw materials, climate-change mitigation, sustainable land use or poverty reduction? This gap is filled by the present report.

Since digital technologies make it possible to change human beings to a previously unknown extent, and since human beings are at the focus of all sustainability considerations, the WBGU has greatly broadened the thematic radius of its deliberations on the topic of the

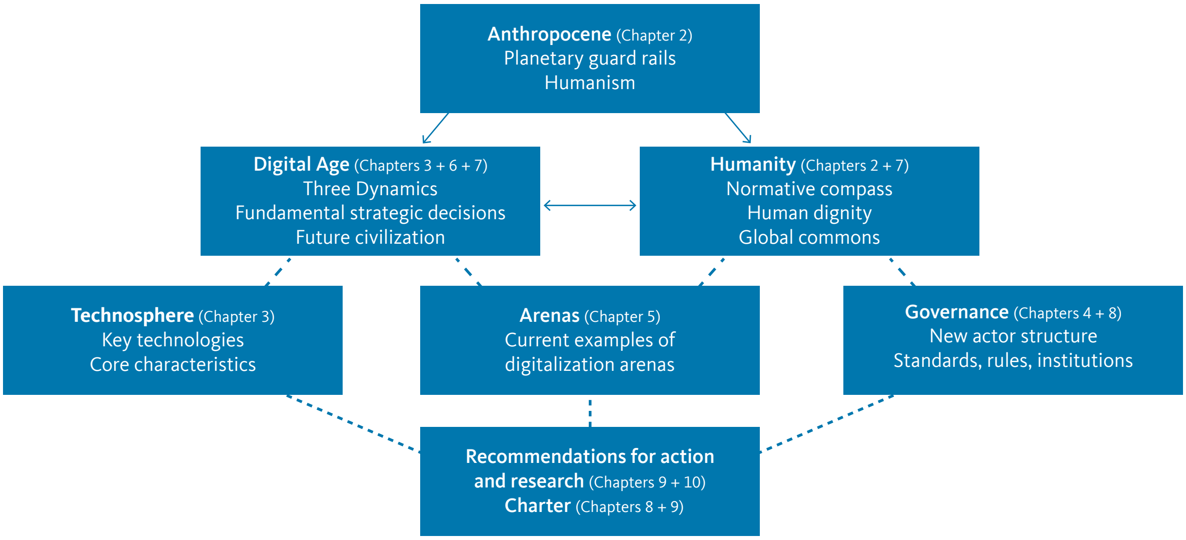


Figure 1-1
Overview of the topics covered in the flagship report.
Source: WBGU

'Environment and Development' in this report. It therefore also addresses fundamental normative questions such as human dignity.

Furthermore, shaping the transformation towards a sustainable society in the rapidly changing Digital Age is not just a question of implementation, it also involves a high degree of uncertainty. For this reason, this report also addresses, and makes recommendations on, the challenges of taking action under uncertain conditions and the role of science and research in this global creative task. Strategic foresight and technology-impact assessment are important elements for policy making.

The use of digital technologies for globally sustainable development is, after all, a new and hitherto little-examined challenge for global governance and policy-making at the national, regional and local levels. The report shows that, although many global initiatives have been launched, the international institutional structure is inadequately equipped to shape global digital change. At this point, the WBGU's reflections go back to the emergence of the Brundtland Report in 1987 and the Rio de Janeiro Earth Summit in 1992, and raise the question of how a similar new start and paradigm shift could be initiated and developed for the topic of 'Digitalization and Sustainability'.

Structure of the report

This introduction is followed by Chapter 2, 'Sustainability in the age of digitalization', in which the report's subject is embedded into the WBGU's perspective on sustainability. A central role is played here by compliance with planetary guard rails and social cohesion (Figure 1-1). The normative basis of the report is presented in the form of a 'normative compass', and references are made to enlightenment and respect for human dignity.

Chapter 3, 'Understanding the Digital Age', provides basic knowledge and develops a conceptual angle on the facets of the Digital Age. The chapter analyses the historical development towards the Digital Age, its basic functions, key technologies and essential characteristics, as well as foreseeable changes to key areas of human civilization, i.e. to the Earth system, the economy, society, human beings and technology. The main questions include: How are these spheres of life changing in the Digital Age? Which technologies need to be given special attention from the point of view of sustainability and ethics? How do international organizations in the field 'Environment and Development' address digital change?

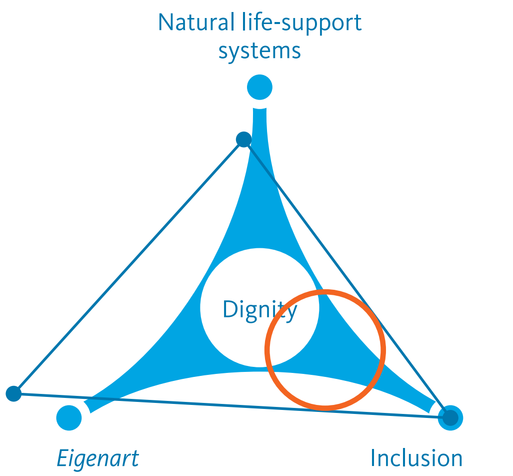
In Chapter 4, 'Actor constellations in the digital transformation', the WBGU examines how digitalization changes the ability of different actors to act, shape and plan, how it affects their power to steer the process of shaping global sustainability, and how the actors themselves influence digitalization.

Chapter 5, 'Arenas of digital change', deals with 21 selected fields of action that are particularly important for the Transformation towards Sustainability. Some of the arenas are at the direct interface between the environment and digitalization, dealing, for example, with energy and resource consumption or land use. Others throw light on the interaction between digitalization and key social and economic dimensions of sustainability (e.g. working environments of the future, the international division of labour, digitally supported mobility). Finally, topics are addressed which, although already the subject of debate today, will only impact on society in the longer term (e.g. the development of a collective global awareness for sustainable development).

Chapter 6, 'Blueprints of the future and visions for digitalization and sustainability', presents possible future scenarios of digital change. It describes conceivable utopian and dystopian developments and juxtaposes the opportunities and risks associated with them.

Chapter 7, 'Digitalization and sustainability – synthesis', describes the connection between digitalization and sustainability with its fundamental questions and dynamics moving into the future. Three 'Dynamics of the Digital Age' are presented. Action-guiding principles are presented for these three dynamics.

Chapter 8, 'Global governance for the Transformation towards Sustainability in the Digital Age', deals with the key challenges for international sustainability policy, and submits concrete proposals for political decision-makers and societies. Proposals are made on how the international community can agree on joint guiding concepts, principles, regulatory and institutional frameworks, and ethically justified boundaries. The report concludes with recommendations for action and research (Chapters 9 and 10).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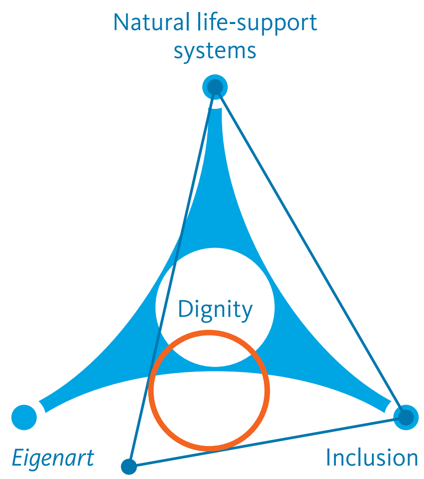
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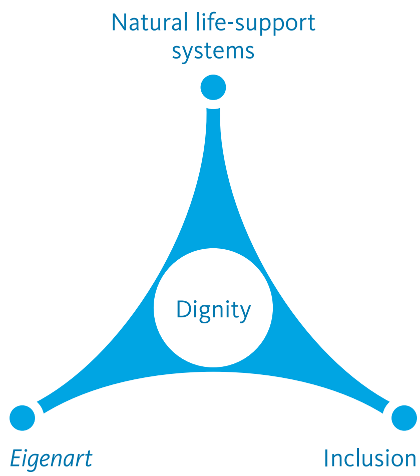
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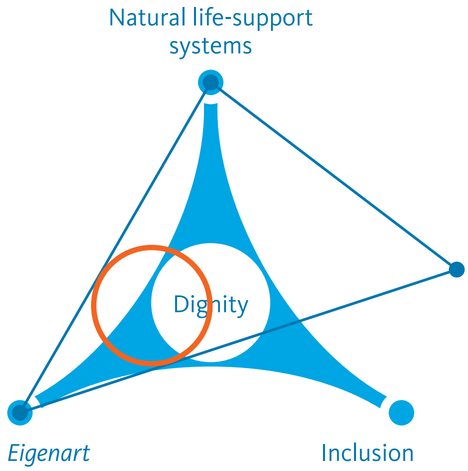
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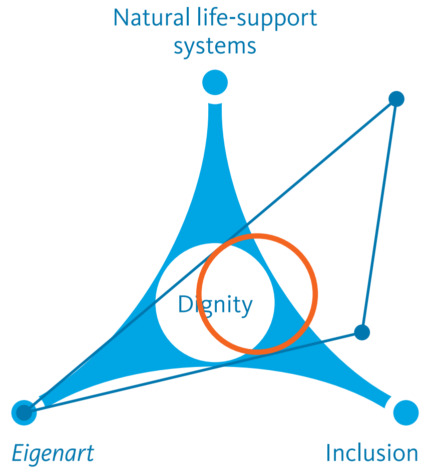
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Sustainability in the Age of Digitalization

2

The WBGU views digitalization from a sustainability perspective that explicitly draws on a foundation of critically reflected enlightenment and respect for human dignity. It proposes a 'normative compass', the dimensions of which include, first, sustaining natural life-support systems, second inclusion, and third *Eigenart* (a German word meaning 'character'). Human dignity is both the explicit starting point and the target vision of the normative compass, since it is of particular importance in the Digital Age, and protecting it is a key priority in shaping digitalization.

2.1
A comprehensive understanding of transformation must take the megatrend of digitalization into account

In 2015, two major world conferences paved the way for the Great Transformation towards Sustainability. In New York, the 2030 Agenda with its 17 Sustainable Development Goals (SDGs; Box 2.1-1) was agreed and in Paris a binding target was set to limit global warming to well below 2°C. Both agreements, the 2030 Agenda and the Paris Agreement, define a clear system of objectives and create the basis for a global transformation process. Based on the need to sustain the natural life-support systems, the WBGU regards the *Great Transformation towards Sustainability* as a global modernization process integrating both target systems and moving towards a low-carbon society (WBGU, 2011; WBGU, 2016b).

In the WBGU's view, the goals of any transformation are the basis for further in-depth societal debates. Change takes place as a learning and search process for society as a whole, shaped by actors from business, politics and civil society, as well as citizens and consumers. The WBGU regards societal participation and broad discourse among all actors as prerequisites for a democratically legitimized transformation. The Great Transformation cannot be shaped without an agreement on normative principles and without jointly developed or enhanced guiding concepts that describe the future in a new way (WBGU, 2011).

To provide orientation in the complex transformation processes, the WBGU has suggested a normative compass as a guiding concept for the Great Transformation towards Sustainability (WBGU, 2016a). Along with inclusion and the need to sustain the natural life-support systems, this compass takes into account diversity and formative freedom as fundamental prerequisites for a transformation process, captured in the German term *Eigenart* (Section 2.2).

This normative basis can be greatly influenced by fast technological and socio-cultural changes in the course of digitalization. Digital solutions are already fundamentally changing societal systems such as work or the dissemination of information and knowledge. Yet digitalization is hardly taken into account in the context of the Great Transformation and features only marginally in the SDGs. In this report the WBGU examines not only the impact of digitalization on 'sustaining the natural life-support systems', but also the challenges for 'inclusion' and '*Eigenart*' (Section 2.2). Both as a starting point and as a goal, the WBGU furthermore refers to the containment of technical and societal developments in order to protect human dignity.

Box 2.1-1

Transforming our world: the 2030 Agenda for Sustainable Development

In September 2015, the '2030 Agenda for Sustainable Development' was adopted by all member states at a UN summit in New York (UNGA, 2015). Together with the Paris Climate Agreement adopted in the same year, it is a multilateral milestone and key reference point for global efforts to achieve change towards an inclusive, responsible and low-carbon economy and lifestyle worldwide. The 2030 Agenda is an action plan of the international community for People, Planet, Prosperity, Peace and Partnership. These '5 Ps' form the five guiding principles of the 2030 Agenda.

- *People:* End poverty and hunger in all their forms and dimensions; ensure that all human beings can fulfil their potential in dignity and equality and in a healthy environment.
- *Planet:* Protection of the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that the Earth can support the needs of the present and future generations.
- *Prosperity:* Ensure that all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature.
- *Peace:* Foster peaceful, just and inclusive societies which are free from fear and violence. There can be no sustainable development without peace and no peace without sustainable development.
- *Partnership:* Mobilize a revitalized Global Partnership for Sustainable Development, based on a spirit of strengthened global solidarity, focused in particular on the needs of the poorest and most vulnerable and with the participation of all countries, all stakeholders and all people.

At the heart of this concrete vision, and the core elements for its implementation, are a catalogue of 17 Sustainable Development Goals (SDGs) with 169 associated targets which are integrated and indivisible. The SDGs combine all three classic dimensions of sustainability and integrate ecological, social and economic aspects of sustainable development. The SDGs are as follows (UNGA, 2015):

SDG 1 End poverty in all its forms everywhere.
SDG 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
SDG 3 Ensure healthy lives and promote well-being for all at all ages.
SDG 4 Ensure inclusive and equitable, quality education and promote lifelong learning opportunities for all.
SDG 5 Achieve gender equality and empower all women and girls.
SDG 6 Ensure availability and sustainable management of water and sanitation for all.
SDG 7 Ensure access to affordable, reliable, sustainable and modern energy for all.
SDG 8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
SDG 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
SDG 10 Reduce inequality within and among countries
SDG 11 Make cities and human settlements inclusive, safe, resilient and sustainable.
SDG 12 Ensure sustainable consumption and production patterns.
SDG 13 Take urgent action to combat climate change and its impacts.
SDG 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
SDG 15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
SDG 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
SDG 17 Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

The 2030 Agenda has replaced the Millennium Development Goals (MDGs) as a new sustainable development agenda. With its comprehensive system of goals and targets, it has succeeded in combining classic development goals such as overcoming poverty and hunger with classic environmental goals such as the conservation of ecosystems, and in further developing them in an integrated way. The 2030 Agenda is therefore also an important innovation in global governance: for the first time, states have committed themselves in this breadth and concrete detail to a universal political action plan, i.e. one that applies to all. In contrast to earlier development agendas, it is no longer only developing countries and emerging economies that are addressed and called upon to take action; the title 'Transformation of our world' concerns everyone, also industrialized countries.

Although the universality of the 2030 Agenda is an important breakthrough, its target system is non-binding under international law. Its implementation is the responsibility of the nation states and depends on intensified cooperation in existing and new Global Partnerships – explicitly including the contributions of a broad spectrum of actors ranging from (sub-)national governments, local authorities, civil-society organizations and philanthropy, science and universities, to micro-enterprises, cooperatives and multinational enterprises. Children, young women and men are also addressed directly as "critical agents of change" who now find in the 17 SDGs "a platform to channel their infinite capacities for activism into the creation of a better world" (UNGA, 2015: 12). Like the Paris Climate Agreement, the 2030 Agenda is therefore a central attempt by the international community to define a global perspective of the common good and to establish it as a nexus of global cooperation (Messner and Scholz, 2018).

Implementation has been disappointing to date, however. The central governance instrument is limited to short, voluntary national reporting on efforts and progress to the annual plenary sessions of the UN High-Level Political Forum on Sustainable Development (HLPF). More than 150 voluntary national reviews had already been received by 2019 (UN, 2019). However, the pressure to act and systematic accountability within this framework are still inadequate – which is why the review mechanism and the participation of non-state actors should be reformed and substantially improved (Beisheim, 2018; Sections 9.3.1, 4.2.8).

Although the currently slow pace of implementation is a problem known in international politics, the importance of the 2030 Agenda should not be underestimated. With its universal catalogue of objectives, it is not only a guiding concept for global sustainability policy and a central paradigm of global governance, it also emphatically calls for a polycentric architecture of responsibility for the "transformation of our world" (Chapter 4).

Digital change can also play an important role in achieving the SDGs; this involves new opportunities as well as new risks (Section 8.2).

2.1.1 Digitalization poses fundamental challenges to the Great Transformation towards Sustainability

In this digitalization report, the WBGU takes technological developments as the starting point for its analysis. Digitalization impacts on the physical coupling processes between infrastructures and the Earth system. In theory, they thus offer enormous potential for the sustainable use of resources and for sustaining natural life-support systems. For example, decarbonization can be promoted by intelligent networking and feed-in regulations for renewable energies, and the environment can be spared through precision agriculture. However, digital technologies do not only provide the fundamental infrastructure for controlling the industrial metabolism, they also consume resources themselves (Rosol et al., 2018). In addition, there are interactions between societal and economic processes and digital infrastructure systems. Depending on economic framework conditions, societal fields such as employment conditions (e.g. work automation) and individuals' social and financial resources can change. As an accelerator of existing and not-very-sustainable forms of production and consumption patterns, digitalization also poses dangers for the Great Transformation, threatening to increase the likelihood of planetary guardrails being breached.

Starting from the various interactions between sustainability goals on the one hand and rapid technological developments and changes for society, the economy, technological systems and individuals on the other, the WBGU examines three dynamics of the Digital Age:

The *First Dynamic* (Section 7.2) concerns the concrete combined approach to digitalization and the Great Transformation. On the one hand, digitalization has the potential to solve global environmental and development problems better and faster. On the other hand, if it is not shaped and, where necessary, countered, digitalization can exacerbate existing environmental problems and inequalities (Chapter 5; Table 5.1-1).

With the *Second Dynamic* (Section 7.3) the WBGU looks at incipient changes in societal and economic areas (such as the future of work or digitalized education). Fundamental questions on societal forms – such as data handling, privacy, security, health, inequality, the rule of law, well-being and the common good – are becoming more relevant as a result of digital technology.

The emerging *Third Dynamic* (Section 7.4) involves uncertainties and tense debates about fictitious futures for humanity that have been spawned by digitalization (e.g. Kehl and Coenen, 2016). Questions are raised about what it means to be human and the *conditio humana* – i.e. human beings themselves (Box 2.1.1-1, 2.1.1-2)

2.1.2 Combining our thinking on digitalization and the Great Transformation directs attention towards human beings themselves

The possible consequences of digitalization for individuals and society require the WBGU to emphasize its normative compass even more explicitly than before as a starting point and orientation aid for the debate – and to call for digitalization to be shaped for the benefit of society.

Digitalization raises the hope that new technological and societal breakthroughs could make it possible to fully develop civilizational and human potential. The WBGU proposes using the diverse challenges of the interaction between digitalization and the Great Transformation as an opportunity to focus on human beings and their potential for development. In the second half of the last century, humanistic psychology, which was developing at that time, showed that people draw satisfaction and well-being from being able to be – or become – themselves (Rogers, 1963). In contrast to the psychoanalytical approach, human beings were credited with a self-reflective understanding of their needs and the possibility of self-development (Maslow, 1974; Rogers, 2002). The tradition of psychological humanism summarized here ties in with modern humanistic trends (Box 7.3-2).

The WBGU takes up this positive notion of self-realization through self-reflection; it is seen in humanistic psychology as a prerequisite both for empathy and for creativity in the sense that people are in principle open for experience, express their ideas and impulses, and can actively shape themselves and their environment (Maslow, 1974). With digitalization, another new phase is beginning in which human curiosity, diversity and physicality can be freed from material limitations and

Box 2.1.1-1

Ethics of technology and responsible computer science

New, often unforeseeable problems are frequently created when solving problems with the help of technology (Grunwald, 2012: 81). The societal and technological results of the Enlightenment are therefore contradictory and should be subjected to critical scrutiny. Only humans bear the responsibility for the technologies created by them and their consequences. Thus Hans Jonas' principle of responsibility, according to which the effects of human actions must be compatible with securing genuine human life on Earth and all (technical or political) actors have a responsibility to maintain the conditions for a dignified existence (Jonas, 1979), also applies here. In the context of digitalization, Joseph Weizenbaum (1986) reminded "computer professionals" of their "power to alter the state of the world fundamentally and in a way conducive to life" (Weizenbaum, 1987: 43). Since in extreme cases information processing can both save lives (e.g. in medicine) and kill (e.g. in drone warfare), in the sense of Enlightenment 2.0, this power must be used and promoted as much as possible (Ullrich, 2014: 698). Thus, there is a need for an "enlightenment about digital enlightenment", which is capable of "distancing itself intellectually from the digital zeitgeist, instead of merely trying to disseminate it" (Capurro, 2017: IX). Digitalization is a human endeavour and should use pro-active technology design to pursue objectives that serve the general public, human dignity and autonomy. Although many areas in the world are being modelled with increasing success using methods of computer science, this does not change the fact that these are models, and models always simplify reality. Its numerical and thus computable representation in data sets becomes problematic if the model is inadequate and its simplification too crude, thus ignoring or even distorting essential elements (Ito, 2018). Where people are the object of the representation, the danger is not only that they are inadequately categorized on the basis of selected behavioural data and thus reduced to individual aspects of their existence; rather, the individuals are not perceived in their entirety but as mere objects. The only parts seen are those that can be depicted in the model; the rest is ignored. This is not compatible with a concept of humankind that is oriented towards dignity and freedom. Examples include deficient software for 'predicting' recidivism among prisoners, or the excessive use of scoring procedures (Ullrich, 2018: 11). In short therefore, in terms of the Enlightenment, we must ask "whether we have the technology we need" and "whether we need the technology we have" (Kornwachs, 2009: 39). In other words, technology must be there for the sake of humans, not humans for the sake of technology.

constraints, and the conditions needed to largely overcome deprivation and conflict and for self-realization can at last be created for all people. The WBGU's vision here is that of a more profound humanization of people with the help of technical systems. Digital technologies are already enabling and universalizing transnational communication, networking, and information and knowledge growth in unprecedented ways. The conviction inherent in humanism that rational people become capable of cooperation and civilization by reflecting and living out their needs (as also formulated in the United Nations Universal Declaration of Human Rights in 1948; UN, 1948) is seen by the WBGU as the starting point for the hope that digitalization can strengthen these human abilities and even help them develop further.

The emancipatory hope of a *new humanism with digitalization* can only be legitimized and realized as a societal process of searching and shaping. The WBGU therefore sees an urgent need to create spaces for a discourse on democratic self-understanding about possible futures (Schöppner, 2016). The WBGU proposes regarding digitalization and the associated societal discourses on education and transformation as an opportunity to examine the future viability of societies. The aim is not to prepare people for a changed digital environment, but to create a framework in which human potential can develop in a digitalized and ecological environment.

In concrete terms, this means empowering people to shape the future, and reflecting on our current understanding of education. Historically, every great transformation of societies has been accompanied by a transformation of rules and norms, of thinking, forms of communication, and culture. These immaterial changes often took place before the structural ones: human observation, reflection and imagination drive deviations, experiments and innovations.

The 2013 report by the International Social Sciences Council (ISSC) and UNESCO introduced the concept of futures literacy (future viability): "people's capacity to imagine futures that are not based on hidden, unexamined and sometimes flawed assumptions about present and past systems" (ISSC and UNESCO, 2013: 69). The ability to imagine and evaluate futures is influenced by the individual world views of actors acting intentionally and also by a striving for power, interests and a sense of justice. The central idea for the implementation of sustainability is that of reflection: "systematically exposing blind spots, allowing us to experiment with novel frames for imagining the unknowable future, and on that basis, enabling us to critically reassess actions designed in the present" (ISSC and UNESCO 2013). Here, future is not understood as a condition to be predicted as accurately as possible – a future that is approaching and for which we must prepare. The future is regarded as a result of decisions made and actions taken today that is pre-structured, but open in the long term. This also means that future is not singular, but that many different futures are conceivable. Thus, the discussion about shaping the future comprises both plausible and possible as well as desirable futures. In order to make necessary or structurally forced transformation processes as democratic and conflict-free as possible, it is therefore important to be aware of this selective effect of paradigms and assumptions about the world. Looked at positively, it could be said that a society's ability to reflect and its level of education directly influence its transformability and future viability.

2.2 The WBGU's normative compass in the Digital Age

In 2016, the WBGU presented a normative compass (WBGU, 2016a) as an extended normative foundation for the Great Transformation towards Sustainability (WBGU, 2011; Section 2.1) – and spelled it out with a view to the transformative power of cities. In the present report, this compass is applied to the specific challenges of digitalization. The compass offers three basic orientations relating to the need to sustain the natural life-support systems, ensure inclusion and secure *Eigenart*.

2.2.1 Sustaining the natural life-support systems

Sustaining the natural life-support systems is a core concept of the Great Transformation towards Sustainability and forms one of the three dimensions of the normative compass developed by the WBGU (2016a: 133). On the one hand, this dimension includes compliance with planetary guardrails, the breaching of which would have intolerable consequences either today or in the future. On the other hand, it involves avoiding local environmental problems whose impacts may result in complex interactions with global environmental changes (WBGU, 2016a).

Digitalization exerts a fundamental influence on our current ways of life and doing business; it is thus also changing our options for sustaining the natural life-support systems and securing a long-term, solidarity-based quality of life on our planet. The various effects of digitalization on resource and energy consumption must be critically examined in terms of their impact on the geophysical, biological and atmospheric processes of the planet and of local environments (e.g. Sections. 5.2.1, 5.2.6). An extensive global assessment of these effects is currently not possible, not least because of the difficult data situation (Köhler et al., 2018). However, their increasing relevance is not disputed – especially in view of the urgency of global and local ecological problems. This makes it necessary to actively shape digitalization in such a way that planetary guardrails and local environmental changes are taken into account. Two core questions result from this requirement. Firstly, to what extent can the opportunities offered by digitalization contribute towards sustaining the natural life-support systems? Secondly, how can the rapid processes of change associated with digitalization be prevented from exacerbating existing ecological crises? The sustainability dimension of the normative compass provides a fundamental orientation aid in answering these questions.

2.2.1.1 Planetary guardrails for global environmental change

The concept of planetary guardrails developed by the WBGU since 1994 (Box 2.2.1-1) defines "quantitatively definable damage thresholds, whose transgression either today or in [the] future would have such intolerable consequences that even large-scale benefits in other areas could not compensate these" (WBGU, 2011: 32). The concept was taken up by Rockström et al. (2009) and Steffen et al. (2015b) as 'planetary boundaries' and, in part, even adopted as a political target (e.g. stopping global warming below the 2°C climate guardrail of the Paris Agreement). In its reports, the WBGU has developed planetary guardrails for specific areas, including climate (WBGU, 1995, 1997), poverty (WBGU, 2005) and the oceans (WBGU, 2006). The WBGU refers to the following six guardrails (Box 2.2.1-1; WBGU, 2014b):

- Limit climate change to a maximum of 2°C,
- limit ocean acidification to 0.2 pH units,
- stop the loss of biodiversity and ecosystem services,
- stop land and soil degradation,
- limit hazards due to pollutants with a long life-span (e.g. mercury, plastics, fissionable material),
- stop the loss of phosphorus.

The resource and energy effects of digitalization have a substantial impact on the possibility of complying with planetary guardrails. For example, there should be a critical examination of digitalization's impact on the possibility of complying with the 2°C climate guardrail, on stopping land and soil degradation, and on establishing more sustainable consumption patterns. In addition to the hoped-for efficiency gains and possibilities for resource conservation through a circular economy or dematerialization, rebound effects should be taken into account, as should possible increases in the demand

Box 2.1.1-2

Transcending humankind? Concepts of humankind in trans- and posthumanism

Trans- and posthumanism are philosophical movements that rethink the traditional conception of what it means to be human (Table 2.1.2-1). Unlike the humanist ideal, which seeks to emancipate the responsible human being from the 'animal and barbarian' through culture and education, the aim of transhumanism is to use the possibilities of scientific and technological progress to expand human capabilities, thereby initiating a new stage of human evolution. In technological posthumanism, on the other hand, the focus is on transcending humans and their physicality by creating a technology-based species. Critical posthumanism distances itself from these schools of thought. It concentrates on the critical further development of the humanistic world view, negating the special position of humans assumed in humanism and looking at humans as part of a continuum of nature, culture and technology.

The term transhumanism was coined at the beginning of the 19th century; as a school of thought it has developed into a movement since the 1950s (Loh, 2018: 34ff.). However, this movement is just as heterogeneous as the many orientations and approaches that the term incorporates (Coeckelbergh, 2018: 81). Among the supporters of this movement, economic liberals and libertarian representatives of Silicon Valley (e.g. Kurzweil, Thiel) in particular have attracted a lot of attention (Kehl and Coenen, 2016).

Transhumanists argue that advances in areas such as AI, nanotechnology, biotechnology and neurotechnology will expand the human being's natural abilities to reach a new stage of evolution. The transformation into a posthuman being will, it is claimed, be brought about using such emerging technologies as regenerative medicine for improving human characteristics (such as health and intelligence). The logic of improvement, body control and disembodiment has had a formative effect on the discourse on human enhancement, which aims to overcome existing boundaries of body and mind (Kehl and Coenen, 2016) Technological posthumanism, by contrast, is oriented towards more speculative technologies such as the transfer of consciousness to computer systems (mind uploading) to overcome human corporeality and to achieve the eternal existence of the individual mind (Ferrando, 2014). Furthermore, representatives of both movements discuss opening up new habitats such as outer space with people adapted to the living environments there, or even using artificial super intelligence.

The ideas of both movements, which cannot always be clearly distinguished, are controversially discussed not only with regard to their concept of humankind, which focuses on its shortcomings, but also with regard to a "philosophical naïvety" and contradictory arguments (Loh, 2018: 15). The basic philosophical insight into the limits of human experience and knowledge is frequently missing, as is the epistemological virtue of corresponding modesty (Coeckelbergh, 2018: 92). The often inadequate understanding of human happiness and the probable overestimation of technical possibilities are also criticized: "Transhumanism is usually based on a utilitarian ethic, whose central orientation towards usefulness – for the individual or for a community – is not subject to the proviso of human dignity, however defined" (Schöppner, 2016: 47). The experience of and behaviour towards suffering is rather "an essential dimension of human self-conception shared by many" (Schöppner, 2016: 47). Furthermore, it is claimed, the supposed transcending of human vulnerability during the process would inevitably lead to new vulnerabilities and thus create further physical or psychological suffering (Coeckelbergh, 2013a: 19ff.)

Both transhumanism and technological posthumanism "largely ignore the fact that an (individual) human being [...] cannot be completely controlled, calculated and predicted as 'humankind'" (Loh, 2018: 79). Such simplification "on the one hand involves a kind of trivial anthropology, and, on the other, a fatalism that is frequently even expressed explicitly"

Table 2.1.2-1
Typology of present-day humanisms.
Source: modified on the basis of Loh, 2018: 14, 31

	Humanism	Transhumanism	Technological posthumanism	Critical posthumanism
Method/ Concept of humankind	Enlightenment, autonomy; culture and education as subjective activities	Human being as an object of technological 'improvement' to Human X.0	Transcending humankind by creating a technology-based species	Further development of the humanistic concept of humankind and criticism of trans- and technological posthumanism
Role of technology	Ambivalent	Medium and means	(Priority) aim and purpose	Core category of criticism
Post-human being/creature	–	Human X.0	(Primarily) artificial new being/creature	New understanding of the human being
Body and mind	In harmony	Are transformed	Transcending the body ('everything is information')	In harmony
Emancipation	From the animal and 'barbarian'	From Human 1.0	From humans *per se*	From the humanistic concept of humankind

(Loh, 2018: 80). Methods of human enhancement (see Topic box 5.3-2) are essentially contrary to humanist education, since transhumanism – unlike humanism – "degrades humans to a passive object of design" (Loh, 2018: 84; see also Damberger 2016). In addition, visions of the future 'posthuman' commit an epistemological category error, since the goal of human self-transformation lies outside the human horizon of experience. Technological posthumanism's reduction of the mind to a collection of information in turn raises the question of whether the essence of a human being can actually be expressed in terms of information (Damberger, 2016: 32ff.). It is also questionable whether, in the vision of mind uploading, the copy of a person is still 'the original'.

By contrast, the perspective of critical posthumanism (Braidotti, 2014; Mol, 2002), which has been emerging since the 1990s and is based on the humanistic foundation of digital environmental science, sees a continuum of nature, culture and technology. For this reason, the 'post' does not refer to a futuristic world 'after' humankind, but stands for a new humanism beyond anthropocentrism that does more justice to the diversity of humans in their environment. The posthuman subject is understood as complex, embodied, embedded, relational and affective and unfolds agency and consciousness from collaborative, more-than-human processes (Braidotti, 2014; Haraway, 1991; Bennett, 2010). In the age of digital and ecological transformations, differentiated analyses of these links are necessary in order to "critically and creatively reflect on who or what we are in the process of becoming" (Braidotti, 2014: 17).

This posthuman sensitivity thus makes it possible to deal with the complex ethical and political issues of digitalization and ecological crises without falling back on the mental barriers of the historically formative dualisms of body and mind, nature and culture, nature and technology. In these ethical discussions the focus really is on humanistic values of justice, as well as on individual and collective freedom and responsibility (Braidotti, 2014; Rose, 2017). It is not a question of reversing the achievements of the Enlightenment and humanism, but of extending them to do greater justice to the multitude of human-techno-ecological realities. Posthumanism in the critical sense "thus does not mean being indifferent to human beings or dehumanized"; on the contrary, it "involves a new connection between ethical values and the well-being of the community in a more comprehensive sense that also includes our territorial and ecological interrelations" (Braidotti, 2014: 193). Critical posthumanism also deals with the question of whether not only *Homo sapiens*, but also other living beings or even entire ecosystems should have a right to exist in dignity (Holland and Linch, 2016; Whatmore, 2002).

for energy or negative consequences of novel material flows which should be prevented (Köhler et al., 2018; Arvidsson and Sandén, 2017).

Technical developments can help our understanding of the Earth system with its complex interactions, tipping points and planetary guardrails. Examples include the real-time measurement of temperature, salinity and ocean currents, which have become indispensable for the climate and marine sciences (e.g. Roemmich et al., 2009). Scientists have been trying to maximize these advances since the 1990s. Under the catchphrase 'Digital Earth' they hope to give every person digital access to a scientifically sound model of the Earth that makes historical and future changes to the planet tangible and understandable in detail (Goodchild et al., 2012; Section 3.3.5.1).

2.2.1.2
Local environmental problems

In addition to global guardrails, specific environmental problems must also be kept in mind – even and especially if their effects only show themselves in the local context or are limited to individual states, regions or (e.g. marginalized) population groups. Local environmental changes often interact with global phenomena, are amplified by them or can, in turn, amplify them (WBGU, 2016a: 134). Numerous increasingly globalized economic processes, such as textile production, mining or aluminium production, are already having concrete impacts on local environmental systems. In many cases, effects like these follow the pattern of the externalization society (Lessenich, 2016), according to which the costs of the lifestyles of the wealthier countries and population groups are predominantly shifted to poorer countries and population groups.

Such local or regional pressures on ecosystems, which become invisible from a globally aggregated perspective, can also be caused or promoted by digitalization. For example, the extraction of raw materials critical for information and communication technologies, such as rare-earth elements, precious metals and rare semiconductor materials, has highly differentiated effects on local ecosystems and population groups (Yang et al., 2013). The high innovation frequency of the digital economy and the planned obsolescence of digital end devices also leads to a continuous increase in global electrical and electronic waste (Section 5.2.5). In the future, local environmental problems are likely to be exacerbated by the further development and diffusion of such technologies as wearable computing, pervasive computing and the Internet of Things (Köhler et al., 2018). Given the momentum and speed at which digital innovations are changing global and resource consumption, normative guidelines such as planetary guardrails and the avoidance of local environmental problems are important for shaping digitalization in the sense of the Great Transformation towards Sustainability.

Box 2.2.1-1

Planetary guardrails

The concept of planetary guardrails developed by WBGU since 1994 pursues the approach of identifying those states of the Earth system that should be avoided at all costs in order not to endanger humanity's natural life-support systems. Since then, the WBGU has proposed and substantiated guardrails for very different areas of global change, such as climate change, biodiversity, ocean acidification, sea-level rise and soil protection (WBGU, 1997, 2000, 2006, 2009b). The concept was taken up and further developed by Rockström et al. (2009) and Steffen et al. (2015b) with the concept of 'planetary boundaries'. International policy also includes approaches that correspond to the idea of planetary guardrails – e.g. the goal agreed in the Paris Agreement to limit the global temperature increase to well below 2°C.

The WBGU has described planetary guardrails as quantitatively definable damage thresholds, whose transgression either today or in the future would have such intolerable consequences that even large-scale benefits in other areas could not offset this damage (WBGU, 2011: 32). Firstly, however, it should be noted that guardrails do not represent clear-cut system boundaries where all damage could be averted on this side of the guardrail, and severe, direct damage or disasters would have to be expected beyond the guardrail. Secondly, the quantification of guardrails is always a normative act, since the demarcation between tolerable and intolerable consequences is necessarily based on values. Science can make well-founded proposals here, but the decision on setting guardrails should be subject to a democratic process.

Building on this work, the WBGU proposed a set of six guardrails in a policy paper in 2014 and gave detailed reasons for them (WBGU, 2014b). This paper also contains a detailed discussion of the background to the guardrail concept. The proposed guardrails are:

1. *Limit climate change to a maximum of 2°C:* In order to comply with this guardrail, global CO_2 emissions should be reduced to zero by about the middle of the century; emissions of other greenhouse-gas emissions should also be reduced.
2. *Limit ocean acidification to 0.2 pH units:* Compliance with this guardrail also requires CO_2 emissions to be reduced to zero. Other greenhouse gases, on the other hand, do not influence ocean acidification.
3. *Halt the loss of biodiversity and ecosystem services:* To achieve this, the anthropogenic drivers of biodiversity loss – e.g. the conversion of natural ecosystems – should be halted by 2050 at the latest
4. *Halt land and soil degradation.* Net land degradation should be stopped worldwide by 2030 – globally and in all countries.
5. *Limit the risks post by long-lived and harmful anthropogenic substances (e.g. mercury, plastics, fissile material)*: The substitutable use of mercury and anthropogenic mercury emissions should be stopped by 2050. The release of plastic waste into the environment should also be stopped worldwide by then. The production of nuclear fuel for use both in nuclear weapons and in civilian nuclear reactors should be stopped by 2070.
6. *Halt the loss of phosphorus:* The release of non-recoverable phosphorus into the environment should be stopped by 2050; phosphorus recycling should be achieved worldwide.

2.2.2
Inclusion – the basis for a good life

Societal inclusion for all is an essential goal of the Great Transformation towards Sustainability because, without it, "neither a good life nor sustainable development is possible" (WBGU, 2016a: 137). Inclusion aims to open up equal opportunities for all people to get involved in society and to realize their potential. The WBGU bases its concept on human rights and the Capabilities Approach (Box 2.2.2-1).

2.2.2.1
Substantive inclusion as a basic category

Substantive inclusion forms the foundation for economic and political inclusion. It includes basic opportunities for personal realization and societal participation and thus the minimum prerequisites for a decent life. Based on human rights and in line with the corresponding goals of the 2030 Agenda for Sustainable Development, these include, from the WBGU's perspective (2016a: 138), qualitatively and quantitatively adequate access to:

- food,
- clean drinking water,
- sanitary facilities,
- housing,
- healthcare,
- education,
- modern energy and telecommunications services,
- mobility,
- waste disposal,
- healthy environment,
- security.

Furthermore, with regard to digitalization, it is pivotal to enable equality of inclusion in ICT infrastructures and the virtual world with the data, information and knowledge artefacts that are available there. If this is not sufficiently guaranteed, political and economic inclusion ultimately suffers. Access to public ICT, the continuous expansion of broadband networks and public information services, as well as network neutrality in the sense of equal data packages – instead of an internet with several classes – are therefore important prerequisites for substantive inclusion (Section 5.3.5). The same applies to reliable and secure infrastructures and information. Furthermore, the conditions for autonomy, freedom of information and education in the sense of digital competence, self-determination and

Box 2.2.2-1

Basic human capabilities

In addition to human rights, the WBGU's inclusion concept is explicitly based on the capabilities approach (CA), which goes back to Amartya Sen (1985) and Martha Nussbaum (1999; WBGU, 2016a: 149, 156). The CA conceptualizes and analyses individual well-being primarily through people's activities or capabilities. It thus embodies universal access to basic opportunities for human realization ('capabilities'), which simultaneously remains open enough to do justice to their diversity. The common basis is the protection of human dignity – regardless of the context of life. In the societal context, individual well-being is oriented towards possible capabilities and activities; individual freedom in the sense of a self-determined life represents the central normative category (Graf, 2017: 312). Due to its global perspective, the CA has also become the basis of the UN Human Development Index.

Beyond Sen's (1985) rather open-ended method, Nussbaum (1999) emphasizes the key capabilities to live a life (1) in one's own environment and in one's own context, (2) worth living in its full length and with good health and nutrition, (3) with adequate satisfaction of needs as well as use of the five senses (if fully available), and (4) avoiding unnecessary pain, but also (5) in connection with nature as a whole while treating it caringly. It is therefore necessary to also shape digitalization in order to maximize human quality of life. For example, with regard to transhumanism, neuro or body enhancement (as opposed to healing), it needs to be clarified where, within the framework of human dignity, the borderline with dystopian paths needs to be drawn and what, by contrast, is left to individual preference and *Eigenart* (Section 2.2.3).

sovereignty must be guaranteed in order to counteract problems such as the fragmentation of the digital public sphere, the discourse power of large corporations or the manipulation of users, and to make economic and political inclusion possible. Ultimately, substantive inclusion amounts to being able to recognize and shape the world even in the Digital Age, since otherwise there is a risk of "structural marginalization" of those affected if they are excluded from a digitally pervaded world (Apprich, 2015: 76).

2.2.2.2 Economic inclusion instead of exclusion

Closely interwoven with substantive inclusion, economic inclusion means not only integration into an economic system but, above all, access to formal and informal markets (WBGU, 2016a: 139). While the WBGU flagship report on urbanization especially highlighted the labour and real-estate markets, digitalization influences the dynamics of the economic system itself. Shaping this epochal change is also about reducing social inequality and preventing exclusion. In the global context (UNIDO, 2017: 19) as well as at national level, further economic divisions of society are already emerging in the course of digitalization (Couldry and Mejias, 2018). Questions should be raised here, for example about the value of data, their ownership and control, as well as about the future role of gainful employment and new systems of remuneration and social security. It is also becoming apparent that the financial and monetary system will continue to change as a result of new technologies. With these changes, security and transparency are relevant to decision-making processes shaped by algorithms (SVRV, 2018). Since the imbalance between the power of the most important ICT companies on the one hand, and individual users and the 'network community' on the other, is likely to get worse rather than better in the future, further societal debates are necessary here, too (Chapter 9).

2.2.2.3 Political inclusion as a democratic basis

Political inclusion is not only a prerequisite for the Great Transformation towards Sustainability and the development of a new social contract (WBGU, 2011; Messner, 2015), it also plays a central role in co-shaping the digitalized society. The minimum requirements for political inclusion (WBGU, 2016a: 141) – electoral, information and participation rights as well as collective rights and legal protection – are already significantly affected by digitalization. Central to this is initially the new structural change in the public sphere (Imhof, 2011; Fraser, 2010; Capurro, 2017) caused by phenomena such as digital filter bubbles (Pariser, 2011), echo chambers and the dissemination of 'fake news' in social media, or the continuous challenge to classic journalistic business models (Section 5.3.2). In addition to the freedom of information and speech necessary for the forming of political will and political inclusion, at the collective level a group-related right to privacy and data protection is just as relevant as a reliable legal basis, especially in an international and global context. Further challenges concern more direct connections with decision-making processes within and beyond established nation states (e.g. direct democracy, e-government, governance of the internet – but also transnationalization, glocalization and global stakeholder processes).

2.2.3 *Eigenart* as a foundation for self-effective individuals and societies capable of transformation

The WBGU already made it clear in its last flagship report (WBGU, 2016a) that enabling and recognizing diversity is relevant to transformation. The compass dimension called *Eigenart* emphasizes this value of diversity both as a resource for transformation and as an important condition for well-being and quality of life.

Three such conditions are the potential for *self-efficacy*, for *social cohesion* and for *identity*. People experience themselves as self-effective in (co-)shaping their own living environment, i.e. in the concrete experience of being effective in their own actions (Bandura, 1977). Social cohesion, i.e. the cohesion of societal groups, is an important resource for successfully addressing demands and providing social support. Social cohesion emerges from interpersonal exchanges, from the experience of living together, exchanging ideas, and feeling connected (Diener and Seligman, 2004; Kahnemann and Krüger, 2006). As regards identity, identifying with groups is just as relevant as the possibility of keeping one's distance from them. An important prerequisite for this is being able to regulate privacy. Westin (1970) defined privacy as the demand of individuals, groups or institutions to decide when, how and to what extent information about them is passed on to others. Taking up this notion of privacy, the psychologist Altman (1976) assigned profound significance for psychological integrity and well-being to the regulation of privacy, i.e. self-determination about which self-interests and self-expressions may be revealed to whom. The possibility of privacy regulation is thus an important prerequisite for the realization of *Eigenart*.

2.2.3.1 *Eigenart* as a guiding concept for the protection of individual freedom of development

Eigenart and the conditions for quality of life can be both called into question and strongly reinforced in the Digital Age. This involves at-times-considerable challenges for individuals.

The disappearance of *Eigenart* is at the core of many dystopian visions of the future (Chapter 6) in which digitalization and technical progress frequently lead to uniform post-privacy societies, where omnipresent surveillance and punishment for deviation not only increase direct pressure for uniformity, but also indirectly strengthen self-censorship and thus threaten *Eigenart*.

Risks – such as the loss of privacy and protected areas, lack of transparency about how private data are used and automated decisions made, or the logic of nothing being forgotten in the digital environment – can complicate identity development and create a pressure towards uniformity. If playing with different identities and trying things out in enclosed, protected areas helps people form their own identity from childhood to old age, then digital transparency involves the threat of an increase in self-censorship. In this context, the notion that information is permanently stored on the net (instead of being eventually 'forgotten') probably also creates stronger control over self-representation, i.e. a restriction of diversity.

On the other hand, futures are also conceivable that perfectly enable *Eigenart* – i.e. creativity and comprehensive identity development. For example, this could be a notion of a society in which people have space for meaningful activities that generate identity. Since the internet offers the possibility of anonymity, it can represent an additional playing field for trying oneself out and testing one's identity. Precisely because digital technologies offer many people spaces for creativity, new forms of expression and self-efficacy, viable ways (in the sense of *Eigenart*) should be found to strengthen this potential and, at the same time, effectively contain the dangers.

Digitalization thus opens up paths for many different possible worlds and it is this tension that makes the protection of privacy, autonomy and self-determination the core demands of *Eigenart*. Mental health and positively experienced relationships require permanent negotiations on making contact and withdrawing – and thus also the need to determine how much information about oneself may be passed on to others (Trepte and Reinecke, 2011; Trepte and Masur, 2017). Violations of privacy occur when people are unable to act in this regard, and information is made public against their will or without their authorization and used for other purposes.

People and societies should therefore have the ability to negotiate and discuss in situations where the application of technological developments by states, companies or other individuals affects their privacy, autonomy and self-determination. The special duty to protect *Eigenart* is thus concretely translated in many areas of a digitalizing world, for example as e protection of individual and group-related privacy, the right to be forgotten, effective data protection and effective data security. People should have a right to times, places, actions or spheres of life that are not monitored and where no data are collected.

This protection of privacy is currently best covered by the legal concept of the protection of a person's private life. Private life in the legal sense, pursuant to

Article 7 of the EU Charter of Fundamental Rights, includes "the identity and development of the person, as well as to the right to establish and maintain relationships with other persons and the outside world" (Sydow, 2018). Germany's Federal Constitutional Court describes the general personality rights enshrined the German Basic Law (Articles 2(1) and 1(1) of the Grundgesetz – GG), from which the right to privacy is derived, as follows: it has the task of guaranteeing the more narrow, personal sphere of life and the preservation of its basic conditions, which cannot be conclusively covered by the traditional guarantees of freedom (BVerfG, 1969; BVerfG, 1973). This includes the integrity of the personality in the mental-emotional and spatial – also virtual-spatial – sense (Murswiek and Rixen, 2018). The protection of private life enshrined in human and fundamental rights is therefore a prerequisite or condition of privacy. If the private life, understood as a legal position, is violated, individual privacy may be threatened.

In the private and public spheres, many questions relating to the protection of privacy are currently still unsolved from the *Eigenart* perspective.

2.2.3.2
Eigenart as a socio-political guiding principle

The *Eigenart* dimension is of enormous importance in relation to systemic change processes in the context of digitalization. Anyone can use digital possibilities to develop his or her own *Eigenart* at an unprecedented level of quality to manage interest groups (for special hobbies or special needs), for creative work (using text, audio, video and novel combinations), for digitally supported activities (e.g. novel, digitalized business models), or for self-portrayal (in fashion or one's own digital images). On the one hand there is potential, on the other there are risks: as a result of using ICT, people can be either degraded to transparent and passive users, or equipped as individuals with substantive data sovereignty and a strong right to privacy (SVRV, 2017). In the best sense, digitalization can open up potential, e.g. to radically decentralize and diversify production and consumption (right up to the visions of a networked commons economy). This networking of the miscellaneous, the sum of the diversity of local, regional or transnational sub-publics and counter-publics, holds out the promise of a free global network (Section 5.3.2).

2.3
Dignity as the starting point and target vision of the normative compass

Human dignity – as a central element of an enlightened and humanistic way of thinking – has hitherto implicitly been the WBGU's fundamental normative starting point (Figure 2.3-1). If the natural life-support systems are not sustained, dignified life on Earth is fundamentally impossible, both at the present time and for future generations (Steffen et al. 2015b). For a dignified life, individuals need fundamental opportunities to realize their potential and a chance to participate in shaping society, i.e. a minimum level of inclusion. Protecting the individual's *Eigenart* also means valuing it as endowed with human dignity and recognizing such fundamental categories as vulnerability or mortality as part of human *Eigenart*.

In this report, the WBGU explicitly specifies the inviolability of human dignity – and the resultant right to be respected and protected – as an orientation aid for shaping digitalization in the sense of the Great Transformation.

Article 1 of the Universal Declaration of Human Rights states that "all human beings are born free and equal in dignity and rights" (UN, 1948). The concept of human dignity has not yet been conclusively clarified, either philosophically or in terms of jurisprudence or history (Debes, 2017). What is certain, however, is that the protection of human dignity is a globally and universally valid right by dint of being enshrined in the UN Declaration of Human Rights, the European Charter of Fundamental Rights, many state constitutions (e.g. Germany, Colombia, Russia), and as a component of international customary law (Dreier, 2013; see Box 2.3-1 on the concept and protection of human dignity in Germany's Basic Law). Moreover, human dignity has shaped history in many ways, not only during the European Age of Enlightenment (Debes, 2017), but also during the Roman period (*dignitas*, Griffin, 2017), in the East Asian region (Wong, 2017), and in Islamic and Christian doctrines (Shah, 2017).

2.3.1
Dignity as a highly controversial topic in the Digital Age

The dawning Digital Age brings with it new challenges for the protection of human and fundamental rights. In the digital domain, the protected areas and possibilities for exercising human and fundamental rights are changing, so that new assurances are required here.

Human dignity, as the source of all other fundamental and human rights, is the central, immutable point of reference (Section 4.3). The renewed controversy over respect for, and the protection of, human dignity in the Digital Age is explained on the basis of some typical examples of potential benefits and risks, and later examined more profoundly in different arenas (Section 5.3).

For example, in their proposal for a charter of fundamental digital rights, European citizens argue that no technological development must undermine human dignity (Zeit-Stiftung, 2018). It follows from the history of the proposal's origins that this technology-neutral formulation is today intended to address in particular threats to human dignity posed by big data, AI, the prediction and control of human behaviour, mass surveillance, the use of algorithms, robotics and human-machine fusion, and the concentration of power in private companies (Zeit-Stiftung, 2018).

The effects of digitalization on social and ecological framework conditions ('digital Anthropocene') also show how urgent a normative return to dignity now is. As outlined by Capurro (2017), for example, digital communication can provide significant support for fleeing refugees; on the other hand, new technologies make governmental and private surveillance possible on an unprecedented scale. Likewise, our understanding of the global climate benefits enormously from improved supercomputers, models, simulations and AI (Jones, 2017), and digital change promises efficiency gains and resource optimization. At the same time, given the great speed of digital change and potential path dependencies, there is also a risk of an increase in resource consumption that would be incompatible with a dignified life on Earth.

In addition, dignity is under threat when core areas of human integrity (physical, psychological, emotional) and identity are encroached upon and autonomy is subverted (Christl and Spiekermann, 2016). Such threats can arise, for example, through scoring (Fourcade, 2016; Section 5.3.3) the use of automated decision-making and decision-making support (Box 4.3.3-1) and other comprehensive data compilations (e.g. Section 5.3.7), when decisions about individuals that are not open to scrutiny are made on the basis of data. The protection of life itself also remains a fundamental issue, e.g. in contexts ranging from possible armed conflicts with automated or autonomous weapons systems to new, threatening possibilities of digitally supported mass destruction (Delahaye, 2017).

Ensuring dignity for all people and for future generations on Earth is thus a central ethical pointer for shaping digitalization in line with the Great Transformation towards Sustainability.

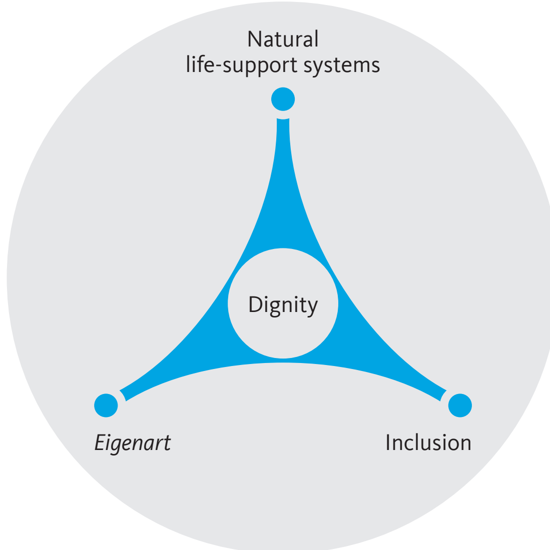


Figure 2.3-1
Normative compass for the Great Transformation towards Sustainability in a digitalized society. The transformation can be achieved by interaction and a balance between the following three dimensions:

- *'Sustaining the natural life-support systems':* Comply with planetary guardrails and avoid or solve local environmental problems.
- *'Inclusion':* Ensure universal minimum standards for substantive, political and economic inclusion.
- *'Eigenart':* Recognize the value of diversity as a resource for successful transformation and as a condition for well-being and quality of life.

Up to now, human dignity has been the WBGU's implicit normative starting point. It cannot be realized without the three compass dimensions, but it is becoming an increasingly sensitive issue in the Digital Age due to numerous challenges. For this reason, the WBGU explicitly names the inviolability, respect for and protection of *dignity* as guidance in the sense of the Transformation towards Sustainability.
Source: WBGU; diagram: Wernerwerke, Berlin

2.3.2
Two key aspects of dignity: protection against objectification and substantive individual rights

The WBGU regards two aspects of the concept of human dignity as pivotal when it comes to digitalization.

Firstly, human dignity relates to the *protection of every person* from *objectification,* i.e. from fundamental attacks on their subjectivity (Box 2.3-1). This definition goes back to Immanuel Kant's formula of humanity in the Categorical Imperative. He argued that every human being should be seen as a being capable of reason and morality and never simply as a means to an end or an object, but always as an end in itself (Kant, 1919). In this respect, the right to human dignity prohibits humiliation and ostracism, for example through torture

Box 2.3-1

Human dignity in Germany's Basic Law

Article 1 (1) of the German Basic Law (Grundgesetz, GG) states:

"Human dignity shall be inviolable. To respect and protect it shall be the duty of all state authority."

Human dignity is of the highest constitutional value, the 'fundamental constitutional principle' and thus the most important value judgement enshrined in the Basic Law (Jarass, 2018).

Human dignity enjoys total protection ('inviolable') by the Basic Law. A violation of human dignity cannot, therefore, be weighed up against other conflicting constitutional rights, as is the case with other fundamental rights (e.g. health protection, Article 2 (2) sentence 1 of the GG). The concept of dignity in Article 1 (1) sentence 1 of the Basic Law must therefore be interpreted very narrowly: only the core of what constitutes a human being is totally protected; the guarantee of human dignity in this sense defines taboos (Höfling, 2018). Animals or objects are not protected. Whether the fertilized ovum in the womb is already protected, or protection does not begin until nidation in the uterus (as stated by the Federal Constitutional Court), is a matter of controversy. Every human being possesses dignity; this does not depend on an awareness or any specific behaviour. Even after death, people have a right to postmortal protection of their dignity

All state power, i.e. the legislature, government, administration and judiciary, is obliged to protect human dignity. Furthermore, "German sovereignty must not help other states to violate human dignity" (BVerfG, 2015).

Infringements of the core area of human dignity

As a result of the crimes committed during the Nazi period, the historical authors of the constitution placed human dignity at the beginning of the Basic Law, thus making it clear that the focus of the Basic Law is on the human being and not on the state (Jarass, 2018). According to the Federal Constitutional Court, it is not compatible with human dignity to make a human being a "mere object of state power". Every human being has a "claim to the social value and respect" (BVerfG, 2004) which is due to him/her because of his/her being human (Jarass, 2018).

What belongs to the core area of human dignity has not been conclusively defined. A human being becomes an object of state action when s/he is humiliated, branded or ostracized, i.e. when his/her claim to respect as a human being is denied. Accordingly, torture, slavery, bonded labour and stigmatization violate human dignity. Not only physical, but also psychological, emotional and intellectual integrity is protected from state intervention. It has also been clarified that state observation and listening-in to core spheres of a person's private life violates human dignity (BVerfG, 2004). It has not been clarified which digital applications permitting extensive conclusions on, and insights into, people's private lives are now deemed to be intruding on this core area.

Human dignity can also be violated by the state's failure to act. In its ruling on Hartz IV unemployment benefit, the Federal Constitutional Court (BVerfG, 2010) clarified that everyone has a right to a minimum subsistence level for his/her physical existence. This includes food, clothing, household goods, the maintenance of human relationships and a minimum of inclusion in societal, cultural and political life. It has not been clarified whether this also includes a claim to inclusion in the form of digital media.

Human dignity is further violated when a person is denied of his or her fundamental equality with other people, i.e. there are no second-class people before the law. Human dignity is therefore an anti-discrimination imperative (Dreier, 2013). The more societal interactions take place in the digital sphere, the more important it becomes to also implement this anti-discrimination imperative in that field.

Human dignity also includes rights: the right to self-portrayal (external; promoted by digital technology) and self-demarcation (internal; endangered by digital technology: Höfling, 2018).

At the level of international law, agreements are being (and have been) sought to limit threats to human dignity through rapid biotechnological progress that also benefits from digital technology (Dreier, 2013). A Convention on Human Rights and Biomedicine by the Council of Europe has already come into force. There has not yet been a discussion on whether, and to what extent, the claim to respect resulting from the dignity imperative can be lost as a result of future human enhancement through digital technology (Topic box 5.3-2).

Private actors are not directly bound by Article 1 (1) of the Basic Law (Jarass, 2018). However, the state must enact regulations under private and public law in order to prevent the impairment of human dignity by private actors; the state thus has a duty to protect (Jarass, 2018). This means that the state must also prevent threats to human dignity posed by digitalization and take corresponding legislative precautions. Since the technological transformation of the last few decades has been primarily driven by a small number of digital corporations, which have thus increasingly gained economic and formative power, this state responsibility must be particularly emphasized and demanded.

or slavery. The disputes and discussions of the last two centuries have made it possible to overcome discriminations that still existed in the Kantian concept of human dignity, in particular racism and misogyny, and to extend the concept to all human beings, as in the UN Universal Declaration of Human Rights.

Secondly, the guarantee of human dignity not only protects individuals from state intervention (negative definition); *human dignity* also results in substantive individual rights (positive definition). This second aspect of the dignity concept is expressed, for instance, in Article 22 of the UN Universal Declaration of Human Rights (UN, 1948), according to which every person has "economic, social and cultural rights indispensable for his dignity and the free development of [their] personality". The WBGU has already enlarged upon this second positive aspect of dignity in the compass dimensions of inclusion (Section 2.2.3) and *Eigenart* (Section 2.2.4).

Box 2.3.2-1

Human beings as subjects and objects in the human sciences: tensions and educational potential

The contradiction between studying the human being as a scientific object and turning towards the human being as a subject is fundamental to the human sciences (Foucault in Dreyfus and Rabinow, 1982). As soon as general laws are adopted to explain human functions, for example in philosophy, sociology and especially psychology, and statements are made about 'the human being' (e.g. limited rationality or social determinacy), s/he is made into an object. At the same time, a potential for overcoming limitations and thus an enlightening element emerges from this perspective. This is demonstrated by the Rosenthal effect: only after Rosenthal and Jacobson (1968) had shown how stereotypes shaped teachers' perception of their students, thus influencing interaction with them, could a pro-active, stereotype-transcending compensatory style of interaction be demanded.

There has been a discussion in psychology for decades on the conditions under which – and the problems for which – it is justifiable to turn people into objects (e.g. Groeben and Scheele, 1977). One conclusion is that forms of objectification should always be explicitly justified and discussed. They are permissible in situations where statements are made about people in general on a meta-level (e.g. young men in Germany have a higher risk of becoming criminal than other age groups). Objectification is critical when conclusions are drawn about a specific individual, especially when it is unclear whether the the justifications given have been understood and voluntarily agreed upon (e.g. among children, Woodhead and Faulkner, 2000). From this perspective, Big-Data analyses that draw conclusions on individuals, for example, can in many cases be described as inadmissible forms of objectification.

The distinction between the subject perspective and the object perspective is also firmly established at the individual level in the human sciences. Therapies use theories on subject/self object relationships to enable patients to overcome boundaries and problems, to delimit and reflect on subjective experience and feeling in relation to others (e.g. Butcher et al., 2009).

Discussions about the relationship between subject and object have the potential to enable people to reveal and reflect on possible mistakes and limitations for themselves and others, whether in research or for personal well-being. This simultaneity of the subject and object perspective, its potential and tensions, should also be systematically reflected on in digitalization processes: data analyses, for example, are permissible aids; people and scientists use them as heuristics to provide orientation. At the same time, it should be taken into account that people's individual dignity must not be disadvantaged by the use of such heuristics.

There is a tense relationship between the negative and positive dimensions of the protection of human dignity. On the one hand, the inviolability of human dignity means that individuals are unconditionally bearers of dignity from birth and can thus ward off certain interventions. However, certain conditions must first be created to ensure a dignified life for individuals (Schulz-Nieswandt, 2017: 29). This tense relationship becomes evident when it comes to the borderline between the private and public spheres – which, in the Digital Age, must be rebalanced between the individual, the state and the market. On the one hand, the legislative protection of privacy from state or economic interference seems existentially necessary in order to prevent attacks on human dignity, e.g. so that people are not seen purely as objects of state authority or as profit opportunities for digital corporations. On the other hand, the state's withdrawal from the increasingly digitalized private world of individuals also makes unequal treatment and acts of violence by third parties possible, which, in turn, restricts the dignity of many people. In particular in the context of digitalization, these tensions between the private and public spheres and between dignity as a defensive right and a protective imperative should not be eliminated, but shaped (Schulz-Nieswandt, 2017: 63).

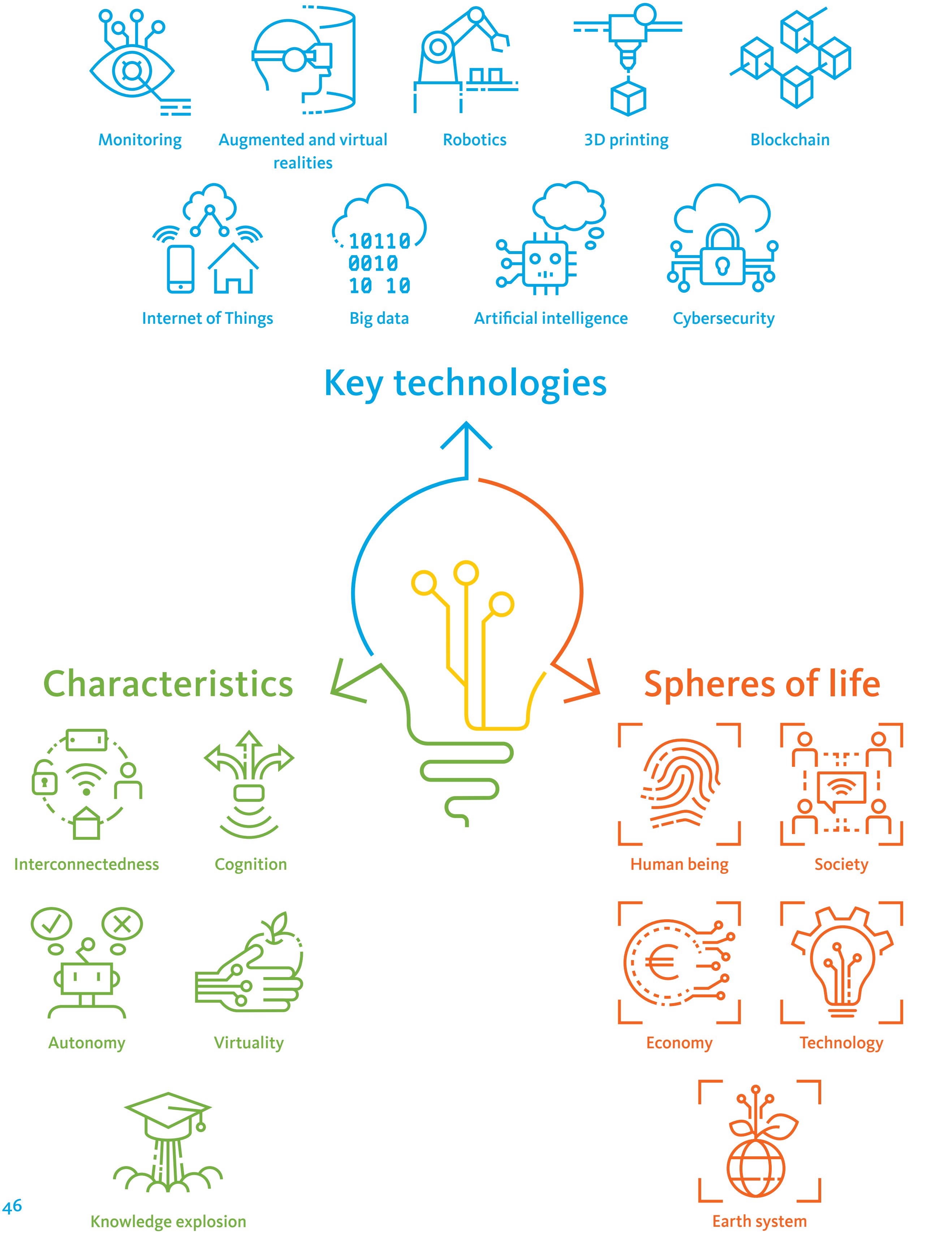
Not only in the legal sciences but also in the human sciences, the objectification of the human being has been the subject of discussion and reflection since Foucault at the latest (e.g. Foucault in Dreyfus and Rabinow, 1982). Guidelines for dealing with algorithms and big data can be derived from these systematic reflections both on the enlightening potential of the objectification of human beings as an object of study and on the threat to the integrity of the individual through objectification (Box 2.3.2-1).

2.4 Conclusions

The Great Transformation must look at digitalization not only to exploit its potential for – or to contain its threats to – sustaining the natural life-support systems. The megatrend of digitalization impacts on all areas of society relevant to transformation and can reinforce these areas both positively and negatively. In this way, the shaping of the Great Transformation and the assurance of its normative foundations gain further relevance.

The WGBU bases this comprehensive transformation on a normative compass for sustainable development and shows, using examples, how digitalization can be shaped in the field of tension between the three compass dimensions of sustaining the natural life-support systems, inclusion and *Eigenart*. Furthermore, digitalization is changing the protected areas and the options for exercising fundamental rights, so that new assurances are required here. The WBGU explicitly places its normative compass for this on the foundation of respect for human dignity as the source of all other fundamental and human rights.

Finally, digital technologies also have enormous potential for societal development processes. They enable transnational communication, networking, and information and knowledge growth in an unprecedented way. In the long term, this could stimulate the human capacity for a more profound culture of cooperation and mutual global solidarity.


Monitoring
Augmented and virtual realities
Robotics
3D printing
Blockchain
Internet of Things
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Cybersecurity
Key technologies
Characteristics
Spheres of life
Interconnectedness
Cognition
Human being
Society
Autonomy
Virtuality
€
Economy
Technology
Knowledge explosion
Earth system

Understanding the Digital Age 3

In order for digital change to be placed at the service of sustainability, the potential benefits and risks must be understood. The WBGU offers an analysis of the historical development towards the Digital Age, its basic functions, key technologies and essential characteristics, as well as the resulting foreseeable changes for key areas of human civilization. The shaping of the Digital Age towards sustainability involves great uncertainties, so that adaptable governance is necessary.

Digitalization is opening doors to the next epoch of human civilization. If digital change is to serve the UN's sustainability goals (SDGs; Box 2.1-1) worldwide, then the potential benefits and risks of digital technologies and solutions must be understood; they must be used and shaped as instruments of the Great Transformation towards Sustainability. This chapter summarizes the development to the Digital Age, important basic concepts and key technologies, its essential characteristics, the foreseeable changes in human civilization, and the current state of sustainability analyses in the Digital Age.

3.1 Development leading up to the Digital Age

The WBGU first approaches the characteristics of the Digital Age from different angles: (1) the evolutionary history of human civilization, in order to derive parallels with, and differences to, the current transformation, (2) the development of information history, in order to pinpoint the quantities and qualities of the Digital Age, and (3) the economic development, which illustrates the impact of the Digital Age as visible to date.

The WBGU has a broad, comprehensive understanding of *digitalization* as the development and application of digital and digitalized technologies that dovetail with and augment all other civilizational technologies and methods. Digitalization has a profound effect on all economic, social and societal systems and is evolving an ever greater transformative power, which in turn is having an increasingly fundamental impact not only on the planet, but also on our societies and on people themselves, and must therefore be shaped.

3.1.1 Humankind and its development as the starting point

In this section, we look at the evolution of human civilization with regard to digital change from the perspective of *humans themselves* and their abilities. The decisive factors for the development of human civilization were, on the one hand, the constantly evolving human abilities such as language and culture and, on the other, the increasing systematization and mechanization of work and life processes. *Homo sapiens* has developed complex languages, which can convey conceptual, abstract and future content, and created increasingly complex social systems using pronounced skills of learning and cooperation – from the first human communities and small settlements to cities, nation states, globally operating corporations and production systems, the UN, and global cultural, political, social and scientific networks.

Equally decisive in the history of humanity was the successive and ever more sophisticated expansion and partial substitution of precisely these abilities in human interaction with the world. For example, the first great transformation of humankind, the *Neolithic Revolution*, was characterized by the mechanization of human *physical* strength in the transition from hunter-gatherer societies to sedentary societies, to animal breeding and plant cultivation, and to the development of agriculture and sharp-edged stone implements. While this transformation was spread over several millennia, the second major transformation, the *Industrial Revolution*, led to massive changes in the context of the Enlightenment in the space of just one century. Starting in England in the second half of the 18th century, industrialization processes successively covered the whole of Europe and the world, with considerable effects on individual, economic, societal and, not least, Earth-system configurations (WBGU, 2011:81ff.).

The decisive element was again a new stage in the mechanization of work and life processes – this time through the use of fossil fuels. The substitution and multiplication of human and animal muscle power by the combustion of fossil fuels was the basis for the transition from craft and peasant manufacturing to large-scale industrial production. In addition, technical innovations, especially electrification, enhanced human manual skills, e.g. through machine tools. The consequences were unprecedented upheavals in production, productivity explosions, but also fundamental changes in economic and social conditions, population growth, and increasing environmental destruction. It was only over the course of lengthy and fundamental social and political conflicts in societies and as a result of two world wars that governance systems attempting to contain these issues emerged in western societies. Industrial market dynamics were steered by democracy (which restricted concentrations of power), social-security systems (which cushioned social exclusion and the consequences of permanent economic structural change), and environmental regulations (to limit the destruction of natural life-support systems).

In 2011, the WBGU recommended actively promoting the *Great Transformation towards Sustainability* in order to avert Earth-system change and the ongoing erosion of human civilization's natural life-support systems (WBGU, 2011). In the meantime, however, a further, ever more powerful *change through digitalization* has been emerging, which challenges humanity as a whole and in which, above all, the *cognitive* abilities of humans are now being extended enormously by computers. Man-made artificial intelligence (AI), algorithm-based systems (Section 3.2.3) and self-learning autonomous systems can extend or replace previous thought and decision-making processes and challenge and globally reconfigure our current ways of thinking, doing business and organizing society. For the Digital Age, too, containing governance systems will therefore be necessary.

The question is what impact will increasingly digitalized automation have on labour markets and the international division of labour (Section 5.3.8)? Will there be a strengthening of national and international inequality trends? Can worldwide prosperity and Earth-system stability be better reconciled in the Digital Age than up to now? Does digitalization act as a ‚fire accelerant' or as a powerful instrument for achieving the goals of the 2030 Agenda? In whose interests are ‚intelligent' systems being designed and used? Who controls their application and, above all, who is controlled or manipulated by their application? And, looking ahead, how will the interaction, cooperation and collaboration of sociotechnical, self-learning systems with humans and the environment develop? What is it that constitutes humankind and human civilization in the Digital Age with its diverse digitalized automatisms, intelligent robotics and AI? It is already clear today that the concepts of sustainable and civilizational development must be reconsidered and further developed, but also defended, in the Digital Age. The UN already must contain and use digitalization for the 2030 Agenda, but also focus on it beyond the target year 2030. It is necessary to look for ways to make the Great Transformation to Sustainability a success using the means of digitalization (WBGU, 2018a).

3.1.2
The road to a digitally networked society in the Anthropocene

The WBGU analyses digitalization as a sociotechnical upheaval caused by technological progress and intertwined with society – an upheaval that can and must be shaped. Digitalization does not predetermine society. However, purely technology-centred approaches often generate unexpected new problems in the form of ‚side effects' (Mainzer, 2016:217). These drive new problem-solving cycles and, at the same time, provide the momentum for further innovations and economic prosperity (Mokyr, 2013:292). In this respect, the digital transformation is neither a completely rational shaping of technology nor the uncontrolled progress of its development, because shaping and development are processes which are realized by people and for which people are responsible (Grunwald, 2012:31ff.; Grunwald, 2018; Kehl and Coenen, 2016). Society does not one-sidedly determine technical progress, nor is the opposite the case. Nevertheless, „technological innovations are greatly influenced by the social context of their creation," which is why there are „effective possibilities for framing them in a political and legal context" (Misterek, 2017:3). The most relevant development paths of society, the economy, technology and the environment are therefore presented as an overview in the following in relation to digitalization.

In principle, the influence of information and communications technologies on society and the environment dates back to well before modern times. From cuneiform tablets in ancient Mesopotamia to papyrus scrolls in the Roman Empire and medieval codices, to modern printed letters, to submarine cable telegraphy or today's ICT infrastructure, ever smaller and faster ways of transmitting messages and information are used while, at the same time, mobilizing ever larger societal and material systems (Rosol et al., 2018).

The economic boom after the Second World War in the transition from the war economy to the consumer society and from coal to oil led to the ‚Great Acceleration' (Steffen et al., 2004, 2015a; Mathiesen et al., 2015), which manifested itself as an exponential increase in many key socio-economic and Earth-system indicators. Advances in the fields of information theory, computer technology, semiconductor physics and cybernetics had a mutually inspiring effect. Gross national product, fertilizer use and population growth increased enormously. To this extent, Anthropocene (Crutzen and Stoermer, 2000), ‚Great Acceleration' and digitalization are interlinked (Rosol et al, 2018). The main technological drivers of digitalization from the mid-1970s onwards were the continuous development of integrated circuits (‚microchips'), powerful communication technologies and, most recently, big data (Section 3.3.2) and AI (Section 3.3.3).

3.1.2.1
From the first computers to the digital network

The introduction of integrated circuits (ICs) laid the foundation for the continuous further development of microelectronics in the 1950s. The circuits, which are projected onto silicon chips using a photolithographic printing process, required less and less space from year to year, thus allowing more complex designs. From the 1970s onwards, this made programmable microprocessors possible whose speed and memory capacities have increased by a factor of one billion since then (Burckhardt, 2017:60f.). The first digital computers of the 1950s were developed „in close cooperation between state and private-sector organizations, had to be operated by a team of specialists, and were extremely expensive," while, from 1960 onwards, far less expensive „cabinet-sized ‚minicomputers'" became widespread, especially at North American universities; they „could be operated by individuals, and simplified interaction with the user through new input and output interfaces (e.g. screens)" (Schrape, 2016:12).

In addition, the Advanced Research Projects Agency (ARPA) was founded in 1958 in the context of the ideological competition between the eastern and western blocks, and in particular as a result of the USSR's strong lead in space travel (‚Sputnik shock'). The Agency was assigned to the US Department of Defense and led to the development of the ARPANET from 1968. This networked communication infrastructure initially involving only four universities was based on the concept of packet-switching data, i.e. splitting longer messages into individual data packets – a basic principle of today's internet. However, it was not foreseeable at that time „that ‚the internet' would develop from the ARPANET" (Lang, 2017:10). Its decentralized architecture, created for military reasons, and the TCP/IP (Transmission Control Protocol/Internet Protocol), designed for outages, resilience and robustness, already contained the basics of today's internet with regard to independence from subnets and error tolerance. Nevertheless, it still took more than 20 years before a version was developed in the 1980s that met with broad acceptance and became the standard protocol. Another key step was the development of the Hypertext Transfer Protocol (HTTP) for transferring data at the application level and for creating links between data. The development initiated by Tim Berners-Lee ultimately led to the World Wide Web (WWW), which is commonly regarded as the internet today, although it ultimately only represents the access to applications, services and data for end-users (Schrape, 2016:14f.).

In the subsequent years, the new technology sector and the internet opened up economic potential. According to Lang (2017:17), the foundations for the emergence of a service sector on the internet and its boom in the 1990s were „essentially three factors": first, extremely easy access for ICT companies to credit due to the USA's low interest-rate policy; second, „open architecture, free software and patent-free protocols"; and third, „state investment in infrastructure". However, high expectations of global growth potential in the ICT sector led to the bursting of the speculative bubble in the new or dotcom economy in 2000 (Goodnight and Green, 2010; Pierrakis, 2010). Falling share values, liquidity problems and insolvencies contributed to rising market concentration, and „Google, Amazon, eBay, Paypal emerged from this period as its entrepreneurial winners" (Lang, 2017:18).

With the development of the internet into a mass medium, „the dynamic network was finally able to assert itself as the leading metaphor of our time. This rise soon revealed itself in the political, cultural and economic world which imagined itself as a network in the early 1990s" (Apprich, 2015:127). This also the basis of a modern form of data-driven, networked ‚intelligence' which has become a reality today (Rosol et al., 2018; Section 3.3).

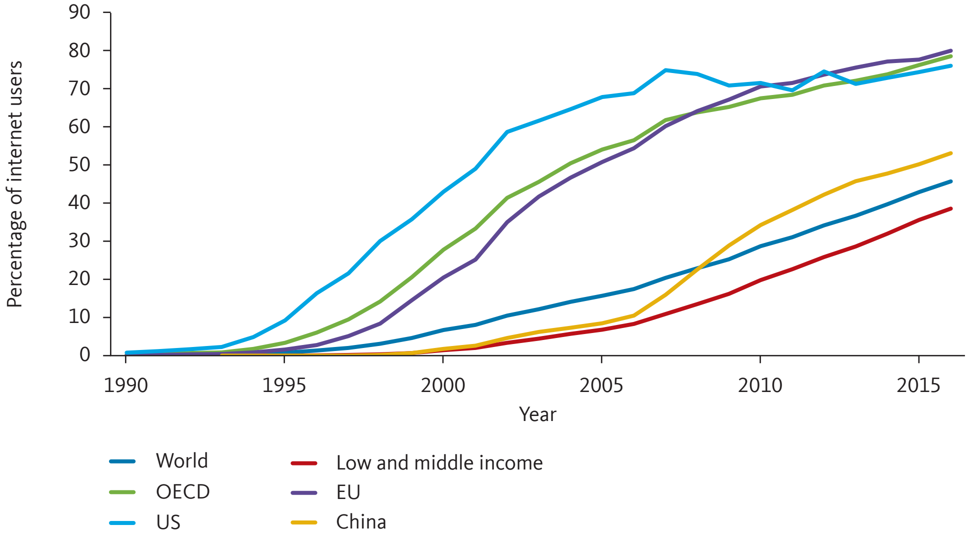


Figure 3.1.3-1
Internet users as a percentage of the total population.
Source: World Bank, 2018b

3.1.2.2
Origin and expansion of social platforms

The rise of networking to the new leading social metaphor was accompanied by the emergence of a „new social structure [...] consisting of networks in all significant dimensions of social organization and practice" (Castells, 2017: XXII). Against the background of an increasingly globalized economy, society's demand for individual freedom and open communication, and, ultimately, advances in the ICT field, digitally networked societies emerged that allowed the development of entirely new information, media, and automation systems (Apprich, 2015:67). With regard to the latter, the „initially technical, and later increasingly economic, dynamics of Silicon Valley [...] in the 1990s" led to the formation of a „Californian ideology" which interpreted the effects of ICT in terms of technological determinism and attributed societal change to technical innovations (Misterek, 2017:4f.). Digitalization is thus interpreted by some actors, e.g. ICT companies, as an inevitable civilizational step of evolution, emphasizing opportunities and disregarding risks as far as possible (Barbrook and Cameron 1996). This ideology of technological determinism, which developed to the extremes of ‚trans-' or ‚posthumanism' (Box 2.1.2-1), was initially accompanied by utopian, even emancipatory visions such as increasing transparency and democratization (Kehl and Coenen, 2016). Since Edward Snowden's revelations in 2013 about the permanent global surveillance of digital information flows by the NSA in the USA and by other secret services, however, the „technological-deterministic narrative of a better future has come under increasing pressure" (Misterek, 2017:1f.).

Beyond the visions and intentions of the actors responsible for the positive or negative aspects of the development towards a digitally networked society, its actual dynamics and global dimension emerged as a result of increasing commercialization. Corresponding offerings were initially developed and advertised primarily for the younger generation. This helped ‚e-commerce', online commerce and the market leaders in those fields to achieve strong growth. Numerous private (and partly public) investments were made in the infrastructure in response to the rising demand.

The expansion of broadband access and technical advances in multimedia platforms led to large sections of traditional media and communication formats moving from radio, television and print media to the internet. Further software innovations enabled interactive applications and social platforms that rapidly spread under the catchwords ‚Web 2.0' or New Media (O'Reilly, 2007). Since then, multimedia content and, in particular, video data have taken up a large proportion of data sent via the internet. According to the Cisco Visual Networking Index (Cisco, 2019) 6,821 petabytes of video and 4,691 petabytes of non-video were sent per month in 2017; in 2018 already as much as 12,051 petabytes of video and 6,959 petabytes of non-video were transferred per month, i.e. almost twice as much video as non-video data.

By the mid-2000s, the foundations had thus been laid for the *rise of globally operating ICT companies* and their data-driven, platform-based business models (Schrape, 2016:15). For their core business, these com-

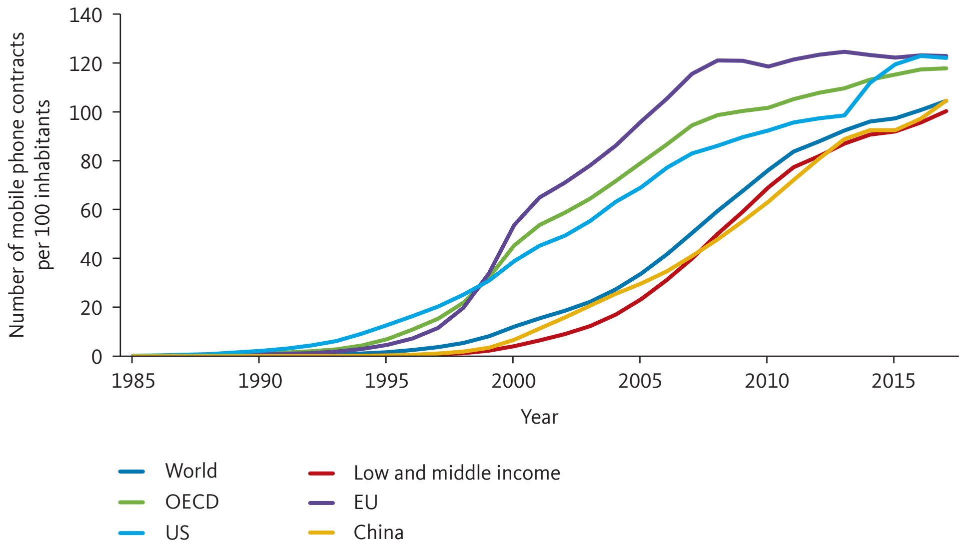


Figure 3.1.3-2
Development of the number of mobile phone contracts per 100 inhabitants.
Source: World Bank, 2018b

panies develop and aggregate data and offer devices and services in return: today, Google/Alphabet, Apple, Facebook, Amazon and Microsoft (also known as GAFAM or ‚Big Five' for short) provide the central infrastructural foundations of the Web world. In this way, they shape the online experience of many media users in a fundamental way. This concentration of providers can lead to a „concentration, unique in media history, of private-sector power of disposal over interaction data and infrastructures, ultimately amounting to a privatization of personal data protection" (Schrape, 2016: 17). While more than half of the world's population is already networked via social platforms, the comprehensive establishment of platforms in production, mobility, politics and administration, for example, has only just begun.

3.1.3
Economic development towards the Digital Age

Since the 1980s, technological progress in ICT and its dissemination throughout the economy and society has been accompanied by a discussion about its importance for the economy as a whole. The general perception of a broad technological revolution is clearly reflected in indicators of microeconomic developments, such as the development of the market values of the largest internet groups and the societal spread of technologies, e.g. the number of internet users. However, the importance of ICT and its impact on productivity and economic growth are not yet equally evident at the macroeconomic level.

Microeconomic importance and societal penetration of ICT

The importance of ICT for the spread of new media described in Section 3.1.2 is directly reflected in the rapid development of the number of internet users and mobile-phone contracts (Figures 3.1.3-1 and 3.1.3-2). Although statistics continue to show a marked lead in the spread of ICT services for industrialized countries, the development in developing countries has been no less dynamic. However, the aggregated statistics do not reveal the differences that exist between regions and countries or societal groups.

Also noteworthy is the growing decoupling of internet access from computer ownership (Figure 3.1.3-3), which can be observed particularly in developing countries and is due to the increasing importance of mobile internet access. As a rule, internet access via mobile phones is not only less expensive than via fixed-line devices such as PCs, it is also less dependent on telecommunications and electricity networks, which are not fully developed in all countries. From a development-policy perspective, mobile communications is a typical example of leapfrogging: it enables many people in developing countries to participate in telecommunications for the first time and, via mobile internet access, to use banking or insurance services without the country having to build a more capital-intensive cable-based network infrastructure, as happened historically in the industrialized countries (World Bank, 2016).

The rising penetration of ICT in the economy and society was favoured by in-some-cases massive falls in prices for ICT equipment based on considerable technical development progress. Over time, digital electronics

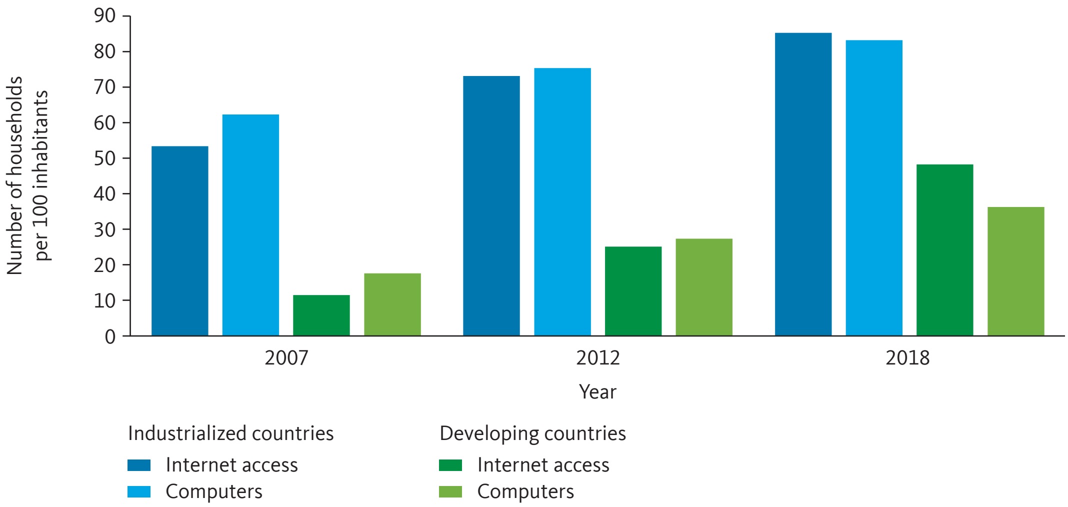


Figure 3.1.3-3
Development of the percentages of households with internet access and computers in industrialized countries (blue) and developing countries (green) in selected years.
Source: ITU, 2018

in the form of computing, storage and transmission capacity has become more and more efficient, smaller in design and, at the same time, cheaper to manufacture. One of the best-known indicators of the high innovation dynamics in the field of digital electronics is Moore's Law. It goes back to a prediction made by Gordon E. Moore, a co-founder of Intel, in 1965. Originally it said that the number of components or transistors on a given area of integrated circuits doubles every year; Moore later corrected this ten years later to every 18 months (Moore, 1965; Flamm, 2018). This prediction has been valid since the 1960s and is expressed by the logarithmic linear scale in Figure 3.1.3-4a. The successes in the miniaturization of digital electronics were accompanied by big increases in computing capacities. In standardized test procedures, for example, (micro-) processors improved their results in the second half of the 1990s by approx. 60% per year, and by over 15% in between 2005 and 2016 (Flamm, 2018). The increase in computer performance overall in the course of the 20th century is no less impressive: depending on the underlying measure of computing capacity used, there are increases by factors between 1,700 and 76,000 billion compared to manual computing methods (Nordhaus, 2007). The considerable reduction in the production costs of digital electronics over time can be seen, for example, in storage costs per gigabyte of data volume, as shown in Figure 3.1.3-4b for the years 1982 to 2018.

All these developments were reflected in the market prices of ICT components and equipment and in the prices of computing operations in general. Between 2000 and 2018, ICT equipment, which includes computers and related hardware, fell in price by more than 80% in the eurozone and the USA (Figure 3.1.3-5). Price falls of a similar magnitude also took place in the past; estimates state that the (real) price of ICT equipment fell by more than 80% between 1970 and 1989 and again by over 77% between 1989 and 2007 (Crafts, 2018). Over the period from 1940 to 2014, standardized computing operations became cheaper by an average of 53% per year (Nordhaus, 2017). These dynamics have been observed to weaken over the past years; the prices of microprocessors – whose prices fell by more than 70% per year in the late 1990s, taking quality improvements into account in the form of performance and efficiency gains – declined by only just under 3% in the years from 2010 to 2013 (Flamm, 2018: Table 6). The continuation of Moore's law and the resulting developments in costs and performance capacities into the future therefore no longer appears secure in view of the current technical approaches and architectures (Flamm, 2018). As early as 2016, the processor manufacturer Intel announced the law's foreseeable end within a few years, since further miniaturization was reaching its physical limits (Walsh, 2018: 181).

As a result of this price decline and technological advances, geographical distances became (in some cases considerably) less important for production structures, although they did not become completely irrelevant (World Bank, 2016: 57ff.). In particular, faster and more cost-effective communications since the 1980s made it possible to split multi-stage production chains and to gear their international distribution to country-specific location advantages (e.g. raw material deposits, wage levels, market proximity). Trade volumes and (foreign) direct investments also rose conside-

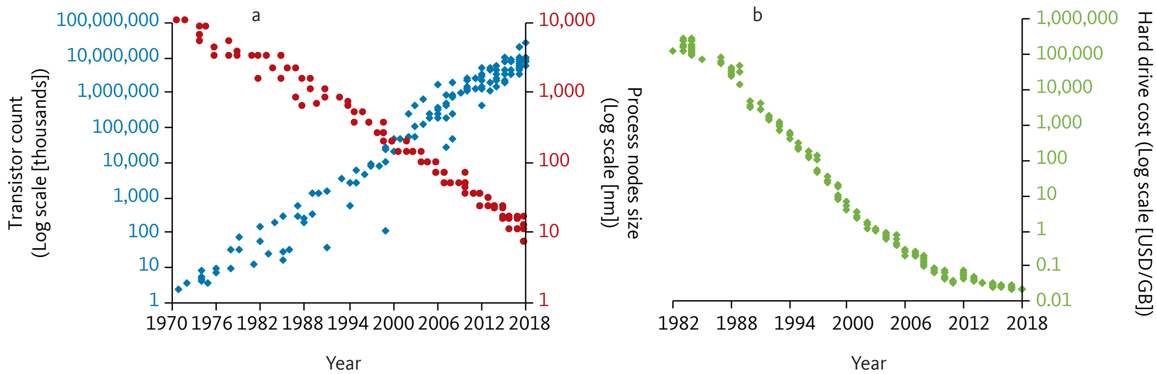


Figure 3.1.3-4
Number of transistors per CPU and technology node generation (a), memory costs per gigabyte (b).
Source: OECD, 2019a: 38

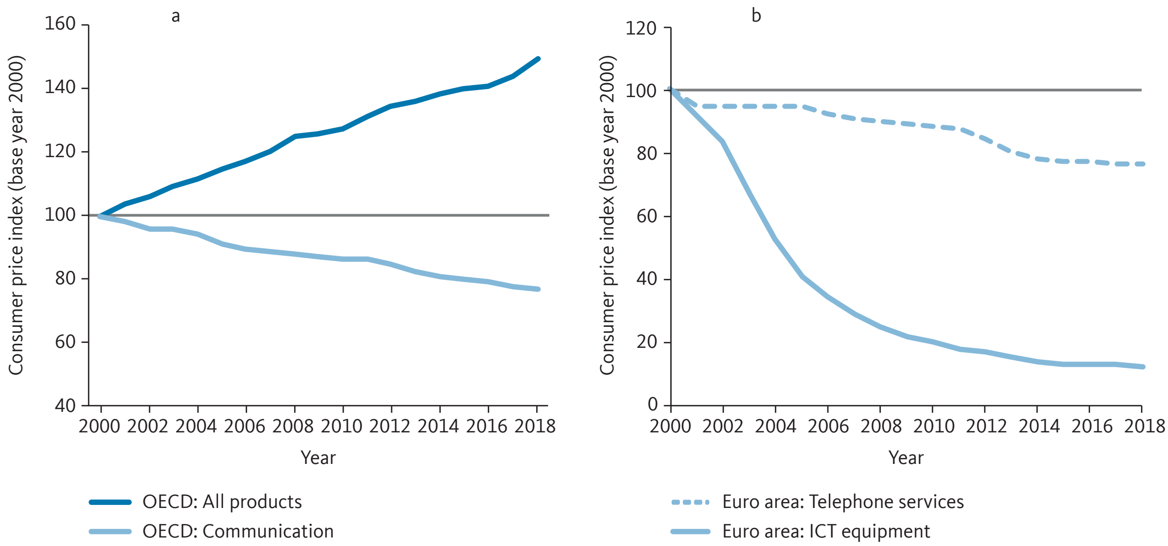


Figure 3.1.3-5
Comparison of (consumer) price developments, basket of all goods vs. ICT goods and services (a); comparison of price developments of telephone services, and ICT devices in the eurozone countries (b), in the period 2000 to 2018.
Source: OECD, 2019a: 38

rably; trade relations were consolidated, and developing countries were more strongly integrated into newly emerging global value chains (Section 5.3.8). The price slump and performance explosion in the field of digital electronics also considerably cut the cost of computing operations and the applications based on them compared to labour (Nordhaus, 2007). Developments in the field of industrial robots were a pivotal example compared to the existing digitally supported automation of work processes. After adjusting for improvements in quality and performance, their price in the six largest industrialized countries in 2005 was only one fifth of what it had been in 1990, which, of course, contributed to their widespread use (Graetz and Michaels, 2018).

The increasing penetration of the economy and society by digital technologies led to an increase in the importance of the digital and/or technology sector compared to other sectors. One indicator of this increase was the development of corporate values. Looking at the companies with the highest values worldwide, Exxon Mobile, a company operating in the field of fossil resources, was the number one in 2009, followed by companies from a range of sectors (Table 3.1.3-1). This picture has changed fundamentally in the meantime. Today, the top positions are dominated by representatives of the digital and/or technology sector, partly by companies that were not even among the world's 100 most valuable companies in 2009 (Figure 3.1.3-6; OECD, 2019b).

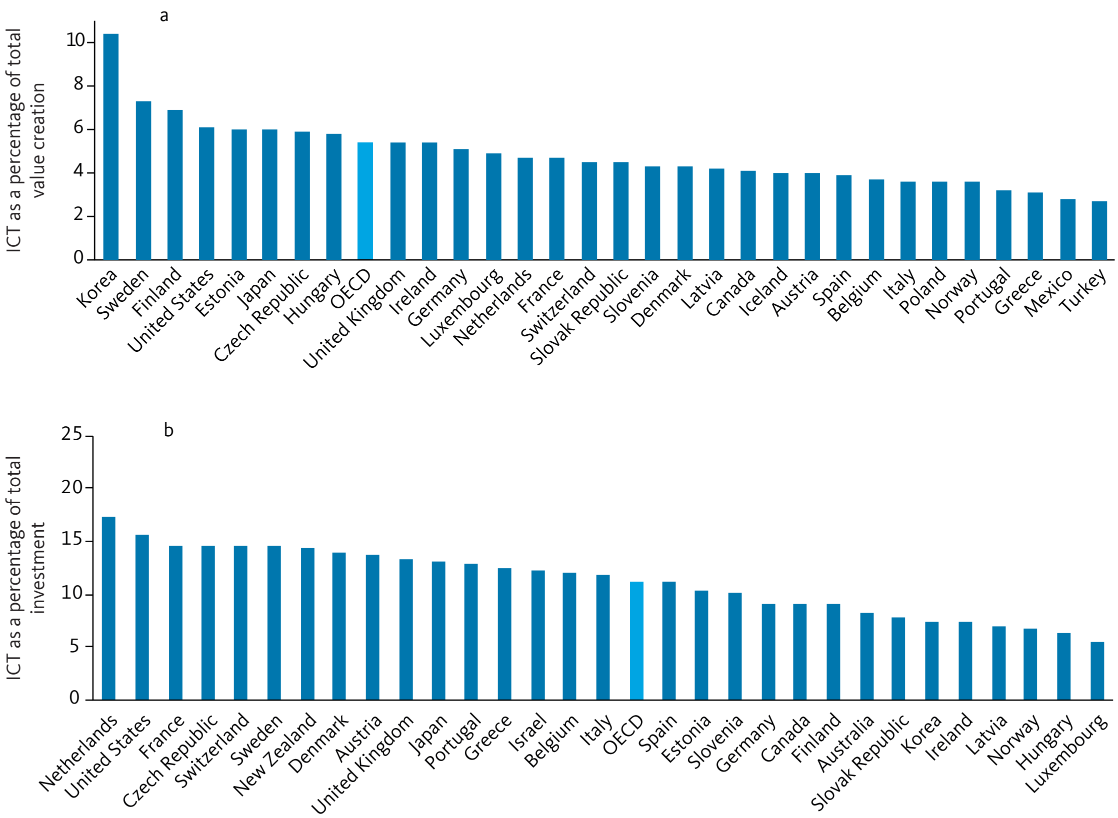


Figure 3.1.3-6
(a) ICT sector's value-added as a percentage of total value-added in various OECD countries; (b) ICT investment as a percentage of total investment in various OECD countries.
Source: (a) OECD, 2017c: Figure 3.3; (b) OECD, 2017c: Figure 5.2

Influence of ICT on macroeconomic development

Although, in microeconomic terms, digital companies are today among the world's largest companies by market capitalization, and digital technologies are rapidly entering many areas of life and the economy, this dynamic has hitherto only been reflected to a limited extent in indicators at the macroeconomic level.

The ICT sector's purely statistical share of total value creation ranges between 4% and 8% in most countries, in some cases it is thus well below the shares of industry or manufacturing (e.g. in the EU in 2017 according to OECD data: industry including energy 19.6%, manufacturing 16.4%; Figure 3.1.3-5a; OECD, 2017c). The ICT sector's share of employment is similarly low, mainly due to this sector's low labour intensity. The capital intensity of the ICT sector is reflected in the high proportion of total investment activity compared to its share of value-added (Figure 3.1.3-5b). However, the exact definition and delimitation of the ICT sector is unclear (IMF 2018), and its share of total value-added does not fully reflect the economic importance of digital technologies. As in the case of the energy sector, for example, its importance is also boosted by ICT applications in other sectors (e.g. industry, retail trade, agriculture).

Evidence of the economic importance of digital technologies for economic growth and productivity has so far been limited. Studies of causal relationships are afflicted with methodological problems and inadequate data availability (World Bank 2016) and show rather weak correlations to date (Stanley et al. 2018). ‚Growth-accounting' studies suggest that about 20% of global economic growth in the period from 1995 to 2014 was attributable to investments in ICT (World Bank 2016: 56f.), whereby the contribution to economic growth increased over time, at least in the USA. Simulations of the US growth path show an ICT growth contribution of 5% during the 1980s, 10% during the 1990s and over 30% since 2000 (Eden and Gaggl, 2018: 27).

Currently, increasing contributions to growth from ICT are coinciding with a slowing of economic growth and (labour) productivity (Crafts, 2018; Paqué, 2016). This observation is sparking a discussion about the importance of the digital technology revolution compared to earlier technological revolutions (Gordon, 2014,

Table 3.1.3-1
The ten largest companies in the world by market capitalization in 2009 and 2018.
Source: PWC, 2018

	2018			2009		
		Market capitalization [US$ billions]	**Ranking in 2009**		**Market capitalization [US$ billions]**	**Ranking in 2018**
1	Apple	851	33	Exxon	337	12
2	Alphabet / Google	719	22	PetroChina	287	26
3	Microsoft	703	6	Walmart	204	16
4	Amazon	701	–	ICBC	188	11
5	Tencent	496	–	ChinaMobile	175	39
6	Berkshire Hathaway	492	12	Microsoft	163	3
7	Alibaba	470	–	AT&T	149	7
8	Facebook	464	–	Johnson & Johnson	145	10
9	JPMorgan Chase	375	28	Royal Dutch Shell	139	15
10	Johnson & Johnson	344	8	Procter & Gamble	138	34

2018) and about the Solow paradox. As early as the 1980s, Robert Solow pointed out the apparent paradox between declining growth rates on the one hand and perceived productivity increases due to computer technologies on the other: „You can see the computer age everywhere but in the productivity statistics“ (Solow, 1987).

Different explanations are given for the weak development of economic performance and productivity, especially in developed economies (Crafts 2018; Brynjolfsson et al., 2018). In this context, problems in statistical data collection can also play a role, for example (Jorgenson, 2018; {Brynjolfsson et al., 2019a, b), particularly since many digital products and services are offered free of charge; they are therefore not directly covered by the macroeconomic statistics, even though they contribute to prosperity. However, such problems seem to only party explain the observed development, if at all; the same applies to the apparent contradiction between technological dynamics and weak economic development (Syverson, 2017).

However, it is also generally unclear whether the weakening of growth and productivity might reflect a long-term trend in developed economies that would have been even greater without digital progress. For example, there are indications that temporary increases in productivity growth in the USA in the 1990s were essentially due to the highly productive computer industry, without which productivity growth would have declined even more or even been negative (Aum, 2018).

Apparent contradictions between observed technological development and appearances in macroeconomic indicators are not completely new. Even during the first and second industrial revolutions, steam engines and electricity did not show their full potential in the form of boosts to growth and productivity until the technologies had not only been deployed, but the economic structures and business models had also adapted accordingly (Crafts 2018). ICTs are often seen as general purpose technologies which – like electricity – are characterized by a large, broad impact and the potential for long-term technological and economic stimuli (Bresnahan, 2010; Brynjolfsson et al., 2018). Compared to the earlier industrial revolutions, technological change in the field of ICT has already taken place faster and had a greater impact, for example in terms of labour productivity (Crafts 2018:453). It is (as yet) too early to say whether digital progress will generate similarly far-reaching, long-term stimuli from an economic point of view as the previous industrial revolutions (Aghion, 2017).

3.1.4
Conclusions: the Digital Age is emerging

Up to now, every age of human civilization has gone hand in hand with a technological boost and has been essentially triggered and shaped by it. More and more people are saying that digitalization also represents such a fundamental technological boost and that this is currently one of the first stages of a Digital Age. However, empirical analyses are difficult to carry out in such transitional situations, and findings are therefore provisional. Nevertheless, the generality of digital technologies and their applications in all areas of human life and work and the changes associated with their applications are unmistakable.

At the same time, it is undisputed that the Great Transformation towards Sustainability (WBGU, 2011) has already begun and has reached the societal mainstream (WBGU, 2016a: 128). In some areas, progress is visible, albeit not always fast enough; in others progress is not visible or too slow. In this situation, digitalization offers both opportunities and risks and can thus not only become an instrument for the Great Transformation, but must equally become an object to be shaped in the sense of the Great Transformation. As a result, the process of shaping the digital and digitalized technosphere in a way that is in line with climate and sustainability goals moves to the centre of attention. Furthermore, the next push of humans influencing the environment (the Anthropocene) using new technological means also seems likely to involve new possibilities for humans to influence or shape humans – with opportunities for therapies and healing, but also with risks to humans as biological beings, their *Eigenart*, societal inclusion and human dignity.

3.2 Selected basic terms and functions of digitalization

Terms from the field of informatics or information technology are sometimes used incorrectly or falsely in the digitalization debate. In order to close gaps in understanding, this section explains selected basic terms and basic functions of digitalization and offers some initial reflections on the interaction between people and digitalization. They form a foundation for the subsequent description of key technologies, the resultant characterizations of the Digital Age, and initial analyses of its effects in the ecological, economic and societal context.

3.2.1 Features and basic functions of digital sociotechnical solutions

To improve our understanding of digitalization, there now follows a brief excursus on the basic features and functions of a digital solution, i.e. on its tasks, modes of action and theoretical possibilities.

Every digital solution uses calculating machines. One of the first, then-mechanical calculating machines was the pinwheel, which goes back to Gottfried Wilhelm Leibniz (1646–1716). Today's calculating machines are electronic and use semiconductor-based digital electronics. For interaction with the environment using sensors and actuators, analogue-to-digital or digital-to-analogue converters are used which convert voltages that are proportionally dependent on a measure into numerical values or vice versa (Lee and Seshia, 2017: 180). Digital calculating machines (computers) are widespread, and there are numerous different types: nano-, micro- and mini-computers, high-performance and supercomputers, computer farms, desktop computers, laptops, smart pads, smartphones, as well as embedded control devices, smart cards and other single-chip systems. Indeed, most computers are evidently not (domestic) PCs, but are hidden in embedded systems (ESs; Lee and Seshia, 2017: x). Approximately 98% of the microprocessors produced are in ESs (BITKOM, 2010: 7–8). They are defined as "computer systems that are embedded in devices, plants and machines and process specific applications" (itwissen.info, 2013). ESs are specialized minicomputers that often perform only one or a few functions and contain software and hardware designed specifically for this purpose (ESI, 2019).

According to Moore's Law, the complexity of the integrated circuits used in digital electronics doubles every 1.5 years at comparable cost (Moore, 1965). Although this has held true since the 1960s, semiconductor technology is now reaching the physical limits of further compaction and thus of further increases in performance. This is one reason why research is being conducted into alternative models for calculator machines to reach the next level of computer performance.

Computer hardware, i.e. a computer's computing, storage and transmission units, as well as its input and output devices, are programmed using software that defines a computer's logical mode of operation in the form of algorithms (calculation rules, Section 3.2.3). Software is essentially prepared by transformers (e.g. compilers) for runtime environments (e.g. for the Java programming language) of the hardware, and executed using the operating system and drivers.

Such software-based systems are not tied to a single computer; they can also use a number of connected computers, each of which performs different tasks for presentation, control, business logic, data access or data storage (Figure 3.2.1-1). Specific computer architectures, software architectures, system architectures and network architectures are not dealt with here. Instead, references are given to further literature (Bourque and Fairley, 2014; Knuth, 2011; Goodfellow et al., 2016). The actors in the development and operation of software-based systems are shown schematically in Figure 3.2.1-2; their usage contexts are shown in Figure 3.2.1-3.

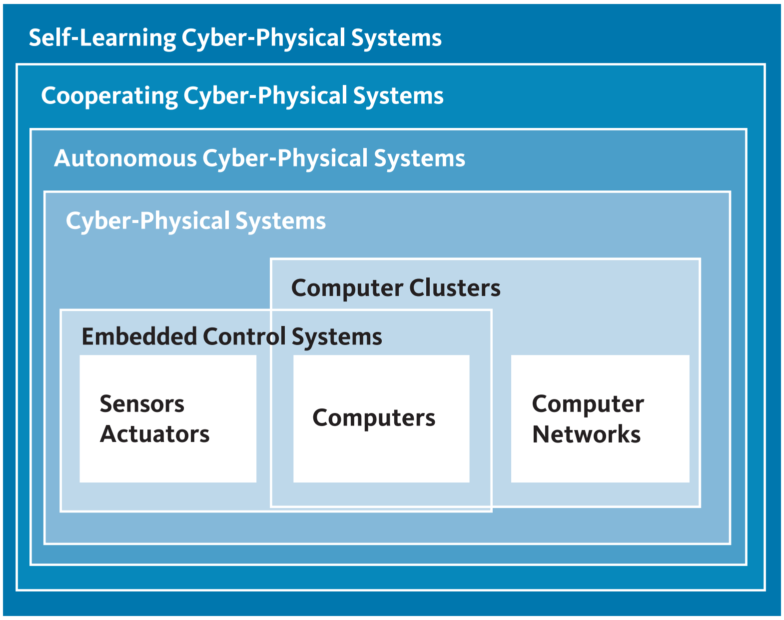


Figure 3.2.1-1
Types of software-based systems: computers are networked to form computer clusters. Computers with sensors or actuators form embedded control units (e.g. in automobiles, aeroplanes or robots); if they are in a network, they are called cyber-physical systems. Recent and current R&D examines the autonomy, cooperation and self-learning of these systems.
Source: WBGU

The software-based, partly networked systems process data (Section 3.2.2) according to the programmed calculation rules – the algorithms (Section 3.2.3). The data can be permanently programmed, or be used via software parameters – or else they can 'calibrate' the calculation rule as training data. Data are not only generally recorded and syntactically processed by calculations, their meaning is also semantically analysed and processed by logical reasoning or machine learning in order to prepare or make decisions. To this end, data are also collected, aggregated, transported, transformed, combined and/or visualized. This is done both with individual values and with simple number series – or complex simulation models or 3D-360° visualizations and animations in multimedia rooms.

As Figure 3.2.1-3 shows, the basic functions of digital systems comprise computation, storage, communication, experience, reaction and cooperation. This ultimately corresponds to the development path from simple computers via the established internet of computers to the incipient Internet of Things and the forthcoming Internet of Cooperation.

(1) *Computation* is performed on processors based on different processor architectures, for example the well-known Von Neumann architecture with 'single instruction, single data' or the lesser known architectures with 'multiple instruction, multiple data'. Processors are often used in parallel in clusters ('multi-core' in the case of similar processors and 'many-core' for different processors).

The data required for computing are (2) *stored* temporarily via sensors or networks, or permanently via internal and external *memories;* they are thus either temporarily passed on or made permanently available.

Communication networks are used for (3) *communication* – both for the exchange of information and for interaction – between computers. They differ, for example, according to the physical transmission paths (wired or wireless, e.g. Local Area Networks – LANs or Wireless Local Area Networks – WLANs) and according to their ranges – from very short in Personal Area Networks (PANs) to very large in Wide Area Networks (WANs). Communication protocols such as the Transmission Control Protocol (TCP) or the User Datagram Protocol (UDP) are used for transmissions in these communication networks. These protocols control and secure the exchange of data at different logical protocol levels – from physics via bits and bytes to logical connections, transactions and application logics. For example, today's internet is designed as a network of networks in which three main network types can be distinguished: *backbones* are the core networks of internet service providers (ISPs) and between them; *intranets* (local networks) are used by companies, organizations, scientific or other institutions, as well as by municipalities or private individuals. They are given access to the internet via access networks. The hardware structure of the worldwide internet, in which data transport is possible with internet protocols and their applications, consists of wiring, transmitters/receivers and network nodes, as well as switches, gateways, routers and servers. It can be supplemented by overlay networks, which make it possible to implement logical network structures, often with their own address spaces and protocol stacks for dedicated communication requirements and service qualities such as throughput (e.g. in Mbit/s), delay (e.g. in ms) or bit-error rates (in faulty bits per transmitted bit). Such overlay networks can be

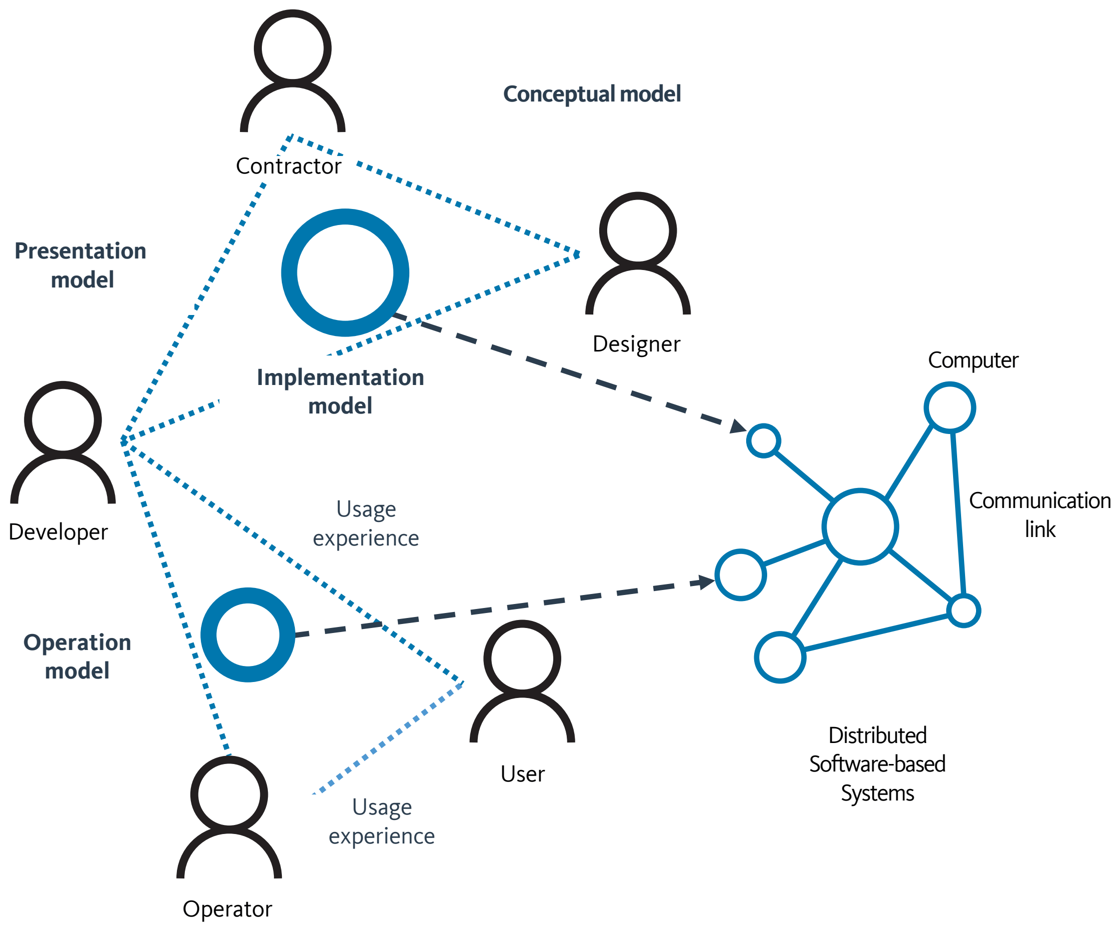


Figure 3.2.1-2
The actors of a networked software-based system in the development and usage context. Today, a software-based, often networked system, also known as a digital networked system, is typically accessible to users via graphical user interfaces. The computers involved and the services offered are configured, maintained and offered by the operators according to an operation model. The options of the operation model are determined by the functions of the software-based system, as designed in the conceptual model, presented to the contractors and implemented by the developers.
Source: WBGU

set up and operated more flexibly with the help of concepts for virtualizing network functions and for defining networks using software.

The ability to (4) *experience* is implemented by sensors that use various methods, e.g. mechanical, thermoelectric, resistive, piezoelectric, capacitive, inductive, optical, magnetic, optomagnetic or virtual (for data collection from the internet), to measure data and make them available in either analogue or digital form. For analogue sensors, analogue-to-digital converters are required to process the measured physical quantities digitally (Lee and Seshia, 2017: 180). The data collected in this way from the real or virtual environment are forwarded in the Internet of Things (IoT; Section 3.3.1) to the networked, software-based systems for further processing – either directly at the point of data collection (fog computing), or indirectly (edge computing), or remotely from the point of data collection (cloud computing). Examples of sensors include speedometers in cars, thermometers in buildings, cameras in public spaces, and various environmental sensors (e.g. for measuring air quality). These days, even a typical smartphone contains a variety of sensors such as accelerometers, rotation sensors, GPS sensors, magnetic-field sensors, cameras, microphones, brightness sensors, proximity sensors, barometers, hygrometers, pulse monitors, thermometers, eye trackers or fingerprint sensors.

(5) *Action* is implemented by actuators that generate effects in the real or virtual environment through movement, deformation or information. So while sensors measure physical quantities, actuators influence them (Lee and Seshia, 2017: 179; Gunes et al., 2014: 4245f.). Actuators can be based on mechanical (pneumatic or hydraulic), electromechanical, biological, optical, thermal, electronic or digital principles. They are digitally or analogue-controlled, whereby the latter requires digital-analogue converters for the informa-

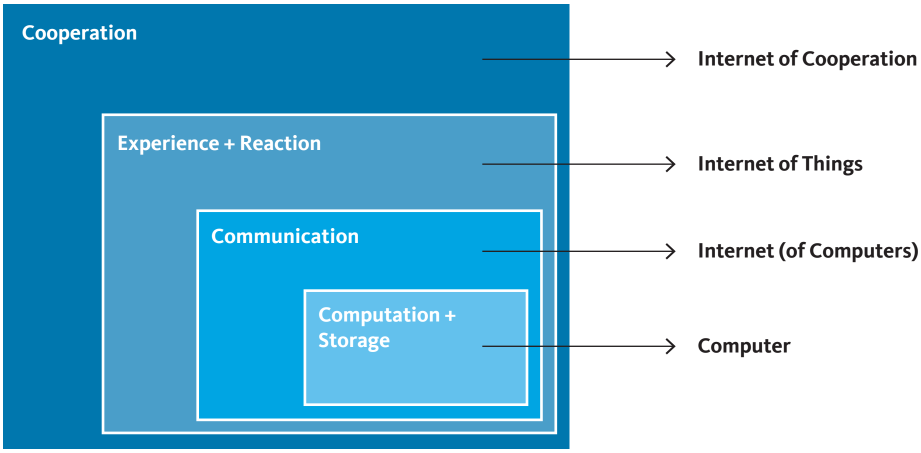


Figure 3.2.1-3
Basic functions of digital systems in their temporal and future development. The basic functions of digital systems include, in order of their historical and future development, (1) computing data and (2) storing data, (3) communicating (forwarding data), and (4) experiencing (capturing data). They can (5) act in their environment and (6) cooperate with the environment and its actors. This ultimately corresponds to the development path from simple computers via the established internet of computers to the incipient Internet of Things (IoT; Section 3.3.1) and the forthcoming Internet of Cooperation.
Source: WBGU

tion from the control unit. "The best known actuators are electric motors and electromagnets" (Gerke, 2012:5). One actuator in a smartphone, for example, is the vibration motor.

Input and output devices of computers that are equipped with sensors for *experiencing* and/or actuators for *influencing the environment*, use various physical, chemical or biological measuring procedures, which are connected to the computer using analogue-digital or digital-analogue converters. Well-known input devices such as keyboard and mouse can also be regarded as sensors; monitors are actuators. Touch panels or smart glasses, which are used for both input and output, function simultaneously as sensors and actuators. The results are made available to users via output components or output devices (Figure 3.2.1-4).

(6) *Cooperation* refers to human-machine interactions, machine-machine interactions, and machine-environment interactions. In the context of autonomous systems, such as robots in industrial automation or automated driving, all three forms of interaction are currently experiencing new developments in the design of cooperation forms. In human-robot interaction, for example, a distinction is made between forms of cooperation and collaboration. Forms of cooperation are implemented in workspaces that are permanently physically separated or have virtual fences, or sometimes in workspaces that can be shared, where various restrictions are defined for velocities and forces, and a suitable system of workspace monitoring is used. In human-robot collaboration, on the other hand, there is conscious, deliberate contact between humans and robots, with both working on a project simultaneously and able to coordinate their movements, e.g. through guidance by hand.

3.2.2
Data, metadata, data catalogues and data rooms

In terms of information technology, data are representations of information in digitalized form that are (machine-)readable and editable and can be (further) processed, stored, transmitted and (re-)interpreted. In general, data are represented in bit strings and can be understood with the help of descriptions of correct character strings (syntax), descriptions of correct value sets (type system) or descriptions of logical relationships between values and value sets (ontology, Krcmar, 2015). Data can be categorized in many different ways:

- according to their structure as either unstructured data (i.e. they do not have a given structure; e.g. texts), semi-structured data (i.e. data with a mix of specified and unspecified structures; e.g. documents with fixed content specifications and free contents), or structured data (i.e. data which completely follow a specified structure; e.g. data used in machine-to-machine communication);
- according to their contents, e.g. environmental data, mobility data, energy data, etc.;
- according to their reference to individuals, such as personal data (data that relate directly to an individual), person-related data (data that can be indirectly assigned to an individual), non-personal data

or non-person-related data;
- according to their source, such as sensor-generated, behaviour-generated, measured or empirically recorded data;
- according to their originality in raw data (e.g. direct measurement results) and derived data (i.e. data derived from other data) or aggregated data (i.e. data generated from the combination of several data);
- according to their consistency as transient or persistent data;
- according to their topicality as real-time, near-real-time or historical data;
- according to their condition as discrete data (i.e. data at a countable number of points in time) or continuous data (i.e. data at every point in time, also referred to as data streams).

Furthermore, data that describe the structure and content of other data are referred to as metadata. For example, the (content) data of a telephone call includes the actual conversation; data on who held the conversation when, with whom and where are stored in the metadata.

Metadata allow data to be categorized and traced. The metadata can also contain copyright and usage rights, responsibilities, or storage locations and versions of the data (Klessmann et al., 2012:424ff.). Just as books are administered using their bibliographic information in library catalogues, data are managed using their metadata in data catalogues. Data catalogues, too, are in turn subject to copyright and rights of use, and can be understood in their entirety as data which are in turn described using metadata (Krcmar, 2015).

Using data catalogues and the associated data, data rooms can be created, making joint technologies, tools and procedures for data processing available to providers, processors or users. Access to such data rooms can be provided either within an organization, across organizations or to the general public (Schieferdecker et al., 2018; Section 5.2.7.4).

The term data market has become established for commercial data rooms that sell data and the services built upon them. Examples include mobility-data marketplaces, energy-data marketplaces and marketplaces for geoinformation. The term data portal is often used for generally accessible data rooms. From a societal point of view, regional data rooms are of particular interest because they can offer transfers between the various data offerings of the public sector, companies, academia and politics (Schieferdecker et al., 2018) and often reflect regional societal and economic interactions.

On social platforms, where value-added is often drawn from the behaviour-generated data of the platform users, neither the data, metadata nor underlying commercial processes are currently made explicit; they thus largely elude possibilities for transparency and control. High-quality data, metadata and data catalogues have high informational, knowledge and economic potential. They are therefore typically subject to special data-security requirements in terms of access options and/or encryption. Personal and person-related data are also subject to data-protection regulations, e.g. the EU's Basic Data Protection Regulation (GDPR). There is still no uniform worldwide data regime that equally covers data quality, data security, data protection and data trading. At the European level, the GDPR has taken the first step towards achieving greater data sovereignty for platform users and application users and the underlying commercial data markets. Discussions on the value of data and possible pricing are underway worldwide (Lim et al., 2018; Seibert and Gründinger, 2018; van Lieshout, 2015) with the aim of integrating the transactions associated with the data more seamlessly into existing economic and control structures. The EU is working on a European data room and has developed initial regulations to this end with the GDPR and the PSI Directive (Directive on the re-use of public sector information).

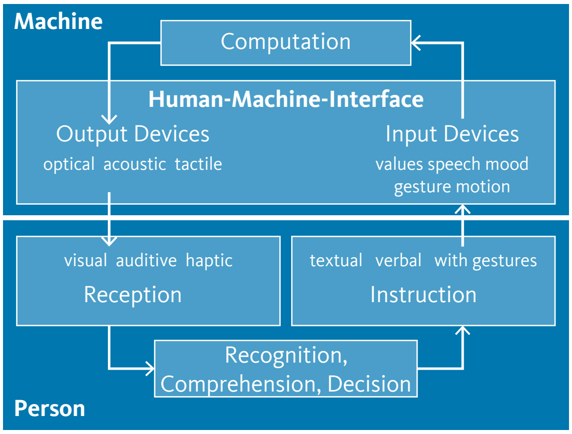


Figure 3.2.1-4
Human-machine interaction: Via human-machine interfaces, machines receive textual, verbal or gestural orders from the users, which are transmitted via input devices and then calculated. The results are given to the users visually, haptically or auditorily via output devices. The orders received by machines from other machines via machine-machine interfaces are not shown here.
Source: WBGU (extension of Schlick et al., 2018)

3.2.3
A brief introduction to algorithms, computability and heuristics

Alongside data (Sections 3.2.2, 3.3.2) and AI (Section 3.3.3), the term algorithm is currently on everyone's lips. In general, this term is associated with increasing automation through digitalization, which extends into system-relevant societal areas such as finance (e.g. high-frequency trading), police work (e.g. automated video surveillance and facial recognition) and social systems (e.g. automated social notifications).

In general, an algorithm is a rule of action for solving a given problem (or, more precisely, a class of problems). Algorithms are therefore always explicit and well defined, even if the respective manifestation of this rule of action in the application of an algorithm using concrete data and calculations cannot always be traced.

Algorithms already existed before digitalization. They were used, for example, in ancient Egypt to create right angles with the twelve-knot cord in civil engineering (Cantor, 1894: 64) and in antiquity to determine the largest common divisor with the Euclidean algorithm (Ziegenbalg et al., 1996: 60ff.). With the development of calculating machines, however, the definition of an algorithm was formalized mathematically by Alan Turing (Turing, 2008), Alonzo Church (Church, 1962), Noam Chomsky (Chomsky and Lightfoot, 2002), Andrei Markov (Markov, 1954) and others. Mathematically, an algorithm corresponds to a calculable function; in terms of information technology, an algorithm is a deterministic calculation rule. Based on current information, all definitions of algorithms are equally powerful; they can thus solve the same class of calculation tasks (problem classes) and be realized using the Turing machine, a basic computing model developed by Alan Turing in 1936 (Eberbach et al., 2004; Siegelmann, 1995). The Church-Turing thesis states that the class of Turing-calculable functions corresponds to the class of intuitively calculable functions, i.e. they can be calculated with a Turing machine. Mathematically, computability is characterized by μ-recursive functions (Cooper, 2017). In computers, algorithms, the logical calculation rules, are realized by programs in software or hardware including the required data. At this point it is important to point out that verified and validated algorithms, i.e. algorithms proven to be correct, can be incorrectly implemented in software, hardware and/or data, or be incorrectly configured and used, so that the algorithm ultimately used can produce incorrect results. Even if an algorithm is correct, this certainly does not mean that it is implemented or operated correctly.

The limits of computability are currently being explored in two directions: on the one hand, it is expected that quantum computing (Section 3.2.6) with its 'qubits' requires a potentially new calculation model – although quantum computing can be simulated with the existing computer infrastructure. On other hand, machine-learning methods (Section 3.3.3) use in particular statistical methods to classify data, which can apparently be realized with today's computer infrastructures, but could nevertheless mean a different access to computability. A better understanding of uncomputability is therefore also being sought (Soare, 2007; Cooper and Piergiorgio, 2003; Cooper, 2012; Box 3.2.3-1).

3.2.4
A brief history of automation and artificial intelligence

While the term 'automat' in the sense of an independently (autonomously) functioning machine was already coined in antiquity in a literary context, automation has been a practical, technical and scientific reality since the beginning of modern times. From Leonardo da Vinci's construction plans to Baroque, clockwork-driven automatons to the human/machine imagery of the French physician and philosopher Julien Offray de La Mettrie, the age of mechanics laid the first foundation stone for a naturalistic-deterministic view of the world and the human self-image. The latter culminated not least in Leibniz's slogan "Calculemus!" and thus in a universal form of mathematics that reduced thought and knowledge to arithmetic and led to the first mechanical calculators. The next important step towards (algorithm-based) sequential program control was made in the cloth factories of the 18th century, first with rollers and later using wooden punch cards, which led to different weaving patterns. This principle was in turn transferred to calculating machines by the (never constructed) 'analytical engine' of the English mathematician, philosopher and inventor Charles Babbage. Mathematician Lady Ada Lovelace, who collaborated with Babbage, already foresaw that such machines would also process other things apart from numbers and, for example, compose music, but would always only be able to obey commands (Mainzer, 2016: 7ff.)

The advances in electrical engineering at the end of the 19th century made novel systems possible, such as the Hollerith machines (electromechanical machines for processing punched cards) and the first automaton chess player in 1911, which, however, could only handle a scenario involving the final moves of a match. In the 1930s, the breakthrough of digitalization laid a foundation stone for the development of universal program-controlled computers. Now, computers could be

Box 3.2.3-1

Uncomputable problems

Both theoretical and practical uncomputability play a role in the context of the possibilities and limits of digitalization (Cooper, 2017: 78). According to today's understanding, on the one hand there are uncomputable problems, which do not sound so complicated at first sight. On the other hand, there are problems that are computable but whose calculation is very time-consuming; using today's ICT, it can end up taking a matter of years, decades or even centuries to calculate a solution. In other words, although much can be automated by means of digitalization, there are also relevant problem classes that cannot be automated (not even in the future) because there are no (or no efficient) algorithms. This is important to note when discussing the basic possibilities of AI compared to human intelligence: many things are possible (mathematically), but not everything is possible with digitalization.

Among the uncomputable problems is, for example, the halting problem (Cooper, 2017: 78): No program exists that decides for arbitrary programs and arbitrary entries whether the program call of this program will ever stop. Furthermore, there are problem classes that are very time-consuming to calculate: the non-polynomial problems (NP). Even polynomially solvable problems (P), to which the linearly computable problems also belong, can be very complex in the calculation of a solution if their calculation polynomials contain complex powers. The question of whether the class of polynomially solvable problems is equal to the non-polynomially solvable problem class (i.e. whether P = NP), i.e. whether algorithms exist for all NP-complete problems in polynomial time, is an open question of mathematics, theoretical computer science and complexity theory. It is one of the seven millennium problems of mathematics. However, it is believed that there are problem classes that cannot be solved efficiently, i.e. that P ≠ NP. These are the NP-complete problem classes (Priese and Erk, 2018: 450ff.). They also include generally understandable problems, which are usually assumed to be easy to solve, such as the backpack problem or the travelling salesman problem. The travelling salesman problem describes a salesman who must find the shortest route to visit a number of cities in such a way that each city, apart from the first one, is visited only once and the first city is also the last (Cooper, 2017: 205; Priese and Erk, 2018: 485).

Again, it is important to understand that, despite the NP completeness of problem classes, it is often possible to find efficient, exact or heuristic methods for solving smaller problem sizes and thus to efficiently calculate solutions for typical problems like the travelling salesman problem, despite NP completeness (Wendt, 2013: 16ff.).

used for any algorithm to solve calculable problems (Section 3.2.3).

Universal programmability also made it possible to start research into AI (Section 3.3.3). While its first phase in the 1950s and 1960s was marked by euphoric expectations, shortly afterwards, in the wake of the practical results, the theoretical principles of (non-) computability were established with regard to computers' ability to solve problems.

Since specialized applications yielded better results, the second phase up until the mid-1970s saw a specialization of programming and application. Typical of this phase was "the construction of specialized systems, methods of knowledge representation and an interest in natural languages" (Mainzer, 2016: 12). From the mid-1970s to the mid-1980s, a third phase focused increasingly on knowledge-based expert systems. After storing special knowledge, these AI programs automatically draw diagnostic or problem-solving conclusions, although without having cross-context background knowledge like humans: "In the mid-(19)80s, E.A. Feigenbaum, one of the pioneers of this development, compared the development of knowledge-based expert systems to the history of the automotive industry. The world of AI was like the situation in 1890 when the first automobiles appeared. They were hand-operated horseless carriages, but already automobiles, i.e. self-propelled vehicles. Just as Henry Ford further developed the first prototypes for mass production at the time, so, according to Feigenbaum, knowledge-based systems would also go into mass production. Knowledge-based systems were thus understood as 'automobiles of knowledge'" (Mainzer, 2016: 13).

3.2.5 Algorithm-based systems in the societal context

Every digital or digitalized solution uses hardware and software whose logic is defined in algorithms and expressed by data. These are algorithm-based systems, also known as algorithmic systems. They are increasingly incorporated into decision making and decision-making support in areas that are critical to society (e.g. in elections), in areas that are critical for business and relevant to *Eigenart* (Section 2.2.3; e.g. in online commerce, Section 5.2.4), or in areas relevant to self-determination (e.g. in online media). There is a growing discussion about necessary guard rails for designing, developing and operating these sociotechnical systems; they lie in the interplay of technology and societal embedding. They address technical properties (such as correctness, reliability, robustness or cybersecurity), operational, organizational or regulatory framework conditions for the deployment of the systems (such as the rules for algorithm-based systems, which are described briefly below), as well as ethical guidelines for the design and development of the systems (such as the ACM Code of Ethics; ACM Ethics, 2018).

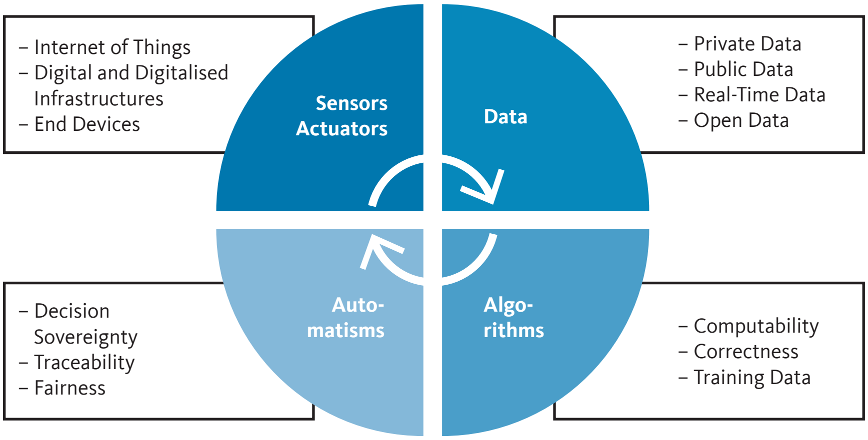


Figure 3.2.5-1
Elements of an algorithm-based system. Sensors that can be used generally via the Internet of Things (Section 3.3.1) – or via special digital or digitalized infrastructures or end devices – generate private or public data (Section 3.2.2), also in real time, sometimes provided openly as Open Data. Algorithms (Section 3.2.3) use these data in their calculations, and also as training data (Section 3.3.3). The performance of the algorithms is limited by questions of computability and, in certain circumstances, by the (in)correctness of their computational logic, data, implementation or application. Automatisms for decision making or decision-making support can have an effect on the environment via the actuators.
Source: WBGU

Figure 3.2.5-1 shows how algorithm-based systems function in principle. These systems are already embedded into society and receive a societal connection during design, but especially during operation and use. They are sociotechnical systems that can be understood neither purely technically nor purely sociologically, but always in the interplay of societal, social, economic and ecological relations. From the point of view of use and application, the current focus of societal discussions is particularly on the traceability, explicability and fairness of algorithm-based systems and, ultimately, on people's decision-making sovereignty (Box 4.3.3-1; Section 8.3.3). In order to reliably implement these properties of algorithm-based systems, various sets of rules are currently being drawn up, such as AI4People (Floridi et al., 2018), the Algo.Rules (Bertelsmann-Stiftung and iRights.Lab, 2019) and the Ethics Guidelines for Trusted AI prepared by the EU's High-Level Expert Group on Artificial Intelligence (European Commission 2019c; Box 3.2.5-1).

In view of ongoing sociopolitical discourses and controversies, as well as rapid technological developments, all three sets of rules listed as examples in Box 3.2.5-1 are designed as dynamically updatable documents. Their operationalization is an open field for implementation and regulation at the national, European and international level. There is an urgent need for action here, for, important as ongoing discourses are, they remain ineffective if they do not lead in parallel to the best possible implementation in the respective time context, while preventing one-sided influence from vested interests.

3.2.6 Quantum computing as a future computer generation

Despite rapid technological development, ultimately today's computers function "according to the same basic principles as the early calculating machines" (Homeister, 2015). "The stages along the road from the cogwheel via relay, tube and transistor to the miniaturized circuit can therefore be regarded as different technical implementations of the same idea", while the development of quantum computers (Aharonov, 1999; Feynman, 1986) aims at a "completely new way of computing: "Whereas in a classical computer a bit is set to either 0 or 1, a quantum bit can assume both values simultaneously, i.e. be in two states at the same time". This is known as the superposition (Homeister, 2015: 1f.).

Calculating with qubits (short for quantum bits) is inherently probabilistic and is statistically evaluated. The basic calculation model is the probabilistic Turing machine: the Turing machine extended by random executions. In compliance with the extended Church-Turing thesis, according to which any computability can be simulated mutually with polynomial effort, the probabilistic Turing machine is just as universal (Nielsen and Chuang, 2002). It would therefore correspond to the current understanding of computability (Section 3.2.3). Like the Church-Turing thesis, the extended thesis has not yet been proven.

The principle of entanglement allows multiple qubits to be correlated, allowing quantum computing to search

Box 3.2.5-1

Overview of current rules and regulations on the use of AI and algorithm-based systems

AI4People

AI4People is a multi-stakeholder forum launched in February 2018, bringing together all actors interested in shaping the social impact of new applications of AI – including the European Commission, the European Parliament, civil society organizations, industry and the media (Floridi et al., 2018). The result is a 'living document', whose current preamble is as follows (Floridi et al., 2018):

"We believe that, in order to create a Good AI Society, the ethical principles identified in the previous section should be embedded in the default practices of AI. In particular, AI should be designed and developed in ways that decrease inequality and further social empowerment, with respect for human autonomy, and increase benefits that are shared by all, equitably. It is especially important that AI be explicable, as explicability is a critical tool to build public trust in, and understanding of, the technology.

We also believe that creating a Good AI Society requires a multi-stakeholder approach, which is the most effective way to ensure that AI will serve the needs of society, by enabling developers, users and rule-makers to be on board and collaborating from the outset. Different cultural frameworks inform attitudes to new technology. This document represents a European approach, which is meant to be complementary to other approaches. We are committed to the development of AI technology in a way that secures people's trust, serves the public interest, and strengthens shared social responsibility. Finally, this set of recommendations should be seen as a 'living document'. The Action Points are designed to be dynamic, requiring not simply single policies or one-off investments, but rather, continuous, ongoing efforts for their effects to be sustained."

Algo.Rules

"The Algo.Rules are a catalogue of formal criteria for enabling the socially beneficial design and oversight of algorithmic systems. They provide the basis for ethical considerations as well as the implementation and enforcement of legal frameworks. These criteria should be integrated from the start in the development of any system and therefore be implemented by design. Given their interdependence on each other, the Algo.Rules should be treated as a composite unit. Interested stakeholders and experts are invited to join us in developing the Algo.Rules further and to adopt them, adapt them, expand them and, above all, explore opportunities to apply them in practice. Dynamic by design, the Algo.Rules should be fine-tuned, particularly in terms of their practical implementation" (Bertelsmann-Stiftung and iRights.Lab, 2019). The wording when this report went to press was as follows

1. "Strengthen competency: the function and potential effects of an algorithmic system must be understood.
2. Define responsibilities: a natural or legal person must always be held responsible for the effects involved with the use of an algorithmic system.
3. Document goals and anticipated impact: the objectives and expected impact of the use of an algorithmic system must be documented and assessed prior to implementation.
4. Guarantee security: the security of an algorithmic system must be tested before and during its implementation.
5. Provide labelling: the use of an algorithmic system must be identified as such.
6. Ensure intelligibility: the decision-making processes within an algorithmic system must always be comprehensible.
7. Safeguard manageability: an algorithmic system must be manageable throughout the lifetime of its use.
8. Monitor impact: the effects of an algorithmic system must be reviewed on a regular basis.
9. Establish complaint mechanisms: if an algorithmic system results in a questionable decision or a decision that affects an individual's rights, it must be possible to request an explanation and file a complaint."

Ethics Guidelines for Trustworthy AI (High-Level Expert Group on Artificial Intelligence of the European Commission)

For the European Commission's High-Level Expert Group on Artificial Intelligence (EU-HLEG; European Commission), trustworthy AI is based on three necessary components that are ideally in harmony, despite possible conflicting goals: first, conformity with the law, second, ethics, and third, robustness to "ensure that, even with good intentions, AI systems do not cause any unintentional harm" (European Commission, 2019c35). The normative principles are as follows:

- "Develop, deploy and use AI systems in a way that adheres to the ethical principles of: *respect for human autonomy, prevention of harm, fairness and explicability.* Acknowledge and address the potential tensions between these principles.
- Pay particular attention to situations involving more vulnerable groups such as children, persons with disabilities and others that have historically been disadvantaged or are at risk of exclusion, and to situations which are characterized by asymmetries of power or information, such as between employers and workers, or between businesses and consumers.
- Acknowledge that, while bringing substantial benefits to individuals and society, AI systems also pose certain risks and may have a negative impact, including impacts which may be difficult to anticipate, identify or measure (e.g. on democracy, the rule of law and distributive justice, or on the human mind itself). Adopt adequate measures to mitigate these risks when appropriate, and proportionately to the magnitude of the risk" (European Commission, 2019c: 2).

In addition, the current version contains sections on requirements, as well as technical and non-technical methods for implementation and evaluation. However, the philosopher Thomas Metzinger, who is involved in the EU-HLEG, has sharply criticized the current result in a bilingual op-ed in the Tagesspiegel newspaper on the subject. Under the title 'Ethics washing made in Europe' (Metzinger, 2019a), he deplored the composition of the group, the lack of non-negotiable ethical principles ('red lines' were defused), and described the guidelines as "lukewarm, short-sighted and deliberately vague," since they glossed over difficult problems with rhetoric, violated elementary principles of rationality, and pretended to "know things that no one really knows" (Metzinger, 2019b). On the other hand, the section on long-term risks that disappeared from the final version showed that the same accusation could also be levelled at Metzinger: "Metzinger and others had pointed out the danger that systems could eventually become so intelligent that they could become independent, develop their own consciousness or even their own morals. Metzinger admits that these scenarios known from science fiction are very unlikely. Nevertheless, such risks should not be ignored. For other members of the group, this was going too far. In particular, computer scientist Virginia Dignum and philosopher Luciano Floridi [...] had threatened to resign if the concerns remained in the document" (Köver and Fanta, 2019).

larger solution spaces. With such n-qubits, quantum computing can solve a 2^n-large solution space efficiently with polynomial effort. This means that a larger problem class than P (Section 3.2.3) can be efficiently solved by quantum computing (e.g. the factorization of large numbers with the Shor algorithm; Shor, 1994). Here lies the great speed advantage over classical computers, allowing complex climate models, for example, to be calculated more efficiently. The problem classes solvable with quantum computing in polynomial time are called bounded-error quantum polynomial time (BQP). It is suspected that NP ≠ BQP ≠ P, but this has not been confirmed (Arora and Barak, 2009). In addition, further problem classes have been identified that can be solved more efficiently with quantum computing (Deutsch and Jozsa, 1992). Solutions for factoring whole numbers, searching for routes in networks and the backpack problem can be efficiently calculated with quantum computing.

Algorithms for quantum computing are formalized and realized as quantum circuits, i.e. calculation sequences with quantum gates that perform Boolean operations on qubits, or else are simulated on conventional computer infrastructures. Electron-based approaches were pursued for a long time for the physical realization of quantum gates, but up to now it has not been possible to scale this to more than several dozen qubits. Instead, many scientists today hope for photon-based circuits, which seem to be making big advances recently (Rudolph, 2017).

With regard to the Von Neumann architecture for computers, quantum circuits are supplemented by components, e.g. for error correction. However, they cannot store results. Quantum computers thus ultimately 'only' perform computational tasks, like the central processing unit (CPU) or an application-specific integrated circuit (ASIC), so that classical computers will not be replaced by quantum computers for the time being in the vast majority of applications, only in the specifically computing-intensive ones.

3.2.7 Conclusions: digitalization in a nutshell

This section describes the central technical, conceptual and methodological foundations of digitalization. Everything that is being taught over several years in training occupations and courses of study in computer science, technical computer science, applied computer science, etc., and is consolidated in further years of active learning, has been condensed here onto just a few pages with the aim of making the information as easily understandable as possible. Of course, the choice and depth of the description represents a challenge in itself. As theoretical computer science also shows, there are some basic concepts relating to algorithms and computability, data and metadata, as well as sociotechnical and algorithm-based systems, which are explained to provide a basic understanding of the digital possibilities. These each form the basis of key digitalization technologies that are described in Section 3.3. That the number of basic concepts and functions cannot yet be conclusively defined, even from a technological standpoint, is shown by the brief outlook on quantum computing which, according to today's state of the art, will make the next qualitative stage of digitally supported calculations possible.

However, despite the advances made in expanding human intelligence by technical means, the following maxim will most likely apply: "More computation does not makes us more 'intelligent', only more computationally powerful" (Ito, 2018). The intelligent use of new technologies is proving to be a substantial challenge for the design of sociotechnical systems, especially in the age of massively increasing computational capacities. Since it is only possible to calculate what has been computably modelled beforehand, it is necessary to disclose the implicit assumptions of the calculations. Only then does it become clear what is respectively (not) included in a calculation and to what extent problems arise, for example with regard to distorted categories or partial data: "We must always ask ourselves what had already been inscripted into these systems before we inscribe further models in the course of further development" (Guagnin and Pohle, 2019: 18).

3.3 Key technologies of digitalization (also) in the sustainability context

The focus of this section is on a selection of digital technologies expected to have considerable disruptive potential for the Great Transformation towards Sustainability. The technologies described here, which were

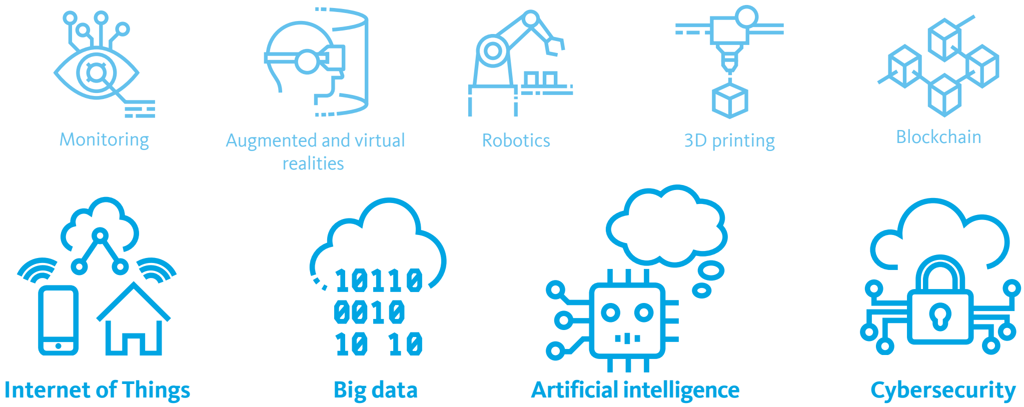


Figure 3.3-1
The main current digital technologies that are changing the technical system. Key technologies are the Internet of Things, big data, artificial intelligence and cybersecurity; further technologies important for sustainability are monitoring, augmented and virtual realities, robotics, 3D printing, and blockchain and distributed-ledger technologies.
Source: WBGU

chosen for their relevance and in accordance with pertinent reports (Sections 3.6.1, 3.6.2), can promote and accelerate the Great Transformation towards Sustainability, but they can also have a negative impact. In particular, new dynamics of digitalization are developing in the wake of the increasing documentation and control of the natural and technical environment, the associated expansion of the data pool via the Internet of Things (IoT), and the resulting huge amounts of data (big data). This is in turn leading to qualitatively novel results in artificial intelligence (AI) and is again based on increased capacity in computing, memory and transmission (Kühn, 2018). Trustworthiness, reliability and therefore especially cybersecurity are key to every digital solution. The four technologies mentioned here – Internet of Things (Section 3.3.1), big data (Section 3.3.2), AI (Section 3.3.3) and cybersecurity (Section 3.3.4) – are seen as key technologies because they are mutually dependent and mutually reinforcing. Other technologies such as monitoring, augmented and virtual realities, robotics, additive manufacturing (or 3D printing), and blockchain or distributed-ledger technologies are important for sustainability and also briefly explained and evaluated (Figure 3.3-1).

Like basic terms and functions of digitalization (Section 3.2), current debates on its key technologies are often characterized by a lack of conceptual clarity. This frequently leads to misunderstandings, e.g. through the inappropriate translation of everyday language into scientific terms or a different understanding of terms in different disciplines, and sometimes to a humanizing use of language (Box 3.3-1).

A clear understanding of the current key technologies of digitalization is therefore indispensable, also in order to be able to adequately assess their respective potential benefits and risks. The following chapters provide a compact overview of these socio-technical systems, embedded in a broad understanding of sustainability (Chapter 2).

3.3.1 Internet of Things

The Internet of Things (IoT) is a concept that describes the ever greater networking and thus fusion of digital and physical infrastructures in interaction with the natural, analogue or artificial, digitalized environment (Horvath, 2012:1; Fraunhofer FOKUS, 2016:4; Lackes, 2017; Atzori et al., 2010:2787). The idea was born as early as the 1990s. First, Mark Weiser (Weiser, 1991) used the term 'ubiquitous computing' to describe the future of computers in the 21st century in the form of omnipresent, small, lightweight and networked devices. The term 'Internet of Things' was first used at the turn of the millennium by Kevin Ashton to assign a digital identity to real objects, e.g. via QR codes or radio frequency identification (RFID; Fraunhofer FOKUS, 2016:4; Li et al., 2015:243f.). Since then, numerous other technological developments have contributed to the advancing realization of the IoT vision (Li et al., 2015:244). The IoT is therefore not an individual technology, but is based on the linking of many technologies, some of which are presented in their own chapters in this report.

From a technological point of view, the IoT refers to objects or things of any kind that are given a distinct identity by means of physical identity carriers such as barcodes, QR codes, RFID or smartcards and which can be networked with the internet or with each other via communication technologies such as Bluetooth, Near-Field Communication (NFC) or mobile telephony (Horvath, 2012:1; Fraunhofer FOKUS, 2016:4; Lackes, 2017; Li et al., 2015:243f.). More recent standards such as the 5th mobile-communications generation (5G) and the 6th version of the internet protocol (IPv6) are therefore important prerequisites for a breakthrough of the IoT (Atzori et al., 2010:2787). The spectrum of objects to be networked is manifold and ranges from household and home appliances such as televisions, windows, heaters and doors to objects in industry, healthcare (e.g. medical sensors or devices, assisted living), and the entire public infrastructure (e.g. networked car traffic, intelligent power networks, buildings; Horvath, 2012:1; Li et al., 2015:253ff.). Systems that focus on "linking physical, biological and/or structural components" (Janiesch, 2017) using (networks of) sensors for digital capture, and actuators for exerting physical influence, are also referred to as cyber-physical systems, particularly in science (Gunes et al., 2014:4248). Therefore, technologies are used not only for localization, but also for positioning things (Fleisch, 2014; Sprenger and Engemann, 2015). To ensure perfect interaction between the many different kinds of sensors, actuators, devices and software components, a suitable architecture is required that adequately combines the IoT elements (Li et al., 2015:246ff.). Moving applications into the cloud also plays an important role, as does the use of big data (Section 3.3.2) and machine learning (Fraunhofer FOKUS, 2016:5).

While the IoT was still predominantly described as a vision around 2010 (Horvath, 2012:2; BCS and OII, 2013; Atzori et al., 2010:2793), and even today the majority of applications are still at an early development stage (Li et al., 2015:243), it is expected that 20 billion 'things' will be interconnected worldwide by 2020 (Gartner Inc., 2017). Since the effects of the IoT are expected to be comparable to or even more revolutionary than those of the internet (Hoepner et al., 2016:70), a look at the potential benefits and risks for sustainability is urgently needed.

Potential benefits and risks

The IoT is seen as a key solution for today's societal challenges (e.g. Geisberger and Broy, 2012; Li et al., 2015:253). Applications for the IoT range e.g. from industrial production, transport and logistics, to health, the environment, energy, agriculture and people's personal lives (Atzori et al., 2010:7ff.; Fraunhofer FOKUS, 2016:9ff.; Li et al., 2015:253ff.). For example, sensors are used in agriculture to measure the moisture and heat content of the soil. The recorded sensor data enable farmers to see from a distance whether they need to take measures to water the soil or protect the plants against fungal attack (Gropp, 2016; Section 5.2.9). This makes it possible to improve and facilitate work processes and conserve resources. The use of the IoT in the healthcare system has similar advantages, for example for monitoring patients' health or supporting them in their living environment (Atzori et al., 2010:9; Li et al., 2015:253ff.). In the energy sector, IoT applications are already being used to control the energy supply in 'smart grids' according to demand (Fraunhofer FOKUS, 2016:10; Section 5.2.6).

In industry, 'Industry 4.0' and 'smart manufacturing' are probably the best-known fields of application, but are not to be equated with (industrial) IoT (Liao et al., 2018:4523). 'Industry 4.0' is concerned with a far-reaching internal and external corporate change process that aims to enable largely automated, decentralized, flexible and networked production as well as the tracking and control of entire value chains and systems (Neugebauer et al., 2016; OECD, 2016b:81; Li et al., 2015:253). From the point of view of sustainability, this could create opportunities for the circular economy (Sections 5.2.1, 5.2.2, 5.2.5).

In the mobility field, the IoT is being used as the basis for a comprehensive reorganization of traffic flows. This applies to both passenger and freight traffic as well as to logistics as a whole, where a breakthrough has already been made with RFID. Here, IoT technologies are expected to make it possible, among other things, to network means of transport with each other or with the transport infrastructure, which could ultimately lead to autonomous driving (Section 5.2.8). Many of the fields of application mentioned concentrate in particular on the *urban environment*, but at present still exist mostly in isolation side-by-side. In the vision of the 'smart city', they and others are networked via IoT (Fromhold-Eisebith, 2017; Geisberger and Broy, 2012; Section 5.2.7). One example is linking electromobility with the energy system in the context of sector coupling (Section 5.2.6).

In addition to these potential benefits, there are also numerous challenges and risks. From a technical point of view, problems that need to be solved include a lack of interoperability and insufficient cybersecurity in IoT infrastructures, interfaces and protocols and their standards (Li et al., 2015:243). Societal challenges include issues ranging from informational and personal self-determination to human dignity and ethical aspects in the interaction between (semi-)autonomous, intelligent systems and things (Bendel, 2016:109f.). From an environmental point of view, too, there are considerable dangers, for example in the form of rising energy consumption and increasing e-waste due to the ever-growing number of digital or digitalized 'things' (Sections 5.2.5, 5.2.6), which could cancel out any sustainability gains as rebound effects.

In the potential conflict between sustainability potential and commercial interests, one must ask whether the latter are not actually the driving forces behind IoT development (Günthner et al., 2008) and what consequences this has for the realization of the former. On the one hand, the economic advantages include improved possibilities for monitoring and controlling objects and infrastructures through the continuous and automated collection of data, as well as process automation and thus process optimization. For example, it is hoped that the large amount of data collected can make better decisions possible, as correlations can be established and more accurate forecasts made (Fraunhofer FOKUS, 2016: 12). On the other hand, Kagermann for example (2017: 244) states for the field of Industry 4.0: "However, change through Industry 4.0 must be actively managed. This is not just an industrial policy issue. Industry 4.0 also addresses environmental and social challenges: resource efficiency and environmental protection, demographic change, urbanization, as well as democratic participation and better work. Accordingly, the Industry 4.0 issue must be discussed broadly involving the most important stakeholders from business, science, politics – but also civil society."

Issues of data protection and data security in particular are among the main topics discussed as risks of the IoT. The IoT is also described as a "data-collection and correlation engine" (Fraunhofer FOKUS, 2016: 15). The interlinked things also collect – possibly unbeknown to users – a large amount of data with direct or indirect personal references, which can be misused, for example by creating user profiles or monitoring people (Coetzee and Eksteen, 2011: 5; Weber, 2010: 24). If data collection by devices and applications becomes a functional part of public life, effective and traceable data protection would be almost impossible to implement (Leopoldina, 2018: 43). Moreover, the supposed decentralization through universal networking paradoxically generates economic and political concentration tendencies, both among private actors such as the large technology groups (GAFAM or 'Big Five') and in authoritarian states such as China or Russia, since the background infrastructure (e.g. data and computer centres and cloud applications) are highly centralized and concentrated on a few actors and locations (Sprenger and Engemann, 2015).

Furthermore, an increased risk of cyber attacks resulting from the networking of things and systems is under discussion in connection with the IoT (Li et al., 2015: 255; Convington and Carskadden, 2013: 7; Atzori et al., 2010). As events in the past have shown, the focus of such attacks is on consumer goods (e.g. car brakes, heating systems, smart-home solutions), industrial plants and critical infrastructures such as hospitals, energy or transport systems (Hofmann, 2017: 14). Inadequately secured systems, networks and infrastructures can therefore cause extensive damage not only to the users themselves but also to third parties (Hofmann, 2017: 14). In addition to the increased risk of eavesdropping from the wireless communication of IoT systems, another subject of discussion is the poor energy and computing capacity of IoT components, which makes it difficult to implement complex security systems to protect the systems (Atzori et al., 2010: 15). For example, the new, automated forms of interaction increase infrastructures' susceptibility to attack (Hoepner et al., 2016: 70). Furthermore, manufacturers save money on necessary components for system security, since the damage caused by security gaps are borne by the users (or their insurance companies) and not by the manufacturers (Hofmann, 2017: 14). In addition, the diversity, complexity and high speed with which IoT products change, as well as the internationality of the markets, make it difficult to establish binding quality and safety standards (Hofmann, 2017: 14).

However, if the risks of the IoT can be mastered, it can form the foundation for the delivery of the data (Section 3.3.2) required for further automation and decision-making support (Section 3.3.3), and provide the instruments for optimizing the technosphere using actuators and control circuits and systems.

3.3.2
Big data

Big data is currently developing from hype to a basis technology (FZI, 2018). This development can also be described as 'datafication' in the sense of processes which increasingly – and partly in real time – depict the physical world in the form of large quantities of machine-readable and quantifiable data (Section 3.2.2; Reimsbach-Kounatze, 2015).

According to estimates by the US consulting firm International Data Corporation, the volume of data generated worldwide could double every two years and rise to 180,000 billion gigabytes worldwide in 2025 (IDC, 2014; Press, 2017). Whereas a great deal of data has so far been obtained by elaborate collection procedures such as surveys or experiments, today every object in the IoT (Section 3.3.1) can be converted into a data source with a network connection and a sensor. The use of sensors is increasing rapidly. They are used in areas such as security, healthcare (in the future possibly also inside the body as 'smart pills'), the environment and transport, and allow a detailed representation of the measured processes and objects in real time.

For example, cameras make it possible to observe public spaces (in London, 40% of public space was already being video-monitored in 2004; Kees, 2015) or to monitor natural areas (Steenweg et al., 2016; Section 5.2.11). Sensors in a smartphone generate data that can be used to determine the owner's mood, stress level, socio-demographic characteristics, smoking habits, sleep patterns, physical movements and much more (World Bank, 2016). In addition, there is an increasing availability of data that has not been collected for a specific purpose, but was created as a by-product of digital processes. As a result of increasing digitalization, every social interaction leaves a data trace behind. Using a mobile phone, the internet or any internet-based application generates e.g. communication and connection data, log files from websites, or health data. In public administration, labour-market data can be obtained from the social-security registration procedure, and traffic data can be derived from the toll data collected by the Toll Collect system (Sarreither, 2015). The resulting data allow applications that go beyond the context in which they occur. Mobile-phone data, for example, are used for traffic monitoring and planning (Schmidt and Männel, 2017). Since mobile-phone penetration in most OECD countries is over 100%, it is already possible to conduct a full survey of, say, people's whereabouts and movement patterns.

'Big data' is currently interpreted in different ways more as a leitmotif or even a slogan than as a clearly defined term (Pietsch and Wernecke, 2017). The early definition according to Laney (2001) based on the three Vs included a large data volume (volume), high heterogeneity as regards data types and sources (variety), and a high speed of data generation and processing (velocity). Other authors speak of 'five Vs', including data quality (veracity) and the added value that data analysis promises (value); others or seven or even more Vs. (Eckert et al., 2014: 6f.). Irrespective of how many Vs such a definition covers, it cannot reflect the fundamental epistemological and methodological challenges posed by big data and data-intensive science ('data science') when it comes to collecting and processing large amounts of data (Pietsch and Wernecke, 2017: 39). Big data is often associated with great potential for business, science and society, e.g. for the optimized planning and control of processes (Eckert et al., 2014: 5; Lohr, 2012). Some also speak of 'evidence-based decision making' without taking sufficient account of potential risks and problems. Thus, "academics from different disciplines see a range of societal, ethical and legal problems [...] from data protection and security, to transparency and accountability, to problems of bias and discrimination" (Rieder and Simon, 2018: 162). Despite such concerns, the historical embedding of big data into a long culture of measurement and quantification is discussed comparatively rarely. A change of definition beyond the Vs has recently been proposed to reach a better understanding of "the norms and values underlying the current data hype" (Rieder and Simon, 2018: 163): "Instead of a narrow definition of big data according to purely technical notions [...], it seems more productive to regard the term as the terminological manifestation of a complex socio-technical phenomenon based on an interplay of technological, scientific and cultural factors."

Potential benefits and risks

In precisely this socio-technical context, the potential benefits and risks of big data also become apparent in a more precise way, especially in view of the "widespread belief that comprehensive data sets offer a higher form of intelligence and knowledge which can bring insights that were previously impossible" (Boyd and Crawford, 2012). Big data undoubtedly has great innovative potential in automated pattern recognition – but only if ethical and epistemological boundaries are handled responsibly and with methodical competence. Otherwise, a data set – regardless of its size – does not automatically generate new or better insights, but irrelevant, misleading or even false ones. In this respect, the hitherto widespread practice in dealing with big data is often inadequate from a scientific point of view, because, "instead of the mere collection of mass data or masses of data, the focus must be on content that is actually valuable. The targeted evaluation, application and use of protective measures," implementing concepts like privacy and security 'by design' and 'by default', "must take the place of exploratory analyses" (Federrath, 2018: 18). Only if these core elements and work steps are an obligatory part of big data technologies can they become smart data. Such a concept of smart data, as represented by the accompanying research of the BMWi's Smart Data Programme (Begleitforschung Smart Data, 2018), goes beyond a purely technical understanding. In the face of often heterogeneous and poorly annotated data sets, this targets big data that is either generated with a clear semantic structure or is structured subsequently to enable faster and more comprehensible decisions for data-analysis applications. A broader understanding also creates

Box 3.3-1

Humanization and misleading use of language

When names are given to aspects the capabilities of digital systems, terms are often used that were previously used primarily to describe human abilities; prominent examples include AI and machine learning (Rehak, 2016; Section 3.3.3). Terms like 'intelligence' or 'learning' are embedded in many scientific discourses, especially those influenced by philosophy and psychology. As a rule, they are 'charged' with many accompanying connotations that cannot be derived from the technical performance itself. For example, 'learning' is associated with human achievements (such as curiosity, spontaneity) that serve competence and self-determination (Deci and Ryan, 2000, 2008) or human free will. Computers, however, have no free will beyond speculations, e.g. via thought experiments (Bostrom, 2014), and corresponding conceptual associations are inappropriate in the field of machine 'learning', because up to now this has been primarily about modelling, calculation and optimization (Walsh, 2018).

Charged concepts and exaggerated associations have been – and still are – often intended, as in the case of the term AI, to promote a research project (Section 3.3.3). Such language use is problematic because it can arouse exaggerated expectations and fears (Burchardt, 2018) and indicate future development possibilities that cannot be described in technical terms. The term 'superintelligence' (Bostrom, 2014), for example, implies a possible future superiority of technical systems, yet its threat potential can be neither precisely described technically nor, therefore, precisely assessed (Section 7.4). One part of threat scenarios is often the attribution of 'goals' or even 'consciousness' to technical systems. The latter, however, is a term that requires a very differentiated debate. In this context, the recognisability of technical systems as such plays an important role (Box 9.3.1-1).

Then as now, the language of information processing affects the humanities, especially cognitive psychology – and not the other way round, as might be expected. Information processing models have been used to explain psychological phenomena such as perception (as the reception of information), processing (by means of the working memory) and remembering (as storage). Concepts and metaphors of information technology and cognition then co-evolved (Winograd and Flores, 1986). A proximity was seen between computer science and cognitive science: assumptions about perception processes, representation and further processing steps were modelled and programmed. The functionality of the assumptions was tested, sometimes forgetting the difference between the defined model and reality – a phenomenon that can still be observed today in discussions about the boundaries between humans and machines. In order to assess the risks and potential benefits of digital technology, decision-makers should therefore also address the underlying language use. Examples of terms that are used metaphorically and differently charged in different disciplines include AI, machine learning and superintelligence, but also cognitive computing and even neural networks – which do not consist of neurons but of simplified models of neurons (Section 3.3.3). Some of these terms are taken up here as examples.

Example: intelligence and machine learning

In such disciplines as psychology and cognitive sciences, there is a long tradition of discourses on the appropriate definition of human intelligence (intelligence theories, e.g. Spearman, 1904; Thurstone, 1924; Wechsler, 1958; Cattell, 1987; Sternberg, 2013). 'Emotional' aspects are not usually included in these theories. The theories are predominantly concerned with 'cognition', i.e. perception and attention, absorption of information, memory retention and problem solving. The concept of intelligence proves to be "blurred […]," also from a philosophical point of view, "because there is no satisfactory theory of intelligence" (Kornwachs, 2009:37). Beyond the blurriness with regard to humans (which becomes apparent in controversies about uncertainty in intelligence tests), applying the term to computers often leads to humanizing misinterpretations both in science and among the public, or conversely to a technologized reduction of what is human to form a 'human-machine', which disregards or even devalues human characteristics (Ullrich, 2017:188). Research on AI did not begin until the late 1950s. Learning here is not meant in the sense of human learning, but rather in the sense of characterization, classification or optimization by machines. Since the 1990s, the term 'machine learning' has been used to describe a sub-methodology in AI; systems are 'trained' with 'training data' using new mathematical and probabilistic methods (big data), for example to recognize patterns and process images. Research on human memory, intelligence, AI and machine learning can be reciprocally related: "what we learn about human intelligence suggests extensions to the theory of machine intelligence, and vice versa" (Cohen and Feigenbaum, 2014).

Example: empathy

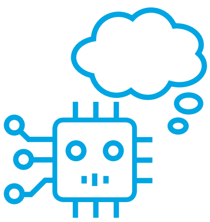
The core of empathy is 'to empathize with other people'. Empathy makes it possible to resonate along with other people's positive feelings like joy, but also with their suffering. The term empathy received special attention when 'mirror neurons' were discovered, first in monkeys (Rizzolatti et al., 1996) and later in humans (Botvinick et al., 2005). Technical developments such as avatars and robots are also sometimes referred to as 'empathic systems' (e.g. the BMBF projects EmpaT – visual empathic training system for job applications, or SenseEmotion – emotion management for senior citizens). 'Empathy' here means the imitation of an emotional feedback, for example that the avatar smiles with someone or follows their movements. The avatar itself is not empathic, but triggers in humans feelings of being empathetically understood by means of (programmed or self-learned) reactions. Study participants also react empathetically when pain is inflicted to a robot hand (Suzuki et al., 2015). Even with minimal humanization, such as when an object is given a human name, experiment participants react empathetically (neural reaction when a vegetable with a human name is 'painfully' stimulated; Vaes et al., 2016).

Example: consciousness

Consciousness is an ancient problem that researchers in philosophy and psychology and the neurosciences are still concerned with. Simplified consciousness can be understood as a state of recognition of inner events and the outer environment. Waking consciousness includes perceptions, thoughts, feelings and desires. Self-awareness is referred to as the highest level of consciousness and designates the recognition of the autobiographical character, personal history and identity (Zimbardo and Gerrig, 2004). However, speculations about artificial consciousness are still unclear, not least because – even if we could model it – we would still be dealing with a model. The assumptions and value inscriptions on which this model is based and their potentially serious consequences would then have to be questioned – as would those in today's modelling of the world by socio-technical systems (Section 3.2).

"confidence in and acceptance of smart-data solutions, from which we will all benefit in the future – be it in medicine, industry or mobility" (Federrath, 2018:18). Ultimately, user confidence can determine the success or failure of big data (Kranich, 2018:32ff.), particularly in view of big data's share in what is historically probably the largest range of technical possibilities available for a totalitarian dictatorship (Grunwald, 2018:57; Zuboff, 2018). To this extent, "in view of big data, there is an obligation to reflect on the fact that we are responsible not only for doing what we do, but also for not doing good things" (Dabrock, 2018:41). This is also true for AI, which is currently hard to separate from big data, as the latter serve as training data for machine learning.

3.3.3
Artificial intelligence



The term artificial intelligence (AI) was coined in 1956 as part of the Dartmouth Summer Research Project on Artificial Intelligence organized by John McCarthy. The basic theory was that "every aspect of learning and other characteristics of intelligence can be described so precisely that they can be simulated with the help of machines" Burgard, 2018:2). In view of the unsatisfactory definition of human intelligence (Kornwachs, 2009), AI, then as now, is "not a completely unproblematic term," even for AI researchers (Walsh, 2018:23), and often arouses exaggerated expectations and fears among the public (Burchardt, 2018; Box 3.3-1). As in the case of 'intelligence', there is still no uniform definition of AI; it is understood in many different ways. Definitions generally begin by looking at "a research question aimed at the autonomous solution of problems using technical systems" (Djeffal, 2018). Basically, intelligent systems are characterized by the ability to solve problems autonomously and efficiently (Mainzer, 2016:2). In line with its conceptual genesis, AI is "a discipline within computer science that deals with the development of software systems which provide functions whose execution requires what is typically referred to as intelligence" (Burgard, 2018). Such algorithm-based, data-based or machine-trained functions can be realized purely on the software side, but can also be coupled with hardware, e.g. in robotics. AI thus proves to be a "collective term for those technologies and their applications that ascertain a result by digital methods on the basis of potentially very large and heterogeneous data sets in a complex machine-based processing method that imitates human intelligence and may be automatically applied if necessary" (Datenethikkommission, 2018:1). The 'Turing test' proposed by Alan Turing in 1950 (Box 3.3.3-1) is, at least according to his intention and contrary to widespread misunderstanding, "not a test that a computer practically has to pass" in order to be considered 'intelligent' (Walsh, 2018:69); rather, it shows how easily people can ascribe intelligence or other abilities to a machine once a certain level has been reached.

The Turing test, however, illustrates the human tendency, recognizable then as now, to regard programs as more intelligent than they are when they, at least at first glance, approach our level of intelligent behaviour. In doing so, "we succumb to the false conclusion that they are human-like. The more tasks computers take over from us, the more willing we are to believe that they are more intelligent than they really are" (Walsh, 2018:78). Apparently, machines are often overestimated, since people are tempted to create references to similar human achievements and encourage an unfounded humanization of machines. Such humanization can evoke emotions such as sympathy or fear (Box 3.3-1).

Potential benefits and risks

In most application areas of AI, the aim is not to imitate human abilities as accurately as possible anyway. In some areas, technology (and not only digital technology) is far superior to humans. The speed of data processing and the higher storage capacity alone enable AI systems to, for example, calculate, translate texts and recognize and predict patterns faster than humans and handle larger amounts of data. They remain, however, only "a tool that expands the possibilities of humans and supports their decisions" and, despite some successful applications, e.g. in medicine, "have absolutely no understanding of medical interrelationships and cannot provide any explanations for the diagnoses" (Burchardt, 2018:13). AI systems solve many problems differently than humans, which is why, according to Moravec's paradox, many actions that are simple for humans are difficult for AI, and difficult tasks for humans are often easy for AI to carry out (Moravec, 1988). An AI-based system always solves just one single task (e.g. chess) and is not universally applicable (e.g. for chess, speech recognition *and* image classification). Accordingly, during the application of AI specific problems and sources of error appear that require special scientific attention. Since these often stem not from the AI procedures themselves, but rather from their incorrect use or the underlying data, the limits of computer science are inevitably exceeded here (Mainzer, 2016; Broussard, 2018).

Box 3.3.3-1

Turing test and ELIZA

The Turing test is a thought experiment devised in 1950 by the British mathematician and AI pioneer Alan Turing in which a human being is connected via a computer interface either to a real person or to conversation-simulation software. If it was not possible to distinguish between human and machine, the computer would have passed the 'test'. Contrary to the reception over the last decades, Turing's intention was not to practically test computers for 'intelligence', but only, in the context of his time, "to gain clarity about what is understood by a 'thinking machine' and what its existence would mean" (Walsh, 2018: 69). Rather, it becomes clear that subjectively attributing human intelligence in human interaction with a software simulation is not a good criterion for 'intelligence'. It is therefore necessary for people to know when they are interacting with machines.

This was also shown by the ELIZA speech-analysis system developed by Joseph Weizenbaum from 1964 to 1966. Today it would be called a 'chatbot', which, in simulated psychotherapeutic conversations, syntactically converts the statements of the patients into questions without having any semantic understanding (Walsh, 2018: 47ff.). By revealing the source code of the program, Weizenbaum hoped that users would be able to see through its relatively simple structure (even though it was a big step in speech analysis at the time) and understand that computers could not have real conversations but only a syntactic simulation that could be interpreted as such. In principle, nothing has changed in this situation to this day; even current digital assistants (Alexa, Cortana, Siri) and current (psycho-)'therapeutic' chatbots are nothing more than technically refined simulations of a conversation without actual speech comprehension.

AI is not only embedded as a socio-technical system in its societal applications, but also in the actors' ideas about the present and future world. This is shown both by the impact of science-fiction discourses in Silicon Valley (Kehl and Coenen, 2016), and by often implicit philosophical assumptions about the predictability of the world (Pietsch et al., 2017) – from the 'general problem solver' to speculations about various stages of a future 'superintelligence' (Bostrom et al., 2016; Section 7.4). Similar to today, the first phase of AI research from the mid-1950s to the mid-1960s was driven by euphoria, for example when, within the framework of the General Problem-Solver Program, general problem-solving methods for computers were to be formulated along the lines of Leibniz's 'Mathesis Universalis'. This failed, however (Mainzer, 2016: 11). Leibniz's 'Calculemus' – in the sense of the mathematical resolvability of differences of opinion – could also be interpreted as a "wicked satire against his contemporaries" (Ullrich, 2017: 153). Nevertheless, even today such ideas of an 'AI global formula' can be observed in popular scientific writings, for example in speculations about a 'master algorithm' (Domingos, 2015), AI merging with humanity to form a 'singularity' (Kurzweil, 2005), or even a 'Homo deus' (Harari, 2015; Section 7.4) resulting from 'data-ism' (Brooks, 2013). What all these notions have in common is the concept of a completely computable world, including biology, biochemistry and physics and humans themselves. However, this idea is fundamentally criticized by both philosophers and computer scientists (e.g. Królikowski et al., 2017; Mainzer, 2018; Ullrich, 2019).

After the failure of the General Problem Solver Program in the face of disappointing practical results, the second phase from the mid-1960s to the mid-1970s was characterized by specialized systems for specific fields of application, such as mathematical problems or natural languages, as well as methods of knowledge representation. In the third phase, from the mid-1970s to the mid-1980s, expert systems were increasingly developed which could store knowledge (e.g. in the form of facts and rules) about a certain field and draw conclusions automatically (Mainzer, 2016: 12). However, these systems only had rule-based special knowledge without any connection to general global or background knowledge and thus had no "sense of the whole as the basis for correct decisions" (Mainzer, 2016: 53f.).

This approach changed in the 1990s with the use of new mathematical, especially statistical, methods, with which machine learning began. This has become the most prominent approach of AI in recent years, not least due to big data (Section 3.3.2), although 'learning' in 'machine learning' is no less misleading than 'intelligence' in AI. For example, reinforcement learning, a method of machine learning (Kaelbling et al., 1996), is the basis for solving classification problems; it makes pattern recognition and image processing possible and, on this basis, facial and speech recognition. In reinforcement learning there is a step-by-step assessment of target achievement by giving "feedback from the environment at each step as to how well or badly it is achieving the goal. Its strategy is to 'optimize' this feedback" (Mainzer, 2016: 119), and the algorithm thus 'learns' something more – so-to-speak (Burgard, 2018). For this, the system requires large amounts of corresponding training data, i.e. data or examples on the basis of which learning can take place.

The accelerated calculations by GPU computers – which use the computing power of graphics processing units and large amounts of data via IoT (Section 3.3.1) and big data (Section 3.3.2) – can be seen as key to the recent breakthrough in machine learning. The fundamental methods, however, are models of artificial neural networks, which were initially virtually unusable at the end of the 1950s. These models are based on a simplified structure of a nerve cell (neuron) that had been modelled for the first time more than ten years previously (McCulloch and Pitts, 1943). Today's 'deep learning' (Goodfellow et al., 2016), which refers to multi-layer neural networks, shows "an impressive performance that often eclipses other well-tried technologies" (Walsh, 2018: 95), not least thanks to massively increased computing power, storage capacity and data availability. However, this statistical technique for classifying data patterns using many layers of artificial neural networks (Marcus, 2018: 3) is hardly comparable with human 'learning'. Artificial neural networks consist of input and output units, between which there is a variable number of hidden levels, the depth of which, in the sense of deep learning, refers to their large number of possible links. A typical case of the application of such networks would be, for example, image data of handwritten numbers, which are on the input side, while the output unit consists of the numerical categories from 1 to n to which these are assigned.

In addition to image recognition, deep learning is increasingly being used successfully in speech recognition and processing, as well as in learning complex game rules. However, the successes always apply only in certain domains or contexts – and as long as no attempt is made to deceive the AI system by means of more or less subtle attempts at manipulation (adversarial examples), some of which are not recognizable to human senses (Box 3.3.3-2). Furthermore, the precision of deep-learning methods (Schmidhuber, 2015) has grown enormously compared to traditional methods of machine learning, but only in special applications does it exceed that of human classifications. Deep learning currently faces many challenges (Marcus, 2018: 6ff.; Box 3.3.3-2).

Thus, despite spectacular progress in selected domain-specific AI applications, it would be "wrong to now assume that machine learning has brought thinking machines within reach and that techniques such as deep learning need only a little more refining and the problem of intelligence has been cracked" (Walsh, 2018: 95). All today's applications are based on specialized AI, so-called 'weak' AI. The endeavour to achieve the same intellectual abilities as humans or another 'greater' intelligence, on the other hand, is embodied by the term 'strong' AI. Whether and when 'strong' AI as a domain-spanning form superior to human intelligence might be realized and even form an artificial consciousness (Searle, 1980, 1990) can only be speculated on scientifically from today's point of view. The same applies to artificial general intelligence (AGI). Unlike 'superintelligence' (Bostrom et al., 2016), which is associated with reason, consciousness and self-set goals, AGI could solve any problem solvable by humans equally well or better, even without these qualities (Walsh, 2018: 130ff.). The initially failed idea of a general problem solver proves to be powerful, at least on a visionary level (Chapter 6). On the other hand, the currently pressing questions about designing AI as a socio-technical system tend to be overlooked: who will feel the positive or negative effects of using AI, and when, how and where? Apprehension, ignorance, false fears or overreaction could lead, not to a 'Good AI Society' (Floridi et al., 2018; Figure 3.3.3-1), but to the underuse of AI, which would waste its potential if dangers caused by overuse or misuse were attributed to the technology and not to the socio-political conditions governing its design, e.g. by setting the wrong incentives.

On the other hand, confidence-building (European Commission, 2019) and responsible use of AI offers increasing potential for an extension of human intelligence and improvement of human ability to act in the sense of 'augmented intelligence' or 'smart agency', as well as for human well-being and dignity – and also for sustaining the natural life-support systems (Floridi et al., 2018; Cath et al., 2017). However, research on this subject, particularly on the latter topic, is only just beginning (Chapter 10; Hilty and Aebischer, 2015). Research into 'explainable AI' is somewhat more advanced, but also still in its initial phase. It is aimed at methods for creating transparency in deep learning, which has so far often been regarded and applied as a 'black box' (Box 3.3.3-2). Ultimately, explainable AI could achieve both a further demystification of AI and, above all, great epistemological and methodological progress. Currently, AI 'cheats' in over 50% of the cases tested by an interdisciplinary team (Lapuschkin et al., 2019) when it arrives at correct categorizations on the basis of false premises (e.g. rails as an indicator for the recognition of a train). Several frequently used training data sets for image recognition and simple computer games were used for the test. The sobering conclusion is that the usual evaluation metrics are blind to such circumvention strategies, which is why "the current broad and sometimes rather unreflecting application of machine learning in all industrial and scientific domains" should be questioned (Lapuschkin et al., 2019: 7). In the view of the team of authors, such analyses in the area of 'explainable AI' are a first significant step towards the future development of trustworthy, fair and accountable AI systems in accordance with such regulatory requirements as the EU-GDPR (Lapuschkin et al., 2019: 7). In view of these methodological deficits and the high energy requirement for data processing

Box 3.3.3-2

Possible applications and limitations of AI and deep learning

Games

Success stories, such as AI having independently learned to play chess or Go, have contributed to the distorted public image of what it can do. From a technical point of view, this field of application should be assessed much more soberly. Games are a popular testing field for AI research with a relatively simple world – ideal for AI. This is due to precise rules, the still limited number of possible actions (although sometimes highly complex for human players), and simple ways to evaluate success. By contrast, the real world is much less ordered, not always precisely regulated, and sometimes even characterized by an unlimited number of possible options for action. Its evaluation, too, is usually by no means very clear and dualistic. The effort required to obtain large amounts of high-quality training data is many times greater than in a game. When neural networks compete against themselves or against each other in order, in the end, to play exactly this (but no other) game better than human players, they only optimize the course of the game; they do not understand a single rule of the game in the human sense (Walsh, 2018: 118ff.; Marcus, 2018).

Machine vision

Machine vision basically comprises several general subtasks (recognition of objects, analysis of movements, position determination). In addition, there are specialized applications such as optical character recognition (especially traffic signs), face recognition, and recognition of spatial elements (scene labelling). In the field of image recognition, good progress is also being made in the real world, largely with deep learning. However, illustrations like those in the AI Index (Shoham et al., 2018: 47) on the ImageNet competition, in which AI was supposedly superior to humans as early as 2014, are by no means generalizable. Although the error rate of the respective winners fell sharply (from 28.2% in 2010 to 3.57% in 2015), according to Walsh (2018: 113) it will "probably take a while before human performance is achieved," given error rates of up to 20% in "top 1 accuracy, which measures the percentage of images where the most likely label has been misallocated." Adversarial examples (Hosseini and Poovendran, 2018: 5; Eykholt et al., 2018: 7) show that even minimal changes, be they conscious manipulations or different conditions in the (in this respect incomplete) training data set, can massively increase the error rates up to total failure.

The fact that the consequences of an inadequately trained neural network can be serious is shown not only by the example of manipulated traffic signs (Eykholt et al., 2018), which often hardly exist in their pure form in major cities. Several accidents (including fatal ones) in the field of autonomous driving – ranging from an unrecognized white truck to a collision with the central crash barrier on a construction site – have shown that AI can only recognize objects in contexts in which it has been trained. On the other hand, major technology corporations are now also warning about the societal risks of face recognition. Irrespective of how well it works under real conditions, it is a risk technology in terms of possible surveillance (Kees, 2015). However, deep learning is not only susceptible to manipulation, it is also a possible way to manipulate images, video or audio material. Well-made forgeries, e.g. videos in which politicians say completely different things than in the original (deep fakes), are not only a new methods of disinformation or even slander (e.g. changing faces in pornographic videos), but also a challenge both in face recognition and in the new field of research on the technical recognition of deep fakes (Korshunov and Marcel, 2018; Li and Lyu, 2018).

Automatic language processing

Machine processing of natural language comprises the areas of speech recognition and machine translation, as well as text summary and answering questions. In the first two areas, progress has already been so good, at least for the most internationally prominent languages with a correspondingly large pool of training data (thanks to deep learning), that voice control of devices such as smartphones or digital assistants has entered the everyday lives of many people in the western world. Machine translation also achieves good results in many areas, depending on the language combination (e.g. English/French) and context. However, challenges remain where languages are differently structured, the semantics are complex, complete paragraphs need to be translated, or long spoken texts need to be put into writing (Walsh, 2018: 115ff.).

Current challenges in deep learning

The first aspect that must be emphasized in this field is the enormous need for data. Currently, this requires thousands, millions or even billions of training examples, most of which are assigned by humans. Furthermore, the lack of process transparency has been under intense discussion for years. In view of millions or even billions of parameters relating to relations within neural networks, the majority of researchers agree that 'deep learning' is a 'black box' whose processes and results are not comprehensible to humans. A separate research area called 'Explainable AI' has been developed to counteract this lack of transparency. Although in general the distinction between correlation and causality is of great importance, e.g. with regard to algorithmic decision making, it has received surprisingly little attention in the literature on deep learning, apart from a few exceptions (Marcus, 2018). This could be due to the fact that what machines learn there are particularly highly complex correlations. Prior knowledge has so far been minimized, and it would be unclear how it might be appropriately integrated into the system. Answers to complex open questions cannot be found in training data sets. Inference problems where the answer to a given question is not explicitly present in the text, or is distributed over several sentences in the text, have therefore caused great difficulties up to now. The combination of rule-based AI and machine-learning-based AI is therefore also a current area of research. Deep learning is furthermore blind to dynamic changes because it works best in highly static worlds with stable rules, such as games. Yet social worlds such as politics or business are subject to constant changes in their rules; they therefore elude AI systems – at least they have done so up to now (Marcus, 2018).

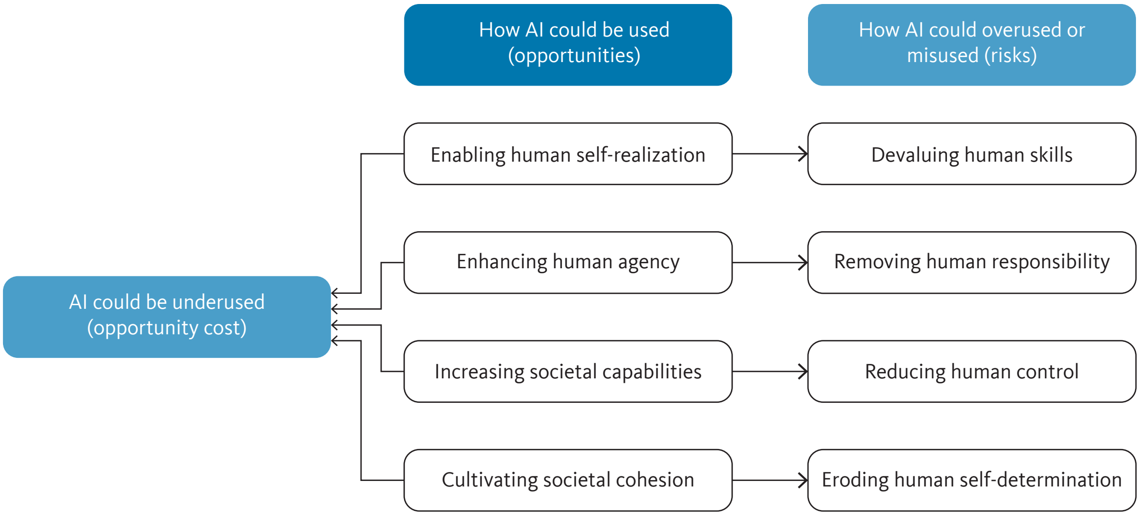


Figure 3.3.3-1
Overview of the four core opportunities offered by AI, four corresponding risks, and the opportunity cost of underusing AI. Source: Floridi et al., 2018

and storage, the decisive step to be taken to further develop AI is not a supposed international 'race' in machine learning, the endpoint of which is difficult to imagine, but "the responsible further development of AI based on ethical principles and human rights" (Dignum, 2019; Section 9.3.2). First drafts for regulations on this basis have already been developed (Box 3.2.5-1).

3.3.4 Cybersecurity

Realizing the sustainability potential of digitalization stands and falls with the security of the underlying technical systems. Even though, as in society, there can never be hundred-percent security in the ICT sector, security is essential in view of ever greater interconnectivity; it must at least be maximized and implemented as well as possible. It is no exaggeration to say that cybersecurity (also known as IT security) is a necessary precondition for the functioning of all other technologies outlined in this Section 3.3. As already became clear at the outset, especially in the case of the Internet of Things, which is notoriously insecure in its current form (Section 3.3.1), the success or failure of ongoing digitalization will depend on cybersecurity. The term cybersecurity refers to the entire field of security in information and communication technology (BSI, 2019a) and describes the aim of reducing the risks caused by threats to and vulnerabilities in the use of IT to an acceptable level by taking appropriate security measures (BSI, 2019a).

Scenarios in which (inadequate) cybersecurity plays a role include criminal activities such as data theft, deliberate manipulation of systems, and espionage. Cybersecurity is impaired by organizational and technical deficiencies such as operating or configuration errors, security gaps caused by faulty software, technical failures and faulty reactions by technical systems as a result of construction or design errors, or force majeure, e.g. catastrophic failure of (sub)systems (Menz et al., 2015:7; Festag et al., 2017:46f.). In other words, the much-quoted hacker attacks are just one of many problems.

In general, a distinction is made in the security discussion between functional safety and cybersecurity (or information security). Functional safety refers primarily to the physical protection of people and the environment from a system, i.e. external protection. Cybersecurity, on the other hand, refers to the protection of the internal values of a system, i.e. internal protection, the misuse of which can also cause immaterial damage externally, for example when a person's privacy is violated. Due to the increasing digital networking and fusion of the digital and physical worlds in the Internet of Things, the two can no longer be clearly distinguished from each other; they influence each other. Cybersecurity is the protection against attacks or intentionally performed interventions on a system from outside (e.g. zero-day attacks or distributed denial-of-service attacks). By contrast, functional safety (also known as operational safety) focuses on protecting people and the environment from a system's possible negative effects (e.g. due to technical faults or faulty systems; Menz et al., 2015: 3, 7f.). If, for example, a vehicle's brakes are impaired by a hacker attack via a Bluetooth interface within the vehicle, this cybersecurity attack directly reduces the vehicle's functional safety (Checkoway et al., 2011).

In the following, the focus lies on cybersecurity, and relevant, related terms include in particular data security, data protection and general information security. Although it is difficult to define the terms precisely, as they can be interpreted differently according to the author or the context, the following definitions are given here as a guide:

- The classical protection goals of information security include confidentiality, integrity and availability. *Confidentiality* means the protection of data, information and resources from unauthorized access. *Integrity* refers to the protection of data, information and resources from unauthorized changes. The *availability* aspect, on the other hand, refers to the fact that access to data, information and resources should be possible when required (Sackmann, 2014).
- In *data protection* – protecting natural persons from violations of their personal rights – further objectives include *authenticity* (certain identification of the author), *attribution* (indisputability of authorship), *transparency* (traceability, verifiability and evaluation of data processing), *non-linkability* (no data link beyond the original purpose) and *intervenibility* (users' ability to ensure data protection; Opiela et al., 2016: 10).
- *Data security*, which involves the protection of technical systems and in particular the protection of data from loss, destruction or manipulation by unauthorized persons – and thus also data protection in the case of personal data – can be challenged by weak points in software, malware, identity theft and targeted complex attacks (Rescorla, 2005).

Procedures for *anonymization*, such as randomization and generalization, are available to irrevocably eliminate personal references in data. Randomization refers to technologies that make it impossible to directly connect data to a specific person, while generalization refers to technologies that allow the reduction of information by changing scale and magnitudes (Hoepner, 2017: 19). *Pseudonymization* technologies make it possible for personal data to be changed by an assignment rule in such a way that individual information can no longer be assigned to a person without knowledge or use of the assignment rule (Ernestus et al., 2019).

There are many different mechanisms for secure networking, secure internet access, client and server security, and mobile security. One example is perimeter security: protection e.g. by means of firewalls. A firewall is a security system consisting of software and/or hardware components that protects networks against unauthorized network intrusions (BSI, 2019a). An intrusion detection system (IDS) detects an intrusion or attempted intrusion by unauthorized persons or computers into a computer system or network (Heasman and Movle, 2009). An intrusion prevention system (IPS) detects attacks and prevents or blocks them. In many systems and applications, perimeter security is only partially possible or not possible at all, which is why the resilience of systems is gaining in importance (Hoepner et al., 2016). Resilience refers to the ability of systems to deal with, prevent, protect themselves from, cope with and adapt to adverse events, i.e. human, technical or natural disasters (e.g. terrorist attacks, major industrial accidents) or change processes with catastrophic consequences (e.g. extreme weather conditions resulting from climate change (Scharte et al., 2014: 121f.) and thus their ability to "work towards minimizing potential or existing damage to the physical and material well-being of the population" (Scharte et al., 2014: 54). In order to guarantee resilience, resilience engineering must include technological concepts of security problems early on in planning and implementation activities in societal projects (Scharte et al., 2014: 125). In this way, it is supposed to be possible to keep critical subcomponents of technical systems in controlled operation in the event of damage, even outside the standard requirements. The technological solutions for increasing the resilience of individual infrastructures include self-healing, adaptive transmission networks, and constructions smartly designed by energy-autonomous, automated sensor networks (Scharte et al., 2014: 125).

In order to design suitable security measures in the respective impact classes according to the required security levels and to minimize the potential target for cyber attacks in this way, the idea in *security by design* is to already take security requirements into consideration during software and hardware development; this makes security independent of the respective user and the specific application (Hoepner et al., 2016: 100).

For example, digital identities and possible identity thefts are part of current work on security by design. Identity thefts are aimed at digital identities, which include "all procedures in which people, objects and processes authenticate themselves online via certain attributes in order to prove their own identity" (Bundesdruckerei, 2019). Digital identities protect technical systems and infrastructures and ensure the trustworthiness and security of sensitive data (Rieger, 2015: 6). For example, objects in the IoT (Section 3.3.1) also require a unique identity in order to identify and describe them, communicate with them and control them (Hoepner et al., 2016: 54).

Box 3.3.4-1

Cryptography

In classical cryptographic methods without the use of electronic computers, the character sequence was changed (transposition) and/or characters were replaced (substitution). These procedures are now considered insecure. In modern cryptographic encryption methods, by contrast, individual bits are used, so that the number of possible changes is increased and non-textual data processing is also possible. Modern cryptographic methods can be divided into symmetric and asymmetric methods. In symmetric processes, a single secret key is used per communication relationship for encryption and decryption. In asymmetric procedures, on the other hand, one private and one public key are generated per user (Jahnke, 2014).

Files encrypted with the recipient's public key can then only be decrypted with the corresponding private key. The sender's private key, in turn, allows data to be digitally signed. The public key can be used to verify the originality (authenticity) of the data. To transmit messages securely, communication partners can exchange their digital certificates, with the result that messages can be encrypted in such a way that only the opposite side can decrypt the message and verify the sender's digital signature. A digital certificate consists of the user's public key and other information, such as the person who issued the certificate and the validity period of the certificate. Public-key infrastructures (PKIs) are used to simplify and enable the exchange of certificates between mutually unknown communication partners (BSI, 2019c).

A *public-key infrastructure* is a hierarchy of digital certificates based on asymmetric encryption. First, a root certificate with a private and public key is generated at a certificate authority (CA) that is regarded as trustworthy by all communication partners and acts as a trust anchor (BSI, 2019c).

Between the potential certificate user and the CA there is an intermediary registry (registration authority – RA) which records and authenticates the identity of the potential certificate user and forwards the certificate request to the CA (GBS, 2016). The other certificates are then signed with the private key belonging to the root certificate or with another private key whose certificate was signed with the private key of the root certificate. A signature is only issued by the certification authority if special requirements defined by the CA (e.g. proof of the identity of the potential certificate user and the secure storage of the key by them) are met (BSI, 2019c). A PKI can be used to establish the integrity and confidentiality of information as well as its authenticity (identification and indisputability).

One application in which a PKI can be used is secure communication in virtual private networks (VPN; itwissen.info, 2017). VPNs are networks that are physically operated within another network (e.g. the internet), but are logically separated from it. They enable the integrity and confidentiality of data to be guaranteed by means of cryptographic procedures during transmission in untrustworthy networks (e.g. the internet). A distinction is made between three types of VPN: (1) site-to-site VPN where two computer networks are connected via a VPN, (2) end-to-end VPN where a VPN is created between two end devices, and (3) end-to-site VPN or remote-access VPN where a VPN is created between an end device and a network (BSI, 2016: 332).

Identity management (IdM) technologies are used to ensure the identity of a person or of IT components and confirm their authorized access to data, information and other resources. IdM is the management of the information necessary for identification and authentication (BSI, 2016: 170). "An IdM system provides the functions to store, manage, retrieve and protect identity information" (Fraunhofer FOKUS, 2017: 137f.). One of the challenges of IdM is to ensure the protection of identities while, at the same time, enabling personalization in digital spaces (Hoepner et al., 2016: 54f.).

When using services, it must be ensured that only legitimate access is permitted. The process of verifying whether a user actually possesses the identity claimed when attempting to log in is called authentication. The users prove their legitimacy by presenting one or more authentication factors, e.g. user name plus password (knowledge), smart card (possession) plus PIN (knowledge) – also known as two-factor authentication – or biometric features such as a fingerprint or iris geometry (Rieger, 2015: 5).

In addition to identity management, there is also *access management,* which refers to processes that are necessary for assigning, withdrawing and controlling the rights of a user with regard to entry or access to information or services. Both procedures consist of organizational and technical measures and can be supported by IT applications. In order to ensure the highest possible level of security, the granting of rights must be handled sparingly and in a task-related manner. Background systems allow the storage, evaluation and therefore traceability of activities that have taken place (BSI, 2016: 170).

Cryptographic methods, procedures and tools can be used for protection against unauthorized data access or misuse. The aim of cryptography is to protect against manipulation and unauthorized reading of information or to authenticate a person, e.g. by making them unrecognizable with the help of an encryption key (Box 3.3.4-1). The encrypted text can be converted back to plain text using a (possibly different) decryption key (Jahnke, 2014).

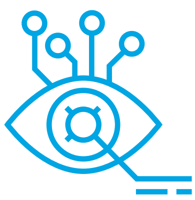
Potential benefits and risks

With regard to the issue of cybersecurity, it can be said that, in view of IT threats (e.g. malware) and the growing digital vulnerability caused by manipulated operating systems or network nodes, the protection of increasingly digitally networked critical infrastructures such as energy or water supply systems is becoming more and more important. Furthermore, targeted security measures (such as security by design or BSI IT-Grundschutz) are required, which, in turn, can be secured by security certificates (such as ISO Common Criteria). In addition, massive identity thefts, reported surveillance activities that are not democratically legitimized, and digitally caused supply failures have led to a loss of confidence in societies worldwide. The use of digital technologies to achieve sustainability goals must therefore be based on a well-founded cybersecurity strategy. The necessary funds and resources must be available in order to implement it effectively and thus restore trustworthiness and reduce risk in the face of increasing digital networking.

3.3.5
Other relevant technologies

After the detailed description of the key technologies in the previous sections, further technologies that are also relevant in connection with sustainability are presented in compact form below. These include monitoring and modelling (Section 3.3.5.1), augmented and virtual realities (Section 3.3.5.2), robotics (Section 3.3.5.3), 3D printing and additive manufacturing (Section 3.3.5.4), and blockchain and distributed-ledger technologies (Section 3.3.5.5).

3.3.5.1
Monitoring and modelling



Monitoring is the systematic observation of objects, processes or environments, for example to record their properties, behaviour or compliance with threshold values. It can collect data to gain knowledge or form the basis of control processes. Monitoring the Earth system and environmental conditions is of particular importance for sustainability and is expanding rapidly as a result of the fast-growing use of ICT. The combination of long-established monitoring technologies (e.g. remote sensing by satellites) with new data-acquisition options (e.g. networked sensors of the IoT; Section 3.3.1) and new data-analysis options is already being discussed under the term 'smart Earth' (Bakker and Ritts, 2018). Hundreds of terabytes of Earth-system data are generated daily, while the capacity to analyse them meaningfully is a long way from keeping pace (Reichstein et al., 2019). Monitoring benefits from automated data acquisition and analysis, and the ongoing process of digitalization and networking allows large amounts of data to be aggregated, while interpreting this data often requires complex modelling.

Remote sensing is usually based on the evaluation of electromagnetic waves (e.g. light, infrared or UV radiation, radio waves) or sound waves, from which conclusions can be drawn about the observed objects. Remote sensing can be carried out by satellites, from flying or floating platforms such as drones, or from the ground. The systems can be active, i.e. emitting radiation and analysing what is reflected back (e.g. radar); however, most function passively, i.e. reflected sunlight or the radiation emanating from the observed object itself is analysed. The quality of the information obtained about the observed objects depends to a considerable extent on the efficiency of the (usually computer-aided) evaluation, as well as on the availability of supplementary information, e.g. from in-situ measurements.

In-situ measurements are measurements that are carried out directly on site. A wide variety of detectors can be used to record chemical and physical parameters, for example temperature, pressure, brightness, acceleration, pH or humidity. In the course of digitalization, there has been a dramatic increase in the dissemination of sensors, which are increasingly being networked via the internet and provide data in near real-time (Section 3.3.1). Today, sensors can be found almost everywhere: in the traffic infrastructure, in ocean buoys, in trees and in the ground, on vehicles – and in smartphones (Gabrys, 2016:7). Smartphones alone already contain a large number of sensors such as cameras, microphones, acceleration and pressure sensors which are also suitable for citizen-science projects (Cartwright, 2016).

Measurements and simulations have long played an important role in the climate field. Satellites can permanently observe different atmospheric components such as CO_2, ozone or aerosols, achieving almost global coverage, but require supplementary measurements from the ground or from the air, as they cannot resolve processes and material flows on a smaller scale (Kulmala, 2018). For example, the possibility is currently being discussed of obtaining a complete picture of greenhouse-gas emissions from measurement data (combinations of in-situ measurements with ground-based and satellite-based remote-sensing data), which initially only measure their concentrations, with the aid of inverse modelling (i.e. calculation methods intended to trace an observed result back to its causes). The increasing amount of data combined with greater computing power suggests that this can develop from research projects and pilot operations into stable monitoring systems within a few years.

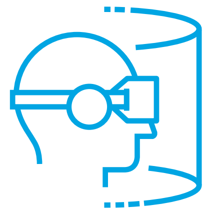
At the EU level, the Copernicus Earth Observation Programme, operated jointly by the European Commission and the European Space Agency (ESA), is currently key. Copernicus is based on a specially created network of European satellites, but also uses data from national and commercial satellites and measuring stations (ESA, 2019). Parts of the system are still under construction. The aim of the programme is to bring together a large amount of data from remote-sensing and in-situ measurements and to make information available to different user groups in real time via 'services'. 'Core services' are land monitoring, marine surveillance, disaster and crisis management, monitoring the atmosphere and climate change, and security services (surveillance of borders, resources and critical infrastructure, and monitoring of international agreements). Many observation systems also already exist at the global level, such as the Global Climate Observing System (GCOS) at the World Meteorological Organization (WMO) and the Global Ocean Observing System (GOOS), which are continuously being further developed to integrate new technologies, achieve better regional coverage and make data accessible.

Digitally supported technology is also increasingly being used to monitor biodiversity and nature conservation (Section 5.2.11). Here, the possibilities range from the spatially and temporally high-resolution observation of land-use changes, by analysing satellite data (Hansen et al., 2013), to the tracking of individual wild animals. In many cases the animals themselves are used as carriers for sensors, the results of which can then be read out via satellites (Curry, 2018). In addition to industrial processes, other areas in which monitoring already plays a major role today include transport (Section 5.2.8), buildings (Section 5.2.7), agriculture (Section 5.2.9) and the human body (Section 5.3.7).

Real-time monitoring systems can form the basis for early-warning systems such as underwater sensors that can issue tsunami warnings (Witze, 2019). The increasing availability of data streams and real-time data analysis also makes real-time environmental regulation possible, i.e. regulation that can react to unforeseen developments (Bakker and Ritts, 2018). The evaluation and use of the data, however, requires considerable (energy) resources and often cannot keep pace with the ever more cost-effective data acquisition. The qualitative added value that AI (Section 3.3.3) can provide in this respect is an open research question. It also raises issues of accessibility, interoperability and quality of data and evaluation results.

Ideas in research even go so far as wanting to record the human environment as completely as possible with sensors, model it comprehensively, and make it available as a virtual image or as augmented or virtual reality (Section 3.3.5.2), thus transforming the real world into a 'browseable environment' (Zuboff, 2018: 242; Paradiso, 2017). But this supposed digital omniscience can have its downsides. For example, it is not always clear whether and how it is always possible to ensure the privacy of people living in the observed regions or interacting with the observed objects, plants, animals or processes. Nowadays, sensors are often so small that they can easily be overlooked. In addition, sensor technologies themselves have an ecological footprint and generate considerable amounts of e-waste (Section 5.2.5).

3.3.5.2
Augmented and virtual realities



The term virtual worlds includes augmented reality (AR) and virtual reality (VR). AR and VR have gained in importance in many areas outside the entertainment industry as a result of falling prices for electronic hardware (e.g. displays, graphics processors, tracking systems, CPUs and camera systems), while functionality has simultaneously increased (Dörner et al., 2016: 31, 37). In addition to the military, these areas include the automotive industry, science, medicine, the education sector and many other fields in which simulations are necessary (Brill, 2009: 2; Kaminski, 2016: 274; van Looy, 2017: 54ff.).

AR describes an interactive environment in which end devices (e.g. smartphones, special glasses, PCs or televisions) are used to display virtual content in the correct perspective in the user's environment, thus enhancing reality (Dörner et al., 2016: 33). The proximity to reality is reinforced by the fact that the display is adapted to the new perspective in real time when the user moves. AR serves to enable users to access important data, information and images via an interface (van Looy, 2017: 52). An example of an AR application is head-up displays used in aircraft or cars to project important information onto an additional glass panel in an aircraft or onto the windscreen in a car. This might be, for example, the speed limit, the most efficient route to the destination, or the car's distance from the vehicle in front. AR intelligently combines large-volume data from different sources with powerful output options (e.g. animations, text, language). This is done using technologies such as big data, analytics (a sub-area of big data that serves to predict or evaluate behaviour), or cognitive computing as a sub-area of AI, which allows human thought processes to be simulated (Winkelhake, 2017: 69). AR systems consist of hardware and software components. They include input systems that are used to capture the real environment, such as cameras, sensors, keyboards, touch screens and mechanical devices. Processing systems are used to track the situation and to include virtual elements and other data to represent the overall situation. Output systems present the overall situation for the observer. They include data glasses, monitors or contact lenses with a display (Winkelhake, 2017:70).

While AR applications augment reality, VR applications go one step further. Here, the real world is hidden and a completely different virtual world is created (van Looy, 2017:57). The WBGU defines VR as "a world simulated by computers and corresponding programs which is imparted to users using special techniques and interfaces and with which they can interact" (Brockhaus, 2017). Interaction with VR, such as the possibility to move within it or to influence it to a limited extent, is made possible by input and output devices. They include data gloves, full-body suits, head-mounted displays such as VR glasses, positioning systems, earphones, interaction and navigation devices, or devices that record gestures or address the user's haptics (Rizzo et al., 2002:244; Schreier, 2002:43). Technologies like sensors or machine-vision methods serve to determine the user's position in relation to their surroundings. Based on this, the position, perspective and orientation of the virtual contents are calculated and presented (Dörner et al., 2016:33). This is used, for example, in intelligent factories in Industry 4.0 and supports interaction between humans and machines (Section 5.2.1)

Immersion – "the users' feeling of actually being within the virtual environment" (Brill, 2009:6) – is made possible by the input and output technologies mentioned above. According to Brill (2009:6), it depends on the one hand on the correspondence between the real and virtual world, and on the other hand on the extent to which the users can influence the virtual world. The main thing is that users accept the representation as real. It is less relevant whether the representation is actually completely realistic (Brill, 2009:6f.).

The input and output technologies trigger stimuli that appeal to the user's different senses e.g. visual, auditory, olfactory, thermo-receptive or haptic perception (Dörner et al., 2016:30). Multi-user VR enables multiple users to become part of virtual worlds using avatars (Lattemann, 2013). An avatar is a graphic representation, animation or caricature through which the user is embodied in whole or in part (Duden, 2017). In order to generate presence in single-user VR, on the other hand, all that is needed is an interactive representation of hand-held interaction devices that is correct in terms of perspective, and vision tracking in agreement with the body's perception of its own position.

Potential benefits and risks

According to van Looy (2017:56) the VR could "have a transformative effect similar to that of the internet; and perhaps VR will even revolutionize the internet […]." In general, virtual worlds have the potential to expand the possibilities of the real world and create new worlds (Welzel, 2017). For example, VR offers physically restricted persons an opportunity to appear in the virtual world as physically intact persons and thus overcome physiological limitations. New ranges of possibility also emerge with regard to individual self-portrayal. All in all, VR creates new potential for action and design, as well as potential for overcoming physical borders (Zweck, 2006:24).

In the field of education, VR and AR applications can impart knowledge visually (van Looy, 2017:57). In medicine, for example, they can be used for training purposes in preparation for difficult surgery. In this way, operations can be tested on virtual patients without risk (van Looy, 2017:54, 57). VR technologies can also be used to treat psychological disorders. In the case of an anxiety disorder, users can be moved into a virtual world where they are confronted with their fears (van Looy, 2017:58). In construction projects, VR and AR can be used to visualize designs more realistically and thus avoid planning errors – or eliminate them more cost-cheaply (Dörner et al., 2016:31). Virtual prototypes can also be created using AR (van Looy, 2017:54). VR can be used to visualize conditions in crisis regions. For example, the UN and UNICEF have produced 360° VR documentation entitled 'Clouds over Sidra'. It enables viewers to gain an insight into life in a refugee camp. Donations to UNICEF increased by 100% after the video was published (van Looy, 2017:59).

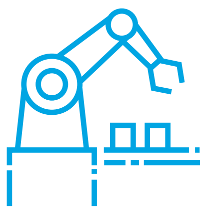
Accordingly, VR is said to have the potential to promote empathy and pro-social attitudes by giving users an opportunity to put themselves in the position of individuals in a foreign group, to understand them and empathize with their experience (Hagendorff, 2016:25f.). However, VR can also reduce social cohesion, because immersing oneself in a virtual reality makes it necessary to isolate the user. VR users can be removed from their social context, with potential negative consequences for social cohesion (Hagendorff, 2016:25). The literature, too, assumes that VR will also have cultural effects (Zweck, 2006:40f.). For example, the way in which VR is designed can be expected to have an impact on structures, hierarchies, and communication and interaction processes, as well as on the way the users think. Further risks lie in security issues. As AR glasses have spread, for example, the aspect of data protection has been critically scrutinized, because there is a possibility that photos can be taken, videos recorded or other sensitive data accessed via AR glasses without the wearer's knowledge.

Box 3.3.5-1

Typology of the term 'robot'

Technical definitions, e.g. "robots are sensomotoric machines for extending the human capacity to act" (Christaller et al., 2001: 19), are, according to Remmers (Remmers, 2018b), often either too unspecific or too narrowly defined. The term covers the reality of robotics from industrial robots to service, household and care-giver robots, to nanorobots and social robots, includes the current state of anthropomorphic robotics, but also remote-controlled machines (telerobotics), as well as visions known above all from science fiction (Kehl and Coenen, 2016). The degree of human-machine interaction also differs – greatly in some cases. As Kehl and Coenen (2016: 100) stress, the three criteria typically associated with robots, "autonomy, embodiment and (artificial) intelligence [...] can be attributed to a multitude of systems, not least because of their vagueness." For example, autonomy (Lin et al., 2012) does not adequately include classical industrial or telerobotics, especially since the concept of autonomy is ambiguous and unclear from a philosophical point of view. This also applies to the associated attribution of intentional characteristics, which would be necessary at least for an action-theoretical interpretation. Robots do not act in the real sense because their movements are not based on an intention, i.e. they do not make real (i.e. free) decisions and do not possess intentionality. According to Remmers (2018b), however, robots can certainly be understood as machines whose functions are interpreted in relation to actions. This compact understanding, which does not describe a supposed essence of the robot, but rather its attribution by humans, is based on a two-part definition (Remmers, 2018a), according to which robots are firstly "technological tools for the simulation or spatial transmission of actions," and secondly "different from purely automated systems in that, in their interactions, they require certain attitudes on the part of humans that are normally only adopted towards persons (or animals)."

3.3.5.3
Robotics



Robotics or robot technology "deals with the design, creation, control, production and operation of robots, e.g. industrial or service robots. In the case of human-like robots it is also a question of the production of limbs and skin, facial expressions and gestures, as well as natural language abilities" (Bendel, 2016: 191f.). The overriding purpose is to "promote the development of systems that advance the automation of human activities" (Kehl and Coenen, 2016: 120). Already at this point it becomes clear to what extent, for example, industrial robots or even telerobots differ from human-like robots in terms of the possible degree of autonomy intended. In this respect, the definition of the term 'robot' has by no means been clarified, although, since it was coined by the artist Josef Capek and his brother Karel Capek in 1920/21 – meaning humanoid apparatuses that take over human work or services (Sombetzki, 2016: 357) – it has become more and more embedded in everyday language with fictional, utopian and mythical associations (Box 3.3.5-1). In this respect, robotics also marks anthropological border issues relating to reflecting on and clarifying the human self-image (Chapter 2).

Potential benefits and risks

Since the price of industrial robots is lower than the annual wage of the workers to be replaced in many countries today, the advances in robotics have led to 'dark factories', for example in Japan, where in some cases industrial robots are even used to produce industrial robots. In many of the factories with human workforces, which are still far more numerous, industrial robots already took over assembly-line jobs like welding or painting years ago because they are faster and more precise. The presence of industrial robots is also increasing in warehouses, agriculture and mining (Walsh, 2018: 108). However, opposite trends are also discernible. After considerable quality problems, Toyota has switched its production to a hybrid concept of collaboration between humans and machines (Bork, 2019).

Another current area of application is automated driving, where cars can drive on motorways or in city traffic – in some cases fully automatically without any human intervention. Apart from the potential benefits and risks for innovative mobility concepts (Section 5.2.8), the aim is to avoid or at least reduce accidents, especially those that cause injuries. There is a risk that an over-hasty general construction or reconstruction of a networked mobility infrastructure may lead to people being forced to adapt to it – even though, in the interests of the common good, for example with regard to life in cities, the infrastructure should be adapted to human needs and not vice versa (Section 5.2.7; Daum, 2018). Autonomous mobility is also a dual-use technology, since automated vehicles and weapons systems are, in many respects, not far apart from a technical point of view: "In the meantime, military personnel are developing and testing the use of robots on every conceivable theatre of war – in the air, on land, at sea and underwater. An arms race to automate war is underway" (Walsh, 2018: 109). Already, drone warfare that is 'only' remote-controlled and not fully automated has long been a deadly reality. The Kalashnikov Concern has recently produced a 'kamikaze drone' which is comparatively inexpensive even for

Box 3.3.5-2

Drones – robotics in the air

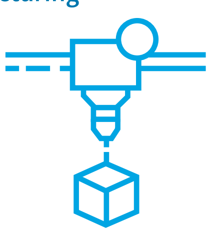
One type of robot that is currently the subject of much research is the drone. The use of drones has increased considerably as a result of the miniaturization and price reductions of sensory devices (Sandbrook, 2015). Drones generally refer to reusable unmanned aerial vehicles (UAVs) or unmanned aerial systems (UASs). The latter include not only the aerial vehicle itself but also the control station on the ground and communication systems. The following remarks refer to drones in the form of unmanned aerial vehicles or systems which either fly autonomously or are controlled (remotely) by a pilot (Sandbrook, 2015; Finn and Wright, 2012: 184) and can be used for both military and civilian purposes. Drones vary in terms of e.g. weight, maximum altitude, range, endurance, speed, production costs, possible wing loading and size – they can be as small as an insect or as big as an aircraft (Finn and Wright, 2012: 184; Sandbrook, 2015; Hassanalian and Abdelkefi, 2017: 100). Drones can carry cameras, sensors, actuators (including weapons), communication hardware (such as loudspeakers), or user interfaces for operating the drone (Finn and Wright, 2012: 184; Beard and McLain, 2012: xi; Sandbrook, 2015). As a rule, drones are equipped with imaging sensors and probes adapted to the respective area of application, e.g. for measuring temperature, humidity or pressure. With the aid of built-in actuators, drones can convert electrical signals into movements and thus clear emergency escape routes, for example. Drones equipped with signalling systems can warn of dangers (Schmoll, 2017).

Drones are versatile in terms of their deployment. In the military context, they are used for reconnaissance and target location, target simulation, and for combating radar installations and other ground targets (even including individual human beings; Brockhaus, 2016). In many cases, however, drones are used for civilian purposes, for example in logistics, agriculture, in the film and entertainment sector, in the fields of 'security' and 'disaster control', or, in the environmental sector, in climate research (Beard and McLain, 2012: xi, Brockhaus, 2016) and ecosystem monitoring (Section 5.2.11). Drones can also be used in hostile places such as outer space or in deserts. Facebook has experimented with a solar-powered drone that was to stay in the air for over three months and provide people in remote locations with access to the internet (Winkelhake, 2017: 76; Herbig, 2019). In addition to being deployed in places that are not accessible to humans or in hazardous situations, drones can also be used to make certain activities easier. For example, the use of drones has in the past been tested in agriculture and for transporting parcels. The advantage of drones is their precision, constancy and the robustness with which they work in different situations.

From an ethical point of view, the use of drones can be problematic, especially their use in armed conflicts. This topic received a great deal of media attention following the targeted killing of terror suspects by the USA using drones (Steinke, 2013). Critics of drones state that their use lowers the inhibiting killing threshold (Hickmann, 2013). In the case of the targeted killing of terror suspects, it is added that they were executed without a prior trial (Steinke, 2013). However, arguments in favour of the use of drones are also put forward in the debate. According to their advocates, drones could reduce the number of civilian casualties because targets could be hit with greater precision (Brockhaus, 2016). On the other hand, critics of the use of drones point out that civilians are repeatedly injured in attacks and that it is often impossible to make a clear distinction between civilians and fighters (Steinke, 2013). Risks also exist involving the possible illegal use of drones for terrorist purposes, such as assaults or air attacks on opponents. Furthermore, because of the surveillance possibilities offered by drones, their use can contribute to the violation of civil liberties, such as the right to privacy, and the discrimination and marginalization of certain groups of people (Finn and Wright, 2012: 189f.), especially in view of the fact that non-experts are increasingly using drones.

"small armies"(Bünte, 2019). The further miniaturization and automation of such weapons systems is being strongly promoted by the arms industry and, regardless of the medium in which they will operate, it can be assumed that – like today's drones (Box 3.3.5-2) – they will not make the world a safer place.

3.3.5.4 3D printing and additive manufacturing



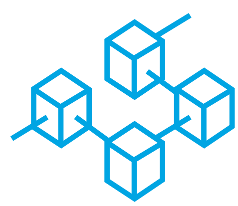
The term additive manufacturing refers to various processes in which "the desired component is successively constructed on the basis of a digital 3-D model by the targeted layer-by-layer application of the starting material" (Caviezel et al., 2017: 9). Since the manufacturing process has some similarities with 2D printing, the term '3D printing' is also commonly used (Bourell, 2016: 2). Additive manufacturing is computer-aided in three phases: data preparation (e.g. 3D model), application of the materials (printing) and post-processing (Caviezel et al., 2017: 29; acatech, 2016: 12; ÖFIT, 2016). The layer-construction principle makes it possible to produce complex geometric structures that cannot be made using conventional subtractive manufacturing processes (where the material is removed, e.g. by milling, drilling, lathing) or can only be produced with great effort (Bauer et al., 2016: 4). The commercially most important processes at present are, for example, fused deposition modelling and laser beam melting (acatech, 2016: 6). The various additive manufacturing processes differ with respect to the starting materials ('filaments' such as plastics, metals, ceramics, building materials), the size and geometry of the workpieces, the accuracy, speed and cost of production, and the properties and applications of the products (Caviezel et al., 2017: 12, 79).

Despite such differences in details, the processes have common features: single pieces, small series, pilot series or spare parts can be manufactured on demand. This shortens development and production times and makes it possible to realize lightweight construction concepts and complex geometries or individualized products (Bauer et al., 2016: 17). This can also be seen in the development of additive manufacturing, which took place – and is still taking place – in four overlapping and complementary phases (Rayna and Striukova, 2016: 216f.). Additive manufacturing has been used in industry for about 30 years: first, since the 1990s in product development (rapid prototyping); second, in the manufacture of tools and casting moulds (rapid tooling); and third, since the turn of the millennium, increasingly in the manufacture of end products (rapid manufacturing or direct digital manufacturing) such as small components, small series, unique specimens in the jewellery industry or in medical and dental technology (Caviezel et al., 2017: 10, 29; acatech, 2016: 10; Rayna and Striukova, 2016: 216f.). In the fourth phase, additive manufacturing in the form of comparatively inexpensive '3D printers' has been increasingly used for personal or home fabrication in private households, as well as at places of experimentation and decentralized collaborative production, e.g. schools, universities, maker spaces, fab labs and open workshops (Caviezel et al., 2017: 14, 29f.; Kohtala, 2015). Specialized online platforms – and increasingly brick-and-mortar shops – are further important offers (Rayna and Striukova, 2016: 217).

Potential benefits and risks

Additive manufacturing creates a special link between the 'digital' and 'physical' worlds and therefore has many sustainability implications. Compared to conventional production methods, additive manufacturing has both advantages and disadvantages for sustainability. Opportunities are seen primarily in improved resource efficiency through improved products and processes, extended product life (e.g. through reparability) and reconfiguration to shorter, simpler and more local value chains (Ford and Despeisse, 2016: 1573). Additive manufacturing requires less material input and generates less production waste (Gebler et al., 2014: 166), which holds potential for the transformation to a (digital) circular economy (EEA: 17; Section 5.2.1). Exploiting these opportunities involves a number of challenges to sustainable manufacturing which need to be addressed together with general technological and economic requirements (Weller et al., 2015: 44ff.). This applies, for example, to the environmental impact of the filaments used (Ford and Despeisse, 2016: 1573; Kellens et al., 2017: 5) and to the selection and design of the procedure and related processes (Kellens et al., 2017: 8). In particular, account must be taken of specific energy consumption, which can be one or two orders of magnitude higher as that of conventional production processes and must be offset by 'sustainable' use or the product's life cycle (Kellens et al., 2017: 15). The legal framework is also challenged in terms of product liability, the protection of intellectual property (e.g. against the theft of product designs), and the safety and health of persons who could be endangered, for example by privately manufactured weapons or pollutant emissions during production (Kellens et al., 2017: 14; Bourell, 2016: 14; Kietzmann et al., 2015: 213). As an essential element of decentralized digital production, additive manufacturing also opens up opportunities for inclusion (e.g. in fab labs; Section 5.2.2), but there is also a risk of a growing digital divide. The latter could affect above all the future of work and the international division of labour (Sections 5.3.8, 5.3.9), because work may be redistributed between employees with different levels of skill or between countries if production is relocated or reorganized by multinational enterprises using additive production (Gebler et al., 2014: 166; Rehnberg and Ponte, 2017: 19). It is still unclear whether home use will spread in a similar way to PCs, (paper) printers or internet routers (Rayna and Striukova, 2016: 216). This also applies to undesired or rebound effects like those that have occurred in the above-mentioned comparative examples as increasing quantities of e-waste and energy or paper consumption.

3.3.5.5
Blockchain and distributed-ledger technology



Blockchain, or to use the more general term distributed-ledger technology is seen as an innovation that is expected to lead to far-reaching societal and technological changes (Schlatt et al., 2016). In addition to cryptocurrencies, there are numerous possible applications in other societally or economically relevant sectors. These include, for example, the creation of land registers, securing health data, and elections (Schlatt et al., 2016: 5, 30; Boucher, 2017: 18f.). Assessments vary greatly, however, as to whether this technology actually will (or should be) widely used (Chapron, 2017; Boucher, 2017). Distributed-ledger technology makes it possible to overcome a certain characteristic of digital objects, namely their almost unlimited and cost-free copiability, and to create digital objects that exist only once or are unequivocally identifiable (Schwab, 2018: 88). Thus, this technology enables the creation of cryptocurrencies such as bitcoin (Box 3.3.5-3), which is only one of many conceivable applications. Using cryp-

Box 3.3.5-3

Bitcoin

Cryptocurrencies are the best-known application of blockchain technology. Bitcoin especially is widely discussed by the public. Bitcoin is a public blockchain without access restrictions. Up to now in finance it has been mainly intermediaries, the banks, that have recorded, executed and secured financial transactions (Welzel et al., 2017:7). As central instances trusted by all the parties involved, such intermediaries are responsible for recording, executing and securing transaction inputs and outputs (Boucher, 2017:5). For example, a bank makes sure that the sender's account is covered when a transfer is made, that the payment arrives with the payee, and the transferred amount is debited from the sender's account (Welzel et al., 2017:7). For users, the functionality of the classical accounting system and the data used are non-transparent and not fully traceable (Boucher, 2017:5).

Blockchain technology, on the other hand, enables bitcoin transactions to be handled in a decentralized and transparent way by the users themselves, thus potentially simplifying and accelerating the process (Welzel et al., 2017:7). The legality of a transaction is ensured by the participants in the blockchain (Boucher, 2017:5). A decentralized record on their own PC and those of all other users enables each participant to track all transactions conducted. Transactions are secured on the basis of a combination of technical procedures that are carried out automatically and on behalf of the users. These include digital signatures (encryption), coding solutions, and peer-to-peer networks (computer networks without intermediaries; Schlatt et al., 2016:8; Welzel et al., 2017:7). In order to participate in the blockchain for bitcoins, the user must install a certain software program and provide computer power (Stratmann, 2017).

Users who wish to carry out a transaction must first digitally sign it and thus verify themselves (cryptography; Section 3.3.4). Each transaction is recorded together with other transactions in a block, which is connected with the blocks that already exist. The blocks are linked chronologically by a cryptographic signature, so that the chain of blocks, the blockchain, contains all previous transactions (Schlatt et al., 2016:7). The accounting, i.e. checking and logging initiated transactions, is carried out by miners. These create new transaction blocks and monitor transactions that have been made (Welzel et al., 2017:8).

Mining, i.e. the process of creating new blocks by solving a cryptographic puzzle (the hash value), is complex and requires a lot of computation. The effort required to create new blocks is intended to ensure that the blockchain is tamper-proof, because new, incorrect transactions cannot be added easily. The miner receives a reward for the effort of creating a new block, e.g. in the form of a financial allowance, perhaps in bitcoins (Boucher, 2017:5; Welzel et al., 2017:9). A new block will only be accepted by the other users if it has been ensured that all transactions are correct. The correct transactions are added back to the list of open transactions (Welzel et al., 2017:9). The already mentioned linkage of the blocks via the hash value guarantees that the security of the blockchain cannot be tampered with.

tographic methods, transactions of the corresponding digital objects are verified and stored decentrally in a peer-to-peer network. There is therefore no single central person or institution of trust that exercises control over the processes (intermediary). In a way, the role of the intermediary, such as a bank, is fulfilled by the program code (Zimmermann and Hoppe, 2018:39), while decentralized verification and storage in the network promises transparency and traceability for all parties involved.

Distributed-ledger technology furthermore allows the creation of smart contracts, i.e. the connection of programmable actions and transactions (Schwab, 2018:88). For example, the system can automatically recognize whether the conditions specified in the contract have been fulfilled. Subsequently, the corresponding contractual performance, such as the payment of a quid pro quo, is set in motion by the program (Welzel et al., 2017:25). In bitcoin and most other blockchain applications, the transactions are verified by the network via 'proof-of-work', in which participants in the network compete for the verification, which promises them a quid pro quo (Schwab, 2018:91; Box 3.3.5-3). Other methods aimed at reducing energy consumption are currently being developed (CLI, 2018:85), including, for example, the proof-of-stake method, in which for each verification only one participant in the network has to make a calculation (Zimmermann and Hoppe, 2018). At present, however, it is still unclear which methods will prevail in the future.

Potential benefits and risks

Protection against manipulation and the transparency of transactions are particularly emphasized in the discussion on blockchain and distributed-ledger technology. Information is also protected against influence, e.g. in the form of censorship and control (Welzel et al., 2017:19, 26; Purvis, 2017). Server failures are less problematic because the digital signature verification and the database entries are no longer stored centrally in only one place; rather, copies are stored decentrally on each participant's server. In this respect, the blockchain guarantees a high level of reliability and thus a high level of data availability (Schlatt et al., 2016:35).

Possible application examples of this technology can be found, for example, in the field of certification, record-keeping or the administration of land registers. It makes it possible, for example, to prove the legality of ownership relations transparently and comprehensibly by recording them in the blockchain. It could also make production and value chains or maintenance cycles traceable, or allow the sustainable management of supply chains. For example, blockchain allows the documentation of the origin of products and goods: by assigning a digital identity to a product, it is possible, after a transaction, to trace how and into what the product was processed (Welzel et al., 2017: 20). Cryptocurrencies could replace institutions such as banks and enable people who do not have a bank account to conduct banking transactions, thus gaining access to the global trade and financial markets. This is particularly relevant for developing countries, where the necessary infrastructure is often lacking. The UN World Food Program is experimenting with blockchain-based payment systems in refugee camps (Juskalian, 2018). Decentralized control, distribution and billing systems for electricity, water or gas, for example, are being discussed as areas of application for smart contracts. For example, electricity generated locally by a private provider from a photovoltaic system could be fed into a local grid and then purchased by people in the neighbourhood for a small fee in a virtual currency. Without an intermediary entity in the form of a large energy utility, transaction costs would be much lower than if electricity were purchased by a large utility (Diermann, 2016). The use of smart contracts is also being discussed in the field of climate-change mitigation and adaptation, for example for success-based payments for adaptation (CLI, 2018). They could also dismantle existing barriers to a circular economy by facilitating the formation of business networks. Overall, hopes are pinned on blockchain technology to create institutional structures that have not previously existed, or to strengthen confidence in existing, not-very-trustworthy institutions.

Criticism of the blockchain technology is expressed in particular with regard to its consumption of resources and the effects on the environment (Zimmermann and Hoppe, 2018: 45). Estimates for bitcoin range up to 300 kWh of electricity needed to conduct a single transaction (de Vries, 2018), which, with 200,000 transactions per day, would represent a level of electricity consumption of around 60 million kWh per day and 22 TWh per year. High electricity consumption due to increased blockchain use could thus jeopardize the necessary transformation of energy systems and climate protection (Section 5.2.6). There is also controversy over the extent to which blockchain technology actually promises a time advantage. In the meantime, for example, the blockchain in which bitcoin transactions are documented has become so long that processing transactions is comparatively slow (Schulz, 2016). It remains to be seen how new approaches to verification can solve these problems.

Security and susceptibility to manipulation are also central issues for blockchain applications. Experience with blockchain has shown that programming errors in blockchain implementations have already led to major security gaps and considerable financial losses (Diermann, 2016; Rehak, 2018: 56). Security gaps also arise in small blockchain networks if a user manages to bring more than 50% of the computing power under his control, enabling him to confirm his own, and thus also false, transactions (Welzel et al., 2017: 26). Another problem in this context is that, in the distributed network of the blockchain, the users themselves are responsible for the security of their IT and must ensure that their private key with which they sign transactions is not spied out by third parties or lost (Welzel et al., 2017: 26). In addition, a blockchain always verifies only the correctness of transactions of virtual values, but not the truth of the information entered and the real existence of its equivalent outside the blockchain (Rehak, 2018: 56). Thus, for applications relating to the physical world, the problem of the 'last mile' (Schwab, 2018: 96), i.e. ensuring congruence between the digital and the real identity, remains.

The use of this technology in elections poses problems in terms of ensuring the anonymity of voters, as well as the possibility of strategic voting and vote-buying (Welzel et al., 2017: 22). Other open issues include liability for technical problems, risk management and unintended impacts arising with applications in the financial field, the real economy or the humanitarian field. Questions are also raised on standard-setting and interoperability between different applications (Schwab, 2018: 96). The hope that intermediaries are no longer needed is partly deceptive. Ultimately, the intermediaries are replaced by program codes, and the question arises as to who controls these codes and is responsible e.g. for necessary adjustments or quality controls.

A further criticism is that, contrary to the original idea of greater decentralization, blockchain technology has led to centralization and a concentration of power due to the financial incentives associated with the creation of new blocks, because large companies with computing power much higher than individual actors have assumed a dominant role in block creation (Rehak, 2018: 55). Hence, Rehak (2018: 57) criticizes that "the absence of institutions that balance out power asymmetries [...] ultimately leads here to the anarcho-liberal law that (computing) might is right."

To sum up, it can be said that blockchain is a resource-intensive technology – a fact that must be borne in mind and weighed up carefully in supposedly 'sustainable' applications. It should be used where the integrity of information and transactions storage cannot be ensured otherwise. For various applications, it must be specified in detail who can verify entries and check their content for correctness. The legitimation of the miners and those who do the job of verification plays a prominent role here. The traceability of transactions also leads to the question of how sensitive information should be handled. Overall, blockchain technology is still in its early stages, so that final evaluations are not possible.

3.3.6
Conclusions: key technologies must be shaped with sustainability in mind

Section 3.3 has described from today's perspective fundamental digital technologies in terms of how they relate to sustainability issues, and assessed them with regard to selected potential benefits and risks. No one can predict what innovation surges can be expected in the future. Nevertheless, emergent characteristics of the Digital Age are already taking shape today – new characteristics that emerge from the interaction of technical and societal components in their socio-technical context and are recorded as core characteristics in the following Section 3.4.

Whether further core characteristics will emerge remains open; the same applies to future technologies and their relevance. According to evolutionary economics, socio-technical innovations develop in a similar way to biological evolution: innovations are similar to mutations and are selected by markets (Mainzer, 2016). The societal, economic and/or political framework influences innovation, just as ecosystems influence biological evolution. Unlike biological evolution, however, socio-technical innovations involve people and their values – people who can consciously or unconsciously control or influence technological change as the basis for socio-technological innovation. Conversely, socio-technical innovation influences human values and in turn, with this feedback effect, future development – something which is also called the normative power of the factual (Mainzer, 2016). In the same way that biological evolution allows for diverse, sometimes contradictory futures, socio-technical innovations are open to different visions of the future. This possibility of shaping the future correlates with the responsibility to actively use it. To this end, the changes in key areas of life that digitalization can bring about must be understood (Section 3.5) and proactively shaped (Section 3.6).

3.4
Core characteristics of the Digital Age

The interactions of digitalization with key civilizational areas of life (Earth system, economy, society, human beings, technology; Section 3.5) can be understood via core characteristics of the Digital Age. These are essentially defined by the basic functions of the underlying digitalized technical systems, but not determined by them (Schieferdecker and Messner, 2018). Five characteristics (Figure 3.4-1) that result from the basic functions of digitalization (computing with data, storage, communication, sensing, interaction and cooperation; Section 3.2.1) and the key technologies (Section 3.3) appear so crucial that they will decisively influence and reconfigure all areas of civilization.

None of these five characteristics are fundamentally new; rather, they are all designed to meet people's various needs and are often embedded in history, but have been further developed and accelerated, or addressed in a new way, using the means of digitalization. Driven by the rapid dynamics and the considerable scale of digital transformation, qualitatively and quantitatively new developments are emerging in all areas of civilization and their interactions.

3.4.1
Interconnectedness

The first core characteristic is the comprehensive interconnectedness of technical systems, which also makes it possible to network objects, people and organizations in their different roles and at many different actor levels. Interconnectedness is already so advanced that its effects could easily be overlooked. For decades it has been possible for machines to communicate with one another and in this way extend or copy people's basic communicative abilities, or even develop more advanced communicative skills (Ellison, 2007; Leiner et al., 2009; Tennenhouse et al., 1997). In the course of the development and spread of the internet and the increasing expansion of the Internet of Things (Section 3.3.1), interconnectedness is becoming more and more comprehensive, permeating all areas of life and work (Akyildiz et al., 2002; Al-Fuqaha et al., 2015; Chen and Kotz, 2000).

This is also evident on a global level: e.g. the internet is accessible even in remote regions of the world. Economic globalization and transnational opportunities for

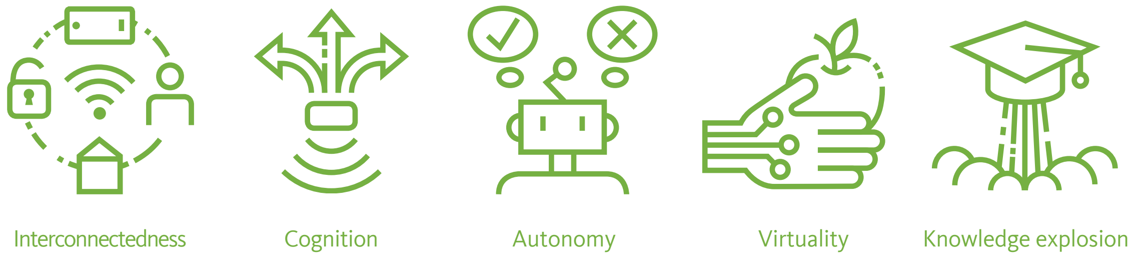
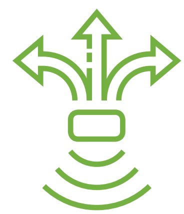


Figure 3.4-1
Core characteristics of the Digital Age: (1) the all-embracing interconnectedness of things, systems, processes, persons and organizations, (2) digital technology's increasing cognitive capabilities, (3) the growing autonomy of digitalized systems such as robots or vehicles, (4) the increasing use of virtual spaces and virtualized technical services– and, as a result of all these (1)-(4), the equally revolutionary further development of many scientific disciplines that are leading to a hitherto unknown (5) explosion in knowledge.
Source: WBGU

cooperation between societies are both the result and drivers of this digital interconnectedness. Similar to the structures in the internet, which can be characterized as a network of networks, increasingly complex, digitally supported connections are developing in society in the course of digital interconnectedness. There is an increasing interweaving of individual actors and actor structures, which differ in size and type. This intensive interconnectedness contributes to the emergence of completely new, large-scale exchange and cooperation relationships. This makes it all the more important to regulate the diversity of dependencies between actors, which often exist transversely to existing (national and international) regulatory systems. This affects, for example, relationships between digital corporations and individuals (e.g. Facebook), between states or communities of states and large multinational corporations, or between individuals among themselves (e.g. in social networks).

The increasing interconnectedness of technical systems can raise the criticality of public infrastructures. For example, critical infrastructures in the fields of energy, water, heat, food, mobility or health care depend on reliable, safe and efficient ICT and can no longer function without it (Byres and Lowe, 2004; Roman et al., 2011). A high degree of cybersecurity is therefore required (Section 3.3.4). Regulations for the necessary resilience of public infrastructures must be called for and further developed (BSI, 2017). Cyber attacks should be prevented with the necessary consistency and prohibited under international law (Bothe, 2016).

3.4.2
Cognition

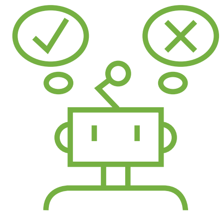


The second core characteristic concerns the development of cognitive abilities by technical systems and the extension of human cognitive abilities by means of technical systems. Beyond controversies within and between scientific disciplines, cognition is generally understood to mean grasping, recognizing and learning. Cognition aims at the collection, processing and use of information by humans or, within the framework of corresponding models (Section 3.2), also by software-based systems and thus machines. From a human point of view, the latter, if we think in terms of a mirror of reality, have "by and large become externalized intelligence and imagination," whose image "turns out to be the original of the projection or a further possible construction of what evidently produced it" (Capurro, 2017: 20). In the sense of an expansion of human intelligence, sensor technology, big data and AI (Sections 3.3.1, 3.3.2, 3.3.3) can often be used to 'perceive' more precisely or more comprehensively than human sensory organs. However, this does not mean that the breadth and diversity of human 'intelligence', which has by no means yet been scientifically clarified, can be reduced to machine models (Ito, 2018: 6; Box 3.3-1). By contrast to humans, however, technical systems with cognitive abilities are characterized – also in the sense of the current 'knowledge explosion' (Section 3.4.5) – by an infinitely scalable quantitative 'memory' and an 'ability to concentrate' that remains stable even over long-term calculations. For the time being, however, they have neither emotions nor physical experiences. Even if attempts at modelling are being made in this direction, the belief that it is possible to reproduce 'artificial life' without selection processes remains a myth from today's perspective, as does "the belief that using different materials or processes in imitating other living beings makes no difference between the natural and the artificial" (Capurro, 2017: 24; Kehl and Coenen, 2016).

Accordingly, many of the cognitive technical applications today still involve a very simple form of cognition. Although current developments in AI and deep learning show the possibilities of more advanced cognitive abilities of technical systems, these are still very training-intensive and essentially refer to very concrete tasks (Burgard, 2018; Section 3.3.3). For example, AI-based recognition of speech or image patterns can handle large amounts of data and work more precisely than humans as long as the pattern recognition problem to be solved is adequately covered by the training data. Applications include handwriting recognition, speech recognition, machine translation and automatic image description. They are used in industrial robotics, autonomous driving or medical technology. However, classification, pattern recognition, characterization or a logical conclusion will always fail in situations involving special data or patterns, for example when recognition of traffic situations is made difficult by poor visibility, unexpected movements or unexpected objects in traffic. A universal form of AI that can solve arbitrary and not only specific problems (Sections 3.2.2–3.2.5) is not in sight at present, although the search for it continues (Schmidhuber, 2009; Hutter, 2012) and significant successes are being achieved, although they all refer to selected problem classes such as classifications or logical reasoning.

The development of technical systems that can recognize and reflect people's emotions and use them in interaction with people, for example in working, training, educational or traffic situations, is still in its infancy; however, there are already some interesting approaches in care-giving and therapy (Bernard-Opitz et al., 2001; Minsky, 2007; Mayer et al., 2016; Wang et al., 2018). By contrast, brain machine interfaces (BMI; brain computer interfaces – BCI) and brain-controlled neuroprostheses (Birbaumer, 2017) are becoming more suitable for everyday use. They are increasingly being used to support disabled people (e.g. with locked-in syndrome) or to help paraplegics steer wheelchairs via EEG-caps (Stamps and Hamam, 2010; Lebedev and Nicolelis, 2017) and could potentially lead to a fundamentally new kind of 'technologization of human beings' (Topic box 5.3-2).

3.4.3 Autonomy



The third core characteristic of the Digital Age is the increasing autonomy of technical systems. Essentially, this refers to independent decisions and independent movements and (re-)actions by technical systems like those used in industrial robotics, automated driving, air traffic control or train control systems (Dumitrescu et al., 2018).

In addition to autonomous driving (meaning fully automated driving in every driving situation), the public debate is currently looking at decision-making in banking (e.g. granting loans or share trading) and the social sector (e.g. awarding unemployment pay). The application areas of autonomous machines are continuously expanding thanks to the interaction between digital networking technologies (e.g. Internet of Things, Section 3.3.1), AI (Section 3.3.3) and big data (Section 3.3.2). Technical systems equipped with sensors can identify patterns based on correlations which cannot be made accessible to humans directly (in some cases not even indirectly via technology). Such autonomous technical systems are deployed, for example, in crisis detection and management.

A high level of development dynamics can also be seen in the field of robotics, where great advances are being made in functionality, sensor technology and motor skills (Section 3.3.5.3). Physically strenuous activities and tasks that could not be done by humans were transferred to machines centuries ago; the current developments in the field of intelligent robotics can be understood as the next logical step. Intelligent robotics is said to have the potential to solve social and environmental problems, for example through increased efficiency, but also through the higher resilience, reliability and safety with which robots operate. While the transfer of responsibility for the implementation of physical tasks by robots is comparatively uncontroversial, the transfer of responsibility for solving societally relevant decisions to such machines as decision-making systems is the subject of intense public debate (Section 3.2.5).

In particular, the (functional) safety of autonomous technical systems, i.e. whether they pose a threat to people, society or the environment, is regarded as a risk. It is discussed whether the automatisms of such technical systems are robust and resilient enough to function smoothly even in exceptional situations. Research is therefore looking at security mechanisms of autonomous technical systems on different security levels, but also at ethical and liability issues of algorithm-based systems (Section 3.2.5). Concerning the question of the responsibility of autonomous technical systems, the discussion considers when it makes sense to transfer responsibility to technical systems and when the final decision should be left to humans. Dystopian scenarios, for example, conjure up the danger that data-based, automated governance means the end of the political public sphere and democratic decision-making processes between people (Section 6.2).

3.4.4
Virtuality

Another core characteristic of the Digital Age is the virtualization of physical elements and (sub)systems, i.e. their displacement or partial substitution into virtual space, or their digital extensions. Even if a certain continuity can be seen here, stretching from writing books and producing theatre plays, movies and other media to comprehensive 3D, 360° and real-time virtualization in multimedia, the technical developments are much more far-reaching: for instance, virtualization enables individuals to meet at different locations and, in the future, at different times. Large events can be held in virtual spaces, and discussions can be held between individuals, avatars and social bots. Virtualization can thus promote the transnational interconnectedness of individuals and organizations.

Furthermore, the use of digital AR and VR technology (Section 3.3.5.2) makes it possible to shift planning, design or production processes into the virtual world, e.g. to develop suitable designs, make more accurate predictions, carry out optimizations, and thus save costs. In addition, products and production can be designed in line with requirements, and circular economies can be realized. To exploit this potential, accurate, realistic digital representations and models of sections of the physical world must be generated, further developed and calibrated by monitoring, simulation and validation.

Virtualization also has the potential to virtually create previously inaccessible parts of the world (e.g. at the macro-, meso-, micro- or nano-level or in other time periods), to virtually create completely new environments (e.g. alternative worlds) extrapolated from the world (e.g. to predict possible futures), which can be used in the fields of entertainment, education and further training, or for decision-making. Virtualization makes virtual or hybrid experiences possible for this purpose. For example, it enables the vulnerability of people, groups, ecosystems or the planet to be directly felt and conveyed like real experiences. A global (environmental) awareness (Section 5.3.1 can develop in this way.

However, virtualization can also have a negative effect if key aspects of human life are shifted to the virtual world and completely replace analogous experiences with humans and nature.

3.4.5
Knowledge explosion

The fifth core characteristic of the Digital Age is the considerable increase in human knowledge in all fields of science and research. The Digital Age is generating a massive increase in data and information (Beath et al., 2012), driven by the internet, the Internet of Things (Section 3.3.1) and satellite observation (Section 3.3.5.1). For example, “the amount of data produced daily in genomics [doubles] approximately every seven months. The amount of data required to sequence a single genome is thirty times greater than the genome itself. By 2025, the genomes of more than a billion people will have been sequenced. The storage requirements for this are estimated at 2–40 exabytes per year” (Schadhauser and Graefen, 2017).

This massive data growth is a driver and the result of far more extensive transformations. For example, the majority of scientific disciplines are developing to a considerable extent by means of computing, networking, virtualization and AI. New disciplines are emerging at the interfaces between traditional science and digitalization. For example, present-day climate research, genetic engineering, modern physics and material sciences are largely based on digitalization, particularly on the digitally supported modelling and simulation of different scenarios. These make it possible to uncover previously unknown connections, to prove assumptions or to formulate and substantiate new theorems (Hey and Trefethen, 2003).

Supported by new possibilities in processing and acquiring knowledge, as well as the far-reaching digital possibilities for accessing humankind’s level of knowledge and new scientific findings, the quantity, but also the quality of the available knowledge can increase, because knowledge and scientific results are becoming directly comprehensible, and new ideas or assumptions can be reflected upon, discussed or cooperatively developed worldwide (Nosek et al., 2015; Fecher and Friesike, 2014).

However, there is also the risk of falsified data or facts, manipulated models or analyses. As a result, the

Figure 3.5-1
The key areas of civilization influenced by digitalization: the Earth system, the economy, society, people and technology.
Source: WBGU

increase in knowledge could be hindered by the increase in untruths. Another major challenge is preserving and safeguarding humankind's digital memory, which is part of the digital commons (Section 5.3.10).

3.4.6
Conclusions: the digitalized technosphere as a central building block of society

The technosphere, further developed by digitalization, has become a key societal building block in the Digital Age, just as other key technologies like energy and automation technology have had a major impact on all areas of civilization since the Industrial Revolution. While societal analyses in the past often referred to societal structures, actors and their interrelationships, this is not enough in the Digital Age: the socio-technical nature of all areas of life has become a new momentum of human civilization. Digitally supported interconnectedness, cognition, autonomy, virtuality and the resulting knowledge explosion affect all areas of life in the Digital Age, as further explained in Section 3.5, and must therefore be examined systematically.

3.5
Changes in key areas of life in the Digital Age

Understanding the Digital Age cannot stop at the developing core characteristics, but must be complemented by a critical analysis of the interactions of digitalization with the Earth system, the economy, society, individuals and formerly analogue technical systems (Figure 3.5-1). This analysis is initiated in this section and will be further developed in the course of the report.

Digitalization has consequences for each of the key areas of life – the Earth system, the economy, society, people and technology. Without wishing to fall into blind technological determinism, these consequences can have the power to significantly change the established characteristics of each of these areas. Many of these foreseeable changes could be used positively to leave established pathways in the sense of a Transformation towards Sustainability. However, many are radical challenges with an uncertain outcome. In the long term, great potential benefits as well as risks are possible in each area. Timely action to shape developments is therefore important in order both to contain the risks involved and to harness the disruptive power of digitalization for global sustainability transformation and for overcoming path dependencies.

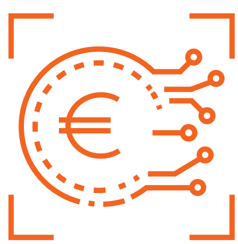
3.5.1
Digitalization and the Earth system perspective

In the Anthropocene, digital innovation encounters an Earth system whose guard rails are being fundamentally being put to the test. The additional effects of digital and digitalized technology systems on the geophysical, biological and atmospheric processes of the planet and local environments must therefore be critically scrutinized. These include not only direct effects of the material flows and energy consumption that accompany the new infrastructures, devices and their use, but also indirect effects on the economy and society as a result of increased knowledge or changes in behaviour (Hilty, 2008). The following three core issues seem to be key:

- *(Over)use of resource- and ecosystems:* In the Digital Age, there is a need to study the cumulative effects of digitalization on the global use of resources and the pollution of the ecosystems. The potential of digital technologies to support the Great Transformation towards Sustainability should be weighed against the risks of digitalization, such as path dependencies and rebound effects – although the current availability of data on energy and resource consumption is not yet sufficient for a final, let alone global assessment (Köhler et al., 2018). There is potential, for example, for increasing the efficiency of energy use and material cycles. Their improved design, control and monitoring can create opportunities for an energy-system transformation, a circular economy and a more sustainable global consumption of raw materials (Sections 5.2.1, 5.2.3). However, there is nothing automatic about whether these opportunities will indeed be taken; rather, appropriate innovation incentives and regulatory framework conditions will be required. For example, with appropriate policies, digitalization can pave the way for a climate-friendly energy system (Section 5.2.6). Among other things, risks are seen in the direct consumption of resources by digital technology and by digital and digitalized infrastructures (Section 5.2.5). In addition to emissions, immissions also have great explosive power: the widespread release of technologically used materials into the biosphere and possible bioactivity by these materials can lead to considerable pollution from toxic substances and have a serious impact on humans and the environment (Section 5.2.5). Furthermore, toxic and persistent substances in digital and digitalized infrastructures and devices should be replaced wherever possible by alternatives (e.g. carbon nanomaterials instead of rare metals, Arvidsson and Sandén, 2017; Section 5.2.5.3).

- *Gaining knowledge and changing environmental images:* Digital technologies increase, accelerate and facilitate the process of gaining knowledge about the Earth system and could thereby revolutionize the relationship between humankind and the planet in the long term. Global interconnectedness with sensitive sensors and petaflop computing capacity enables the (live) monitoring (Section 5.2.11), modelling and simulation of planetary cycles and processes for the first time in human history (Hu et al., 2010; Kramer, 2002; Belward and Skøien, 2015). This increase in knowledge can improve our understanding of the Earth system and thus of the planetary guard rails. This has the potential not only to improve our understanding of humankind's impact on the Earth system, but also to rethink and change it. Whether the change of perspective points in the direction of a Great Transformation towards Sustainability is a matter of controversy. In principle, individual and collective knowledge gains are the basis for more awareness in handling the Earth system. In the sense of the Anthropocene, however, this comprehensive view of the planet could also encourage the hubris of the human species and lead to increasingly risky and intensive interventions in the Earth system. The increasing virtualization of environmental experiences also represents a key change in the relationship between humans and the Earth system, with humans replacing basic physical experiences of the environment with virtual replicas (Baudrillard, 1981). Yet digitalization also holds out the hope that people will, for example, be able to better experience and comprehend the diversity and interconnectivity of planetary life through digital interconnectedness and virtual simulation. For the first time, a kind of global (environmental) awareness could be created, promoting respectful, empathic treatment of the planet's different life forms (Section 5.3.1).
- *Reduction of environmental impacts through virtualization:* Digitally supporting increases in knowledge and changing images of the environment and the world, as described, are important building blocks of the Transformation towards Sustainability. It is also essential that environmentally harmful consumption and production practices are replaced (Section 5.2.3). Digitalization could contribute to dematerializing the satisfaction of human needs by means of sharing models oriented towards eco-sufficiency (Section 5.2.2) and the virtualization of social and economic interactions. First, digital support is increasingly being offered as a service. In 'mobility as a service' (Section 5.2.8), for example, multimodal route-planner apps make environment-friendlier mobility possible (Duan et al., 2015; Xu, 2012). Second, virtualization is seen as an opportunity, e.g. by moving processes to the cloud as far as possible and only keeping those physical components on site that are absolutely necessary (EMF, 2016:39). Furthermore, digitally supported home-working is seen as a way of avoiding traffic. Similar hopes rest on resource savings through the 'paperless office' and the virtualization of a wide range of services (Duan et al., 2015; Xu, 2012). All this must take due account of the risks of resource and ecosystem (over) use and of risks to data protection and privacy.

3.5.2 Digitalization and the reconfiguration of the market and the economy



There is little doubt that digital change is having a considerable impact on economic systems and markets and, in some cases, is fundamentally transforming them. A multitude of new goods and services are being created, some directly connected to physical goods, others in digital, virtual space. Thanks to technical advances in the acquisition and processing of information, data can be obtained and used economically to an unprecedented extent. Digital interconnectedness and communication reduce transaction costs, information deficits and asymmetries. The processes triggered by digital technological change at the economic level are not always new, but they usually occur at an unprecedented speed and with a broad impact.

In aggregate terms, there are three main areas in which digitalization can lead to key changes:

- *Market structure and concentration:* Digital change does not always create completely new market forms: the basic principles of platforms or general 'two-sided markets' (Box 4.2.2-1), and non-monetary barter transactions are known. However, by blurring the boundaries between goods and services or making the temporary use of (durable) goods instead of ownership possible and easier to organize in the digital space (e.g. sharing economy, product-service systems), such market forms are becoming more widespread and more important. The advance of digital technologies is also changing market structures in general. In the longer term, the competition-promoting effects of digitalization are in danger of being overshadowed by strong drivers of increasing market concentration, which are also inherent in digitalization. The low or often negligible marginal costs of digital goods and services contribute to their scalability and their high potential for disruption. However, the consequence can also be that in the longer term only individual dominant providers prevail ('winner-takes-all', 'superstar companies', Autor et al., 2017). Network effects that characterize platforms, for example, and the increasing dependence on data of digital goods and services, as well as further digital technical developments, further intensify these concentration tendencies (Section 4.2.2; Prüfer and Schottmüller, 2017). Moreover, with the advance of digital interfaces, complementary digital services and digital alternatives, these concentration tendencies are spreading to non-digital markets.
- *(Re)distribution of value creation:* Digital change creates a new and ever-more-important factor of value creation: data, which competes with the classic production factors of labour and capital. In addition, increasingly 'intelligent' machines can be used to replace human labour in more and more areas. Although it is as yet unclear how far this substitution of labour by machines will extend and whether the loss of employment will be compensated by new activities and forms of work, this development is associated, at least in a transitional phase, with manifold distributional implications at various levels (Section 5.3.9; Berg et al., 2018). The boundaries between winners and losers run between the 'classical' production factors of labour and capital, between workers with different qualifications, but also between groups with different opportunities to use data and digital technologies (Section 5.3.8). The financing of the state's leeway for action and social-security systems, the importance of which will increase in the future with the need to cushion the consequences of technological progress, will be affected by this change in the labour market, as will the other societal functions of work that go beyond economic inclusion (e.g. societal inclusion and self-esteem; Section 5.3.9). In addition to new systems of social security and the need to ensure economic inclusion, a change in the societally embedded and accepted concept of work seems necessary in the longer term.
- *Public framework:* Development and market dynamics are sometimes extreme as a result of the high speed of digital technological progress, the fast scalability of business models in the digital space, and the ever-closer global interconnectedness of humans and machines. Market regulation, competition regulation and tax systems are often unable to keep pace with these dynamics. There is a danger that they will be unable to cope with the increasing importance of intangible assets and markets with strong network effects. Tax and duty systems, for example, are confronted with new challenges resulting from the need to document the economic value of data transactions, or to allocate profits from the global deployment of algorithms to a certain region (Box 4.2.2-2). At the same time, there is a risk of traditional bases of tax assessment being eroded by the redistribution of value creation away from labour (Section 5.3.9). However, more comprehensive monitoring options and timely information also open up new approaches to taxation, particularly in the fields of pollution and resource use.
- *New economic practices and ways to direct or coordinate economic activities:* On the one hand, reducing information, search and transaction costs in the course of digitalization considerably improves the functionality of markets (Mayer-Schönberger and Ramge, 2017; Goldfarb et al., 2019). On the other hand, markets, hitherto the dominant way of coordinating the economic activities of production and consumption, are being challenged anew by digitalization and new, data-based forms of control and cooperation (Section 4.2). Algorithm-based methods, such as the extension of scoring systems (Section 5.3.3), offer opportunities to implement societal or governmental goals directly in the distribution of goods and resources (Chalvatzis et al., 2019). This

raises fundamental, ultimately societal questions, e.g. which will be the areas in which the distribution of goods and factors takes place via markets, and in which areas should these markets be withdrawn in order not to link them (for societal or ethical reasons) to individual (economic) performance. Such debates are sparked, for example, in the field of the sharing economy. However, the discussion must also take into account the disadvantages and dangers of the new data- and algorithm-based control options, which are associated with a loss of individual freedom of decision, anonymity and privacy, as well as with the dangers of a high concentration of power and manipulation (e.g. of preferences). At the microeconomic level, digital change can lead to the reorganization and restructuring of coordination and production processes within and between enterprises. With the growing importance of goods with no – or with deliberately avoided – direct rivalry, forms of collaborative production processes also seem to become more important (Sections 5.2.2, 5.3.10). Last but not least, digitalization could also promote the transformation from a linear economy to a circular economy (Section 5.2.1, 5.2.5).

3.5.3 Digitalization and the change of societal order

The core characteristics of the Digital Age described in Section 3.4 also have consequences from a socio-political perspective. *Interconnectedness* is manifested as greater interdependence between different actors – as the driver of a polycentric system structure within and beyond state entities (Section 4.4). The aspects of *cognition* are realized in the increasingly pronounced coexistence of automated (including autonomous) systems and humans in almost all areas of society, even involving the societal consequences of a comprehensive collaboration between humans and machines. Automation, autonomous systems and in particular data acquisition and algorithmic decision making (ADM) can become new, often ambivalent drivers of society and the economy (Section 5.3.3). *Virtuality* changes the spatial structure of society and its state and real-life spheres of action (Section 5.3.1). Finally, the increase in available *information* and emerging *knowledge* requires individual and collective processing skills and literacy (Section 5.3.4). For societies, there are four main areas in which digitalization leads to key changes:

- *Privacy:* A protected private sphere is socio-politically not only necessary as an expression and protection of individual freedom, but also as a prerequisite for the possibility of collective action in a democratic community (Jacob and Thiel, 2017). The protection of privacy in the Digital Age is challenged and partly questioned e.g. by algorithmic pattern recognition, data economy and practices of a digitalized public sphere (Section 5.3.2). Privacy is threatened by various actors: by one's own self, by fellow human beings and companies, as well as by public authorities and states (e.g. Sections 5.3.7, 5.3.3). There seems to be division between the total transparency and interconnectedness of a post-privacy world on the one hand, and the search for functioning individual and institutional measures for the sustainable protection of privacy on the other (Section 8.3.1). The decision on which direction to take will have a key impact on dignity, inclusion and, in particular, on *Eigenart*.
- *Democratic inclusion, public sphere, participation and autonomy:* After the initial euphoria over participation opportunities, democratization and transnationalization through digital technologies in the 1990s and 2000s (Siedschlag et al., 2002; Vowe, 2014; Zipfel, 1998), critical debates are increasingly taking place in view of far-reaching changes in the structure of the democratic public sphere – for example on the accessibility of the digital public sphere and the dangers of increasing fragmentation, polarization and trivialization in digital communication (Jacob and Thiel, 2017; Section 5.3.2). Increasing interconnectedness and ICT – including virtuality – could on the one hand enrich democratic communities; on the other hand, it could also shake their basic constitution through algorithmic control, the data economy and the attention economy (Section 5.3.3, 5.3.6). Societies face the important task of re-strengthening their overall integrity and 'collective autonomy' (Section 5.3.2). Institutional and media-policy reforms are just as relevant here as education policy (Section 5.3.4).
- *Statehood, (state) sovereignty, patterns of order:* In the initial phase of the spread of the internet and ICT, the emerging cyberspace was celebrated and feared as a space beyond state claims to sovereignty; in the meantime, digital space is regarded as a "place of hypersovereignty" (Thiel, 2014b), which makes it possible for states to conduct comprehensive surveillance in situations where the democratic rule of law is lost. Further relevant topics regarding the (re) ordering of state sovereignty include cybersecurity and digital warfare, as well as new negotiation and regulation processes in the field of internet gover-

nance (Jacob and Thiel, 2017; Box 4.2.7-1). In addition, digitalization acts as a multiplier for practically all elements of globalization. Interconnectedness, digital communication and virtualization accelerate the further denationalization of economic processes and thus undermine state governance elsewhere, which is often still closely bound to territorial frontiers (Section 4.2.6). In the course of digital change, however, not only are temporal and spatial processes compressed; in addition, the spectrum of active, involved actors is broadening: national institutions and business enterprises are interacting in the polycentric network of actors, as are sub-state and inter-governmental authorities, civil-society groups, individuals and the tech community (Chapter 4).

- *Inequality and inclusion:* Inequality is an overarching, socio-politically explosive issue, both nationally and globally. Inequality issues – both between and within societies – are key in relation to the societal dimensions of digitalization. At the global, inter-societal level, in addition to a digital divide between states with different levels of development (access to digital infrastructures, end devices and the necessary education), there is also discussion on the more general question of the winners and losers of digital change. Within societies, however, digitalization also affects other dimensions of inequality, such as discrimination based on wealth, age or gender. On the one hand, existing patterns of societal discrimination are reproduced in the domain of digital technology; on the other hand, there is potentially also room to overcome them there (Section 5.3.6). Key for questions of distribution and inclusion are also changes in economic structures, as, for example, described in catchwords such as 'data capitalism' or 'digital precarization' on the one hand (Hofmann, 2017; Ehrlich et al., 2017) and positive visions of digital commons on the other (Section 5.3.10). The changes in the world of work and the social effects of digitalization require additional societal attention, especially in view of the above-mentioned challenges for state governance and welfare-state mechanisms – not least in order to contain inequality dynamics in good time.

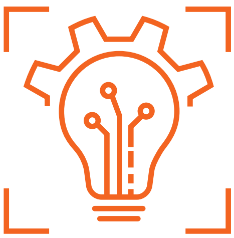
3.5.4 Digitalization on and in humans

Central to the view of digital change – also and especially in the context of the Transformation towards Sustainability – is the way it is perceived by human beings, as explained in detail in Section 3.1. At the personal level, the interactions with the digital technology system range from many small conveniences and positively perceived empowerments to possible restrictions of self-determination or *Eigenart* driven by violations of data protection (Section 5.3.7; Topic box 5.3-2). In aggregated terms, there are three main thematic areas in which change through digitalization can lead to key challenges:

- *Human-machine interaction:* Individual or collective, in some cases collaborative interaction with technical interfaces, robots and AI is already a pivotal and constantly evolving topic today. In this context one can observe extensions of human practices into technical and virtual spheres, and an expansion of technical elements into individual everyday life. By blurring these boundaries and improving the interfaces, there is a lot of potential that could enable people to handle technology in an integrative and successful way. However, there is also a risk of problematic developments: the increasingly sophisticated imitation of human communication by artificial systems makes it necessary to explicitly identify machines in their interaction with people.
- *Individual autonomy and self-determination:* In particular, data-driven services challenge an individual's opportunities for individual autonomy and a self-determined lifestyle, for example through profiling and big nudging (Helbing, 2017; Section 5.3.3). In addition, the acquisition and analysis of data, which is already almost universally possible today, endangers privacy, even if national and international laws represent obstacles in this regard. Here, aspects of education play a role, as do further developed concepts of well-being or solidarity-based quality of life in the Digital Age (Section 5.3.4, 5.2.3).
- *Technologization of human beings:* Digital solutions can already compensate some people's disabilities, but they also enable the 'optimization' of human abilities, from prosthetics to implants and on-body interfaces. In the future, new ways for the further development of humans themselves will be devised (Topic box 5.3-2;Section 7.4). The main critical aspect here is the possible emergence of individual and social pressure as a result of new societal norma-

tive ideas and potentially rising inequality – not only between poor and rich, but also between non-optimized and optimized individuals respectively. The question of the fundamental value, preservation and potential dynamics of human biological nature must also be raised here (Box 7.3-2).

3.5.5
Digitalization of human-made technological systems



More than forty years ago, Friedrich Rapp (1978) already described the technosphere as 'second nature' that does not fit seamlessly into the natural processes as it did in earlier epochs. The term technosphere, which makes up the technical environment of humans, is generally used to describe the totality of technical systems produced by humans and the associated formative changes in nature (Rapp, 1978; Zalasiewicz et al., 2017).

It comprises the technical systems in urban and rural areas, mines, the oceans and the air. These systems include urban infrastructures such as mobility trails, supply and disposal systems, houses and buildings, health facilities, production plants, machines and products. According to Jan Zalasiewicz (2017), the technosphere is a system with its own dynamics and its own energy flows; humans have long been dependent on this system to survive.

Like any other area of life, these technological systems are being significantly influenced, changed and further developed by digitalization. Selected technical systems or parts thereof will disappear or only exist in niches. For example, most films are produced digitally, analogue control technology is giving way to digital, analogue communications centres and radio and television stations are being replaced by digital ones. New technology systems such as the world wide web have emerged. From a sustainability perspective, there are above all three areas that are undergoing changes through digitalization:

- *Communication, information and education:* Digitalization has radically changed the possibilities of communication and information. Today it is possible to communicate almost immediately from anywhere, with any person worldwide and at any time (Popescu-Zeletin et al., 2004) using texts, sound, audiovisual means, multimedia – or interactively on a bilateral or multilateral basis, and soon even haptically. The wide variety of information opens up access to all human knowledge, brings people closer to national and international cultural and natural commons, to current developments, political, economic and scientific facts; in this way it also supports informed decisions on sustainability (Fuchs, 2008). Online services can surpass existing ways to access education and further training (Section 5.3.4; Moore and Kearsley, 2011). Reliable ways of accessing communication and information services should be open to everyone and are discussed in different contexts as part of digital fundamental rights (Hoffmann and Schulz, 2015). It is also important to ensure that individuals can rely on the quality and correctness of information, and that people's opinions remain recognizably distinct from statements made by machines. To this end, personal sovereignty in handling communication possibilities and the information available must be strengthened and supported by training and further-education programmes (Kerres, 2018).
- *Public infrastructures:* The digitalization of public infrastructures, e.g. for water or electricity supply, is driven by initiatives such as smart cities and municipalities (Chourabi et al., 2012; Zanella et al., 2014), smart mobility (Burns, 2013) and smart energy networks (Siano, 2014). What these approaches have in common is that the infrastructures used for administration, mobility or energy supply are digitalized via sensors and actuators in such a way that status information can be collected in close-to real time and used for traceability, forecasts, simulations and decision-making support right up to (partially) automated control (Kitchin, 2014; Zygiaris, 2013). The digitalized observation and control of infrastructures and public spaces will only be reliable, scalable, secure and trustworthy if the standards and regulations for the further use of information, for data security and data protection of personal, person-related, commercial and public data are complied with or demanded. Data sovereignty and data protection and security, as well as inclusivity, accessibility, net neutrality, resilience and robustness of digital and digitalized infrastructures are key requirements for the operation of digitalized public infrastructures (Lewis, 2014). The development of public-service ICT infrastructures could be an option here (Section 5.3.5).
- *Production, logistics and products:* The Industry 4.0 vision addresses the digital interconnectedness of production, logistics and products and their intelligent control and optimization (Section 5.2.1; Drath and Horch, 2014). Industry 4.0 and related digitalized traceability could make the circular economy possible on an unprecedented scale (Kagermann, 2015). On the other hand, Industry 4.0 not only

makes the improvement of production, logistics and products possible, but also lot-size one production, i.e. the product is designed to meet the individual needs of customers or users. This allows both more targeted and longer product use through stronger identification, but also increased consumption. Thus, the increases in demand associated with Lot-Size One production, as well as further efficiency in production, logistics and products, can be to the detriment of the environment and employees (Gabriel and Pessl, 2016). But it can also raise the potential for sustainable consumption (Section 5.2.3), since individualized products support targeted consumption and the minimization of non-use or waste. A further perspective on the interconnectedness of products, logistics and production is a possible increase in behavioural analyses, behaviour influencing or behaviour control of consumers or employees, which can and should be countered by the protection of (digital) privacy.

3.5.6
Conclusions: Understanding and accepting formative tasks

Section 3.5 spans the range of possibilities of how digitalization can affect the ecological, economic, societal and technical systems, as well as individuals, and how it can help humans to comply with planetary guard rails. Decarbonization, resource and emission efficiency and the circular economy could be achieved more easily and quickly with digital innovations than without them. Digitalization could also help to tap societal modernization potential. Globe-spanning knowledge, globe-spanning communication, and global societal interconnectedness in virtual and hybrid spaces can accelerate sustainability transformations, improve human inclusion, strengthen global environmental awareness, and create a transnationally networked society in which intergovernmental organizations, transnational networks and science complement each other and develop and use a culture of global cooperation. These possibilities for a digitally supported Great Transformation towards Sustainability must be rapidly and comprehensively mobilized.

However, this Section also shows that there is no technological determination *per se* relating to the major challenges facing humankind. The digitalization of the past decades – the internet, a wide variety of end devices, the increasing automation of production – has resulted in a constantly growing use of energy and resources, as well as in global production and consumption patterns that are increasingly placing a massive burden on ecosystems and the Earth system as a whole. The current surge of digital innovation is not being automatically translated into sustainability transformations. That requires closely linking sustainability models with technological breakthroughs. Nor is the societal innovation potential of digital change automatic. At present, societies seem to be overwhelmed by the speed and depth of technological upheavals and their use by powerful actors – particularly from the private sector, but also from the public sector.

Consequently, digitalization for implementing the 2030 Agenda is a major formative task that requires a modernization boost at almost all actor levels in order to create digital competencies and link them with the requirements of sustainability transformation. If this does not succeed, technology-oriented and short-term-oriented self-dynamics will prevail; then it will no longer be possible to link digital transformation with the sustainability transformation.

3.6
The Digital Age and sustainability from the perspective of international organizations

The sustainable shaping of the above-mentioned and other areas of life is at the heart of the 2030 Agenda and the activities of various international organizations. International organizations are increasingly focusing on digitalization as a field of action and a mandate for action. This Section uses some examples to illustrate the state of discussion among international organizations on digitalization issues in the context of the Great Transformation to Sustainability.

3.6.1
Selected reports

Global digital change is increasingly attracting the attention of international organizations concerned with sustainable development. This is indicated by the increasing number of reports addressing the effects of the Digital Age on the economy, societal development and the attainability of SDGs. The following section discusses, as examples, ten reports on digitalization and sustainable development published between 2016 and 2018 (Box 3.6-1). The selected studies consistently pursue an application- and solution-oriented approach offering advice for policy-makers from an international perspective. The idea behind the comparative review of these reports is to gain an impression of the framework within which the topic is being covered and the range of recommendations being made for the (political) shaping of the Digital Age.

Box 3.6-1
Ten examples of reports on digitalization and sustainability published between 2016 and 2018 by international organizations

1. UNCTAD – United Nations Conference on Trade and Development (2018): Technology and Innovation Report 2018: Harnessing Frontier Technologies for Sustainable Development.
2. GSM Association und Boston Consulting Group (2017): Embracing the Digital Revolution: Policies for Building the Digital Economy.
3. IEA – International Energy Agency (2017): Digitalization & Energy.
4. OECD – Organisation for Economic Co-operation and Development (2017a): Key Issues for Digital Transformation in the G20. Report Prepared for a Joint G20 German Presidency/OECD Conference.
5. OECD – Organisation for Economic Co-operation and Development (2017b): The Next Production Revolution. Implications for Governments and Business.
6. OECD – Organisation for Economic Co-operation and Development (2017c): Digital Economy Outlook 2017.
7. UNCTAD – United Nations Conference on Trade and Development (2017): Information Economy Report 2017. Digitalization, Trade and Development.
8. The Earth Institute und Ericsson (2016): ICT & SDGs – How Information and Communications Technology can Accelerate Action on the Sustainable Development Goals, Final Report.
9. World Bank (2016): Digital Dividends. World Development Report 2016.
10. WEF – World Economic Forum (2016): Digital Transformation of Industries: Societal Implications. White Paper.

3.6.2
Key messages and recommendations of the reports

World Bank's ‚Digital Dividends' World Development Report 2016

The thematic priorities of the World Bank's annual World Development Reports, published since 1990, have often reflected the respective topic's importance in the corresponding period of international cooperation. The choice of digitalization as the focus of the 2016 World Development Report is an indication that the topic has reached the strategic departments of international organizations. The World Development Report 2016, 'Digital Dividends' (World Bank, 2016), focuses on digitalization's potential for development and poverty reduction and identifies growth, employment and services as the most important returns on digital investments. However, the report states that these digital dividends are still spreading very slowly (almost 60 per cent of the world's population still does not have access to the internet, World Bank, 2016: 5) and that their spread depends on income, gender and the place of residence: "The internet remains unavailable, inaccessible, and unaffordable to a majority of the world's population" World Bank, 2016: 8).

If all regions of the world and all societal groups are to benefit from digital technologies, the remaining digital divide must be overcome, especially in the case of internet access (Figure 3.6.2-1). Affordable access to the internet for all is important, but not enough on its own to achieve progress in development. Digital investments therefore require additional support from 'analogue supplements' in order to become effective, according to one of the central messages of the World Development Report 2016. Such analogue additions include (1) a competitive environment, (2) digital competence of the users, and (3) responsible governments that use the internet to strengthen civil society. According to the World Development Report, the creation of these framework conditions is a necessary formative task for every country. An internet accessible to all population groups can improve inclusion, efficiency and innovation; at the same time, however, it involves risks that must be prevented, such as massive surveillance or control, increasing inequality, concentration of power, or the development of monopolies (Figure 3.6.2-2).

In addition to national policy requirements, the World Development Report stresses the importance of the internet for global cooperation. On the one hand, the internet can facilitate the solution of global problems; on the other, the regulation of the internet itself requires global cooperation (World Bank, 2016: 292ff.). To achieve this, it is necessary, first, to establish *international internet governance*, since the internet requires technical coordination and harmonized standards to ensure smooth operation worldwide. Second, *global digital markets* need to be *shaped*, in particular by removing barriers to cross-border data flows, setting global standards for data exchange, and adapting the protection of intellectual property rights to the challenges of the Digital Age. Third, digital technologies allow much better and more extensive *collection and use of data and information for sustainable development*. The two greatest global challenges, sustaining the natural life-support systems and poverty reduction (World Bank, 2016: 303), require close global cooperation, which can be intensified and improved using digital technologies. This applies equally to the analysis

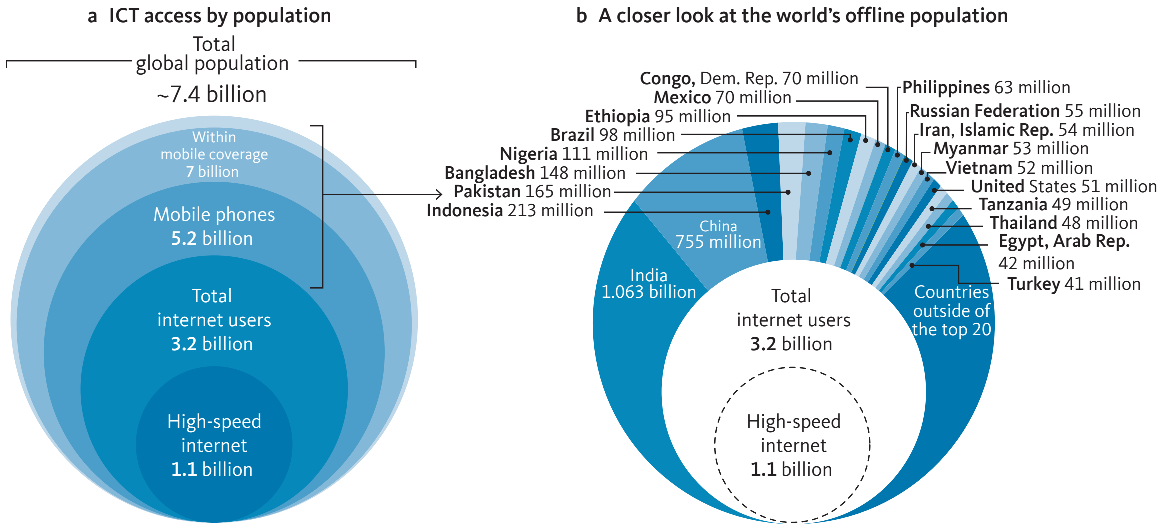


Figure 3.6.2-1
Access to mobile phones and the internet (a) by population and (b) by country.
Source: World Bank, 2016:8

and monitoring of global problems (e.g. with more accurate and comprehensive data) and to multilateral efforts to solve problems and implement the 2030 Agenda (e.g. running programmes, dialogues and exchanges of views).

UNCTAD's Technology and Innovation Report

The United Nations' 'Technology and Innovation Report 2018: Harnessing Frontier Technologies for Sustainable to implement the 2030 Agenda. A package of priority measures is proposed to achieve this. Here, the areas of *development*, *energy*, *climate protection* and *inclusion* have been selected by way of example. According to the report, the necessary framework conditions have to be created. First, a roadmap should be developed to ensure that all public facilities and services have a broadband connection by 2020. Second, the ten recommendations of the UN Broadband Commission Task Force on Sustainable Development (ITU and UNESCO, 2014:20) should be taken into account (including those on affordable connectivity, strategy development, facilitating broadband expansion, market incentives and standardization). Third, the foundations for digital transformation should be laid by rapidly integrating digital technologies in the public sector (primarily in administration and the provision of public services such as health, education and infrastructure). Fourth, the authors of the report advocate public-private partnerships to support broad-based ICT provision tailored to local circumstances and needs. Fifth, the MINT subjects (mathematics, information technology natural sciences and technology) should be upgraded in education systems in order to improve technological competence (Section 5.3.4). Sixth, the use of large amounts of data should be promoted. In particular, open databases using large quantities of data from the public sector and satellites, mobile networks, sensors and other network devices of the Internet of Things should be created (The Earth Institute and Ericsson, 2016:11).

'Embracing the Digital Revolution' report by GSM and Boston Consulting

The digital revolution is a policy-building task; this is the message of the report entitled 'Embracing the Digital Revolution: Policies for Building the Digital Economy' (GSM, 2017). Without political control, the gap between the profiteers of digitalization and those who are digitally dependent threatens to widen. Governments should therefore focus in particular on accelerating the introduction of technology and mitigating the negative economic and social impacts of technological change (GSM, 2017:2). The goal is an 'inclusive digital economy and society'. Inclusion, efficiency and innovation are described – in an analogous way to the World Bank's World Development Report 2016 – as the main mechanisms with which digital technologies can promote development processes (GSM, 2017:19). The report sees a particular need for action in the areas of network investment, legislation (adaptation to the digital world), promotion of the digital economy (data security and data protection, digital literacy, lifelong learning, digitalization of enterprises) and the digital governance of countries ("leading digital economies have leading digital governments"; Figure 3.6.2-3; GSM, 2017:33ff.).

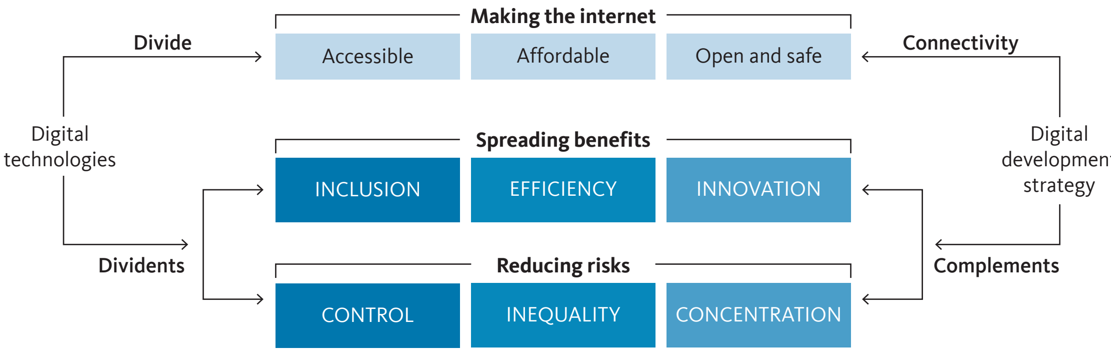


Figure 3.6.2-2
Why digital dividends are not spreading rapidly – and what can be done.
Source: World Bank, 2016: 4

OECD report: 'Digital Economy Outlook 2017'

The OECD's 'Digital Economy Outlook 2017' (2017c) takes the Cancún Ministerial Declaration (OECD, 2016a) as its point of reference. The declaration by the OECD ministers identifies the digital economy as a catalyst for innovation, growth and social prosperity, and argues for a stronger orientation towards sustainable and inclusive growth geared towards prosperity and equal opportunities. At its core, the declaration contains nine commitments, including the free flow of information, broadband expansion, security-risk management and digital literacy. Following on from this approach, the 'Digital Economy Outlook 2017' states that the digital transformation affects all facets of economic and societal life and requires an integrated approach. This can only succeed if traditional policy silos are abandoned, so that cross-sector, nationwide visions and strategies for the digital transformation can be developed (OECD, 2017c: 27). It is essential to create a basis for this: the digital economy can only develop fully if the macroeconomic framework conditions are right (free trade, open financial markets and functioning labour markets). According to the report, the role of governments is to make investment in digital infrastructures possible in a competitive environment. At the same time, it is necessary to promote digital applications as well as the development of digital literacy among the population (OECD, 2017c: 31). Finally, the report highlights the need for enhanced cooperation among OECD countries to develop coherent policies on digital security and the protection of privacy, data security and the protection of critical infrastructures. The issue of adapting society to the profound societal consequences of digitalization is briefly mentioned, but no solution is offered (OECD, 2017c: 33).

OECD report: 'Key Issues for Digital Transformation in the G20'

The OECD report entitled 'Key Issues for Digital Transformation in the G20' commissioned in 2017 by the German G20 presidency is also to be seen in the context of multilateral cooperation (OECD, 2017a). The report is based on the view that ongoing digital change in the economy and society will not only foster growth and innovation, but that successful digital change is also a prerequisite for inclusive and sustainable growth, the implementation of the 2030 Agenda, and for prosperity (OECD, 2017a: 6, 11). At the same time, it highlights the disruptive potential of digitalization, for example in terms of data protection and security (e.g. OECD recommendations on digital security management: OECD, 2015), consumer policy and competition, innovation, jobs and qualification. If these problems are not adequately addressed, the report says, this could lead to economic crises, reactionary politics, a worsening of inequalities, and a further weakening of societal cohesion. The challenge is to contain these risks politically. The report gives eleven policy recommendations for the G20 (OECD, 2017a: 145–149).

OECD report: 'The Next Production Revolution'

The OECD report 'The Next Production Revolution. Implications for Governments and Business' (OECD, 2017b) stands out from the reports discussed here by dint of the explicit reference to the need for long-term thinking and planning beyond 2030. Governments should prepare for disruptive change with profound societal consequences: "[...] such adjustment might be highly disruptive, although the precise pace and scale of inevitable future adjustments are unknown. It may be that, in the worst case, labour will be displaced on a scale and at a speed not seen before, that robots will make income distribution vastly more unequal than today, and that the market wages of the unskilled will fall below socially acceptable levels. Policy makers need

Table 3.6.2-1
Key policy levers to promote widespread digital benefits and inclusion.
Source: GSM, 2017: 33f.

Encourage network investment	Adjust regulation to a digitalised world	Promote digital economies	Demonstrate digital leadership
Have broadband policy with clear goals	Adopt functionally based regulation	Support data safety and security	Encourage usage of digital IDs
Support infrastructure build-out	Prefer *ex-post* approaches (over *ex-ante* prescriptive regulation)	Push digital literacy and life-long learning	Support digital financial infrastructure
Apply investment-friendly spectrum policy	Apply regulatory consistency throughout the ecosystem	Encourage digitalisation of companies	Introduce and push digital government services

to monitor and prepare for such possibilities" (OECD, 2017b: 34). The report recommends integrating foresight processes into political decision-making systems in order to better prepare for unpredictable developments with systemic long-term analyses and scenarios (OECD, 2017b: 50). This requires changes to organizational structures and strategy-building processes. Foresight processes should be linked to policy cycles to ensure that future information is available at the right moment in time. Participatory elements and an exchange between stakeholders and decision-makers are essential to initiate and establish change processes in politics, society and business. Finally, according to the report, a form of institutionalization is needed in order to create a foresight culture and to promote and disseminate future-oriented thinking (OECD, 2017b: 321).

UNCTAD's 'Information Economy Report 2017'

Three of the reports on digitalization discussed below focus on a global view of the themes 'Trade and Development', 'Energy Systems' and 'Industrial Production'. The UN's 'Information Economy Report 2017: Digitalization, Trade and Development' (UNCTAD, 2017) deals with the effects of digitalization on *trade, labour and education*, especially with regard to small and medium-sized enterprises in developing countries. The initial observation is that this group of countries is inadequately equipped for the Digital Age. Political action is particularly important here to ensure that developing countries do not fall even further behind in their socio-economic development in the wake of digital change. The challenge for policy-makers is especially to keep pace with the speed of technological change. For many smaller companies in developing countries, the primary objective is to gain access to the net and to improve understanding and skills within the companies themselves on the potential use of digital technologies. The report identifies improving network access, adapting education systems to digital change, and integrating digital solutions into export promotion as priority areas for action for governments in developing countries (e.g. UNCTAD's 'eTrade for all' initiative). An important prerequisite is improving the knowledge of decision-makers about the interface between trade, logistics, digitalization and e-commerce (UNCTAD, 2017: xv). At the same time, the report says, it is up to governments to ensure data security and the protection of privacy. As data-protection law differs considerably from country to country and, in particular, developing countries often do not yet have legislation in this area, the report proposes a bundling process: "In addition, many developing countries still lack legislation in this area altogether. Instead of pursuing multiple initiatives, it would be preferable for global and regional organizations to concentrate on one unifying initiative or a smaller number of initiatives that are internationally compatible." (UNCTAD, 2017: 7). Finally, the report says there is a need for dovetailing between multilaterally agreed trade policies on the one hand (WTO; bilateral and multilateral agreements), and internet governance negotiated in multi-stakeholder processes on the other, in order to ensure that future trade agreements and the digital economy are designed coherently and sustainably.

IEA report: 'Digitalization & Energy'

The starting point of the International Energy Agency's report on 'Digitalization & Energy' (IEA, 2017a) is the observation that digitalization can fundamentally change energy systems. The electricity sector is at the centre of this change, i.e. where digitalization is increasingly blurring the difference between generation and consumption (Section 5.2.6). At the same time, digital technologies are themselves energy consumers. Political action is decisive as to whether the efficiency gains can compensate for the rising demand for energy that comes from digitalization: "Policy and market design are vital to steering digitally enhanced energy systems onto an efficient, secure, accessible and sustainable path" (IEA, 2017a: 19). Since the structure of a digitalized energy world cannot be accurately predicted, and roadmaps with concrete time and target horizons cannot be developed, the IEA recommends ten no-regret policies to help governments better prepare for the digital transformation of energy systems (IEA, 2017a: 163f.).

WEF white paper: 'Digital Transformation of Industries'

The white paper entitled 'Digital Transformation of Industries: Societal Implications' from the World Economic Forum (WEF, 2016a) focuses on the disruptive societal potential of digital change in industrial production. In areas such as the future of work, income, inequality, health, resource efficiency and security, digital change will confront societies with entirely new challenges (WEF, 2016a). The key question is how digital change in industrial production can be shaped in such a way that it can make a positive contribution to societal development. The white paper identifies a need for action in three areas: (1) training employees for the age of digitalization, (2) using digital technologies for the Transformation towards Sustainability, and (3) building confidence in the digital economy (data protection, data security). The growing ecological footprint of digitalization is cited as a key challenge for the transition to a sustainable world, mainly due to electronic waste and the energy consumption of large data centres (WEF, 2016a: 22). Four measures are proposed to steer the digitalization of industrial production in a sustainable direction, reduce environmental impact, and uncouple growth from resource consumption: (1) embed principles of the circular economy in companies, (2) make a commitment to transparency across the entire production and supply chain, (3) cooperate in the joint use of overcapacity or waste streams, and (4) agree on sector-specific and cross-sector environmental standards for the IT sector (WEF, 2016a: 22).

3.6.3 Selected charters

In addition to detailed reports on sustainability and digitalization, and in some cases following on from them, a number of international organizations have drafted charters for sustainable development in the Digital Age. This Section 3.6.3 provides an overview of them (Table 3.6.3-1). A 'charter' is understood here as a superordinate term for a document whose main purpose and content is to postulate general principles for dealing with digital technology. Such documents are often also called principles, manifestos, guidelines or commitments. The transition to other types of documents is sometimes fluid. Scientific studies and political position papers, too, generally contain recommendations for action and demands. This section, however, only considers documents that are charters in the sense defined above.

In the current charter landscape, several drafts are already devoted to many critical sustainability issues that are identified in this report. These include, for example, the Charter of Digital Fundamental Rights of the EU (published by the Zeit-Stiftung, 2018), which formulates principles on human dignity, privacy, work, education and dealing with AI. However, this proposal's perspective is not one of dedicated and comprehensive sustainability either. Such a draft is not yet discernible in the existing charter landscape. Also important is the process to which existing charter drafts belong, or which they are supposed to initiate, as well as the intentions they aim to pursue. There are also some relevant drafts of this kind. The UN's Internet Governance Forum, for example, occupies precisely the global governance space that the WBGU regards as urgently needed with regard to digitalization, and has published a Charter of Human Rights and Principles for the Internet based on the Universal Declaration of Human Rights (IGF, 2018). A more detailed consideration of these and other draft charters follows at the end of this section. On the whole, however, it should be noted that – although several organizations have already drawn up a number of drafts of their charter – up to now no draft has been, first, thematically comprehensive enough to offer holistic guidelines on sustainability in the Digital Age – thereby covering all three Dynamics as outlined by WBGU (Chapter 7) – and, second, institutionally located at the multilateral level which, like the 2030 Agenda, can offer a target system with the necessary global perspective.

Thematic priorities

The thematic breadth of existing charter drafts varies greatly. While some are broad in scope, others concentrate on specific areas of digitalization such as how to deal with AI (e.g. the 'Asilomar AI Principles' from the Future of Life Institute, 2018), or potential for development cooperation (e.g. the 'Principles for Digital Development': Bill and Melinda Gates Foundation et al., 2017). Within the thematic range, three focal points can be identified that are particularly prominent in the existing charter landscape: AI, human and civil rights and, in particular, data protection and privacy.

In view of the technical developments in recent years – and their societal perception – there is a clear

Table 3.6.3-1
Overview of selected charters for the Digital Age.
Source: WBGU

Title	Year	Publisher	Type of publisher	Key points
ADM manifesto	2016	Algorithm Watch	Civil society	Algorithmic decision making is never neutral, the creators are responsible, processes must be traceable and democratically controllable. Debate is needed on how much freedom should be transferred to algorithms.
African Declaration on Internet Rights and Freedoms	2015	African Declaration Group	Civil society	The internet should be a space for the free exchange of views and knowledge, accessible to all, respecting, inter alia cultural and linguistic diversity, privacy and gender issues.
AI at Google: Our Principles	2018	Google	IT industry	Use AI only for the benefit of people, taking into account security, privacy, etc.; do not develop AI for military use.
AI Now Recommendations	2017	Campolo et al.	Academia	Do not use AI systems as black boxes; instead, research, test, monitor and ethically frame them.
AI Policy Principles	2017	Information Technology Industry Council	IT industry	IT industry is accountable for the responsible development and use of AI; AI systems must be controllable; governments must promote research and use of AI systems; security and privacy must be respected.
Asilomar AI Principles	2017	Future of Life Institute	various	Research is needed to work towards societally beneficial AI. In addition, think about AI politically, culturally, ethically. Ensure human values, privacy and freedoms.
Charter of Digital Fundamental Rights of the EU	2016/ 2018	Zeit-Stiftung	various	Comprehensive charter based on the German Basic Law with rights and goals in the Digital Age: respect human dignity, freedom, equality, freedom of expression in the Digital Age. Protect people's rights. The aim is to establish a legally binding charter of fundamental rights in the EU.
Digital Networking Charter	2014	Deutsche Telekom et al.	IT industry	Digital technology generates prosperity (location factor). Economic use of data benefits society; responsibility and framework conditions must correspond.
Contract of the Web	2019		Civil society	Governments, businesses and citizens should keep the internet (especially the web) open and freely accessible for all, while respecting privacy.
D64 Charter	2012	D 64	Civil society	Promote an open network society that enables inclusion and applies fundamental-rights-oriented data protection. The internet should be a space for network policy and the public sphere.

Ethically Aligned Design	2016	IEEE	IT industry	AI must contain ideals of human rights and benefit humanity and the environment. This principle is applied to value systems in AI, AI research, security, privacy and control, autonomous weapons, economics and law.
Geneva Declaration of Principles	2003	WSIS	International organization	Harness the potential of digital information and communication technologies to achieve the Millennium Development Goals (MDGs).
Human Rights Principles for Connectivity and Development	2016	Access Now et al.	Civil society	Nine principles that investors should follow to shape the internet and its infrastructure in accordance with human rights and economic development goals.
Internet Rights Charter	2006	APC	Academia, civil society	The internet should be an open space for all to exchange views and share knowledge freely, where open standards are developed and the privacy of users is respected.
Magna Carta for the Digital Age	2015	British Library	Civil society	Protect the web from corporate control and government censorship to ensure freedom of expression, information access and privacy.
Montréal Declaration for Responsible AI	2017	Montréal	Academia	AI should only be developed to ultimately increase the well-being of all sentient beings. This principle is applied to justice, privacy, knowledge, democracy and societal responsibility.
Principles for Algorithmic Transparency and Accountability	2017	Association for Computing Machinery	Academia	Principles on which stakeholders (developers, governments, users) should base their behaviour to enable transparent and accountable AI and to be able to adapt those principles where necessary.
Principles for Digital Development	2014/ 2017	Bill and Melinda Gates Foundation et al.	Civil society, international organization	Develop digital instruments in development cooperation together with users, gear them towards sustainability, make them scalable and secure, etc. Target: effective and inclusive digital development cooperation.
The Charter of Human Rights and Principles for the Internet	2014	IGF	International organization	Protect freedom of expression, social justice, privacy, diversity on the internet.
The Japanese Society for Artificial Intelligence Ethical Guidelines	2017	Japanese Society for Artificial Intelligence	Academia	Commitment to conduct research only to serve peace, security, welfare and the public interest. This principle is fleshed out for various areas (law, communication, security, fairness, etc.).
The Onlife Manifesto	2013	European Commission	International organization	European Commission's contribution to the discussion on the *Eigenart* of the human being: “What does it mean to be human in a hyperconnected era?” More a trigger for a debate (there is also an anthology) than a charter.

The Partnership of the Future	2016	Nadella	IT industry	AI must be designed to serve humanity; it must be transparent, respect human dignity and privacy, make understandable decisions, and not discriminate against anyone.
The Toronto Declaration: Protecting the Rights to Equality and Non-discrimination in Machine Learning Systems	2018	Access Now und Amnesty International	Civil society	States have a duty to protect human rights. They must take measures to protect against discrimination through machine learning.
Top Ten Principles for Ethical AI	2017	UNI Global Union	Trade union	AI systems should be transparent, protocol ethical decisions, serve human beings and the planet; humans should retain both control and responsibility over decisions; AI should be unbiased

thematic focus on AI. Examples include the 'Toronto Declaration' (Access Now and Amnesty International, 2018), the 'Asilomar AI Principles' (Future of Life Institute, 2018), the 'AI Now Recommendations' (Campolo et al., 2017) and 'Artificial Intelligence at Google (Google, 2018). None of the charters reviewed argues categorically against the use of AI. Instead, there is sometimes a sharp warning about the risks, but also an emphasis on the opportunities and thus the need for a societal debate. The ADM manifesto from the NGO AlgorithmWatch (2016), for example, stresses that automated decision-making is never neutral, that its use should be carefully considered, and that traceability and democratic control must be ensured. AI should be used in such a way that problems that already exist today can be better solved; at the same time, it must be ensured that people retain control over AI systems in the future. In this context, many charters also call for research on AI to be promoted in this direction.

Human rights and civil liberties are another priority of existing charter drafts. The focus here is not so much on dealing with the fundamentally new challenges that digitalization involves (as with AI); rather, the issue is how existing human and civil rights can be guaranteed under the changed framework conditions of the Digital Age – e.g. interconnectedness, mass evaluation of data – (e.g. Zeit-Stiftung, 2018; IGF, 2018; Campolo et al., 2017; D 64, 2019).

The third main point of emphasis is a special case of this focus on human and civil rights. The key question here is how can data protection and privacy be designed in the Digital Age when data is collected and evaluated automatically on a massive scale (e.g. Digital Charter of the Zeit-Stiftung, 2018)? As with the broader charters on civil rights, formulations often remain abstract: a certain fundamental right should not be affected by digitalization. Although the objectives pursued by the authors of the charter – e.g. to maintain an open, free, democratic society – are often formulated, due to the nature of a charter there is no explicit reference to how the required rights can be guaranteed in the Digital Age.

Some topics that are very relevant for this report, such as the effects of digitalization on the environment or work, are indeed included in some charter proposals, but are not represented as priority topics.

Formats

The majority of the charter drafts come, in roughly equal parts, from the IT industry, civil society, academia and think tanks. In general, two categories of addressees can be distinguished. In the first category, the sender and addressee are identical. Some drafts originating from business or academia are meant as voluntary self-commitments, particularly e.g. to advance the development of AI only if certain principles are maintained. Examples include 'AI Policy Principles' (Information Technology Industry Council, 2017), 'AI at Google' (Google, 2018), and the 'Japanese Society for Artificial Intelligence Ethical Guidelines' (Japanese Society for Artificial Intelligence, 2017). In the second category, the postulated rights and obligations are to apply to society as a whole – be it institutionally embedded on a global scale (IGF, 2018) or at the European level (Zeit-Stiftung, 2018). By contrast to voluntary commitments, these drafts – partly because they do not as yet have any legally binding character – are generally intended to initiate a societal debate. Many of the drafts therefore include interactive elements: you can sign them as an open letter, vote for certain principles, or discuss them on the internet. A number of charters are designed to be continually revised to take into account developments in technology, the current state of research and societal debates (*living documents*). Some drafts also declare the legally binding establishment of the rights and obligations negotiated in this way as their long-term goal (e.g. Zeit-Stiftung, 2018).

Some charters that seem particularly relevant in the context of this report are presented individually below.

'Charter of Digital Fundamental Rights of the European Union'

The 'Charter of Digital Fundamental Rights of the European Union' (Zeit-Stiftung, 2018), published by the ZEIT-Stiftung, is a thematically very comprehensive charter; its structure and language are based on the fundamental rights and state goals in Germany's Basic Law. For example, it covers human dignity, freedom, equality and freedom of expression in the Digital Age. The focus is on safeguarding existing fundamental rights under the new framework conditions of the Digital Age. A revised version of the digital charter was presented to the public in 2018, two years after the first draft. It is intended to further stimulate debate in society and to be continuously revised on this basis. You can vote on and discuss individual articles on the internet. The aim is to make a charter of fundamental digital rights legally binding in the EU.

'The Charter of Human Rights and Principles for the Internet'

The Charter of Human Rights and Principles for the Internet (IGF, 2018b) is relevant in two respects. First, it comes from the UN's Internet Governance Forum and thus from precisely the global governance space which, in the WBGU's opinion, urgently needs to be further developed in the context of digitalization (Chapter 8). Second, the contents of the charter – based on the UN Universal Declaration of Human Rights – are geared towards equality, justice, access, freedom of expression, data protection, etc., and are thus thematically close to the WBGU's compass dimensions of inclusion and dignity (Section 2.2).

'Asilomar AI Principles'

Cosmologist Max Tegmark's Future of Life Institute deals with existential risks for humankind, such as climate change or a possible nuclear war, which would endanger the survival of mankind should they go unchecked and become reality. Also relevant in this context are the Institute's 'Asilomar AI Principles', which regards AI as one such risk (Future of Life Institute, 2018). The signatories of this charter do not reject AI on principle, but emphasize that without the responsible development of AI, the consequences could be catastrophic. Against this background, they call for a number of principles to be observed in the development of AI, such as security, transparency, human values, freedoms and privacy, and ultimate human control, in addition to common-good-oriented AI research. The 'Asilomar AI Principles' have prominent supporters such as the late physicist Stephen Hawking and entrepreneur Elon Musk. The charter is meant as a draft that is constantly being revised.

'Geneva Declaration of Principles'

The 'Geneva Declaration of Principles' (WSIS, 2003), adopted as early as 2003 at the World Summit on the Information Society (WSIS), aims to harness the potential of digital ICT for the Millennium Development Goals (MDGs). The Geneva Declaration was supported by the UN and is a relatively early charter in multilateral cooperation. However, much criticism of the declaration came from civil society in particular, because its general understanding of ICT in development cooperation was not shared by the development community (Souter, 2008). The Geneva Declaration is historically relevant as a relatively early document, and some lessons on the importance of stakeholder involvement can be drawn from its negotiation process.

'Principles for Digital Development'

The 'Principles for Digital Development' charter (Bill and Melinda Gates Foundation et al., 2017) is a good example of a charter with a strong connection to the *active society*, as called for in the WBGU's 'Dynamics of the Digital Age' (Section 7.5). In development cooperation, digital instruments are to be developed in cooperation with their future users, geared to sustainability, scalability and security. The aim is to use digital technology effectively and inclusively for development cooperation. The 'Principles for Digital Development' charter is also a good example of the plurality of authors that characterizes many charters. In this case, these primarily include civil society and international organizations such as the Bill and Melinda Gates Foundation, UNICEF, UNDP, the World Bank and the World Health Organization, but also the national development agencies of Sweden and the USA.

3.6.4 Conclusions: Contours of a landscape of recommendations

Evaluating a selection of reports by international organizations and of charters on the subject of digitalization and sustainable development cannot, of course, provide a complete picture of the current 'landscape of recommendations'. Nevertheless, contours have become visible which show that there is extensive convergence both in the description of the challenges and in the temporal scope of the considerations. It has also become clear that digitalization is a policy field in which constitutive action by policy-makers often lags behind the rapid technological change processes and the sheer speed of digital change; indeed, many of the societal effects of digital change cannot yet be assessed in terms of how they will be manifested in practice. This also raises the question of how to shape political decision-making processes in uncertain and dynamically developing conditions.

Convergence in the description of key challenges

Many of the reviewed reports are characterized by convergences in how they describe the key challenges of digitalization (Section 3.6.2). All the reports evaluated emphasize the need to actively shape global digitalization, referring to key challenges such as overcoming the digital divide and developing digital infrastructures everywhere, developing digital skills and education, creating confidence in digital technologies, handling a world of work in flux and a changing international division of labour; they mention the role of digitalization in the implementation of the 2030 Agenda, the (international) regulation of digital applications, and the connection between digitalization, innovation, growth and prosperity. They also all identify the risks of digital change, above all data protection, data security, privacy, and distortions of competition.

Dominance of a relatively short-term perspective

With one exception, the time horizons of all the reports evaluated reach to 2030; their analyses are limited to the 'First Dynamic of the Digital Age' as identified by the WBGU (Section 7.2). The OECD report entitled 'The Next Production Revolution' occupies a special position and explicitly recommends a long-term perspective and the use of foresight processes in order to be better equipped to deal with any surprising twists or turns of digital change (OECD, 2017b). In this context, it assigns a key role to research, technology and innovation policies in ensuring the accessibility of SDGs (UNCTAD, 2018: 29).

Speed as a challenge

Several reports highlight the possibility that the speed of digital change might place excessive demands on decision-makers and institutions, and that this is a key challenge (UNCTAD, 2017; OECD, 2017b: 35; OECD, 2017c: 26): "Digital acceleration takes place against legacy time frames, slow institutional processes, entrenched behaviours and limited human attention" (OECD, 2017c: 26). Particular reference is made in this context to the unprecedented speed of the future restructuring of labour markets (OECD, 2017b: 35; World Bank, 2016: 118).

Digital change versus the Transformation towards Sustainability

Digital change is predominantly described as a global megatrend that needs to be responded to, managed in the sense of a positive economic development, promoted by expanding the infrastructure, and whose potential negative effects must be regulated (GSM, 2017; UNCTAD, 2017). In this type of report, the environment and development are little more than accompanying aims of policy-making. Successful digital change is seen as a prerequisite for inclusive and sustainable growth and prosperity (OECD, 2017a: 6, 11). Digital change is seen overall as simply an instrument: no attention is paid to its more far-reaching significance for the reorganization of societies and for shaping the future beyond 2030.

Accordingly, few attempts are made to draw attention to the implications that the potentially disruptive power of digital technologies will have on a post-2030 agenda and the global transformation towards a sustainable society. The same applies to the question of which digital development trends should absolutely be avoided to ensure that planetary guard rails are not violated and the application of digital technologies does not lead to rebound effects and more energy and resource consumption. The solution proposed by some reports of speeding up the spread of digital technologies without creating a suitable framework seems unconvincing in view of the risks to the environment, climate-change mitigation and social cohesion (The Earth Institute and Ericsson, 2016; World Bank, 2016).

Shaping the Digital Age using search methods

The evaluated reports also show that in many cases there are no conclusive answers to guide the necessary sustainable shaping of the Digital Age; this is because many of the effects of digitalization on the development of societies and the planet are still unknown. In this respect, some reports should better be read as instructions for designing search processes. The charters indicate the general direction these might initially take. In particular, reports that limit themselves to core messages or core topics, or recommend no-regret measures, face the challenge of acting in a framework of uncertainty (IEA, 2017a; UNCTAD, 2017a, 2018). On the other hand, concrete individual recommendations are given for individual topic areas, such as ICT and climate protection, development and participation (The Earth Institute and Ericsson, 2016). Several reports explicitly emphasize the limits placed on digitalization's potential by the economic and social realities of the analogue world (World Bank, 2016; UNCTAD, 2018).

Because of the existing uncertainties and regional and cultural differences, none of the reports gives general answers to the impending, far-reaching, socio-economic changes that will be brought about by digital change. In many cases, the challenge of disruptive developments is pointed out, but no differentiated solution is offered. So the bottom line is the insight that steering the Digital Age towards sustainability is in many respects a search process that requires adaptable and step-by-step policy-making, as well as a global understanding of the 'common digital future'. Accompanying research and foresight processes will have to play an important role with regard to early warnings and identifying major risks. This will need to be backed up by a robust international institutional structure that above all subjects the hitherto largely unregulated multinational digital economy to stronger democratic and regulatory control (Sections 8.1, 8.4).

Charter landscape

A number of drafts in the existing charter landscape are devoted to many of the critical sustainability issues which this report also confronts (Section 3.6.3). However, none of the charters has yet adopted a dedicated and comprehensive sustainability perspective. Furthermore, the background against which the charters were formulated must also be considered. The WBGU believes it is urgently necessary to merge global governance on climate and sustainability goals with digitalization; it has therefore formulated its own draft charter for a sustainable Digital Age in Box 9.3.1-1.

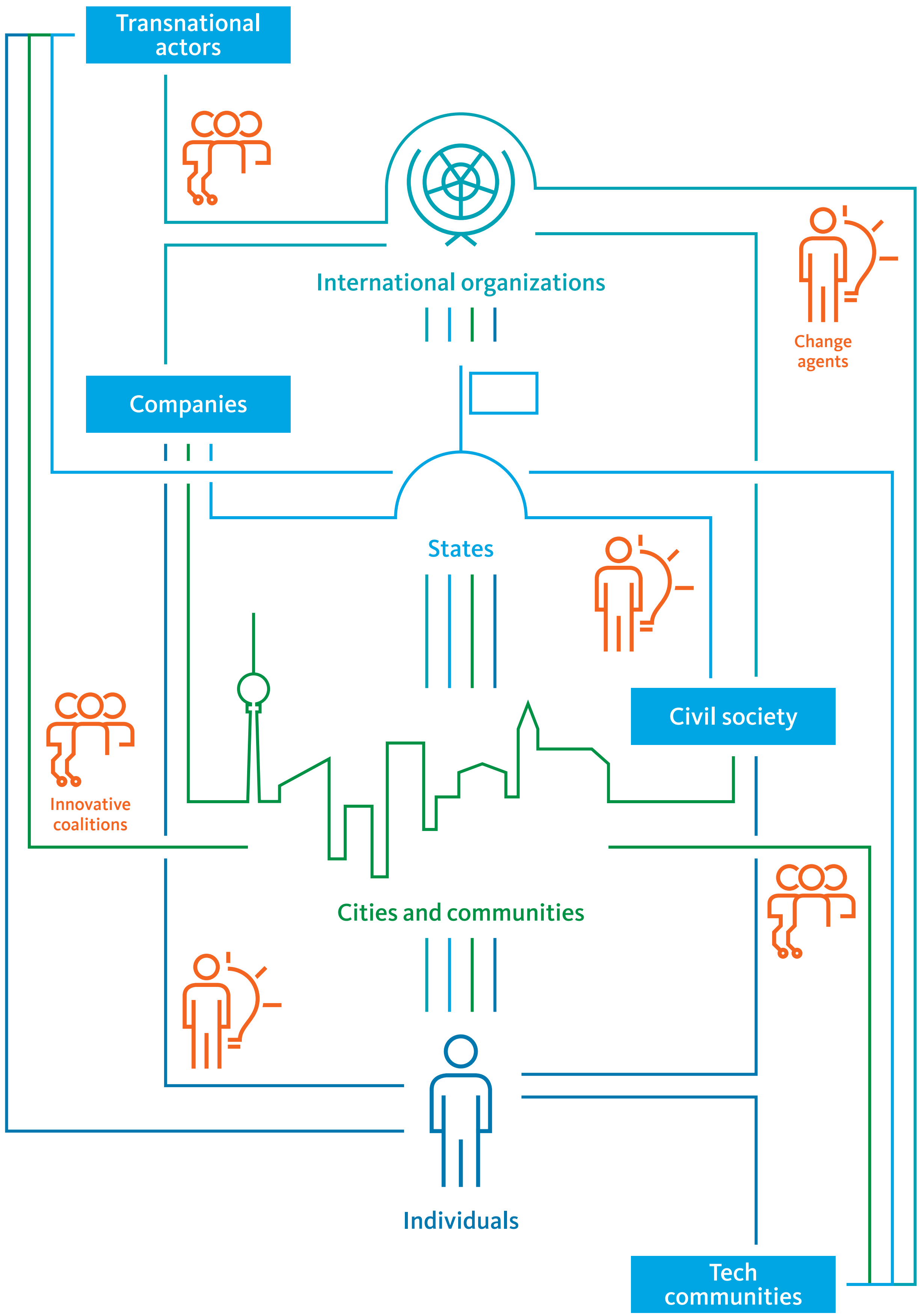
3.7 Conclusions

A new era of human civilization is emerging with advancing digitalization and the associated large-scale changes: the Digital Age (Section 3.1), which must be classified and shaped – also and especially in the context of climate and sustainability goals. This also becomes evident from the global reports and charters analysed (Section 3.6). The Digital Age is essentially marked by a digitalized technosphere (Sections 3.2, 3.3), which is characterized by more and more interconnectedness between technical systems and technically supported processes, further developed cognitive abilities of technical systems and their growing autonomy, the growing virtualization of spaces and technical services, and, as a result, by an enormous knowledge explosion, the digitally supported further development of all scientific disciplines (Section 3.4). There, for example, new opportunities for participation are emerging through citizen science (Section 3.3.5.1) and the emerging paradigm shift towards open science (Sections 5.3.10, 10.2.4.1).

In view of the rapid upheavals of the Digital Age, however, individual autonomy faces new challenges. For example, the appropriate design and use of digital technologies is more important than ever due to their enormous social penetration. In this context, a basic understanding of their basic functions (Section 3.2), including the limits of predictability and modelling, is essential. On the one hand, only on this basis can the potential benefits and risks of individual technologies be realistically reflected and discussed in an overall context (Section 3.3). On the other hand, it becomes clear which values have been, could be and should be written into technology. This question is currently being addressed mainly in the fields of AI and automated decision-making (Box 3.2.5-1). Ultimately, however, this is of key importance for the overall orientation of research and development (Chapter 10), especially when questioning repeatedly from a broad sustainability perspective "whether we have the technology we need, or whether we need the technology that we have" (Kornwachs, 2009:39).

With the effects of digitalization on all areas of life, key formative tasks are emerging (Section 3.5) in order to combine digital change with the necessary Great Transformation towards Sustainability, i.e. the development of welfare, security and democracy within the limits of the Earth system for a global population which will soon reach 10 billion. Even if the development of digital technologies progresses dynamically and cannot be evaluated conclusively, it is already apparent that the unguided further development and application of technologies oriented exclusively towards economic goals must be replaced by a technological change oriented towards climate and sustainability goals – and the societal change necessary for this.

In particular, the challenges of the Digital Age for the protection of fundamental and human rights should be highlighted. In the digital domain, the protected areas and opportunities to exercise these rights are changing (Chapter 4), so that new assurances and perhaps new frameworks are required (Chapter 8). Human dignity is – and will remain – the focal, unchangeable point of reference in this context. In this report, its inviolability and the resulting respect and right to protection constitute explicit orientation for the sustainable shaping of digitalization. Closely linked to this is the need to ensure that the digital revolution is oriented towards the common good and embedded in a strategy of sustainable development. This requires suitable frameworks and demarcations (Chapter 9). Unless actively shaped, global digital change involves the risk of further accelerating the threat to humankind's natural life-support systems.



Transnational actors
International organizations
Change agents
Companies
States
Civil society
Innovative coalitions
Cities and communities
Individuals
Tech communities

Actor Constellations in the Digital Transformation

4

The question arises as to who will shape the Digital Age: are the scopes of action available to individual groups of actors shifting? In addition to individuals, business and civil society, the WBGU focuses on tech communities. The WBGU identifies significant power shifts in the multi-level system of cities and municipalities, states, international organizations and transnational actor groups. In some cases, they lead to blockades and path dependencies, but they also open up new potential for sustainability transformations.

Digitalization processes are not a force of nature; they are driven by different actors and their different, sometimes conflicting interests. The key questions are therefore not only how digitalization has an impact (Chapters 3, 5) and could have an impact (Chapter 6), but how these processes can be shaped. The main issue for the WBGU is to gear the technological-digital revolution towards a successful Transformation towards Sustainability (Chapter 3). This chapter examines the challenges facing the shaping of transformative change (Section 4.1), the functions performed by the actors of digital change, how important they are for this transformative change (Section 4.2), and what opportunities they could currently seize for a Transformation towards Sustainability (Section 4.3).

4.1 Transformative change as a formative task

As early as 2011, the WBGU looked into the preconditions and strategies that would enable a societal reorganization towards sustainability (WBGU, 2011). Today, the 2030 Agenda offers 17 internationally agreed and differentiated Sustainable Development Goals (SDGs) with indicators that are continuously being further developed (UNGA, 2015; Box 2.1-1). The implementation of these goals and strategies is a political project aiming on the one hand to overcome the forces of inertia behind unsustainable developments and trends, and on the other to enable and explicitly support new developments and trends towards sustainability. Corresponding strategy developments are being driven forward at the global, national and local levels, with an international review process reflecting both successes and implementation difficulties.

The terms 'transformation', 'transforming' and 'transformative' can be found throughout the 2030 Agenda. Transformation comprises not only the results to be achieved (e.g. a reduction in CO_2 emissions), but also the fundamental (re-)configuration of processes and organizational patterns with which results are achieved (e.g. progression from a largely centralized supply of fossil-based energy to a flexible, decentralized supply of renewable energy). Such transformations include economic, socio-cultural, political, technological and ecological aspects and are described and analysed in terms of their dynamic and complex interaction (Tanner and Bahadur, 2013). As processes, they cannot therefore be precisely planned or predicted. Nevertheless, it is analytically possible to distinguish between the conditions resulting in relatively slow adaptive societal change and the conditions of transformative change, thus anticipating or supporting the latter (O'Brien and Sygna, 2013:16).

In this context, the term *path dependencies* aims to describe the overall economic, socio-cultural, political, technological and ecological components of current societal configurations when they act as forces of inertia. Specifically, path dependencies will vary from country to country and from village to village. Examples include established societal and political institutions, market structures and actors, physical infrastructures, knowledge resources, and cultural and normative influences (WBGU, 2011:394f.). Understood as structures of a society, they have been created for certain goals and tasks in the context of certain circumstances. At the same time, they form the environment and reality of the actors who are socialized within them and make decisions about future developments. The term 'path dependencies' thus illustrates the fact that societal developments are triggered and driven in a certain direction (Avelino et al., 2018 ; Göpel, 2016: 4ff.).

Transformations are likely to occur when multiple path dependencies are simultaneously affected by changes. Corresponding 'concurrences of multiple changes' (Osterhammel, 2009) indicate tipping points or windows of opportunity for breaking path dependencies, thus making the reconfiguration of societal (sub)systems possible or even unavoidable. The following list contains examples of key areas of societal change from the energy sector.

- *New knowledge and new values* change the assessment both of the current situation and of the scope of opportunities for imaginable futures; deviating solutions become conceivable and convincing, e.g. through computer simulations of climate change.
- *Regulatory measures* change conditions for individual business models, civil-society practice and technological developments, e.g. state subsidies for feeding renewable energy into the electricity grid.
- *Economic processes* become critical as a result of changes in context conditions, stimulating a search for alternative products or business models; e.g. pressure is put on energy companies whose business models are based on the use of fossil fuels by shifts in investment activities and subsidy programmes for renewable energy and a possible pricing of CO_2 or fossil fuels.
- *Civil-society projects* focus on alternative values, narratives and solutions, so that new forms of cooperation emerge, e.g. the anti-nuclear movement or citizen-energy cooperatives for renewable energy in Germany.
- *New technologies* enable alternative products and production processes, new knowledge generation, communication and networking, e.g. photovoltaics or fuel cells (sector coupling) and smart grids that combine different renewable energy sources.

This list should not be understood hierarchically or sequentially; rather, it shows variants of the breaking up and destabilization of existing path dependencies in the energy sector that can lead to mutually reinforcing interactions. In the context of the sustainability transformation, for example, questioning the status quo with new knowledge is highly relevant, since measurement data and computer simulations make it possible to understand and predict the consequences of ecosystem overuse. In the case of digitalization, by contrast, it is the rapid technological development that enables new forms of production, consumption and communication and a multitude of new business models. Seen from a dynamic angle, a transformative breakthrough is accelerated when actors from different fields come to similar visions, goals and narratives through consensus in the areas of knowledge, values and interests. Technologies, investments and production patterns, laws and incentives also become realigned, and public opinion and consumer decisions change accordingly (Figure 4.1-1). The more conscious and coordinated these many different incremental steps are, the more radical or transformative the expected change will be.

Transformative governance through new actor constellations

In the process of overcoming forces of inertia, actor-centred approaches to transformation research attribute a central function to *pioneers of change* (WBGU, 2011). From their different innovation niches, they open up perspectives and pathways for new thinking and actions, which can successively have a broad effect at the regime level (points marked in light blue in Figure 4.1-1). From this perspective, organizations and institutions do not appear as monolithic units, but as groups of people with (to some extent) conflicting ideas, convictions and reservoirs of creative power (Köhler et al., 2019). Pioneers are those among them who explicitly deviate from the respective status quo, i.e. want to interrupt or break path dependencies. The direction in which they deviate is irrelevant at first. Normative assessments as to whether the deviations are positive or negative depend on the respective situation and prevailing knowledge, value systems, world views and societal objectives. From this strictly analytical perspective, both sustainability protagonists and digital disruptors, even right-wing populists, are considered pioneers – albeit in completely different directions in terms of their concrete target perspective and normative profile. Initiating systemic change from different innovation niches was and is highly relevant for the sustainability transformation in order to open up pathways for new thinking and action and have a broad impact successively in different areas of society (Figure 4.1-2).

To further consolidate these stimuli, *coalitions of change* are of great importance. In the implementation of specific changes, they mobilize creative power as coalitions of actors across organizational boundaries

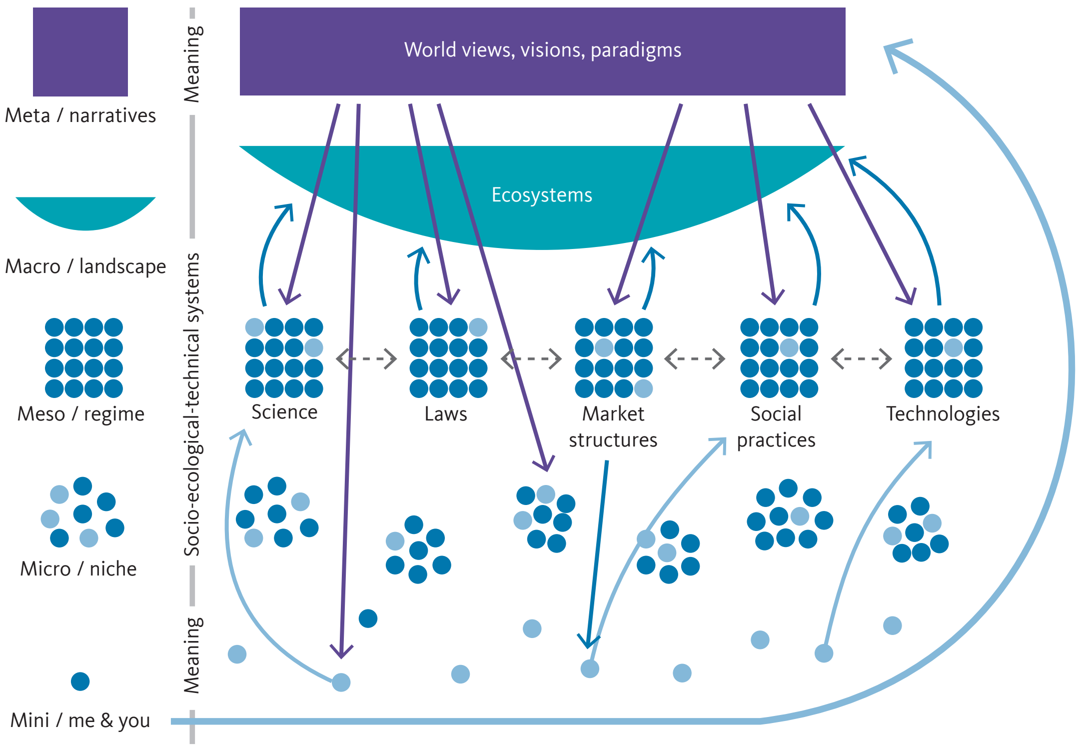


Figure 4.1-1
Multi-level perspective on transformation processes. Individuals (mini level), who make up every institutional structure, are the starting point for change. They provide ideas and action stimuli for changes at all levels. The micro or niche level is the most innovation-friendly level where smaller units can try out new ways, as long as the overall system creates space for pioneering activities. The meso or regime level consists of grown structures and subsystems that change more slowly and tend to stabilize the status quo. The macro or landscape level delineates the background for the developments at lower-lying levels and encompasses comparatively long-term development paths, such as environmental conditions, fundamental infrastructural or market conditions. At the meta level there are world views, visions and paradigms that mediate between the different levels. The violet arrows symbolize the predominant, the light-blue arrows new ideas and action stimuli which penetrate from the individual level into the subsystems of the micro and macro levels. These world views, visions and paradigms form a kind of link between the different units of the overall system.
Source: Göpel, 2016, modified

and sectors, e.g. resources from the private sector, authority from the legislative apparatus and legitimacy from public opinion (Then and Kehl, 2012). Promising actor coalitions often go against typical divisions such as the state versus companies or bottom-up niche activities versus top-down regulation. The interaction with veto players and corresponding coalitions also matters. Subsequently, central support processes also include changes in regulation and market structures. Overarching visions and new narratives frame and motivate transformation processes from the outset to a possible stabilization.

As early as 2011, the WBGU stressed the role of the proactive state *(authority)* in sustainability transformation, which at least initially protects pioneering initiatives competing with established market players and sets the main structural course (e.g. energy system transformation). Also, the reduction of structural advantages and subsidies for non-sustainable actors not only improves the competitive position of established, resource- and energy-efficient companies, but also of the pioneers of change, thus promoting the redistribution of *resources*. As long as, for example, there is a financial competitive advantage in largely or completely ignoring environmental and social costs, sustainability pioneers will have a systematic disadvantage and thus little chance of escaping the niche of environmentally conscious customers with purchasing power. Adjustments to the regulatory framework should therefore promote the systematic integration of all environmental and social costs into corporate and individual decisions. In order to ensure the *legitimacy* and acceptance of the necessary legal changes, this structural reorientation should be normatively supported by the inclusion of all societal groups, e.g. through a new societal contract (WBGU, 2011). The importance of societal movements and the general public as sources of legitimacy and drivers of change is

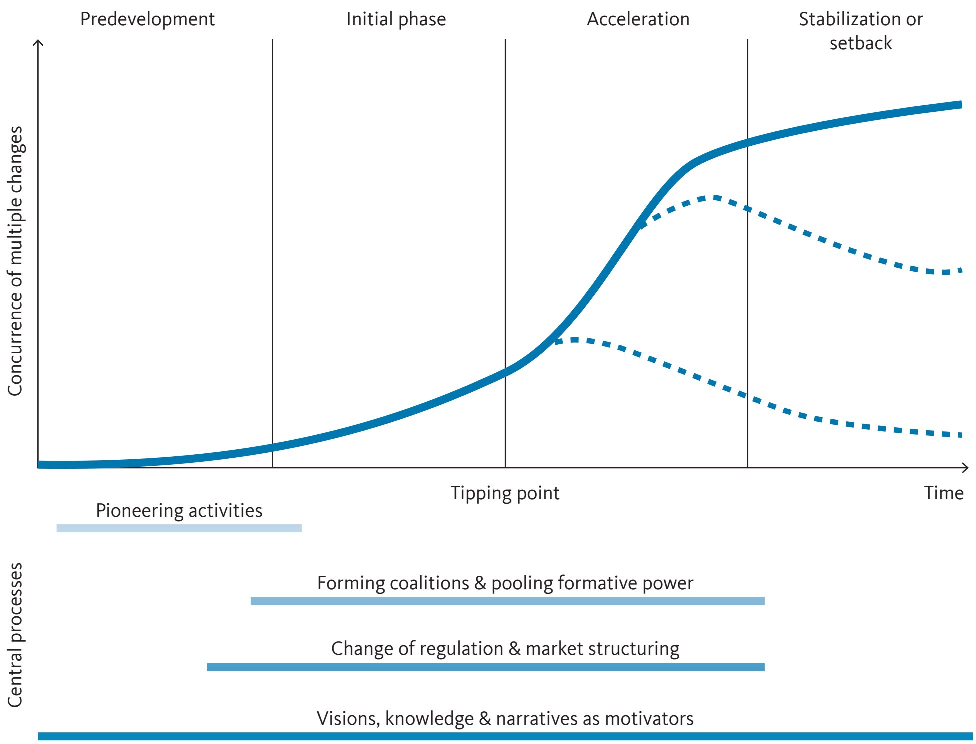


Figure 4.1-2
Phases and core processes of transformative change. Transformation processes can typically be represented by an S curve that illustrates different processes and phases of transformation. In the pre-development phase, societal development moves within the path dependencies. These are rarely challenged. Important processes here are pioneering activities and the emergence of new visions, new knowledge and new narratives. In the initial phase, the overall system picks up on new ideas and concepts. There is no common understanding of routes to a solution or to development pathways; strong resistance against the new solution routes is possible from established forces. Once a certain tipping point has been reached, the transformation enters the acceleration phase: new solutions are recognized and penetrate into the mainstream. At the same time, a strong counter-movement can occur during this phase, initiated by those who may suffer disadvantages as a result of the transformation. In the final phase of the transformation, it becomes apparent whether (a) a new system will become established as a result of the transformation (stabilization), (b) the only change will be innovations becoming embedded in the old system, or (c) the transformation will fail completely (setback). Overall societal/political formative measures and coalitions of change are necessary to facilitate pioneering activities in the pre-development phase and particularly during the initial and acceleration phases.
Source: Göpel, 2016, modified

currently being demonstrated by the many ‘For Future’ movements in Germany and worldwide.

To give global transformative processes normative orientation, the WBGU has further developed its actor-centred perspective on pioneers of change into a polycentric governance approach (‘polycentric responsibility architecture’) that goes beyond vertically conceived multi-level approaches (WBGU, 2016a: 384ff.). For successful sustainable urban development, the WBGU’s flagship report on urbanization (WBGU, 2016a) proposed that not only should as many urban actors as possible be given more participation and responsibility for the sustainable transformation, but that cities and their networks should also be incorporated into governance processes for sustainable development at the national and international level. With the help of this polycentric concept, pioneers and coalitions for sustainability can then be identified across different levels and in all societal groups, which – in a more or less coordinated manner – drive different innovations and interventions forward and thus encourage a ‘concurrence of multiple changes’ towards transformative change.

4.2 Actors in the Digital Age between power and impotence

In the following, the creative power of actors in the Digital Age will be analysed in relation to the transformation perspective introduced in Section 4.1 and to the process of overcoming path dependencies. In the interplay between an analysis of digital change (Chapter 3) and sustainability challenges (Section 4.1), the aim is to identify on the one hand unsustainable concentrations of power and, on the other, coalitions of actors and windows of opportunity that are already focusing the possibilities of digital change on common-good-oriented objectives – such as the SDGs. The following outlines show that digital change can lead to a concentration of power on a previously unimaginable scale, through which many innovation niches with state-like authority (e.g. based on control over new infrastructures), financial resources (e.g. resulting from the economic potential of global network effects), and ostensible legitimacy (e.g. through increasingly important decision-making processes such as multi-stakeholder processes) can be influenced in parallel.

This section shows how the scope for formative action is changing in favour or to the detriment of individual actor groups with a view to sustainable and digital transformation (Figure 4.2-1). After looking at individuals (Section 4.2.1), companies (Section 4.2.2), civil society and science (Section 4.2.3), the WBGU looks at the tech communities (Section 4.2.4) to analyse the role played by this new group of actors in the Digital Age. In addition, the WBGU analyses constellations of actors that can be more closely assigned to the sovereign sphere like cities and municipalities (Section 4.2.5), states (Section 4.2.6) and international organizations (Section 4.2.8), and finally the transnational groups of actors that act independently of (and between) them (Section 4.2.7).

4.2.1 The ability to act and the formative capacity of individuals in the Digital Age

In the Digital Age, the conditions for individual autonomy and self-determination, as well as for individuals' scope for action, are changing with the use of digital solutions (Section 3.5.4). For the WBGU, the questions that arise are where, how and by what means the autonomy and self-determination of individual actors are strengthened or weakened by digitalization processes. Individuals take on different roles within society: as citizens, they participate 'offline' and 'online' in the community and in political opinion-forming and decision-making processes; in economic life they participate as consumers. In the context of digitalization, individuals become users of public or private digital and digitalized services and consumer goods and can act in economic life on the supply and demand sides simultaneously as prosumers of digital or digitally mediated goods.

4.2.1.1 Loss of sovereignty and violations of privacy as risks for users

The consumption and use of digital technology involves a wide variety of risks for individuals – ranging from loss of sovereignty in consumer decisions to unwanted disclosures of personal data that can lead to privacy violations. An individual's *digital sovereignty* is threatened if consumers are restricted in their self-determination, e.g. freedom of choice (the freedom to do or refrain from doing something), or if this freedom is completely abolished – if they become the object of automated decisions (SVRV, 2017). In individuals' digital spheres of action, the world views of powerful actors, e.g. digital corporations, can exert influence and become dominant (Lenk, 2016, 2017: 28; Section 4.2.4). These spheres of action include social networks, search engines and online marketplaces whose design and configurations exert an influence over which data are transmitted, which consumption options are displayed, and how interactions with others take place. The reasons behind concrete decisions cannot usually be traced or monitored, and this results in asymmetry vis-à-vis a small number of private companies and, in some cases, states (Leopoldina, 2018: 40; Section 5.3.3). The decentralized situation of individuals in this context also means a lower degree of organization compared to the well-organized platform operators, who also have a knowledge and information advantage.

The digital disclosure of personal information exposes users to the risk of *privacy violation* (Sections 2.2.3.1, 3.5.3; Leopoldina, 2018). Meta and content data of individuals can be merged using big-data applications (Sections 3.3.2, 3.3.3) in ways that allow intimate insights into an individual's personal life. This significantly changes the position of individuals vis-à-vis those (e.g. governments and business enterprises) that have control over these data (Baumann, 2015: 12). Misuse and the unwanted publication of personal data, e.g. in social media, can have direct negative social and/or financial consequences (e.g. bullying or theft). A further risk for users is that they can be accused of being the ones at fault, e.g. for lack of media literacy. Such accusations can be associated with shame and deflect responsibility from providers (e.g. social platforms) to users.

Categories in which privacy is regulated offline, e.g. protection of the fundamental rights of the home, do not yet function in the use of digital media – e.g. because the necessary security mechanisms have not yet been comprehensively provided or are not legally required, or because they are too complex to use, or users do not understand why they are necessary.

On the other hand, there is also potential for a Trans-

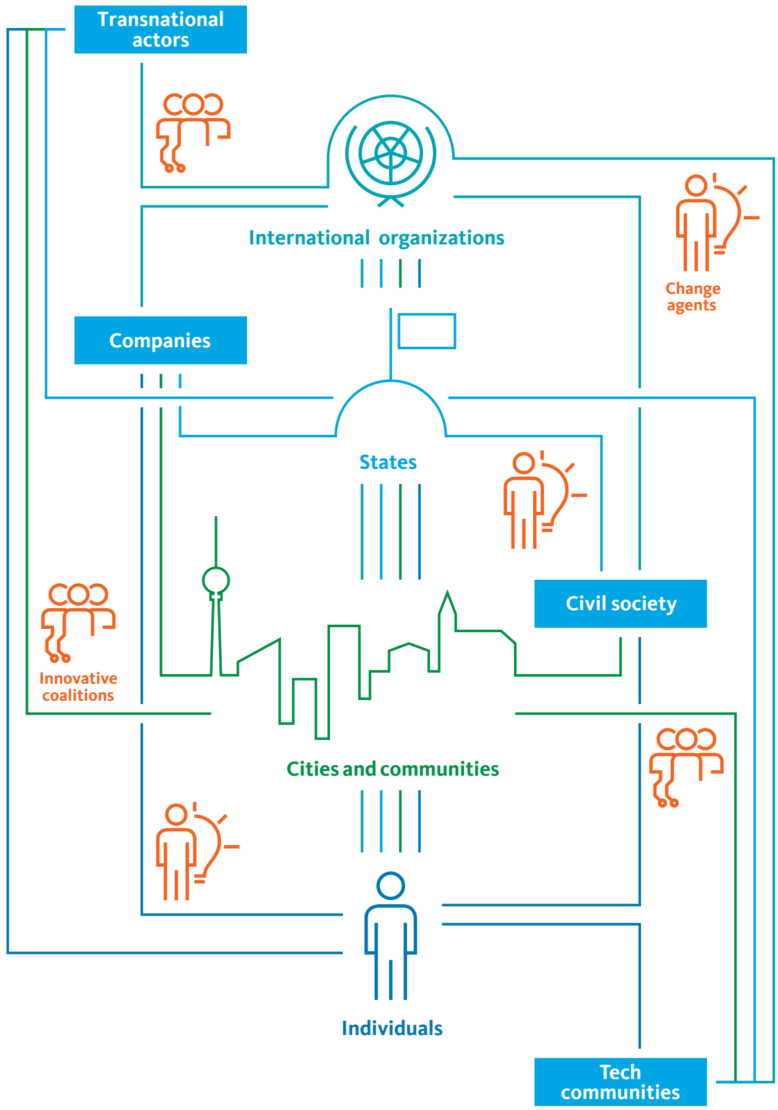


Figure 4.2-1
Key actor groups in the Digital Age. The middle vertical axis comprises the *individuals* and the classic state governance levels, ranging from *municipalities* to *states* to *international organizations*; *civil society* and *companies* are also included, as are the *tech communities* and *transnational actors* that transcend the classic attributions to political levels. Pioneers of change can appear anywhere, and innovative alliances can emerge.
Source: WBGU

formation towards Sustainability in networking with other individuals (Section 4.2.1.2). Individuals can appear online as important actors for change and, for example, mobilize support for sustainability projects in social media. The topic of privacy and promoting its potential for identity, self-determination and creativity, must therefore be discussed in a new and broad way in society (Trepte, 2016a).

4.2.1.2
Users and prosumers as creative enablers of change

Individuals are important for the necessary transformation processes (Section 4.1), especially as pioneers and artists. A digital space enables individuals as well as groups to develop *Eigenart* (Section 2.2.3) by providing them with a stage enabling them to influence society, for example via social media. As prosumers, individuals can generate online content themselves, or (co-)design and mediate goods and offers. Thus, anyone can publish content independently and have a significant impact as a blogger or influencer, or, as a home owner, install solar cells on the roof and feed excess energy into the electricity grid. The room for manoeuvre of these change-makers is considerably strengthened by the fact that they have a variety of online resources at their disposal and can share them with one another, for example through the simple provision of instructions and content or the possibility of being financed by an online group of supporters (crowd funding).

4.2.1.3
Citizens as digitally supported actors of change

The classic way in which citizens can influence politics in democracies like Germany is through elections and voting (Article 20(2) of the Basic Law). Furthermore, the state and its administration involve citizens, businesses and civil society in decision-making processes through other participatory procedures. Digital participation instruments open up new, additional possibilities for supporting both simple (e.g. online consultations, surveys) and complex processes of democratic participation initiated by the state. Inclusive and barrier-free ICT-based forms of citizen participation, e.g. implemented by professional mediators, a representative selection of participants, and support in dealing with digital technology, enable the state and the administration to identify needs, interests and concerns and to incorporate them into decisions. By actively inviting individuals to influence ongoing decision-making processes, governments and administrations provide themselves with a more complete information base for their decisions and make a form of public hearing possible that can potentially lead to the positive experience that a person's individual contributions are valued and valuable. This can help people accept state decisions.

At the same time, such digital participation formats give the individuals involved access to information, as well as an opportunity to evaluate and monitor state decisions. As niche actors, citizens can also monitor the execution of state decisions. In this way, individuals can communicate grievances more easily – if necessary anonymously – and help to collect data (civil science, Section 5.3.10) and provide information. They can also join interest groups and organize themselves.

Collective self-efficacy, i.e. the efficacy of individuals in a community (van Zomeren et al., 2010), can help encourage individuals to embrace these possibilities. It can develop when many actors network and mutually support each other in this way (e.g. collective action; Bamberg et al., 2015). The digital possibilities can lead to citizens not only being actively involved in shaping the Transformation towards Sustainability, but also in being able to drive it forward themselves, especially through extended participation opportunities.

4.2.1.4
The risk of discrimination if citizens are excluded from digital technology

In terms of the role of participating citizens, there is a risk of discrimination through the exclusion of people who do not use digital technology. Social groups and milieus that do not have the knowledge or skills to use digital technology, or have no access to digital services, are at risk of being marginalized to the extent of being refused inclusion. In order to also benefit from the potential of digitalization in the field of inclusion, measures should be taken to ensure that broad participation is achieved and that discrimination against certain people is excluded. Digital forms of participation (e-participation, liquid democracy, e-petitions, participatory budgeting) also require resources such as reliable and trustworthy digital services (Section 5.3.5) and know-how (Section 5.3.4). Not only a lack of digital skills, but also a limited availability of hardware and software can lead to a massive societal divide between poor and rich if only the wealthy can afford them. There is a further aspect of digital discrimination in the global context: the risk of a digital divide is particularly high in developing countries, as can be seen, for example, in the lack of access to appropriate ICT and education in some African countries (Section 5.3.8).

Guaranteeing professional process control, e.g. by independent mediators (Horelli, 2002), the early involvement of the participants, transparent rules, and avoiding the exclusion of groups (the public) are success factors for digital participation (that are transferable from the non-digital field). Individuals must be given help to prepare them to make sovereign decisions in everyday situations (e.g. in digitalized consumption, Section 5.2.3) and in transformation processes (e.g. in the areas of work of the future, Section 5.3.9 or the mobility turnaround, Section 5.2.8).

4.2.1.5
Interim conclusion

In order to be successful, the Transformation towards Sustainability must be supported and accepted by individuals (WBGU, 2011:67). Digital change opens up new opportunities for individuals to participate – not only in the sense of being involved, but also in terms of information, monitoring (in the sense of traceability) and initiative. As pioneers of change, individuals can take advantage of these new opportunities and actively shape the Transformation towards Sustainability, for example through online involvement. At the same time, however, digitalization risks losing acceptance if individuals are instrumentalized and become mere objects for decision-makers over whom they have no influence. Privacy protection and the preservation of individual decision-making sovereignty are indispensable prerequisites for human participation and pioneering activities.

4.2.2
Enterprises between market concentration and competition

Interaction between companies, between companies and consumers in markets, and between companies and states can develop a high dynamic of change. The dynamics and broad impact of digitalization itself illustrate this all too clearly (Section 3.1). The application of digital technologies is no longer limited to businesses in the technology or ICT sector, but increasingly encompasses businesses in all sectors of the economy (OECD, 2019c). For example, new market structures, new business models and new behaviour patterns are becoming established. From the perspective of sustainability transformation, this change dynamic represents both an opportunity and a challenge (WBGU, 2011).

4.2.2.1
Enterprises as actors in digital change: market disruptions

The disruptive potential of digital technologies is initially based on their mostly rapid scalability using economies of scale and network effects (Box 4.2.2-1; Brynjolfsson and McAfee, 2014). Another decisive factor is the high economic potential that lies in the considerable increase in information gained from comprehensive data collection and evaluation, as well as by improved networking of actors and markets. The use of this potential is already seen today as one, if not the decisive competitive factor (Mayer-Schönberger and Ramge, 2017; Goldfarb et al., 2019; Wambach and Müller, 2018; OECD, 2019c; Niebel et al., 2019). It also offers external actors specializing in the economic use of information and networking routes into existing industries and market segments, especially if they recognize the potential at an earlier stage. By linking information from other markets, they can create added value and perhaps make more creative decisions as a result. This is often not possible for incumbent companies in a certain market segment (Schweitzer et al., 2018; Farboodi et al., 2019).

With the help of new networks, information acquisition and new digital technologies, internal corporate processes can also be redesigned. This applies to production and distribution as well as to company decision-making processes. For example, production processes and logistics can be better coordinated. Complex manufacturing processes, e.g. using new production processes such as additive manufacturing, can also be automated and production tailored more individually to customer requirements (WEF, 2017c; WTO, 2018; Section 5.2.1). 3D printing, for example, engenders much more decentralized and individualized production processes and can blur the boundaries between consumers and producers (Sections 3.3.5.4, 5.2.1, 5.2.2). It is a challenge, particularly for established companies, that networking and information gains affect the companies' own organizations, i.e. the way in which business decisions are made and implemented, even if it is not yet clear to date in which direction (Bloom et al., 2014; Brynjolfsson and McElheran, 2016). They facilitate inner-company coordination and thus permit flatter hierarchies and market-like organizational forms with more agile units with more decision-making responsibility. Especially when combined with the use of technical systems that assist decision making or make decisions autonomously, they can work towards a greater centralization of corporate management (Mayer-Schönberger and Ramge, 2017).

But it is not only the internal use of information and networking to optimize internal company workflows and production processes that will be decisive in competition. Rather, it will be of greater importance in almost all industries to create added value and, building on this, new successful business models by collecting and linking information or networking actors. This is reflected particularly clearly in the success of platforms and the data-based business models that underlie them (Levin, 2013; Einav et al., 2016; Schweitzer et al., 2018). With the help of appropriate information systems, platforms bring together suppliers and consumers in a wide variety of life situations and economy sectors faster, more exactly and almost without geographical restrictions compared to 'analogue marketplaces'. Information deficits and, in general, the effort required for search and information processes can be substantially reduced for the users in this way (Goldfarb et al., 2019). The success of platforms can also be explained by the fact that, for example, rating options by users or fundamental guarantees from operators build trust and thus often remove prohibitively large obstacles in the interaction of completely anonymous actors in the analogue world (Mayer-Schönberger and Ramge, 2017; Peitz and Schwalbe, 2016; OECD, 2019c). As market intermediaries, on the other hand, platform operators obtain particularly detailed information on the relationships and profiles of users who are active on their platforms.

Operators often use this particular wealth and depth of information according to data-based business models (Kretschmer et al., 2018): the digital services and access to the platform itself appear to be made available to the users free of charge. However, these offers are financed by the site's further use of the data generated by the use of the platform and services, e.g. for advertising or to develop more pay-services in other markets. The (ostensibly) free access to the platform and the digital services boosts their dissemination. However, such offers below production costs, and 'cross-subsidization' by other customer groups of the operating company, are generally typical of such bilateral or multilateral markets (Rochet and Tirole, 2003; Rysman, 2009; Box 4.2.2-1).

Platform-based business models have contributed to the rapid spread and establishment of search engines,

Box 4.2.2-1

Economies of scale and network effects

The rapid scalability of digital services, often referred to as positive economies of scale, derives from the cost structure of intangible, digital and digitalized goods and services: investment costs are usually offset by low to negligible costs of reproducing or expanding the product range (Levin, 2013). In most cases, purely digital or digitalized goods and services can be scaled up very quickly, i.e. unless there are restrictions on hardware and infrastructure requirements. At the same time, the increasing size of a supplier results in considerable potential for reducing the costs of producing a single unit of a good or service. In the field of classic network industries like the energy grid or rail network, these advantages have the effect that only a private provider prevails in the longer term. Natural monopolies (Wambach and Müller, 2018) develop.

Economies of scale also play a role in data-based business models, i.e. the widespread barter transactions where services are exchanged for data. More comprehensive data sets promise additional information gains. However, saturation effects can also occur with data, so that the increase in value and information from additional data as data volumes rise is (greatly) reduced once a certain minimum volume is exceeded (Varian, 2018). On the other hand, the diversity of the data collected on an actor or an area is of great importance, since additional knowledge can be gained from linking them (economies of scope; Duch-Brown et al., 2017). Correspondingly big incentives exist for companies to cover different areas of the economy and/or life with their digital and digitalized offers and to combine different offers (Dewenter and Lüth, 2018; Bourreau et al., 2017:33).

When it comes to network effects, a fundamental distinction must be made between direct and indirect network effects (Haucap and Heimeshoff, 2014). Ultimately, network effects again form the basis of economies of scale that can favour large actors over small ones and established actors over new ones. Direct network effects describe the rising value of a good or service as the number of users (on the same side of the market) increases. For example, a service for composing and sending messages becomes more attractive the more users are able to receive them. Indirect network effects, on the other hand, describe increases in value for individual users resulting from growth on the other side of the market. Indirect network effects are characterized by so-called bilateral markets, i.e. markets where one supplier or intermediary serves two or more different – but interdependent – groups of players (Rysman, 2009; Schweitzer et al., 2018). Concrete examples in connection with digitalization include in particular digital platforms, the success of which is linked to the effects of indirect network effects: the attractiveness of sales platforms, for example, increases for suppliers as more and more people make purchases on the platform and vice versa.

messenger services and map services as natural companions of many people's everyday lives. One example of the disruptive effect of platforms and new digital business models is the radical changes in the media and music industry and in retailing that were associated with the rise of streaming services and e-commerce or online marketplaces following the market entry of companies like Apple or Amazon (Waldfogel, 2017; Gilbert, 2015; WTO, 2018). As a result of data-based services and platforms, similar radical changes in business models are expected – or already partly visible today – in many other industries. Data-based services such as special maintenance services are becoming increasingly important, e.g. as a competitive factor for the sale of plant and machinery, and extend traditional supplier-customer relationships beyond mere sales (WEF, 2017c). The spread and acceptance of sharing the use of such durable goods as vehicles (sharing economy) is also essentially based on the coordination of different users and on building a reputation via ratings on platforms (Peitz and Schwalbe, 2016; Horton and Zeckhauser, 2016; Einav et al., 2016). In this context, the users' focus is shifting away from buying goods towards the services that are available with the help of these goods: in the transport sector, for example, mobility is becoming more important than owning a vehicle. This has serious consequences for the business models of vehicle manufacturers, who e.g. must develop into mobility providers if they want to avoid missing out on part of the economic potential of the future mobility market (Section 5.2.8). Similar disruptive changes caused by platforms and digital and digitalized services are also emerging in the banking, insurance and energy sectors (Mayer-Schönberger and Ramge, 2017; OECD, 2018a; Doleski, 2017; Box 5.2-1; Section 5.2.6).

4.2.2.2
Companies as digital pioneers of sustainable change?

The decisive question when bringing digital change and sustainability transformation together is the direction in which the above-described disruptive potential of digitalization will affect the economic level in general and businesses in particular. Will breaking up market structures and business models lead to a change towards sustainability, or will the new business models, too, not follow sustainable development paths? The answer is at least ambivalent.

There is no doubt that the described changes at the economic level offer great potential for more sustainable development paths. The reorganization of inner-company workflows and transport routes and the automation of production processes offer potential for considerably increasing the resource efficiency of production (UNCTAD, 2018). Together with the greater transparency of production processes and materials, there are also far-reaching possibilities for closing material cycles (WEF, 2019; Section 5.2.1). The same applies to approaches based on the sharing economy, which in principle can reduce resource requirements by intensifying the utilization of goods (Sections 5.2.2, 5.2.3). New opportunities for the shared use of capital-intensive assets, such as servers in cloud computing, also facilitate access to new markets and technologies for businesses in developing countries (World Bank, 2016).

Sustainability pioneers on the corporate side can also benefit from the general increase in market transparency. Diversity and availability of information, as well as direct interactions with interested parties even over long distances, allow a greater differentiation of goods and services – also along sustainability criteria. Since the scope and visibility of such offerings also increases, groups with special interests or preferences in sustainable development can be targeted, for example through more extensive sustainability reporting or certification. At the same time, the increasing availability and diversity of information can in principle help make private actors more aware of the sustainability impacts of their actions and enable them to make better informed decisions in this respect (Section 5.2.3). Decision-assisting technical systems can prevent actors being overtaxed by the diversity of digital information (Mayer-Schönberger and Ramge, 2017; Stiglitz, 2017b).

From the point of view of sustainability, there is thus every hope that the compatibility of entrepreneurial action with sustainability goals will increasingly develop from a niche into a competitive criterion. However, all these positive aspects must not hide the fact that the basic objectives of entrepreneurial activity are not changed by digitalization. Businesses in the digital economy also primarily follow business interests and develop goods and services with the aim of serving the interests of consumers or arousing their needs, ultimately generating income and profits. The new actor constellations on markets and platforms, or the organizational changes at company level, are no guarantee that more account will be taken of sustainability goals in decisions than has been the case up to now. Reflecting resource use in the prices for goods and services can support the necessary change (Section 5.2.2).

Decisions on the automation or re-shoring of production processes, i.e. the relocation of production stages back to industrialized countries, ultimately follow long-known rationalization strategies, without companies always taking the overall societal value of gainful employment or development-policy dimensions fully into account (Sections 5.3.8, 5.3.9). The same applies to more resource-efficient, digitally supported manufacturing processes (Section 5.2.1), the deployment of which depends on the business's profit prospects: for example whether they offer cost advantages or serve certain demand groups that have a corresponding willingness to pay. Not least, the current success of some asset-sharing platforms and approaches is also based on the fact that existing, cost-driving regulations, particularly in the form of labour or safety standards, do not adequately cover these business concepts. This can be seen, for example, in the different conditions imposed on digitally mediated driving services compared to taxis, or on privately rented apartments compared to hotels (Eichhorst and Spermann, 2016; Peitz and Schwalbe, 2016).

According to current knowledge, it is completely open how autonomously acting or assisting decision-making systems will affect the way sustainability goals are taken into account in corporate decisions. The use of self-learning systems in entrepreneurial decision-making can lead to a perpetuation of known behaviour patterns, as they draw conclusions from past data (Mayer-Schönberger and Ramge, 2017). However, some of these systems reveal completely new interrelationships that are not discernible to humans and could, in principle, also serve to reconcile economic interests with sustainability goals. The reorganization of businesses offers more concrete opportunities, especially with regard to the development dimensions of inclusion and *Eigenart*. Flatter hierarchies and re-organization into independent, more responsible groups can promote employees' creativity and sense of self-efficacy (Mayer-Schönberger and Ramge, 2017). As the networking and coordination of process steps become easier, spaces are also created for further-reaching, alternative corporate forms based on collaboration and interaction between users or consumers, or in the form of a revitalization of cooperative corporate forms, which can also strengthen the economic participation of employees (Peitz and Schwalbe, 2016; Section 5.2.2).

4.2.2.3
Challenges: new path dependencies and the societal power of businesses to shape the future

On the one hand, the disruptive economic effects of digital technologies and the business models based on them as described above promote greater decentralization and competition through greater market transparency and consumer sovereignty, through lower coordination and transaction costs (even over long distances), and thus generally by dismantling market-access barriers and frictions in market mechanisms (Goldfarb et al., 2019; Jerbashian and Kochanova, 2017). On the other hand, the key drivers of the disruptive effect, the cost structures of digital solutions and their business models, the economic potential of networking and information, also strong drivers of increasing market concentration.

For some time, several indicators, such as rising price markups and profits, have indicated increasing market concentrations, not for all countries but globally (De Loecker and Eeckhout, 2018). Although their causes have not been unequivocally identified, these developments are already being explained today by the increasing importance of intangible assets and the effects of ever stronger economies of scale and networks (Box 4.2.2-1; Díez et al., 2018; Bessen, 2017; Guellec and Paunov, 2017).

Due to the growing importance of intangible assets and the effects of economies of scale and networks, competition in an increasingly digitalized economy is developing a 'winner-takes-all' character (Evans and Schmalensee, 2013; Haucap and Heimeshoff, 2014; Box 4.2.2-1): businesses compete not so much for individual users, i.e. within a market, but for entire markets (Brynjolfsson and McAfee, 2014; Bourreau et al., 2017; Van Reenen, 2018). This, too, is reflected in the disruptive effect on markets and business models, especially in the fact that even businesses from completely different industries can dominate markets in a comparatively short time (Farboodi et al., 2019). However, there are increasing fears that this (innovation-driven) competition for markets will become less intense and that the pro-competitive effects of digitalization will increasingly recede into the background. The main reason for these fears is the increasing economic importance of data for innovative services and business models and, above all, for the (further) development of digital technologies themselves, especially for big-data applications and AI systems (Dewenter and Lüth, 2016; Kretschmer et al., 2018; Sections 3.3.2, 3.3.3). Businesses that, for example, have been able to secure (de facto) access to data via once-successful data-generating services threaten to continuously win the competition for 'their' markets in view of these data-driven indirect network or feed-back effects (Prüfer and Schottmüller, 2017; Graef and Prüfer, 2018; Mayer-Schönberger and Ramge, 2017). The penetration of big-data evaluations into the financing sector can also contribute to the dominance of established businesses if they obtain more favourable financing conditions thanks to the availability of broader data sets (Begenau et al., 2018).

Already today, individual businesses and especially the so-called Big Five (also known as 'GAFAM' – Google/Alphabet, Apple, Facebook, Amazon, Microsoft) have achieved considerable size and high capital-market valuations in a very short time using digital technologies and business concepts (Section 3.1.3). While Exxon Mobile, a fossil-resource company, topped the list of the world's ten most valuable companies in 2009, that list has changed dramatically since then: today, the top positions are dominated by representatives of the technology sector, partly by companies that were not even among the world's 100 most valuable companies in 2009 (OECD, 2019c; PWC, 2018; Table 3.1.3-1). This again illustrates the high dynamics and broad impact of digital change. Although the high market valuations of these companies do not supply any direct information about their actual power to shape developments, they do reflect profit expectations which are ultimately only justified if the companies can maintain or even expand their current market positions, which are already dominant in individual segments (Wambach and Müller, 2018: 39; Shapiro, 2018). It can also be observed that established businesses are buying up potential competitors in a targeted manner and at an increasingly early stage, even before innovation-driven competition for markets has been able to develop. The strategy of young entrepreneurs themselves is also increasingly geared to such acquisitions (Wambach and Müller, 2018).

At least in part, these concentration processes have been favoured by the fact that competition-law proceedings have so far often only inadequately done justice to the special economic structures in digital markets and data-based business models (Nyeso and Capobianco, 2017). The competition-law problems involved in dealing with the new actors in the digital economy and new business models in the digital space relate to both the appropriate demarcation of the relevant market and the identification of a dominant position about which high price markups on the (marginal) costs or high market shares have only limited informative value. Among other things, they are based on often unclear and in some cases asymmetrical substitution relationships between different digital offerings, the bundling of different services, the existence of network effects, or often lacking market prices (Bertschek et al., 2016; Krämer and Wohlfarth, 2018). There is also discussion on deficits in merger control, which has not effectively limited the targeted acquisition of young, potential competitors (Schweitzer et al., 2018).

Changes in companies' power to shape development and societal challenges

The extent to which this increasing concentration has an impact on the innovative strength of businesses is at least controversial (Autor et al., 2017a; Bessen, 2017; Gutiérrez and Philippon, 2019) in view of the research and development activities of the main current representatives of the digital economy and the described advantages of information links in innovation processes – by contrast to the classical idea of not-so-dynamic monopolies. On the other hand, it is largely undisputed that increasing market concentration and the resulting information advantage for individual companies have a distributional effect. For example, the decline in the percentage contribution of employees' remuneration to overall value creation in the economy – which has long been observed in many countries – is linked to the increase in market concentration, the shift from value creation to intangible, digital assets, and the rise of 'superstar companies' such as the Big Five (Autor et al., 2017b; Autor et al., 2017a; Guellec and Paunov, 2017; Section 5.3.9). Moreover, with the help of digital technologies and their information advantage over other actors, powerful companies can determine individual preferences more precisely and skim off individual willingness-to-pay with the help of decision-assisting systems or correspondingly differentiated pricing (Stiglitz, 2017; Kretschmer et al., 2018; Goldfarb et al., 2019; Wambach and Müller, 2018).

Furthermore, it is precisely the success of their applications and services across the broad spectrum of society that gives companies, their behaviour and their values in technology shaping ever greater societal relevance, and this engenders challenges to the market power of individual companies that go beyond the purely economic level. The digital technologies and applications essentially created by companies, such as internet search engines, communication services or social platforms, have in the meantime become ubiquitous and thus taken for granted components of private, business and political life in many countries and bear the characteristics of goods (and infrastructures) meeting basic human needs (Section 5.3.5). They represent key sources of information, offer at least ostensibly objective help with e.g. (consumer) decisions in the private and public spheres, and create new spaces for social and political interaction.

This special scope gives the key providers of digital solutions, infrastructures and services an information advantage over other actors – individuals, competing companies and government institutions – as well as influence on core societal areas. This concerns questions of data and privacy protection (Section 4.2.1; Acquisti et al., 2016), as well as questions of decision-making sovereignty at the individual and societal level (Box 4.3.3-1). At the same time, it remains largely non-transparent which data and information are (further) processed, which criteria the processes of redacting and designing data and information flows are based on, how decisions are supported, and whether societal principles such as freedom from discrimination are respected (GCIG, 2016; Kretschmer et al., 2018). Threats to individual and societal decision-making sovereignty can thus emanate from the providers of the services and technologies themselves and be very subtle in view of their information advantage. Today, however, more concrete threats are mainly characterized by the fact that individual companies have created digital spaces and platforms which, due to their reach (but also their great lack of transparency), open up opportunities for third parties to exert influence on information flows and shape opinions. This applies, for example, to the manipulation of political disputes in election campaigns (Section 5.3.2) or targeted disinformation and damage to reputations (Section 4.2.6; Box 4.2.6-1).

There is currently a lack of regulation and control of companies by democratically legitimated state authorities commensurate with the societal importance of digital technologies, infrastructures and services. This may be due to a lack of political awareness or will. Many digital services and networks deliberately or unconsciously elude existing national regulation (Section 4.2.6). On the one hand, digital services and networks in general operate internationally and are therefore difficult to regulate and control nationally. On the other hand, the decreasing importance of physical presence for entrepreneurial activities in the digital space increases the bargaining power of companies vis-à-vis regulatory state authorities. It allows companies to deliberately evade regulatory intervention – for example in the enforcement of social standards on labour markets (Section 5.3.9) or the taxation of profits (Box 4.2.2-2) – by relocating to a different country. The intensified internationalization of entrepreneurial activities already gives greater credibility to the mere threat of emigrating, making it possible to exert influence on the political process.

Too great an information advantage for individual companies, combined with the societal significance of their offerings and services, is neither compatible with the free interaction of supply and demand on markets nor with the principles of democratic societies and the framework-setting role of the state (Mayer-Schönberger and Ramge, 2017). In addition to the distribution implications and the dangers to privacy and the public sphere, as well as to individual and societal decision-making, the strong concentration of information control among individual providers must also be viewed critically for systemic reasons. Although some former restrictions on the collection and processing of information streams have ceased to exist through digital networking and data processing, nevertheless, the danger of wrong decisions and self-reinforcing dynamics decreases if the available information is always evaluated by several independent decision-making actors or technical systems (Mayer-Schönberger and Ramge, 2017) – an aspect of competition between decisions and decentralized information processing that also characterizes the discussion about the susceptibility to crises or resilience of financial markets that are already dependent on algorithm-based systems (Kirilenko and Lo, 2013).

4.2.2.4
Interim conclusion

Digital technical progress and the associated societal and economic changes do not guarantee that economic structures, behaviour patterns and path dependencies are always changed and broken up in a way that furthers sustainable development. Despite exceptions, the positive sustainability effects that digitalization has today are often 'by-products', e.g. more efficiently designed goods production or falling access barriers to markets or education. In addition, there is a certain discrepancy between many actors' claims to be creating something disruptive and their tendency to refuse to take responsibility for the societal effects of these innovations.

In the Digital Age in particular, it is therefore necessary to lay down appropriate framework conditions for economic activity that are geared to the sustainability goals: "A sharing economy is not a substitute for environmental policy, but makes it more necessary than ever if sustainable economic activity is to remain an economic-policy objective" (Eichhorst and Spermann, 2016). Ultimately, this is the only way to reliably reconcile the interests of private-sector actors with the challenges and goals of sustainable development, and thus to prevent the emergence of new, unsustainable development paths with new path dependencies that are difficult to correct. In this context, full use should be made of the new possibilities for monitoring, information provision and regulation that result from digital technologies and data availability.

Regulation and framework conditions are also necessary to counter the processes and drivers of concentration and to limit the excessive formative societal power of individual companies. The key starting point lies in the need to maintain or strengthen competition that really functions. This requires frameworks of effective competition policy, but may also require more fundamental (structural) changes in market conditions in the Digital Age. As the boundaries between the private and economic spheres become increasingly blurred in the course of digitalization, e.g. in the context of the sharing economy, the limits of the market and competition as control mechanisms must also be renegotiated. Otherwise, there is a danger that private-sector actors will introduce markets as steering mechanisms in areas of life that should definitely not – for societal reasons – be controlled by private-sector interests and individual (economic) performance (e.g. in the insurance industry or the health system, Section 5.3.7).

With corporate actors becoming increasingly international and powerful, however, the need to regulate and monitor the framework conditions poses challenges that threaten to overtax nation-state actors. Without enhanced international cooperation, many of their initiatives and efforts are likely to remain ineffective.

4.2.3
Civil society between emancipation and paralysis

In its great heterogeneity, civil society is a pluralistic societal area made up of voluntary associations, located between the private sphere on the one hand and state institutions and private-sector organizations on the other (Keane and Merkel, 2015). One of its core functions is to identify, process and communicate societal problems in the pre-institutional sector. It is thus firstly a bridge, gateway and amplifier between broad society (as an association of many private individuals) on the one hand and the political and institutional core area (e.g. parliament and government) on the other (Habermas, 1992). Civil-society initiatives, movements and non-governmental organizations (NGOs) organize, bundle and represent certain interests, become active themselves and besiege the political system with their messages. The individual civil-society actors are protected by fundamental rights such as freedom of conscience, freedom of expression, freedom of assembly and association, but also by freedom of the press, freedom of the arts and freedom of research and teaching. Secondly, civil society itself creates a plural public sphere in which even marginalized or hardly institutionalized interest groups and issues are given a public place to present themselves and negotiate.

4.2.3.1
Civil-society commitment to sustainability

In the field of environmental, climate and sustainability policy, the pioneering and driving force of civil-society actors is historically and currently extremely relevant worldwide. In Germany, the environmental and anti-nuclear-power movement was an important nucleus for ideas, demands and developments that had long been marginalized in society, but which today have become a societal, political and legal reality in many areas. Today, NGOs play many important roles in national and global climate policy: from agenda setting, providing knowledge and pioneering innovation, to campaigning, education and public relations work, to critically monitoring the implementation of climate policy (WBGU, 2011: 260). The power of civil-society engagement is also evident beyond the established NGO structures , for example in the recent protests by schoolchildren in the Fridays for Future movement. The fact that civil-society involve-

Box 4.2.2-2

Taxation of corporate profits and reform options

The state requires stable financial room for manoeuvre in order to shape the transformation of the Digital Age into a sustainable Digital Age, as well as for new state tasks, e.g. with regard to public-service ICT and digital commons (Sections 5.3.5, 5.3.10). However, today's tax and contribution systems are likely to become less and less able to provide this: contributions to public financing from taxes on (paid) work are likely to fall in the long term (Section 5.3.9). At the same time, the digitally supported internationalization and virtualization of entrepreneurial activities are creating considerable challenges for the taxation of corporate profits. Many people today complain that digital and non-digital business activities are subject to unequal tax burdens, and that there is a growing divergence between a country's possibilities to tax a company and the scale of that company's activities in that country. This perception of fiscal injustice is also reflected by current initiatives by the European Commission (European Commission, 2018e) to reduce tax inequality. However, this discussion does not always make sufficiently clear distinctions between unjustified preference given to digital business models and justifiable differences and the general problems of international tax competition. Some of the cited differences in the tax burden between digital and non-digital business models are due, for example, to deliberate tax incentives for research and development expenditure and the relatively high research intensity of companies in the digital economy, or to depreciation rules that are deliberately more favourable for short-lived intangible capital goods (Fuest et al., 2018).

Challenges like international tax competition and tax avoidance by international corporations have not just arisen recently in the course of digitalization, but they are intensifying. In contrast to public perception, the reason for these problems lies not so much in the power of individual companies in the digital economy as generally in the principles of corporate taxation and the growing importance of data, intangible, digital and digitalized assets, and business models based on them. Today, internationally active companies are taxed according to the source-state principle: corporate profits are to be taxed where they are generated. Since it has already been impossible hitherto to determine this location precisely, e.g. due to synergy effects within companies, tax law approaches the problem by looking at a company's physical presence in the form of its business establishments ('nexus'), e.g. its production sites or sales outlets. Profits are allocated to an establishment using internal transfer prices, according to which services between establishments are invoiced according to the 'arm's length principle': transfer prices may not be set higher than if the service provided by the establishment had been provided externally.

The growing economic importance of intangible assets and input factors, such as data, is driving internationalization and mobility, i.e. the ability to relocate entrepreneurial activities (Devereux and Vella, 2017). The connection between physical presence and the place where corporate profits are generated and value created is thus becoming ever weaker. This is partly caused by possible – but hitherto quite difficult to define – contributions to value creation that can be traced back to the users of digital services or to network effects (OECD, 2015a). At the same time, the new intangible components of the value chains raise valuation issues. For example, the value of data, software or the digital infrastructures used is fundamentally difficult to quantify. Attempts to determine internal transfer prices on the basis of the arm's length principle often already fail because of the need for a suitable basis for comparison outside the company (Becker and Englisch, 2017b), so that individual case assessments become necessary that give companies greater scope for tax structuring.

Possible reform steps are currently being intensively discussed at different levels. Proposals specifically designed to tackle the challenges posed by digitalization range from special regulations to targeted reforms of individual elements of the existing principles of company taxation – to changes in these basic principles themselves. It is widely recognized that an internationally harmonized approach should be sought here. At the OECD level, the BEPS (base erosion and profit shifting) project has already launched a corresponding process to curb international tax competition, but this has not yet led to a solution to the taxation challenges posed by digitalization (OECD, 2015a,b).

In view of these difficult international processes, the European Commission has proposed, as a transitional solution, a separate digital tax (European Commission, 2018a), which, instead of taxing profits of companies in the digital economy, would tax the transactions above certain global and EU-wide revenue thresholds, irrespective of their physical presence. Although the motivation behind the proposal is understandable, the WBGU shares the critical attitude of several observers towards such special provisions for companies in the digital economy (OECD, 2015a; Devereux and Vella, 2017; Wambach and Müller, 2018; Fuest, 2018; Wissenschaftlicher Beirat beim Bundesministerium der Finanzen, 2019). Given the widespread impact of digitalization, the distinction between the digital and non-digital economies is arbitrary and becomes increasingly unclear over time. Moreover, such an unequal treatment of digital and non-digital business models, unlike tax incentives for R&D, is hardly economically justifiable.

A much more effective approach, by contrast, might be a further development of international tax rules as a whole in order to adjust the international allocation of tax-access rights and reduce the possibilities of profit transfer. To do justice to the declining importance of physical presence for value creation, there is also a discussion on further developing the concept of the establishment into a 'digital establishment' or, as proposed by the European Commission, basing taxation on the establishment of a "significant digital presence" (European Commission, 2018f). In addition to risks like over-complicating the tax system, as well as new questions – such as whether individual, data-transmitting vehicles should be seen as taxable establishments (Fuest, 2018) – a further challenge is to continue focusing on concrete local value creation and distinguishing the transactions of digital establishments from those of simply importing goods and services. Location-specific input factors, e.g. data collection or the provision of services, for instance in the form of individualized advertising, are seen as starting points (Becker and Englisch, 2017b), whereas transactions and user or contract figures, as mentioned in the proposal of the European Commission, are viewed critically (Fuest, 2018). Furthermore, the definition of digital establishments is unlikely to have much effect without a reform of the rules on internal transfer pricing (Olbert and Spengel, 2017).

An international agreement on minimum tax rates at the EU, G20 or OECD level – including a right to subsequent taxation in the sales market if these minimum tax rates are not complied with – is also compatible with the current tax system and is being introduced into the OECD processes, for example by the Federal Ministry of Finance (BMF, 2019). However, for minimum tax rates to be effective in curbing tax competition, an additional agreement on the assessment base would have to be reached, a narrow definition of which could otherwise undermine minimum rates – although these minimum rates would not directly counter the criticized deficits in tax justice caused by the divergence between the location of transactions and the location of taxation (Becker and Englisch, 2018).

If the possibility of back tax being paid subsequently in the sales market (if a company's minimum taxation rate is undercut in the country of its registered office; (Becker and Englisch, 2018) is included in the considerations for a minimum taxation concept, then this concept also contains elements of a more far-reaching proposal. Under this idea – in view of the problems with the proper allocation of contributions to value creation and the high international mobility of entrepreneurial activities in the digital field – there would be a stronger general focus on the location of transactions. A moderate step in this direction could also be e.g. to make the exchange of digital services for data taxable under VAT law. Compared to the taxation of data flows, this can be justified insofar as it puts such transactions on an equal footing with conventional business relationships. However, it does not solve the problem of the valuation of the underlying data (Fuest, 2018).

The proposal of a 'destination-based cash flow tax' (Auerbach et al., 2017; Auerbach and Devereux, 2018) pursues the idea of a complete switch to the location of transactions. Instead of taxing the profits of multinational companies, this concept targets their transactions at the location of the end consumer. A company's export transactions are exempt from taxation in its home country, i.e. at the place of manufacture. At the same time, when domestic transactions are taxed, the costs of total production, i.e. including production costs for export, are tax deductible. Conversely, imports to end consumers, but not imports of intermediate products to domestic companies, are fully taxed domestically. If implemented globally, this switch to the country-of-destination principle, including border tax compensation, would mean that key tax-avoidance strategies, e.g. relocating patents and other intangible assets, even entire establishments, to low-tax countries, would become completely ineffective. If introduced unilaterally, the forces of tax competition would continue to work, but mainly in favour of the countries implementing this reform (Auerbach et al., 2017). A switch to the country-of-destination principle goes far beyond the reform steps currently being discussed at the EU and OECD level and raises numerous unanswered, detailed questions, for example with regard to administrative aspects (Auerbach et al., 2017) or to compatibility with WTO rules in the case of unilateral introduction (Becker and Englisch, 2017a). In some cases, far-reaching macroeconomic implications are also expected from the adjustment of international economic structures, as countries with export surpluses would be threatened with a reduction in their tax base (Becker and Englisch, 2017a). Particularly with regard to developing countries, special provisions would have to be made for taxing profits from the extraction and sale of natural resources. To this end, the source-state principle could simply be retained, since resource deposits already constitute a tax base that can hardly be relocated internationally (Auerbach et al., 2017).

New regulations for international corporate taxation are unavoidable to ensure that companies continue to make an appropriate contribution to financing states and communities in the future. However, corporate taxation is not an all-purpose remedy. The challenges posed by the concentration of power, possible violations of privacy or the environmental impact of entrepreneurial activities, for example, can only be inadequately met by taxing corporate profits. A better approach is to use more targeted instruments such as further developed competition law or effective data-protection regulations. In the WBGU's view, the consistent and, wherever possible, international taxation of emissions and other undocumented (external) effects of private business activities, should be used to address adverse environmental impacts (Section 9.2.3.2), using all digital monitoring options available (Section 3.3.5.1). Additional inclusion in the taxation of company profits would then lead to unjustified double taxation. Not least against this background, the WBGU takes a critical view of the proposal to tax data traffic, which is suggested for the tax assessment of companies in the digital economy, but also to strengthen data protection or reduce energy consumption from data flows. Sheer quantities of data, especially without context, do not provide any information about their value, or about any company profits. In addition, a flat-rate burden on data traffic contradicts the sustainability promises of digitalization, which are largely based on the collection, exchange and processing of data.

ment is often not conflict-free and in confrontation with state or private-sector actors can be seen all over the world (e.g. HRW, 2018). All too many activists for citizens' and human rights, freedom of the press and opinion, against land seizure, environmental destruction and resource exploitation are exposed to massive repression and state and private violence under the conditions of weak, corrupt or authoritarian statehood (Global Witness, 2017). Nevertheless, it is precisely the diverse, decentralized civil-society movements which, with their commitment, address the most explosive ecological and social problems, the disclosure of which is often not in the interests of either the private sector or the state.

4.2.3.2 Digitalization and civil-society action and organization

For civil-society organizations, digitalization means, above all, broadening their scope for campaigning and action by using ICT, incorporating digital themes and interactions into their work, and transferring and digitally developing their own practices (Züger et al., 2017: 267). External communication, mobilization and campaigning work, as well as member recruitment, are increasingly – or even exclusively – taking place digitally. Whether digitalization as a complex and highly stratified socio-technical process has an *overwhelm-*

ingly positive effect here on civil society's ability to act is a controversial question. It is true that the basic characteristics of networked communication – especially overcoming the one-way communication of previous mass media with mutual communication possibilities and universal access to information and processes – itself makes essential civic engagement and its development possible (Winkel, 2015: 412). However, the early euphoria about the worldwide liberal-emancipatory opportunities of the internet, freedom from hierarchies and elites, and digitally organized protest and resistance has given way today to sober realism in the face of the "hypercommercialization of the net and [...] the discovery of extensive surveillance practices" (Thiel, 2014a: 459; Section 3.1.2.2). In principle, the use of ICT enables the participation of a large number of citizens. The internet and social media at least potentially allow decentralization and global public mutual communication on an unprecedented scale. The visibility and networking of interests and protest is no longer necessarily dependent on reputation and resources, which previously could often only be provided by established civil-society organizations (Bennett and Segerberg, 2012; Lyon and Montgomery, 2013). At the same time, fragmentation and polyphony can result in a loss of significance or polarization – i.e. and consequently also a loss for public discourse and civil-society interest organizations (Section 5.3.2). Here, the clear advantages of professional support, timely consolidation and the organization of civil-society voices can prove themselves anew, also in the Digital Age.

4.2.3.3
Civil society as a driver of transformation in the Digital Age

In the Digital Age, too, civil-society actors are indispensable as creative thinkers, active pioneers and socio-political drivers of a Transformation towards Sustainability. Productive synergies can result from the mutual rapprochement of, and exchanges between, civil-society movements. Tech communities (Section 4.2.4) also have long-standing traditions of common-good-oriented civic work and critical commitment. The open-source movement, the joint procedures in Wiki projects, the strong voice in net policy of the Chaos Computer Club, which has existed since 1984, or the FIfF (Forum of Computer Scientists and IT Professionals for Peace and Social Responsibility), which has also been active since 1984, are just a few examples of the credible and committed "role of civil-society actors in the further development of the organizational and technical infrastructure of the information society" itself (Winkel, 2015: 416). Not only in the field of political whistle blowing is the power of (and power over) information and data a "recurring leitmotif of digital civil disobedience" (Züger et al., 2017: 269). Access to and the availability and processing of relevant information and digital data for civil society also play a major role in the field of environment, climate and sustainability policy. New innovative approaches emerge from civil-society niches that creatively challenge and drive established politics (e.g. 2030-watch.de) or facilitate individual commitment (e.g. betterplace.org or toogoodtogo.de). At the same time, strong networks of civil-society actors, both national and global, can become a critical sensorium for ecological, societal and human grievances all over the world on a scale unprecedented in the history of humankind (Section 4.2.7). In the polycentric responsibility architecture, civil-society organization and civic action are essential all over the world, specifically as a link between the individual and society ('school of democracy'), but also as a counterbalance and controlling authority of state and economic power, also in the Digital Age. In addition to the valuable civil-society engagement of scientists, there is also an important role for science as such and in its national and transnational alliances.

4.2.4
Tech-Communities – new pioneers of change?

The WBGU uses the term tech communities for actors with technical expertise who are grouped in networks made up of companies, NGOs, state institutions, etc. They are key actors in the technical system (Section 3.5.5). As the digital penetration of society proceeds, the architects of technical systems are digitally pre-structuring more and more areas of life and contextualizing key decisions. For example, the technical design of social networks influences spaces of public discourse (Section 5.3.2), and the development and use of algorithmic decision-making systems influences the financial, health and legal systems (Box 4.3.3-1; Section 5.3.3).

4.2.4.1
Value inscriptions in technology

Digital solutions cannot be understood as transparent and neutral media of human intentionality, since "even the design and not just the use of technical artefacts can have moral consequences" (Simon, 2016: 359; Brey, 2010; Section 3.2.7). Initial ethical, epistemological and scientific analyses in the big-data context show, for example, that value decisions are already applied and manifested in the process of data collection, as well as in the further processing of data and the conclusions drawn from them (Mittelstadt and Floridi, 2016). Selection decisions, evaluations and values thus already play an important role (Brey, 2010; Mittelstadt and Floridi, 2016) during the conception and development of technical solutions – i.e. well before they are actually used. They are 'hardwired', so to speak, so that the implemented values are fixed in the operation and use of the systems (Simon, 2016:359): "Because technologies contain values does not mean that they themselves become moral actors or bear moral responsibility." Responsibility lies with the system designers, not least because of the challenges of formalizing ethics in machine-readable form. However, the tech communities have thus moved to the centre of societal life. With the increasing digital penetration of everyday life, this group of actors continues to gain influence and has attained a 'unique selling point'.

Strategic decisions about the development of new technologies and systems are often made at the management level of digital companies or within research institutions. Later technical design also incorporates unconscious values of the participating developers. A very concrete example of this is the choice of voice colour in the design of human-machine interfaces using voice assistants (voice computing), which (usually unconsciously) convey gender roles and can become widely disseminated in society (Section 5.3.6). Actors in the tech communities thus shape key social environments through conscious and unconscious decisions without any societal debate, since the concrete decision is often outside direct observation or control.

New research fields such as values in design (Simon, 2016) or value sensitive design (Friedman et al., 2006) are developing to systematically determine, analyse and evaluate conscious and unconscious value inscriptions in the development of hardware and software, the underlying algorithms and the data used. The result is that actors in the tech communities – from the management level of a technology company to developers, (software) engineers, data scientists, etc. – have shaped key social environments. As digital technologies continue to spread, the ability of tech communities to shape and design is likely to increase.

4.2.4.2
Ethical discourses in tech-communities

Actors with technical expertise have been addressing the issue of their responsibility to society for some time now. This is exemplified by civil-society organizations like the FIfF (Forum of Computer Scientists and IT Professionals for Peace and Social Responsibility), which emerged from the peace movement in 1984, the Digitalcourage association founded in 1987, and the Open Knowledge Foundation; all are committed to societal concerns and contribute to political discourses. Up to now, dedicated 'techies' have focused primarily on topics such as privacy, (cyber-)security and trust (Simon, 2016). They also influence ethical technology design, ethical areas of application and professional guidelines. This is particularly true in the context of AI development: "When it comes to AI, we have to have a set of principles that guide the development of AI and its use. We want to make sure that anything that we do doesn't amplify bias, doesn't hijack our attention, doesn't sway opinion. These are things where we need to not only build the tools, the technologies – but it's also a set of design principles, a set of ethical principles that we as builders of technology need to have" (Satya Nadella, CEO of Microsoft, Corenote at the 'Inspire 2018' conference).

At the same time, tech communities and their values are repeatedly criticized. Technology companies and expert forums are criticized, for example, for their handling of diversity, sexist attitudes and lack of inclusiveness (Daumé III and Heller, 2018). The digital economy repeatedly finds itself at the centre of public attention because of aggressive business models that are often detrimental to the common good, for tax avoidance or poor working conditions (Berg et al., 2018b; OECD, 2018f.). This reveals the discrepancy between normative commitments, some of which are embedded in corporate guidelines, and the digital economy's commercial interests.

These discourses testify both to a more critical reflection by society of the values represented in tech communities and to an increasing sensitization of actors with technical expertise to the societal consequences of their actions. However, aspects relating to ecological sustainability, such as resource and energy consumption or the impact on climate change, have so far played only a subordinate role in this context.

4.2.4.3
Interim conclusion

These issue are key for the Transformation towards Sustainability: the application areas of digital technologies; whose and which values are inscribed into the design, development and operating processes; and how value conflicts are recognized and decided. Sustainability-savvy tech communities could be natural allies for the Transformation towards Sustainability and become new pioneers of change. On the one hand, they can develop technologies for applications that support sustainable development; on the other, they can embed sustainability values, such as resource efficiency, in the design process and act as pioneers of change in other tech communities. Because of this actor group's growing influence, the WBGU believes that sustainability-relevant discourses in the tech communities should be promoted institutionally and more systematically to boost their ability to shape the Transformation towards Sustainability. For example, in addition to greater corporate social responsibility, technological social responsibility could also be established. The discussions within the tech communities on values by design, corporate social responsibility, the responsible use of technology, and the development of a professional ethic offer good starting points for leveraging potential for the ability to act, shape and plan in efforts to move towards sustainability transformation (Box 4.3.1-1).

4.2.5 Cities and municipalities between technology sovereignty and technology dependence

In the current urban century, cities and municipalities are regarded as key actors in shaping the Transformation towards Sustainability (WBGU, 2016a; Section 5.2.7). Development problems become concentrated in many cities around the world, e.g. socio-economic disparities between gated communities and informal neighbourhoods (digital divide, provision of basic services and infrastructure, etc.), unregulated growth, weak local governance capacity, poor urban and transport planning. Cities also contribute significantly to global environmental problems: they are responsible for about 70% of global energy use and global energy-related CO_2 emissions (Seto et al., 2014). Digital solutions can make a contribution to solving these problems; other key problems of urban development, such as the supply of living space, can still only be solved by 'analogue' means. In any case, competent and capable urban societies acting in the interests of the common good are crucial.

4.2.5.1 Global technology providers: a new challenge for city governments

Urban development is shaped on the one hand by sovereign actors such as mayors, city governments and administrations, architects and urban planners, and on the other hand by non-sovereign actors, such as urban civil society, (international) investors, the real-estate industry and construction companies. A new group of actors – which is becoming significant with the spread of digital solutions and 'smart city' strategies – is made up of large, often global technology and consulting firms. Digitalization presents many city governments with new formative challenges: Which digital solutions are oriented towards the common good and can help solve key problems of urban development? What risks are involved? How can actors contribute to the success of digitally oriented strategies? In addition to the potential for, e.g., better traffic management, multi-modal mobility services, the circular economy, digital networking among actors, and decentralized urban power generation, relevant issues also include potential dependencies on individual technology providers and the need to strengthen the technological sovereignty of cities and municipalities (Section 5.2.7). But it is also a question of sovereignty over data in communal areas, the dangers of total surveillance, and the resilience of critical infrastructures against cyber attacks (e.g. communal electricity, gas or water supply).

4.2.5.2 Effective local governments

There is no blueprint for urban and municipal development, especially when it comes to moving towards sustainability. It is therefore all the more important that cities and municipalities are and remain able to act, also under the specific conditions of rapid digital change. They do not only need technological skills and qualifications (Section 5.3.4), but also sufficient financial capacity to make the necessary investments in (digital and digitalized) infrastructures. Public expenditure by municipalities in Denmark makes up 62% of overall government expenditure and 32.9% of GDP. In a developing country like Kenya, where tax revenues are already lower than in industrialized countries, the share of public expenditure allocated to cities and municipalities is only 1.2%, or 0.06% of GDP (UCLG and Dexia, 2007). The less able the public sector is to shape development, the more digital urban and community development is left to the free play of forces.

In addition to raising their share of public spending from the state budget, the consistent use of fiscal instruments by local governments is an important lever for improving the financial situation of local budgets in order to strengthen their influence (WBGU, 2016a: 163). This concerns in particular levying taxes on land and on the value of real estate, which has seen sharp increases in recent years. In addition, it is also necessary to close tax loopholes such as share deals designed to circumvent land-transfer taxes (WBGU, 2016a: 163).

Cities and municipalities also need more responsibility of their own (WBGU, 2016a: 359), for example through the consistent application of the subsidiarity principle and the recognition of local autonomy by national constitutions, for example the right to local self-government (WBGU, 2016a: 360f.). This facilitates community development that is geared to local needs. In addition, a more efficient allocation of resources and a democratization of decision-making processes are decisive advantages of a decentralized state organization (Porras, 2009: 556). In many developing countries and emerging economies in particular, establishing an effective administration is therefore a major challenge.

4.2.5.3
The digital municipality and the Transformation towards Sustainability

Strengthening urban civil society as a key player in sustainable urban development is an important prerequisite for maintaining and improving sustainability and quality of life in cities and municipalities. In the sense of *Eigenart* (Section 2.2.3; WBGU, 2016a: 142ff.), this is not about creating acceptance, but rather about self-determination. *Eigenart* means "that, within this framework, every city can and must look for its 'own way' (in German '*eigene Art*') towards a sustainable future"(WBGU, 2016a: 132). Furthermore, cities and municipalities play a key role, if societal inclusion and participation rights are part of their municipal constitution. Embedding a digitally oriented municipal development policy in a human-rights-based approach is an important prerequisite, especially in developing countries and emerging economies, to enable sustainable development and strengthen the ability of municipal poverty groups to act and participate (HLRN, 2018; Section 5.3.8).

The introduction and use of digital technologies in cities and municipalities should be consistently embedded from the outset in cross-sector concepts of sustainable municipal development (Section 5.2.7). In particular, technology commissioners and smart-city commissioners, who have recently been appointed in many cities and municipalities, should only make decisions in close cooperation with the respective environmental and sustainability authorities. In this context, digital applications could be subjected to a sustainability review before being deployed.

4.2.6
States between power and loss of sovereignty

As institutions that define and enforce formal, generally binding rules for societal coexistence within territorial borders, states have a special role to play in the Transformation towards Sustainability. Because they are fundamentally binding in nature, state-government decisions and state legislation represent powerful means for establishing the framework conditions for sustainable development. The WBGU has called for a *proactive state offering extended participation possibilities*, i.e. states should act decisively and simultaneously in a way that activates others (WBGU, 2011: 203ff.; Section 4.1). In addition, global environmental and development problems such as climate change require global solutions negotiated by state governments, often within the framework of the United Nations (Section 4.2.8).

The state's aspiration to shape development faces challenges as a result of globalization processes. Because of their global mobility and resource wealth, companies can evade national legislation in intrinsic areas of state responsibility such as taxation and environmental protection (Strange, 1996; Section 4.2.2.3). The effectiveness of setting frameworks for sustainable development by legislation is therefore limited. Furthermore, in the past there has been a lack of international political will and unity. In view of the overall weakness of climate legislation, hopes are increasingly being pinned on sub-state and non-state actors such as cities and companies – also within the framework of the Paris Agreement (Chan et al., 2016; Schlacke, 2016). Due to structural limitations and a lack of political will, states are not the driving force behind the Transformation towards Sustainability that they could be.

4.2.6.1
State capacity to act under the pressure of economically driven deterritorialization

State power structures face particular challenges from digitalization (Owen, 2015). Many conventional policy instruments are becoming less effective in the context of digitalization. Legislation and governance are linked to national territoriality (Weber, 1980 [1922]). The laws of a country apply only within its territorial borders. Just as globalization has de facto weakened the state's ability to act by physically shifting the activities to be regulated to other countries (or threatening to do so; Strange, 1996), in the course of deterritorialization digitalization shifts many processes and decisions relevant to state governance not only beyond territorial borders, but also into the internet (Sassen, 2000, 2002; Choucri, 2012; McAfee and Brynjolfsson, 2017). These virtual spaces and their infrastructures, platforms and contents are largely created and controlled by private actors. In the course of digitalization, the state's power to act therefore finds itself in a particularly tense relationship with the growing power of private-sector actors. Legislation as a central means of state governance loses its assertiveness in virtual, borderless spaces (Boehme-Nessler, 2009). The private-sector providers of digital services are internationally mobile and therefore difficult to define in regulatory terms; they are also generally uncooperative (de la Durantaye, 2011; Hodgson, 2015; Section 4.2.2.3). This restricts the state in its intrinsic areas of action, such as taxation (Box 4.2.2-2). In addition, services are used across borders and potentially misused in virtual space. The challenges of regulating misinformation and hate speech on the

Box 4.2.6-1

Unprecedented state measures: The German Network Enforcement Act and the French Act to Combat Manipulated Information on the Internet

Laws and voluntary measures are in place within the EU to combat the dissemination of false content (fake news) and hate speech. These are intended to protect social platforms from being made liable for content posted by their users – as long as they have no knowledge of the content – and, at the same time, to involve them in the fight against these phenomena through voluntary commitments (Echikson and Knodt, 2018). The EU is tightening up legal requirements particularly in certain sectors, for example in the fight against terrorist content and child pornography.

The German Network Enforcement Act against hate speech

The Network Enforcement Act (NetzDG), which came into force on 1 October 2017 and was to be implemented over a transitional period of three months, aims to combat hate speech on the internet; it thus primarily serves to protect personal rights. Since self-commitments by the commercial providers of social networks to eliminate such hate speech proved to be insufficient, the NetzDG obliges providers with 2 million or more users registered in Germany to remove or block access to illegal content in social networks within 24 hours, or, where cases are unclear, to react within seven days as soon as they become aware of the content (Section 3 (2) nos. 2 and 3 of the NetzDG). The illegal contents that must be removed include criminal offences targeting the democratic rule of law, public order, personal honour or sexual self-determination (Section 1 (3) of the NetzDG), i.e. for example defamation (Section 186 of the StGB), incitement to hatred (Section 130 of the StGB), and distribution of child and juvenile pornography (Section 184b-d of the StGB). Furthermore, the operators must set up a complaints mechanism that allows users to draw attention to violations (Section 3 (1) of the NetzDG), report every six months in German on the complaints filed and how the complaints mechanism is functioning, (Section 2 of the NetzDG), and appoint an authorized agent in Germany as recipient for complaints and official notifications of fines. This agent's contact data must be published and easily accessible (Section 5 of the NetzDG). The obligation to appoint a domestic authorized agent is intended to solve one of the main problems of enforcement in social networks, namely the lack of responsible contact persons among the platform providers (Deutscher Bundestag, 2017b). If providers of social networks violate these concrete compliance requirements or fail to appoint a domestic authorized agent, supervisory authorities may impose fines (Section 4 of the NetzDG). Furthermore, in the event of violations of the obligation to delete content, the responsible regulatory authorities can legally oblige the operators of intermediaries responsible for content (e.g. social networks) to delete.

The NetzDG has attracted media attention worldwide (Eddy and Scott, 2017; Kugelmann, 2018), although individual regulations from the NetzDG have been used as templates for dubious purposes. For example, the obligation of service providers to delete content has been incorporated into a Russian law and extended to include infringements of civil law, with harsh penalties for infringements (Reporter ohne Grenzen, 2017; Article 19, 2017). The Russian law thus goes much further than the German law and can lead to extensive censorship of content. Germany went it alone in the EU with the NetzDG. Although the European Commission has now presented a comparable draft law in the EU against terrorist online propaganda, its scope is much narrower (Echikson and Knodt, 2018).

The French Act to Combat Manipulated Information on the Internet (especially during election campaigns)

On 22 November 2018, the French parliament passed a law to combat manipulated information on the internet (especially during election campaigns). Manipulated information is defined as false or misleading information, or the attribution of a fact to adversely affect the veracity of a future election or vote (Article L. 163-2 of the French Electoral Code as amended). During the three months preceding elections, this French law obliges operators of social platforms to identify the authors of content in the public interest, to disclose remuneration for paid contributions above a certain threshold, and to establish a public register for this purpose (amendment of Article L. 163-1 of the French Electoral Code). During this period, the judges responsible for the summary proceeding must, at the request of the Public Prosecutor's Office, order measures within 48 hours to prevent the dissemination of false information relating to the election (Article L. 163-2 of the French Electoral Code). The law also amends the French Freedom of Communication Act. The operators of social networks are required to take measures to combat the dissemination of false information that can lead to a disturbance of the peace or compromise the outcome of elections or votes, and to introduce an easily accessible and visible mechanism for reporting false information (Article 8 bis of the Freedom of Communication Act). In addition, measures were introduced on the transparency of algorithms, on the regulation of content advertising, on combating user accounts used intensively to disseminate false information, on the provision of information on authors of contributions that shape public opinion, on the nature, origin and modalities of content dissemination, and on education through media and information.

Operators must disclose what measures have been taken and what resources were used for them, and document them in an annual report to the Conseil supérieur de l'audiovisuel (Freedom of Communication Act, Article 8 bis). The French authorities were given additional powers to combat fake news (Article 9 of the Freedom of Communication Act). As in the NetzDG, operating companies must designate domestic authorized agents (Article 9 bis A). Operators using algorithms for recommending, categorizing and/or listing content related to public opinion forming must publish statistics revealing, for each part, what percentage of data was accessed directly (without recourse to algorithmic sorting) and how much indirectly (i.e. through mediation by algorithms for searching or sorting content) (Article 9bis B). Furthermore, learning content about misinformation on the internet was included in the French Education Act (Article 9ter-9septies Code de l'éducation).

Like the NetzDG, the French law was criticized before and after its adoption by Parliament for the risk of restricting freedom of expression and communication and because of uncertain legal concepts relating to the criminal offences at both the national and the UN level (Kaye, 2018; Abgeordnete der Nationalversammlung, 2018; Mitglieder des französischen Senats, 2018). The French law was submitted by members of the Senate and Parliament to the French Constitutional Court (Conseil constitutionnel) for review. The Court declared the law constitutional, but issued guidelines for interpreting various articles, which must be observed in its application (Conseil constitutionnel, 2018a, b).

internet (Box 4.2.6-1 illustrate the challenges of countering infringements in the digital domain.

The guiding principle of the proactive state (WBGU, 2011) is thus challenged in the Digital Age. The EU, for example, is trying to counteract deterritorialization by introducing the principle according to which the user's place of residence is decisive, not the company's registered office (Klar, 2017; Pollmann, 2018). Large internet groups are also responding to increasing public pressure with voluntary commitments to counteract agitation, disinformation and a lack of data protection (Dehmel, 2013; Die Zeit, 2018). However, the limited enforcement power of state governments remains a challenge in the Digital Age. A controversial strategy of some states therefore involves transferring elements of law enforcement to private actors (e.g. German Network Enforcement Act: Box 4.2.6-1).

Another aspect is the fact that new technical possibilities in the Digital Age can also be used for state governance (e-government; Esteves et al., 2013; Frach et al., 2016; Lenk, 2017). This possibility has so far been embraced very differently in different countries – intensively in Estonia, for example (Eixelsberger, 2010; European Commission, 2015a). In general, different strategies for dealing with digitalization can be identified at an aggregated level ranging from laissez-faire to precautionary balancing and active use (Linkov et al., 2018; Goodwin and Spittle, 2002). Technology companies in the USA, for example, benefit from weak regulation (Czada, 2015; Dudenhöffer and Schneider, 2015). In the EU there are signs of a middle course in which the balance of power is to be shifted in favour of the regulating state actors by means of harmonization within the EU and through cooperation (Newman, 2015; Goddard, 2017; Section 8.1.6). The Chinese government, for example, is attempting to use the so-called 'great firewall' not only to extend the state's ability to act and control into virtual space, but also to use it itself as an instrument of control of the physical world through social scoring (Meissner, 2017; Chorzempa et al., 2018; Box 4.2.6-2; Section 5.3.3).

4.2.6.2 Ways to strengthen the state's ability to act sustainably

In dealing with the above-mentioned restrictions on their ability to act, states have a number of ways to compensate for the de facto restriction of their formative power. For example, the power of large technology companies should be seen relative to that of the regulatory institutions. States can regain their capacity to act by acting together. No company can ignore regulation at the EU level if it wants to keep this important market. Measures like the Basic Data Protection Regulation (GDPR) enable the EU to counter the power of technology companies (Box 4.2.6-3). In principle, coordinated regulation of important markets can in turn have a positive spill-over effect outside the participating countries. Contrary to fears, globalization has not led to a general softening of environmental standards (Vogel, 1995; Vogel and Kagan, 2004; Konisky, 2007; Dong et al., 2011; Holzinger and Sommerer, 2011). Transnational companies or firms with a high export share often apply globally the strictest environmental standards they have to comply with in any one country, because differentiation would entail additional costs. As a result, in less regulated markets, these companies even push for stricter standards to avoid being at a disadvantage vis-à-vis local suppliers (Vogel, 1995; Holzinger and Sommerer, 2011; Bradford, 2012; Saikawa, 2013). In the past, there has indeed been a 'Brussels effect' in which EU rules have de facto been adopted outside the internal market (Bradford, 2012). The EU has also made practical use of its influence in negotiations on trade agreements, for example to enshrine basic workers' rights or economic development strategies in partner countries (Meunier and Nicolaïdis, 2006).

However, an analogy to environmental protection should be drawn with caution. Model legislation on data protection, for example, takes the GDPR (Box 4.2.6-3) into account as an important reference point (Privacy International, 2018a). However, since no physical goods are produced, the costs of differentiation in the handling of data are no longer prohibitively high. Furthermore, the core business of many digital companies is the collection of as much data as possible, so that there is a particularly strong incentive to avoid legal restrictions. Whether spill-over effects will also be seen in digital markets is yet to be researched. And whether the GDPR will also apply outside the EU (especially in the USA) therefore remains a relevant – and still open – question.

Beyond simply reacting to the changed conditions, states can also use the new technical possibilities to actively contribute to the Transformation towards Sustainability. However, there is currently no broad understanding or technical knowledge of the opportunities and risks of digitalization, which would first need to be mainstreamed by all state institutions in order to fully tap the sustainability potential of digitalized state action. Unless it is effectively shaped, the intensive use of digital technology could become problematic in terms of civil and human rights and privacy. State monitoring and social control (e.g. Box 4.2.6-2) can have implications for individual development and public discourse (Section 5.3.2) and thus in shaping the Second Dynamic (Section 7.3). 37% of the world's population

Box 4.2.6-2

China's social credit system

Since the Chinese central government presented its plan in 2014 to set up a nationwide social credit system by 2020 (Kostka, 2018), forms of governance supported by data and technology have been attracting increasing international attention. In China, the social credit system aims to integrate individuals, companies, social organizations and state authorities into a centralized points system, which provides behavioural incentives using reward and punishment mechanisms. The individual score assigned to the individual actors changes dynamically depending on their behaviour, and is to be used as a basis for decision-making in various (public) spheres in a similar way to the credit-score system used widely in the financial sector. The aim is to establish an "economy and society based on trust" (Meissner, 2017; Ohlberg et al., 2017).

At present, there is no single national social credit system (yet); rather, a multitude of systems coexist (653 in total, according to the Social Credit Summit held in 2017), administered by both local governments and commercial enterprises (Ahmed, 2017; Creemers, 2018). While the systems of commercial providers such as Tencent, Sesame, etc. are based on voluntary participation, participation in state social credit systems is compulsory for all residents of the respective areas. In July 2018, more than 40 district and provincial governments were running pilot projects (Kostka, 2018).

The number of studies investigating the effects and consequences of already established social credit procedures is currently still small. A recently published field study of the social credit system in Rongcheng – a city of 650,000 inhabitants and 50,000 businesses in the Chinese province of Shandong, selected as a model in January 2018 – reveals a reporting system based largely on human labour (with several hundred certified data collectors) and a complex catalogue of behaviours (with 150 behaviour categories) as a basis for scoring (Knight, 2018). A survey of over 2,200 Chinese internet users has shown that individuals living in an area with a social credit system are changing their behaviour. 94% of respondents stated that they had changed their behaviour, e.g. with regard to purchasing decisions. 18% of respondents said they had changed their behaviour on social networks and removed contacts from their social media network in order to minimize potential negative influences on their score (Knight, 2018).

There is a broad consensus in the scientific community that a centralized social credit system or even several decentralized social credit systems have the potential to radically transform the state governance of both the economy and society (Meissner, 2017; Chorzempa et al., 2018). However, assessments of the social system that has successively changed differ. Some experts see it as a return to a planned economy, since the social credit system gives companies strong incentives to gear their activities to politically set goals (Heilmann, 2017). Others stress that with the introduction of the social credit system, China is entering a new phase of surveillance and social control (Kühnreich, 2017) with implications that extend beyond China's territory (Hoffman, 2018). In the Chinese population, on the other hand, the social credit system is currently seen less as a monitoring system than as an instrument for more effective law enforcement in order to remedy grievances such as corruption, crime or a lack of trust in public institutions (Kostka, 2018). Approval rates are as high as 80% (Alpermann and Thünken, 2018; Kostka, 2018), although large-scale studies are still lacking. Even in regions where a social credit system is in place, there is little knowledge within the population of its existence and how it functions.

In western liberal societies, the idea of such a governance system triggers strong defensive reactions, as it contradicts fundamental principles of the rule of law and is classified as an instrument of power of a totalitarian surveillance state due to the collection of extensive personal data and the determination of desirable behaviour by the central state. Score-based sanctions, as applied in social credit systems, meet with rejection, in Germany for example by 91% of the population (SVRV, 2018).

live without freedom under authoritarian regimes (Freedom House, 2018) that can use digital technology to monitor and control them (Section 6.2). But democratic states also use invasive mass surveillance technology, as shown by the revelations on American and British espionage in summer 2013 (Lucas, 2014; Lyon, 2014).

4.2.6.3 Untapped formative potential of states

When it comes to sustainability-relevant problem areas, states are currently still insufficiently active within their de facto scope for action in view of the dominance of private-sector actors (Section 4.2.6.1). On the other hand, their legislative and executive powers give them especially strong instruments for establishing the framework conditions for sustainable development. Just as the potential for the Transformation towards Sustainability has not yet been exhausted, government action has so far only been used to a limited extent to shape digitalization in a sustainable manner. In order to change this, states would have to act together and regain their capacity for action through multilateral cooperation, setting guidelines for their actions which ensure that existing problems regarding civil rights and privacy are not exacerbated.

4.2.7 Transnational actors between world society and fragmentation?

Transnational actors are non-state, societal actors engaged in international or even global activity, networking and influence. Unlike intergovernmental international organizations (Section 4.2.8), they are not primarily founded by or dependent on state actors, but act as social movements, networks, businesses or formal organizations across national borders. Their heterogeneity corresponds in principle to the diverse area of non-state groups in the national context. Civil-society movements and organizations such as peace, women's and environmental movements – e.g. attac, Greenpeace or Amnesty International – are part of this, as are multinational business enterprises or supranational associations from the fields of science, the media, foundations, business, trade unions, religion and tech communities (e.g. ICANN, Box 4.2.7-1). These alliances of decentralized actors' interests, which have grown in very different ways, make contact with states and international organizations as well as with business and (global) society. Transnational actors are a prime example of the polycentric structure and functioning of today's governance, for example in the field of climate change (Dorsch and Flachsland, 2017).

4.2.7.1
Transnationalization of sustainability policy and digitalization

The transnationalization of global sustainability policy is demonstrated by the many forms of involvement of non-state actors in intergovernmental processes of sustainability policy, and of initiatives that emerge independently of them. For example, the United Nations has initiated a 'Global Compact for Sustainable Development' between companies (unglobalcompact.org). By signing up, companies commit themselves to ten common principles in the areas of human rights, labour, the environment and anti-corruption, and report regularly on their compliance. In the negotiations on international climate-change mitigation, which are dominated by the signatory states, e.g. to the Paris Agreement, non-state actors are increasingly gaining access to consultations, albeit without voting rights of their own. Novel forums for exchange between states and civil society and private actors are being developed (e.g. the Presidency's Open Dialogue at the Conferences of the Parties to the Paris Agreement); however, in most cases no decision-making powers are transferred to them.

Transnational climate governance in particular has developed very dynamically in the last decade in view of the strong differentiation of the subject area and the manifold (also digitally enabled) participation possibilities (e.g. Bulkeley et al., 2018). Often linked to policy processes within the framework of the UNFCCC, but also independent of it, various initiatives are emerging, for example in the area of regional emissions-trading systems like the RGGI, certification models like the FSC, greenhouse-gas inventories such as the Climate Registry, or voluntary environmental and sustainability reporting such as the CDP (Bulkeley et al., 2018: 63). Civil-society participation in global environmental and development conferences regularly breaks records – developing from the UN Rio Conference in 1992 with an exceptional 1,500 registered NGOs, to 6,000 registrations at the World Summit on Sustainable Development in 2002, and peaking at 12,000 registered NGOs at the Climate Summit in Copenhagen in 2009 (Bäckstrand, 2015). Although the example of the climate conference in Copenhagen in particular clearly showed that states still bear the greatest responsibility for the success and failure of an ambitious climate policy, the large number – and even more the great quality – of transnational commitments makes an important contribution to climate policy. NAZCA, the UN portal for climate-change-mitigation projects of non-state actors, lists around 20,000 registered projects involving cities, regions, companies, investors and NGOs (UNCCS, 2018). Especially associations of subnational actors – such as the transnational Cities Climate Leadership Group (C40), Local Governments for Sustainability (ICLEI), an association of over 1,500 cities, towns and regions or the World Mayors Council on Climate Change – are catalysts for climate-change mitigation in many countries, often despite or precisely because of the less ambitious policies of many national governments (Aust, 2018). Academia, which is also transnationally networked to a high degree, is closely linked to the intergovernmental negotiation process via the IPCC, particularly in the field of climate governance. With his encyclical Laudato si', Pope Francis also showed that religious associations and prominent individuals, as transnational actors, can also exert significant influence on sustainability policy (Edenhofer et al., 2015; Heimbach-Steins and Stockmann, 2019).

For transnational business enterprises, general or sector-specific (e.g. mining, finance, textiles) CSR commitments create fragmented transnational regulatory systems that bring environmental and social sustainability issues into business relations (Spiesshofer, 2017). Nevertheless, they suffer from inconsistencies and contradictions compared to the common standards (Spiesshofer, 2017) developed by the UN, OECD, ISO or other organizations. Current CSR guidelines and tools often ignore issues of digital change in this context (Knaut, 2017).

Digital networking and the provision of information have a variety of effects on the ability to act of the growing network of transnational governance actors; for example, they can improve awareness, attract attention or strengthen advocacy for different (e.g. local, economic, particular or marginalized) interests in the global sphere (Talberg and Jönnson, 2010). For all these transnational groups of actors, digital networking very fundamentally creates the possibilities for the dynamic

Box 4.2.6-3

The EU Basic Data Protection Regulation as the EU's approach to shaping digitalization

In the field of data protection and the protection of privacy, the EU's Basic Data Protection Regulation (GDPR; EU, 2016) is without precedent anywhere in the world. It aims to embody a Europe that "effectively protects and defends values and fundamental rights vis-à-vis the commercial and state data-collection mania" (Selmayr, 2018: 197). Since 25 May 2018, the Basic Data Protection Regulation has been directly applicable for all citizens throughout the EU, without the Member States needing to transfer it into national legislation. The GDPR pursues a dual objective: (1) the protection of privacy and (2) the promotion of the free movement of data across the EU's internal borders by harmonizing data-protection standards (Article 1 of the GDPR). It only applies to data relating to individuals, but not to data relating to other objects, such as companies. Member States may adopt complementary national rules in certain areas, for example for data processing by public authorities (Kühling and Martini, 2016).

The most important contents of the GDPR concern the extension of the scope of application and the mechanisms and institutions for the enforcement of the data-protection law; the data-protection provisions were further developed in an "evolutionary rather than a revolutionary manner" (Kühling and Martini, 2016).

Scope of application

With the introduction of the principle, according to which the user's place of residence is decisive, not the company's registered office, in Section 3 II of the GDPR, the scope of application is also extended from processing operations within the EU to all operations in which data of persons located in the EU are processed outside the EU. The application of the GDPR no longer depends on where companies that process data have their headquarters, but on where the customers live. European data-protection standards are thus becoming more important for non-European companies. The introduction of the principle, according to which the user's place of residence is decisive, not the company's registered office, initially only extends the protection of users in the EU on paper. It remains to be seen whether such a broad scope of application can also be consistently enforced outside Europe (Ernst, 2017). However, this standard-setting legislation can be expected to have an impact on third countries, especially developing countries (Kuner et al., 2017).

Data-protection regulations

The GDPR hardly tightens the content of European data-protection law; rather it integrates requirements already established by the case law of the European Court of Justice (ECJ), e.g. the 'right to be forgotten' (right to erasure), an obligation to delete unlawfully processed data (Article 17 of the GDPR). One innovation is the right to data transferability (also called data portability) in Article 20 of the GDPR. A user may request all personal data from one provider in machine-readable form so that it can be transferred to another provider. For example, it must be possible to transfer data (e.g. an address book) from the smartphone of one brand to the smartphone of another brand. The GDPR thus obliges providers to develop and apply interoperable formats for data in order to reduce barriers for users wanting to switch providers (recital 68 of the GDPR). Article 25 of the GDPR enshrines the often demanded principles of 'data protection by design' and 'data protection by default'. Data protection by design means that new products are to be developed in such a way that they enable data protection. Data protection by default means that the default settings of a product must always provide the highest level of data protection, which users can then actively change in their data-protection settings. Article 32 of the GDPR obliges responsible company officers to ensure the security of data during processing operations by taking appropriate technical and organizational measures. In order to prove that these obligations have been fulfilled, these officers are referred to the certification procedures regulated in Article 42 of the GDPR (Article 25 (3), 32 (3) of the GDPR). By introducing the certification procedures in the GDPR, the legislative bodies are focusing on an alternative to the previous data-protection model, which was characterized by strict supervision, and are becoming more active from an advisory rather than a sanctioning perspective (Raschauer, 2018). The embedding of information rights in the form of a right of information for the data subject (Articles 13–15 of the GDPR), extensive documentation obligations for data processing and protective measures (e.g. Article 5 (2)), and obligations to report violations of the protection of personal data to the supervisory authority and the data subject (Article 33 of the GDPR) lead to more transparency and control for data subjects. This strengthens their position vis-à-vis all those who process data.

For high-risk data processing, those responsible must furthermore carry out data-protection impact assessments in advance, on the basis of which the data-protection authorities carry out a prior check (Articles 35 and 36 of the GDPR).

Enforcement of the GDPR

Articles 51 to 76 of the GDPR strengthen the national supervisory authorities and their cooperation. With a view to improving enforcement, Articles 77ff. of the GDPR lay down regulations on the legal protection of the data subjects vis-à-vis the data-processing companies and organizations and their responsible officers. In addition, Articles 82–84 of the GDPR provide for higher fines and penalties for breaches of data protection than in the previous legal situation and extend obligations backed by fines; this means of enforcement is now much more important than under Europe's previous data-protection law (Eckhardt and Menz, 2018). Fines imposed on companies are set out in Article 83 of the GDPR. Group profits are treated uniformly by the authorities when determining the level of sanctions, and the amount of the fines is based on the turnover of the group as a whole (Article 83 of the GDPR). In the case of Facebook, for example, fines of up to 1.3 billion euros could be imposed (Kugelmann, 2018).

Non-EU managers operating on the European market must appoint a representative within the EU. This makes the company more accessible for authorities and affected users. The Basic Data Protection Regulation strengthens the national supervisory authorities and their cooperation in a European Data Protection Board, which can now issue guidelines for a uniform interpretation of the GDPR (Article 70 of the GDPR).

Assessment

The GDPR can be understood as the rather late regulation of a socially important area. At the same time, the emergence of the GDPR illustrates the duration of societal negotiation processes in areas that are sensitive to both business and human rights. Negotiations on the GDPR took from 2012 to 2016; it became valid EU-wide in 2018. It thus took six years for this European law to be drawn up and adopted. The GDPR is perceived as the most influential data-protection regulation that has ever existed; it could influence the development of data-protection law worldwide (Kuner et al., 2017; Privacy International, 2018b). For example, it has been extensively taken into account in the preparations for the currently emerging Indian Data Protection Act (Kipker, 2018). It remains to be seen whether the high level of data protection will also be perceived as a competitive disadvantage and there will thus be pressure to weaken the rules (Selmayr, 2018). The GDPR's success and effectiveness will depend primarily on how it is fleshed out and enforced by the supervisory authorities, the European Data Protection Board and the courts, as well as on how ambitiously the certification procedures and joint rules of conduct to promote data protection supplementing the GDPR are designed. The latter are being developed in cooperation between the Member States, companies, the European Commission and interest groups. The introduction of the GDPR has also led to extensive debates within Europe. Criticism of inadequate support for the introduction process has been voiced, as the extensive documentation obligations under the GDPR have led some small providers, e.g. blogs, to give up in view of the technical requirements of data protection and take their sites down as a precaution (Dachwitz and Kurz, 2018). Professional technical support during the introduction of regulation seems necessary to promote the acceptance of complex regulatory regimes.

The GDPR shows that state or supranational data protection is possible and appears to be becoming increasingly effective across the board. The GDPR will have to prove its effectiveness above all vis-à-vis major data-processing corporations such as Facebook or Google. Facebook founder Mark Zuckerberg calls for an active role of governments in the regulation of companies operating on the internet and a worldwide data-protection regulation similar to the GDPR (Zuckerberg, 2019). Yet Facebook has hitherto only recognized changes for the EU and only at the level of terms and conditions, so that a consistent enforcement at the data-protection level remains open (Privacy International, 2018c). The GDPR has already succeeded in drawing attention to data protection and broadly embedding the topic in institutions. Its introduction has also generated many side effects that could affect acceptance by the population. By applying the principle, according to which the user's place of residence is decisive, not the company's registered office, the GDPR now also applies to companies based outside the EU that process data on EU citizens. It remains to be seen whether companies operating inside and outside the EU will now apply data protection uniformly under the GDPR (Privacy International, 2018b). The GDPR has the status of reference material in international data-protection development (Privacy International, 2018a) and should therefore be the starting point and subject for international cooperation in the field of data protection and data-protection law; this can include a platform with associated case law, support for transfer to other legal systems and international convergence processes in data-protection law (Kuner et al., 2017).

emergence, organization and multiplication of transnational initiatives and connections in the polycentric governance system. Digitally supported environmental monitoring (Sections 3.3.5.1, 5.2.11) or support for policy implementation, for example, can be used to build up effective transparency, accountability and pressure to act within the framework of the 'REDD+' mechanism or the implementation of the Paris Agreement. The relationship with national governments and companies can also be powerfully reinforced here. The Climate Action Network, an umbrella organization of over 1,300 environmental NGOs, monitors the UNFCCC process closely, critically and competently, e.g. with an extensive digital newsletter service covering the UNFCCC negotiations. The Emissions Gap Report, prepared by renowned climate scientists and published by UNEP, is a prominent example of how in future not only the status of climate change, but also the implementation of climate policy can be better monitored and made transparent by non-state actors (UNEP, 2018).

4.2.7.2
Transnational organizations in the management of digital infrastructures

Transnational organizational structures and networks play a decisive role not only in the immediate sustainability context. With globalization, transnational cooperation is becoming increasingly important for the development and management of basic digital and digitalized infrastructures, such as the internet. Under the heading 'Internet Governance', the discussion focuses on how and which common principles and standards can be adopted by governments, the private sector and civil society for decisions and decision-making procedures relating to the internet (WGIG, 2005; Hofmann, 2017). Actor groups involved in this governance include private companies, associations and organizations of the tech community, states and intergovernmentally initiated organizations and forums (e.g. Internet Governance Forum – IGF, NETmundial) as well as civil society (Hofmann, 2017). In particular, the technical development of the internet and the international management and allocation of domain names and IP addresses is mainly characterized by cooperation between private actors, so that this is often used as reference material for transnationalization (e.g. Viellechner, 2013; Spindler, 2014). These non-state alliances

Box 4.2.7-1

The ICANN as a transnational player in internet governance

The Internet Corporation for Assigned Names and Numbers (ICANN) is responsible for the central administration of the internet's basic functions. ICANN manages or oversees the internet addresses for the global community, the internet's unique names and numbers (internet protocols, IP addresses, top-level domains), and root servers as storage locations for the names and numbers, thus ensuring that the content and recipients mediated via the internet can be unequivocally allocated. The ICANN is a non-profit organization under private law based in California. Its primary objective is to ensure stable and secure internet infrastructures (Section 1.1. (a) ICANN Bylaws; ICANN, 2019). In a nutshell, its interest is focused on the standardization, stability, reliability, security, global interoperability, resilience, openness, and usability of the internet and its components (Section 1.2 (a) ICANN Bylaws, ICANN, 2019).

The fact that the internet is administered by a private organization like ICANN is a result of the initially informal development of the internet by the military and scientists (Section 3.1.2.1). The tasks performed by ICANN were entrusted to it in 1998 not by the international community but by US authorities (Hofmann, 2017:25). ICANN has only been operating independently of US regulatory supervision since 2016 (NTIA, 2016), when the USA yielded to long-standing criticism of US influence. Transparency and accountability are now to be established through a complex compliance procedure, which was also a prerequisite for its release into independence. The ICANN network is made up of numerous companies and organizations that work together to develop guidelines and form the link to ICANN's directories.

Decision-making at ICANN

ICANN decides on the basic guidelines for the allocation of unique names and numbers in the internet and on the organization and procedure within ICANN. ICANN's internal decision-making is based on a multi-stakeholder process where, as a rule, anyone can participate in negotiation processes. The basic assumption is that no individual interest can dominate if many stakeholders are involved in an inclusive, open, transparent bottom-up process (GCIG, 2016:80). Although ICANN thus offers opportunities for all to participate, the composition of the decisive Board of Directors is weighted, which is why not all interests are represented in a balanced way. The stakeholders with voting rights on the ICANN's decisions are the (association of) Regional Internet Registries, which administer the IP address areas, the association of regional registrars for country-specific domain names (e.g. '.de'), the association of central registrars for other domain names (e.g. '.org'), and the organization in which internet users can contribute to ICANN's work. The user community can cast one vote out of a total of 16 vis-à-vis the mainly technical and business stakeholders. Government representatives, security experts, technical experts and developers participate in ICANN's decision-making processes in a purely advisory capacity. The individual stakeholder groups are represented by volunteers from all over the world (ICANN, 2018). ICANN's policies are not subject to government supervision, nor are they binding in themselves. They become valid through civil-law contracts (including penalties for violations) with the organizations involved in enforcement (Lahmann et al., 2016), in which the ICANN has given itself extensive authority rights (Jacob, 2018).

ICANN's controversial role and the future of internet governance

The question of whether decisions taken by ICANN are sufficiently legitimate and transparent is a recurring one (GCIG, 2016:78). Decisions are taken without the direct influence of states or the international community. The question of legitimacy is also raised with regard to decision-making via multi-stakeholder procedures, as not all interests can be represented to the same extent (Hofmann, 2017), partly because of the unequal distribution of power and resources.

In response to criticism and as a condition of independence from the US authorities, ICANN introduced mechanisms in 2016 to ensure transparency and verifiability. Since then, the stakeholder groups involved in ICANN (whether with or without a vote on the Board of Directors) have been able to use the 'empowered community' mechanism to form their own organization under Californian law. They can demand accountability from the ICANN Board of Directors and individual organizational units, reject strategies, budgets and important changes to the rules of procedure, replace members of the ICANN Board of Directors and enforce these rights in court against ICANN (Hofmann, 2017). In addition, any person materially affected by an ICANN decision has the right to appeal to an ombudsperson, demand the re-submission of decisions and guidelines for re-decision by the executive board, and request access to a large proportion of ICANN documents (ICANN Bylaws). However, the tightened compliance rules also create further barriers for newcomers to participate in ICANN processes (Hofmann, 2017).

At the ITU Conference in 2014, some states, including China, India and Russia, and some developing countries, called for the amendment of the ITU Founding Treaty with the aim of transferring internet administration to the ITU. Some of these states were perhaps seeking greater influence over the internet's open and liberal organization to their own advantage. Others, particularly less developed countries, criticized the fact that participation and the intensity of stakeholder participation in the multi-stakeholder process depends on their respective economic strength and that the interests of poorer people are thus under-represented (Lahmann et al., 2016:20). The same also applies to the interests of weakly organized groups like consumers, so that consumer-protection concerns such as data protection and net neutrality can be under-represented in the multi-stakeholder process (Deutscher Bundestag, 2013). The growing private power structures in the societally important area of internet administration could require an increase in intervention by state authorities or the EU, particularly to open up the possibility of protecting the interests of all (Hoffmann-Riem, 2016). Nevertheless, there is a consensus among western countries to continue with the multi-stakeholder approach (Lahmann et al., 2016:20), which is justified, inter alia, by the already existing blockade between the different factions (Jacob, 2018). Criticism is not only levelled at the balance of power and the implementation of the interests of the common good, but also at the system's functionality. ICANN has not succeeded in ensuring a rapid global transition from the IPv4 to the Ipv6 Internet Protocol standard, despite the urgent need to switch to IPv6 in view of the growing number of internet users, end devices (e.g. rising demand for IP addresses in the IoT), and newly emerging markets (e.g. in developing countries: GCIG, 2016:52). There is no hierarchical coordinating authority that can order and enforce updates (Hofmann, 2017:10). ICANN's rules on the publicly accessible registration of domain holders also conflict with more stringent data-protection legislation, for example the GDPR (Kramer, 2018; Sarac and Strömer, 2018; Box 4.2.6-3). Furthermore, the Domain Name System (DNS) also has technical data-protection concerns (DNS Privacy Project, 2018).

The question of how ICANN's shortcomings – e.g. the obstacles to participation, the limited influence of states and civil society – can be remedied is the subject of divergent proposals. They range from the creation of a fully decentralized system of internet governance (Verhulst et al., 2014) to a UN declaration that the ICANN should be made an independent United Nations regulator (Jacob, 2018). The IGF under the UN umbrella is a central forum for discussing these issues, although no decisions can be made there (Section 8.1.2).

are organized in the form of associations and organizations of the tech communities; the WBGU takes a closer look at one example of these: the Internet Corporation for Assigned Names and Numbers (ICANN; Box 4.2.7-1). The private organization of digital infrastructures raises questions about the legitimacy of actors – especially since states and civil society, including users, can only have a limited impact on these actors (Hofmann, 2017). However, the provision of services and administration of the infrastructure, network access and communication services – organized without the direct influence of states or the international community – sometimes produces suboptimal results, e.g. lack of transparency and security risks (Hofmann, 2017).

4.2.7.3
Interim conclusion

Transnational actors fulfil numerous functions in the global governance of the sustainability transformation. As activists and lobbyists they campaign transnationally for their interests in the global public sphere, and as experts they support international processes or participate directly in negotiations as stakeholders. Since the adoption of international environmental agreements, particularly climate agreements, they have been involved as a critical public in monitoring and as actors themselves in implementation (Bäckstrand, 2015). With many companies and administrations committing to corporate social responsibility and providing digital infrastructures, transnational business and digital actors de facto often perform tasks in the common interest.

In the best-case scenario, digital networking, virtuality and knowledge growth (Section 3.4) can be positive drivers for the formation and diversification of transnational structures that have already been set in motion and which, in the future, could cumulate in a kind of critical global society or global (environmental) awareness (Section 5.3.1). Global cooperation for common global goals, such as the SDGs, could thus be driven by a multitude of actors from all sectors. As is so often the case, however, digitalization and its technologies are only the means and do not in themselves automatically have a meaningful purpose. Transnational actors and governance, too, are not emancipatory or legitimate per se. It is true that this sphere is a sounding board for transformation pioneers and policy experiments, and a post-national public sphere for mutual understanding and the building of trust; however, the digitalized public sphere can also lead to more abrupt fragmentation, societal polarization and a weakening of shared norms in the global arena (Section 5.3.2). In other words, the conscious use of digital means for the common good is also important in the transnational area to make it easier to achieve environmental and development goals in the long term.

In the field of transnational sustainability governance, digital solutions should be used to enable more empirical knowledge, cooperation and transparency. More and better participation formats for stakeholders are particularly important in the polycentric system of global sustainability policy, in order to include conflicts between very different local, social, national and global demands in the dialogue. In this way, effective and, where possible, legitimate pathways can be jointly developed, for example with regard to shaping structural change through climate change and climate-change mitigation (WBGU, 2018b).

However, the transnational internet governance architecture lacks the participation and influence of civil society, user associations and states. The actors lack viable joint structures in which decisions can be made and societal standards set.

4.2.8
International organizations as actors in sustainability governance

The role of international sustainability-governance organizations is changing in two ways in the Digital Age: first, international organizations are important for shaping the new policy field of globally sustainable digitalization (Section 8.1); second, digital technology can not only improve these organizations' ability to act, but also change their global role and function.

4.2.8.1
International organizations and sustainable digitalization

Since the 1992 UN Conference on Environment and Development, global sustainability governance has made great progress with the adoption of Agenda 21, the Rio Declaration and the three Rio Conventions on climate, biodiversity and combating desertification. In recent years, the Paris Agreement on Climate Change, the Aichi biodiversity targets (CBD, 2010; Section 8.2.3) and the aim of land degradation neutrality (SDG 15.3; UNCCD, 2016) have been adopted. The 2030 Agenda provides a catalogue of goals for global sustainability policy in the next decade. On the other hand, the effectiveness of international organizations is insufficient, given the size and complexity of global environmental and social problems. Climate change, in particular, has not been sufficiently contained up to now. An intergovernmental agreement – for example on the establishment of an international organization – does not necessarily overcome dynamics of interests and power (Bernstein, 2002; Marcoux, 2011; Purdon, 2017).

The challenge is therefore to implement and enforce the 2030 Agenda and the Paris Agreement (Beisheim, 2018). The United Nations, particularly the High-Level Political Forum for Sustainable Development (HLPF), is the central forum for this. Other key actors in international sustainability governance include the Bretton Woods institutions (World Bank, International Monetary Fund), the World Trade Organization (WHO), the OECD, the G7 and the G20 (Section 8.1).

Almost 30 years after the Rio Summit, the question now arises as to whether international organizations, particularly the United Nations, which is in the process of reform, need to reposition themselves in order to shape the Digital Age in a sustainable way. This also involves how the international community deals with new, powerful players in the global digital economy (Box 8.4-1). Similar to sustainability, digitalization involves shaping a cross-cutting task and a policy area with new challenges, including its own institutions and processes. Here, too, crisis phenomena occur when neither national policy nor the international system offers an adequate regulatory framework (Anheier et al., 2018). This applies particularly to rapid and fundamental technological developments that can overtake and overstrain the dynamics of institutional arrangements. A critical public that includes watchdog groups, think tanks and activists and demands transparency and accountability is also a decisive corrective here (Sections 4.2.3, 4.2.7).

Overall, the international community's ability to cope with global challenges has tended to weaken in recent years. There are two main reasons for this: first, areas like digitalization or climate change currently pose immense challenges to the governance capacities of national governments and international organizations and require new modes of governance (Anheier et al., 2018); second, the legitimacy of international organizations – as well as that of the liberal, regulation-led world order as a whole – has been increasingly called into question in recent years by nationalistic and globalization-critical movements in Europe and the USA (Hale and Held, 2017; Ikenberry, 2018; Norris and Inglehart, 2018). The key challenge is therefore how to shape digitalized sustainability societies despite the current crisis of multilateralism. However, the crisis of the multilateral system does not mean its end, as new multilateral institutions can be set up at the same time (Brühl, 2019). Examples include the establishment of new multilateral institutions such as the New Development Bank (NDB) or the Asian Infrastructure Investment Bank (AIIB), which are a response to the Bretton Woods system that emerged after the Second World War and reflect the shifts in the global balance of power, e.g. the rise of China. The same applies to the G20's call for the WHO rules to be adjusted to take China's current global importance into account (Anbumozhi et al., 2017). Seen in this light, the moment of crisis also offers an opportunity to permanently embed the issue of digitalization in international organizations, especially within the framework of the United Nations (e.g. the UN Fit for Purpose debate; Sections 8.1.3, 8.4). In concrete terms, this will involve embedding the issues of sustainable digitalization and digitalization for sustainability, as well as creating a central authority in the United Nations system. Although the UNFCCC process, for example, was protracted and continues to be so, it was a prerequisite for climate change to establish itself as a subject of international policy and for internationally coordinated measures of climate-change mitigation to be agreed upon (Hamilton, 2017). A similar process could also be initiated to deal with privacy or autonomous systems and AI. This would also be a long process, but, as with climate change, the impetus also for digitalization can come from the scientific community, which must go on the offensive and communicate its findings before they can become the subject of political cooperation at international level.

4.2.8.2
Changing role and function of international organizations

Digitalization simplifies and accelerates global communication and information flows – and this applies to all societal actors, organizations, business and individuals. In particular, the expanded possibilities for monitoring will further facilitate and accelerate the reporting system required for reviewing global environmental regimes and enable observations to be made in real time (Section 5.2.11). In addition, digital technologies open up new possibilities for creating global (environmental) awareness (Section 5.3.1), which could, at least potentially, have a positive effect on global sustainability policy. Furthermore, multilateral negotiations have become much more transparent through live transmissions on the internet – as practised, for example, by the Green Climate Fund of the Framework Convention on Climate Change – and could also have a beneficial effect on global cooperation culture. In view of the currently increasing frequency of false information and targeted disinformation campaigns (e.g. on man-made global climate change), international sustainability-governance organizations, which provide central global knowledge resources with their fact-based reporting and reports, will in future have to assume a new role in terms of informational quality assurance.

4.3 Use windows of opportunity for sustainability transformation

Analysis of the actor structures influenced by the dynamics of digitalization in today's societies points to situations of upheaval in which contradictory trends become visible. Sustainability breakthroughs are becoming possible while, at the same time, path dependencies are perpetuating established growth patterns. Digitalization itself also promotes constellations of actors that can inhibit transformations towards sustainability. Digitalization and disruptive technological advances by no means automatically create sustainable behaviour by the actor groups and the alliances and guiding principles of sustainability outlined in Section 4.2, but they do open up windows of opportunity for change. Sustainability strategies and policies must take these moments of dynamic change into account in order to support actor constellations that favour sustainability breakthroughs. Digital change generates change processes characterized by three patterns; these are outlined in the following Sections 4.3.1 to 4.3.3.

4.3.1 New options and change alliances

The dynamics of digitalization change actor constellations and quickly create new actor groups, often with disruptive effects. In just one or two decades, digital companies have become the largest corporations in the global economy and thus transnational actors (Sections 3.1, 4.2.2, 4.2.7). They are transforming production, business models (e.g. with digital startups or virtual value chains), trade and investment flows. In this context, a new group of actors has emerged: the tech communities. They consist of algorithm experts and other digital experts, who influence and change the economy, society and consumption patterns through their work as programmers and software developers, for example. Many people around the globe can now network, exchange ideas, learn and organize themselves politically via social media. Such changes made possible and accelerated by digital technologies are modifying national and transnational networks of people, companies and organizations. Long-established actor constellations and path dependencies are being broken up, a new range of options and opportunities for change in the economy and society are being created. Change alliances, new perspectives and visions of the future can develop. The disruptions caused by digital technology thus also open up opportunities for advancing sustainability processes.

- There is a general tendency for corporate business models and technologies – particularly those of digital companies – to be less directly dependent on the use of natural resources, especially fossil fuels, than in the traditional economy. Knowledge is at the centre of digital business models, not the extraction of (natural) raw materials or the combustion of fossil fuels, although digitalization is associated with considerable energy and resource requirements. Digital companies are more likely to be convinced by ideas of post-fossil and cycle-oriented management than classical industrial companies and can thus become allies in the Transformation towards Sustainability.
- The innovative spirit and power of the tech communities can be combined with sustainability innovations and renewed prospects for the future. The sustainability community demands transformations towards sustainability. The digital economy is creating new, different markets, standards and changing patterns of behaviour. Opportunities could arise here if the digital community's willingness to change and dynamics for change could be combined with sustainability models and perspectives (Box 4.3.1-1).
- Digitalization makes new forms of economic activity and consumption possible. Digital companies oriented towards the common good emerge in which the inclusion of employees is strengthened. Prosumers can manufacture their own products or media offers and thus create their own public spheres. Digital technologies increasingly make it possible to check, document and reveal to consumers where and under what circumstances products have been man-

Box 4.3.1-1

Institutionalize the tech communities' sense of responsibility for sustainable development

The WBGU sees the following possible building blocks for mainstreaming and institutionalizing sustainability issues in the tech communities:

Sustainability by design
Since values inscribed into digital systems affect society as socio-technical realities (Brey, 2010), a critical examination of these value inscriptions should be carried out as a basis for consciously promoting and establishing well-thought-out values, also in order to be able to understand values from the sustainability context (Section 4.2.4). In addition to promoting privacy, trust and (cyber) security by means of appropriate technology design, a concept for 'sustainability by design' could already embed sustainability at the design stage, for example by taking energy and resource efficiency into account at the development phase. This also includes developing guidelines for the value-sensitive development of e.g. data collections, algorithms or heuristics, particularly "in areas in which far-reaching decisions are made on the basis of precisely these data situations and forecasts" (Simon, 2016: 363).

Technological social responsibility
At the company level, technological social responsibility could be established in addition to an increase in corporate social responsibility. Under this label, digital companies in particular should address how their business models and practices affect wider society.

Responsible technology development
Strategic support for the responsible use of digital technologies also comes from research funding. Currently, national and international sponsors are increasingly promoting responsible research and innovation, i.e. research and innovation that is oriented towards societal goals and ideals, including sustainability goals (Responsible Research and Innovation – RRI). The UN's sustainability goals should also be explicitly embedded and demanded (Section 8.2.1).

Weizenbaum oath – a professional ethic for the sustainable design and use of digital technologies
Professional organizations like the Association for Computing Machinery (ACM), the first scientific society for computer science with 78,000 members worldwide, or the German Society for Computer Science (Deutsche Gesellschaft für Informatik) want to give orientation to people who design, manufacture, operate or use ICT systems with recently updated ethical guidelines (ACM Ethics, 2018; GI, 2018). These and similar initiatives provide starting points for the development of professional ethics for the sustainable design and use of digital technologies. A Weizenbaum oath could commit the tech communities to general principles guiding the development and application of digital technologies. These principles should also be an established part of the education and further training of experts.

ufactured. All these possibilities of combining digital changes with sustainability transformations have not yet been exhausted. But the conditions for the possibility of digital sustainability societies are emerging (Section 4.2.4).
- Digital communication allows sustainability movements – such as Fridays for Future activists or committed cities – to network around the world and thus push societal change across borders. Digital technologies can enable NGOs from developing countries to document and globally communicate environmental degradation anywhere on Earth.
- Global communication opportunities allow international organizations to network better with local actors. Global reporting is made easier and multilateral negotiations more transparent through live transmissions on the internet (Section 4.2.8).

New opportunities are emerging for sustainability policy, sustainability movements and sustainability-oriented companies to form alliances in order to initiate changes towards sustainability that are far from exhausted.

4.3.2 Shadows of the past: path dependencies perpetuate destructive growth paths

Path dependencies also persist in open, disruptive moments of societal development. Old business models, forms of unsustainable management and consumption are being continued with digital methods. Traditional industrial companies are using digital technologies not only to increase their resource and energy efficiency, but also to scale up traditional, resource- and emission-intensive business models. Consumers are expanding their consumption of resources via online commerce. High energy consumption, overexploitation of limited raw-materials reserves, and market power used to push through low wages and social standards are not limited to traditional sectors of the economy; they also continue in the business models of digital corporations with market power. Digital communications also facilitate the establishment of global value chains that can multiply resource consumption and greenhouse-gas emissions. Not only sustainability movements use global communication channels; enemies of democracy and aggressive nationalists do so, too. States can also continue promoting resource- and climate-damaging developments and strengthening path dependencies, e.g. by subsidizing the combustion of fossil fuels, thus preventing digital technologies from being mobilized for climate protection.

4.3.3
Digitalization itself creates power alliances and barriers against sustainability transformations

Digitalization is opening up opportunities for sustainability transformations in the current situation of upheaval. At the same time, it is being used to perpetuate unsustainable economic activity and create new power alliances and blocking mechanisms that make the transition to sustainability more difficult. States' ability to act is of key importance for sustainability transformations. States create framework conditions and incentive systems, and are responsible for implementing an orientation towards the common good, without which transitions to sustainability cannot succeed. The ability of nation states to act has already been weakened by globalization, as more and more problem constellations, financial flows and actor networks are becoming international, while states' decision-making sovereignty remain restricted to national territories. Digitalization seems to be shifting the potential for shaping the economy and society further in the direction of private actors:

- Societally crucial infrastructures of the Digital Age – e.g. information sources and communication channels such as the internet – are being created by private organizations and companies, without states exerting enough influence, laying down a socially and environmentally compatible framework, or offering public-service infrastructures based on their obligation to advance the common good and their guarantee responsibility (Sections 5.3.5; 4.2.2; 4.2.6; 4.2.7; Box 4.2.7-1). In addition, the public sector is often dependent on the know-how and financial strength of the private sector when it comes to implementing IT projects such as digitalizing the transport sector (Section 4.2.5). This transfer of responsibility for the infrastructure to the private sector in the digital sphere tends to work against the idea of shaping digital infrastructures in a way oriented towards the common good in the broad sense.
- One can observe the increasing power of large digital corporations to exert influence on core areas of society such as the media landscape, digital security infrastructures and the use of big data. For example, digital companies are documenting human behaviour to an unprecedented extent, evaluating personal data and trying to influence users' and consumers' decision making (Sections 5.2.3, 5.3.7). This results in invasions of privacy, and democratic problems can arise if it is not possible to limit corporate power in a way that is oriented towards fundamental rights and the common good.
- Many countries' room for manoeuvre in corporate taxation has already been significantly reduced in the past by globalization dynamics impacting on the tax base. The further decline in the importance of a company's physical presence in generating profits as a result of virtualization further weakens the ability of countries to tax companies appropriately (Box 4.2.2-2; Section 4.2.6).
- The individual is situated in an area of tension between changing values and knowledge, the digital economy's business models, state regulation and technology. In particular, the conditions for exercising and protecting fundamental human rights are changing in the digital sphere. Because of the use of digital services, different privacy-protection categories become relevant from those that have hitherto regulated privacy offline (e.g. the special protection of the home to ensure privacy). The right to privacy and the associated risks to identity, self-determination and creativity must therefore be discussed anew and intensively (Trepte, 2016a). Negotiations must also be conducted on the scope of freedom of expression and the prerequisites for equal inclusion opportunities. In the Digital Age, the right to the protection of and respect for human dignity (e.g. Article 1 of the Basic Law) is of particular relevance for the interpretation and application of the fundamental and human rights just mentioned (Section 2.3): human dignity must always be respected – in the sense of an *ultima ratio* – in all political negotiation processes and legal evaluation and assessment processes. Otherwise the pendulum might swing in the other direction. Digital surveillance systems based on big data and AI enable authoritarian states to comprehensively control their citizens and punish them for 'inappropriate behaviour'. When thought through to the end, the freedom of the individual, the protection of privacy and democracy itself are called into question in such contexts (Box 4.2.6-2).

Digital innovations create additional, new democratic problems in the Digital Age. Automated decision-making systems, which are increasingly being used (or can be used) by companies, courts of law, the police or even in the design of autonomous mobility systems, raise diverse questions of democracy and transparency that affect interactions between people, institutions and AI-controlled technical systems (Section 4.2.1) – and challenge the decision-making sovereignty of individuals and societies (Box 4.3.3-1). Key questions are

Box 4.3.3-1

Decision-making sovereignty in core societal areas

Since about 2013, developments in AI – especially the analysis of large amounts of data (big data: Section 3.3.2) by means of (deep) machine learning (Section 3.3.3) – have also been widely discussed with regard to their societal impacts (Mayer-Schönberger and Cukier, 2013; Domingos, 2015; Tegmark, 2017 Harari, 2018). Indeed, the implications of automated decision making and decisionmaking support in societally relevant areas deserve special attention. In clearly definable technical processes, the aim of a decision is usually clear and undisputed. An undesirable result would be relatively easy to identify and classify as such. An example of such a process might be self-driving vehicles or production processes in factories. In the defined scenarios and contexts, such systems are supposed to function without direct human intervention.

In societal processes, by contrast, the use of machines for decision making and decision-making support is more problematic. Implementing societal goals, like defining them, is a political negotiation process determined by ideas, norms and interests. Political and normative issues are always characterized by potentially conflicting interests and values. Against this background, when machines are used in decision making and decision-making support, goals cannot be universally defined and results cannot be universally evaluated – unlike, for example, in the case of a self-driving car. Yet machine-based decision-making support also holds great potential for governance: people work slowly, they can be wrong or biased. Automated decision-making support – e.g. in police work, in court proceedings or in economic-policy distribution decisions – removes these weaknesses from the equation, at least in principle because a possible bias can still remain in the training data. However, automated decision making in the context of societal processes – in addition to dealing appropriately with general technical challenges and limitations (Schinzel, 2017; Zweig, 2019) – is fundamentally confronted with the question of where the boundary lies between technically solvable problems on the one hand and normative, political and legal questions and responsibilities on the other. This boundary is not clear-cut and is itself dependent on societal priorities. Against the background of this lack of clarity, a number of problem areas arise for the use of automated decision making and decision-making support and for the use of AI in societal contexts, which are outlined below. Then follows the question of how these problem areas can be contained and which framework conditions and intervention points can ensure human decision-making sovereignty.

Potential problem areas

To begin with, there is the potential problem that automated decisions lack transparency and traceability – in two ways: First, automated decision making and decision-making support in societal processes is to some extent detached from the normative and political character of these processes, because automatisms are subject to rules and data which operate in a 'black box', making them practically inaccessible to the general public (Pasquale, 2015; Lischka and Klingel, 2017). In cases where social perception attributes special precision and objectivity to corresponding systems, the mere fact that a decision was brought about with the aid of machines lends a certain authority to this decision (Beer, 2016) – in a similar way to the already observed quantification of societal decision making (Rieder and Simon, 2016; Mau, 2017). The fact that decisions in core societal areas are characterized by potentially conflicting interests and values can thus be sidelined in society's perception in view of a decision-making process that seems purely technical – which would complicate an appropriate societal debate (Pasquale, 2018). "If there is no room for discourse until after a design process is completed, decisions are more likely to be accepted as given" (Lischka and Klingel, 2017). In addition, problems such as an inherent bias in the underlying data or an insufficient amount of data (Schinzel, 2017; Schwarz et al., 2019; Zweig, 2019) may remain unresolved unless there is appropriate auditing, certification and decision-making sovereignty (Bertelsmann-Stiftung and iRights.Lab, 2019).

Second, challenges for automated decision making and decision-making support in core societal areas can stem not only from the perhaps non-transparent use of technology, but also from the characteristics of the technology itself. Certain forms of AI are not directly comprehensible because of their intrinsic complexity (Domingos, 2015). Solution pathways found through machine learning are mathematically, but not necessarily objectively, comprehensible. Experts can understand the individual steps in the decision-making process, but this does not necessarily make the overall picture accessible. This requires a representative explanation of each case. The question must be asked: according to what measure is a particular solution preferable to the immense number of alternatives? The challenge of making automated decision making and decision-making support comprehensible and verifiable in view of this intrinsic complexity is all the more important – but also more difficult – given the limited institutional capacities and technical knowledge on the part of both the users and those affected by machine-based decision making in societal contexts (Lischka and Klingel, 2017). As a consequence, questions of accountability also arise at the institutional level, i.e. the ability to explain and justify decisions proposed or made (Doshi-Velez et al., 2017; Vedder and Naudts, 2017).

Strategies for maintaining decision-making sovereignty

In view of the problem areas outlined here, it must be ensured that societal decision making and decision-making support, even if they are machine-based, are ultimately the responsibility of people, or at least that people have the knowledge and ability to intervene at all times. It is therefore a question of ensuring decision-making sovereignty. "Decision-making sovereignty refers to the ability to understand the origins of and justifications for decisions and recommendations for action made by autonomous systems and assistants, and to influence them through human intervention if necessary" (Beyerer et al., 2018). Responsible, forward-thinking handling of automated decision making and decision-making support must not be limited to simply referring to existing regulations. Rather, it is entirely in line with the Second Dynamic of the Digital Age (Chapters 2 and 7) to ensure as a precautionary measure that the necessary societal framework conditions are created.

In addition to societal debate and technology-oriented education, it is particularly necessary in this context to ensure that automated decision making and decision-making support in societal processes is always comprehensible, that responsibilities are clearly defined, and that corrective measures can be taken. This requires the establishment of an appropriate institutional framework for accountability within existing legal and political systems covering the use of automated decision making and decision-making support (Scherer, 2016; Doshi-Velez et al., 2017; Kroll et al., 2017; Vedder and Naudts, 2017; Saurwein, 2019). The chance of reasonable traceability can be increased, for example, by 'labelling' the use of automated decision making and decision-making support, disclosing information about underlying data, and giving access for independent third parties to check the quality of machine-based decision making and decision-making support (Lischka and Klingel, 2017; Bertelsmann-Stiftung and iRights.Lab, 2019, Section 3.2.5). Legal responsibility in the sense of liability for machine-based decision making and decision-making support would also create economic incentives to minimize the consequences in societally sensitive areas (Scherer, 2016). Possibilities for correction are offered in particular by defined intervention points in the decision-making process. According to the principle of 'meaningful human control', human beings should retain the right to make the final decisions and the responsibility for machine-supported or machine-made decisions (this is currently the subject of intense discussion with regard to autonomous weapons systems: Horowitz and Scharre, 2015; Crootof, 2016; Santoni de Sio and van den Hoven, 2018). In addition to such specific measures to maintain decision-making sovereignty in societally relevant areas, technical requirements, which should be applied generally in automated decision making and decision-making support, should also be considered in the case of societal issues. These include decentralized decision-making structures, for example in the financial sector, in order to avoid chain reactions or a single point of failure (Contratto, 2014; Section 9.2.2.2).

Finally, however, any application of automated decision making and decision-making support must be critically thought through in view of its societal implications. The solution to the associated challenges may lie not only in the revision or restriction of technical processes, but also in a conscious societal decision never to delegate certain questions to machines. "No algorithmic system can circumvent the necessary and endless conversations that these ultimately political and moral questions demand" (Pasquale, 2018).

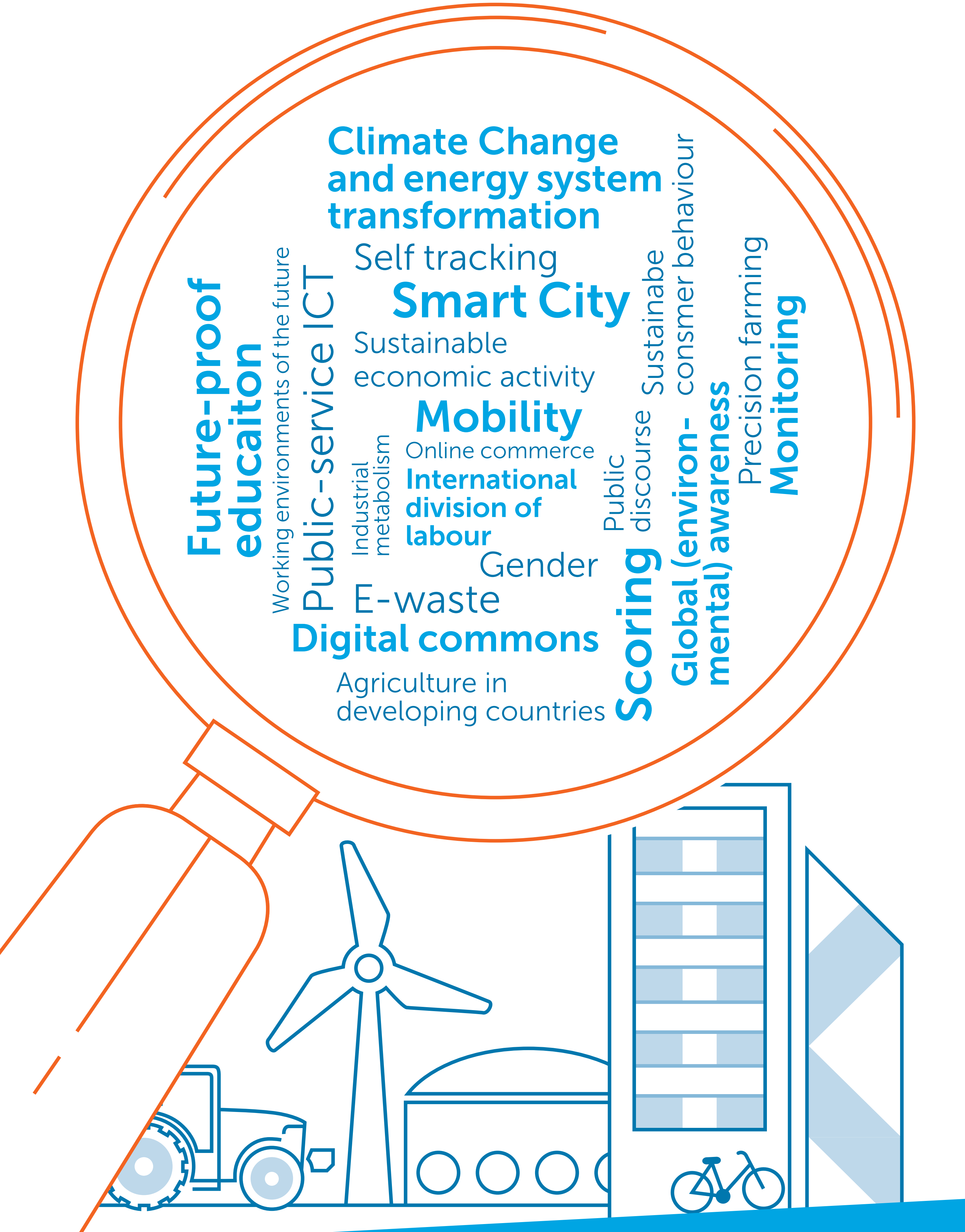
therefore: How can people's ultimate control of societally relevant decisions be ensured? What standards are needed in order to develop, implement and monitor algorithms that are compatible with democracy and human rights?

4.3.4
Conclusions

The analysis of the changes in actor constellations driven by digitalization dynamics shows that today's societies are in motion. Technological developments are profoundly and rapidly changing business models, guiding principles and actor networks. Sustainability transformations no longer only take place in situations of conflict between the climate-damaging and resource-intensive economy and sustainability alliances, but also in societies undergoing digital upheaval. An open situation is emerging in which three interrelated trends are becoming visible. *First*, digital change and sustainability transformation could be brought together by new change alliances linking sustainability and tech communities. Starting points, manifold opportunities, areas where there is ample leeway, and windows of opportunity for such a path to digital sustainability are identifiable. *Second*, it can also be observed that climate-damaging and resource-intensive business models, growth processes and consumption patterns are being continued with digital technologies – this still seems to be the key trend that needs to be reversed. *Third,* it is becoming clear that digitalization can also create new barriers and challenges for sustainability transformations. The use of digital systems can encourage private and governmental abuse of power, undermine the rights of individuals, and create entirely new design challenges, e.g. when it comes to controlling automated technical decision-making systems. All these trends must be anticipated and turned around productively in the sense of the Transformation towards Sustainability (Chapter 7).

Seldom have there been so many opportunities for a fresh start. Sustainability actors who have so far largely neglected digital change dynamics must use the outlined upheavals to steer developments towards sustainability: it is necessary (1) to form new alliances – locally, nationally, trans- and internationally; (2) to develop new guiding principles for the digitalized sustainability society with new partners, so that polycentric responsibility architectures for sustainable digital societies can emerge; (3) to advance institutional and regulatory innovations in the context of this upheaval in order to open up and consolidate sustainability paths; (4) to understand the new challenges of digitalization for a development that is compatible with both humans and the Earth system; and (5) to develop solutions that will at the same time lead to a changed understanding of sustainability.

The Digital Age is an age of networking and it requires shaping in diverse ways using both well-known and completely new governance mechanisms and actor relationships. Instead of a purely top-down approach or relying on the self-healing powers of markets, a polycentric responsibility architecture makes it possible to incorporate the large number of actors who determine the Digital Age as responsible (co-)designers in the Transformation towards Sustainability.


Climate Change and energy system transformation
Self tracking
Smart City
Sustainable economic activity
Mobility
Online commerce
International division of labour
Gender
E-waste
Digital commons
Agriculture in developing countries
Future-proof educaiton
Working environments of the future
Public-service ICT
Industrial metabolism
Public discourse
Scoring
Sustainabe consmer behaviour
Global (environ-mental) awareness
Precision farming
Monitoring

Arenas of Digital Change

5

In view of the broad scope of the two topics of digitalization and sustainability, in this report the WBGU uses an approach based on examples, which it calls arenas of digital change. These are thematic 'deep drillings' that illustrate the prospects and challenges of digitalization in selected areas and provide a multifaceted impression of how they can be shaped in the service of the Transformation towards Sustainability. They deal with interactions between digitalization and the environment, key social and economic dimensions, and issues that will not have an impact on society until the longer term.

5.1
Introduction

This chapter presents examples of 'arenas of digital change' relating to digitalization and sustainability. It gives concrete examples based on scientific evidence to illustrate the status, prospects and challenges of digitalization in view of the need for a global Transformation towards Sustainability. The arenas provide a varied impression of the manifold possibilities, on the one hand, of how digitalization can be shaped in a positive way and, on the other, of the dangers that digitalization can pose in the context of the Transformation towards Sustainability. The arenas of digital change are places or fields of action that have three things in common: (1) they allow an in-depth scientific view of specific subject areas, (2) they are significantly influenced by digitalization, albeit in very different ways, and (3) they have a connection with sustainability and illustrate how digitalization can be shaped in the service of the Great Transformation towards Sustainability. Furthermore, these insights provide a background that makes it possible to better identify the future Three Dynamics of the Digital Age (Chapter 7).

At the centre of the arenas are initially topics at the direct interface between digitalization and sustainability, such as monitoring biological diversity, e-waste and the circular economy, climate-change mitigation, the energy transformation and agriculture. In addition, further arena topics have been identified where potential for both digitalization and sustainability will already become relevant in the near future (e.g. workplaces of the future, sustainable consumer behaviour, smart cities and urban mobility). Finally, topics are presented which, although their full effect will not be felt until the longer term, they will have repercussions for the environment and the Earth system, so that the societal discourse should begin now (e.g. the technologization of human beings).

The selection of the arenas was based, among other things, on the relevance and urgency of the topics at the interface of sustainability and digitalization, their potential and risks for social cohesion and environmental protection, but also their ubiquity and international significance. The sustainability goals of the 2030 Agenda were always kept in mind during the process (Table 5.1-1). Nevertheless, it should be pointed out that the arenas do not claim to be a complete set, nor do they follow a systematic approach; rather, they are intended to provide examples to create an impression of the diversity of digitalization and concrete ways in which it can be shaped in the service of sustainability.

A total of 21 arenas were analysed, and roughly divided into two categories: 'Sustainable economic activity and the environment' (Section 5.2) and 'People

Table 5.1-1
Connections between the 2030 Agenda's sustainability goals (SDGs) and the arenas of digital change, with references to their sections in brackets. Some of the names of the arenas have been abbreviated for reasons of space.
Source: WBGU

	Sustainable economic activity and the environment	People and society
SDG 1 **No poverty**	› Agriculture in developing countries (5.2.10)	› Public-service ICT (5.3.5)
SDG 2 **Zero hunger**	› Precision agriculture (5.2.9) › Agriculture in developing countries (5.2.10)	
SDG 3 **Good health and well-being**		› Future-proof education (5.3.4) › Digital self-tracking (5.3.7) › Technologization of the human being (Topic box 5.3-2)
SDG 4 **Quality education**		› Promotion of a collective global awareness (5.3.1) › Digitalization and public discourse (5.3.2) › Future-proof education (5.3.4) › Public-service ICT (5.3.5) › Digital commons (5.3.10)
SDG 5 **Gender equality**		› Digital technology as a gender bender (5.3.6) › Future-proof education (5.3.4)
SDG 6 **Clean water and sanitation**		› Enforcement of environmental law (Topic box 5.3-1)
SDG 7 **Affordable and clean energy**	› Digitalization for climate-change mitigation and the energy transformation (5.2.6)	
SDG 8 **Decent work and economic growth**	› Industrial metabolism (5.2.1) › Sustainability in online commerce (5.2.4) › Electronic waste and the circular economy (5.2.5) › Sustainable urban mobility (5.2.8)	› Future-proof education (5.3.4) › International division of labour (5.3.8) › Sustainable working environments of the future (5.3.9) › FinTech in the context of sustainable financing (Topic box 5.2-1)
SDG 9 **Industry, innovation and infrastructure**	› Industrial metabolism (5.2.1) › Sustainability in online commerce (5.2.4) › Electronic waste and the circular economy (5.2.5) › Sustainable urban mobility (5.2.8)	› Future-proof education (5.3.4) › Public-service ICT (5.3.5) › International division of labour (5.3.8) › Sustainable working environments of the future (5.3.9) › Digital commons (5.3.10)
SDG 10 **Reducing inequalities**	› FinTech in the context of sustainable financing (Topic box 5.2-1)	› Scoring society (5.3.3) › Future-proof education (5.3.4) › Public-service ICT (5.3.5) › Digital technology as a gender bender (5.3.6) › International division of labour (5.3.8) › Digital commons (5.3.10) › Technologization of the human being (Topic box 5.3-2)
SDG 11 **Sustainable cities and communities**	› Sustainability in online commerce (5.2.4) › 'Smart city' and sustainable urban development (5.2.7) › Sustainable urban mobility (5.2.8)	› Future-proof education (5.3.4) › Public-service ICT (5.3.5) › Digital commons (5.3.10)

SDG 12 **Responsible consumption and production**	› Industrial metabolism (5.2.1) › New forms of digital economy (5.2.2) › Digitalization of consumption and sustainable consumer behaviour (5.2.3) › Sustainability in online commerce (5.2.4) › Electronic waste and the circular economy (5.2.5) › FinTech in the context of sustainable financing (Topic box 5.2-1)	› Promotion of a collective global awarenes (5.3.1) › Digitalization and public discourse (5.3.2) › Scoring society (5.3.3) › Future-proof education (5.3.4) › Sustainable working environments of the future(5.3.9) › FinTech in the context of sustainable financing (Topic box 5.2-1)
SDG 13 **Climate action**	› Digitalization for climate-change mitigation and the energy transformation (5.2.6) › Monitoring ecosystems and biodiversity (5.2.11)	› Future-proof education (5.3.4) › FinTech in the context of sustainable financing (Topic box 5.2-1)
SDG 14 **Life below water**	› Monitoring ecosystems and biodiversity (5.2.11)	› Enforcement of environmental law (Topic box 5.3-1)
SDG 15 **Life on land**	› Electronic waste and the circular economy (5.2.5) › Precision agriculture (5.2.9) › Agriculture in developing countries (5.2.10) › Monitoring ecosystems and biodiversity (5.2.11)	› Enforcement of environmental law (Topic box 5.3-1)
SDG 16 **Peace, justice and strong institutions**	› 'Smart city' and sustainable urban development (5.2.7) › Monitoring ecosystems and biodiversity (5.2.11)	› Promotion of a collective global awareness (5.3.1) › Digitalization and public discourse (5.3.2) › Scoring society (5.3.3) › Future-proof education (5.3.4) › Public-service ICT (5.3.5) › International division of labour (5.3.8) › Digital commons (5.3.10) › Technologization of the human being (Topic box 5.3-2) › Enforcement of environmental law (Topic box 5.3-1)
SDG 17 **Partnerships for the goals**	› New forms of digital economy (5.2.2) › Sustainability in online commerce (5.2.4)	› Promotion of a collective global awareness (5.3.1) › Future-proof education (5.3.4) › International division of labour (5.3.8) › FinTech in the context of sustainable financing (Topic box 5.2-1) › Enforcement of environmental law (Topic box 5.3-1)

and society' (Section 5.3). Each arena concludes with recommendations for action and research. In addition, there are three Topic boxes (5.2-1, 5.3-1, 5.3-2), which highlight focused areas in a more concise form.

Table 5.1-1 shows the relationship between the arenas and Topic boxes and the 2030 Agenda's 17 SDGs. All sustainability goals are addressed, although individual arenas often involve several SDGs. A sharp dividing line in the allocation of the arenas to the SDGs would not be useful, especially since the SDGs themselves are interdependent. The allocation to the SDGs becomes clearer in individual cases when one looks in detail at the quite heterogeneous 169 targets of the 17 SDGs (UNGA, 2015). For example, the arena 'Monitoring ecosystems and biological diversity' (Section 5.2.11) has a very direct reference to SDGs 14 and 15, which deal with life underwater and on land. Indirectly, however, it is also linked to further targets of other SDGs such as climate-change education (SDG 13.3) or crime prevention (SDG 16.5). The section number provided in brackets behind the abbreviated arena names is intended to make it easier for readers to search specifically for references to interconnected SDGs.

Finally, it should be emphasized again that the arenas cannot claim to be complete. The intention is only to give examples – an approach that nevertheless offers an up-to-date overview of important topics at the interface between sustainability and digitalization.

5.2 Sustainable economic activity and the environment

5.2.1 Sustainable Industry 4.0 and the circular economy – how digitalization is changing industrial metabolism

5.2.1.1 Context: digitalization as a driver of an eco-industrial turnaround?

Digitalization is in the process of changing material aspects of goods production, as well as related logistic and other services, by fundamentally transforming the consumption of resources and materials in value chains (Malecki and Moriset, 2008). Despite several highly problematic trends in resource demand in the Digital Age (Köhler et al., 2018), digitalized control of production has raised high expectations as regards potential for making savings and recycling. There is already talk of a ‚transition to a more sustainable industrial system' (Ford and Despeisse, 2016) and of a ‚sustainable fourth industrial revolution' (Herweijer et al., 2017). By influencing the material flows and cycles of ‚industrial metabolism' (Ayres and Simonis, 1994; Sterr, 2003) and making the input-output relations of goods production more controllable, digitalization might achieve some objectives that have long been envisaged from an eco-industrial point of view: production that is highly resource-efficient, low-waste and low-emission, characterized by eco-industrial networks and synergies throughout the entire production system and/or supplier network (Clift and Druckman, 2016; Despeisse et al., 2012; Dumoulin and Wassenaar, 2014; Gallaud and Laperche, 2016; Gleich and Gößling-Reisemann, 2008; von Hauff, 2012). The increasingly prominent concept of the circular economy has the same aim, building on ideas from industrial ecology (Ghisellini et al., 2016) and focusing on sustainability effects via digital technologies (Antikainen et al., 2018; Lopes de Sousa Jabbour et al., 2018; Neligan, 2018; Section 5.2.5). So how can digitalization decisively drive the necessary eco-industrial turnaround towards resource-saving production at the global level? This section will examine selected sustainability implications of digitalization for the production of goods in industrialized and developing countries, taking into consideration the material requirements for digital devices and the effects of new, digitally coordinated production concepts (Industry 4.0), and focusing especially on additive manufacturing processes (‚3D printing', Section 3.3.5.4).

5.2.1.2 Changing material requirements through digital devices and infrastructures

The large material requirements of the digital economy create considerable sustainability problems on a global level, not only due to the quantity but also to the nature of the raw-material requirements (Köhler et al., 2018; Manhart et al., 2016; Yi and Thomas, 2007). For two decades now, the volumes of hardware and infrastructure required have been increasing at a rapid rate; furthermore, demand has been growing for electronic end devices (for data on smartphones and wearables: Statista, 2018a, b), servers, computing centres and transmission networks. In addition, devices are required for cooling and powering these systems. The growing demand for materials is also due to the progressive embedding of electronic control elements into everyday objects, especially into vehicles (Köhler et al., 2018). Even simple consumer goods are now being upgraded with electronic components for digital functions, as illustrated by the trend towards ‚smart' textiles (Schneegass, 2017).

The highly dynamic developments in many ICT fields make it difficult to offer reliable forecasts about the raw-material requirements of advancing digitalization (Köhler et al., 2018), but there are some worrying trends. According to forecasts, in 2050, for example, three times as much copper will be needed than in 2010; four times as much lithium, an important battery raw material, will be needed in 2035 than in 2013 (DERA, 2017; Schmidt, 2017). In the case of ICT end devices, for example, other important raw materials include not only certain precious metals but also various plastics and glass (Manhart et al., 2016; Wäger et al., 2015). Studies also show the increased consumption and toxic pollution of water and higher CO_2 emissions from the production of ICT goods (Higon et al., 2017; Yi and Thomas, 2007). The volumes that are not only in use, but ultimately also in waste to be disposed of, are shown by the estimated figure for 2017 of 46 million tonnes of e-waste worldwide, which is expected to rise above 52 million tonnes by 2021 (Baldé et al., 2017; details in Section 5.2.5). In addition, the operation of digital devices and systems is driving up demand for electricity, which could grow globally by up to 18%

per year over the next two decades, depending on the scenario (Andrae and Edler, 2015). On the one hand, structural change away from traditional industries such as steel production and processing towards the manufacture of ICT products may reduce some CO_2 emissions, e.g. in parts of China (Zhang and Liu, 2015); on the other hand, if traditional goods production continues to relocate internationally, this need not necessarily have a positive impact on the global balance sheet. Overall, ICT could change from a ‚low-carbon enabler' to a ‚power drainer' (Bekaroo et al., 2016).

From the point of view of sustainability, the extensive use of critical metals and rare earths, most of which are only produced in a few places in the world or in small quantities (DERA, 2017; Köhler, 2013; Manhart et al., 2016), is particularly problematic. In many developing countries, mining them causes considerable ecological damage (destruction of the landscape, use of toxic substances to release the raw material) and involves the exploitation of human labour for low wages; there are also considerable health risks. Particularly in sub-Saharan Africa, mining activities often provide little impetus for development or employment, with mechanization leading to ‚jobless growth' and currency appreciation leading to the ‚resource curse'. Furthermore, the rising demand for resources tends to drive corruption and exacerbate social and political conflicts (OECD, 2008). In principle, the trend of combining and fusing different, primarily metallic, raw materials to design certain material properties, e.g. alloys, is also problematic because this reduces recyclability and creates new challenges for waste treatment. For example, a mobile phone contains around 60 different raw materials in a mixture of various metals, plastics, glass and ceramics. The RFID tags that are essential for Industry 4.0 control processes alone can include over a dozen different materials (Köhler et al., 2018). Even products which, in the sense of ‚eco-innovations', are regarded as environmentally friendly or low-emission in operation (Faucheux and Nicolaï, 2011; Jesus et al., 2018) are often not really manufactured in a resource-saving manner or easy to recycle when the entire value chain or life cycle is considered right through to disposal (e.g. digitalized cars require a particularly large number of critical metals; Köhler et al., 2018).

5.2.1.3 More efficient production processes through Industry 4.0 and a digitally coordinated circular economy

While sustainability risks predominate in the field of digital end devices, the further development of digitally controlled manufacturing processes could change the industrial metabolism or the organization of the circular economy positively and offset disadvantages (Higon et al., 2017; Neligan and Schmitz, 2017). Potential is seen especially in reducing material inputs through increased resource efficiency in production, for example based on improved ‚eco-design' of products and better coordinated, multiple use of resources in the course of the circular economy (Section 5.2.5).

The trend theme of Industry 4.0, strongly driven by German companies and business associations (e.g. Dorst, 2016; Kagermann, 2017; Manzei et al., 2017; Schwab, 2018), promises digitally controlled and optimized production processes throughout. All supply and service partners within the value chain or the production system are integrated into the exchange of data via cyber-physical systems or the industrial Internet of Things (Section 3.3.1), and the processed (preliminary) products themselves are capable of communicating with companies and machines. It is true that the expectations of the extensive restructuring of goods production appear in principle excessive, because information deficits and resistance from some actors are still hampering the implementation of Industry 4.0 technologies (Mertens et al., 2017). There is also uncertainty about the cost-benefit balance of production based on Industry 4.0. However, the trend is probably unstoppable and is also receiving massive political support in many regions, such as the EU (Horizon 2020), the USA (National Network for Manufacturing Innovation) and China (Made-in-China 2025). It is precisely for this reason that international control approaches are needed to steer Industry 4.0 towards sustainability and the circular economy. Furthermore, industrial sectors differ considerably in their capacity to absorb such technologies, with mechanical engineering, vehicle construction, the steel industry and the manufacture of technical textiles leading the way (Schwab, 2018). The cross-sectional sector of environmental technology and resource efficiency should also be able to increase its efficiency through digitalization, but the lead markets in particular – the circular economy (waste disposal and recycling) and (raw-)material efficiency – are still poorly positioned for this (BMU, 2018: 165f; Büchele and Andrä, 2016).

The potential of Industry 4.0 to also improve environmental effects by digitally optimizing the organization and coordination of industrial value chains is increasingly a subject of discussion and included in considerations and research (Beier et al., 2018a; IFOK GmbH, 2016; UNECE, 2018; VDI ZRE, 2017; WEF, 2018). For example, in combination with cost savings, it seems possible to increase resource efficiency and reduce material and energy requirements in the production process, e.g. by reducing waste (Kagermann, 2017; VDI ZRE, 2017). However, concrete data on this are still scarce and furthermore point to a quite low potential for reducing material inputs, even using all the technical possibilities. Production companies in Germany estimate the potential at 3–4% for material input and costs (Neligan, 2018: 104; 589 companies were surveyed). Even among companies with a generally high affinity for digitalization, only up to 14% use digital approaches for resource-saving product design or improved management of material cycles. However, companies that are committed to sustainable production often rely on digital technologies (43% in the case of resource-saving product designs and up to 27% for cycle management; Neligan, 2018: 105). In general, however, the cost-benefit ratio of possible resource savings through digital technologies is difficult to determine empirically due to complex process interrelationships; they cannot be estimated in general terms.

From the point of view of industrial ecology, better management of supply chains is also regarded as a key factor for a worthwhile circular economy (Aminoff and Kettunen, 2016; Gallaud and Laperche, 2016), with ‚smart' processes facilitating reuse and recycling (EEA, 2017c; Pagoropoulos et al., 2017; Section 5.2.5). Likewise, Industry 4.0 and digital platforms can be used to improve coordination of inter-company eco-industrial networks for the subsequent use, e.g., of waste heat, by-products or waste products, in the sense of ‚closing the loop' and ‚cash for trash' strategies, thus supporting systems of ‚industrial symbiosis' (Dumoulin and Wassenaar, 2014; von Hauff, 2012; Marconi et al., 2018; Rajala et al., 2018). In general, efficient logistics reduce the number of transport journeys and optimize the use of production factors (Dehmer et al., 2017). Industry 4.0 could thus set in motion novel, regenerative ‚ecosystems' of digital goods production that spare the natural life-support systems (Moreno and Charnley, 2016). In particular, additive manufacturing (Section 3.3.5.4) promises material sustainability effects with a global reach (Despeisse et al., 2017; Gebler et al., 2014; Kellens et al., 2017). It offers great potential for resource-saving process and product innovations, including economical use of materials, on-demand production (‚batch size 1'), and business models and product designs that are better geared to the circular economy. The novel interaction of consumption and production – e.g. in makerspaces or fab labs – is also made easier (Ferdinand et al., 2016; Kohtala, 2016; Petschow et al., 2014; Section 5.2.2). However, critical questions are whether this will stimulate rebound and overproduction effects (where analyses on the cost and energy balance are still lacking), a lower quality of ‚printed' products will reduce their service life, or production stages will be eliminated or relocated.

Locational changes as a result of Industry 4.0 could also promote sustainability, especially the propagated trend towards ‚urban production' (Fraunhofer IAO, 2016; Matt et al., 2014). This term, coined by production engineers, refers to chances of ‚reshoring' by relocating the digitally controlled, ‚clean' production of goods back to locations close to cities in industrialized countries – driven by the advantages of proximity to supplier partners, potential young recruits and R&D partners (Eickelpasch, 2015; Spath and Lentes, 2012; Stiehm, 2017). This process makes the settlement of modern business enterprises and smart factories (Wang et al., 2016a) that generate skilled jobs close to residential areas a sustainability-enhancing component of the ‚smart city' (Bronstein, 2009; Graham et al., 2017a); it also supports an ‚urban metabolism' (Newell and Cousins, 2014), which is advantageous from both an eco-industrial and socio-ecological point of view (Section 5.2.7). Additive manufacturing also favours urban location trends, since the required raw materials or granulates are easy to deliver and there is a wide range of market potential in the direct vicinity (Ferdinand et al., 2016). Industry 4.0 could generally encourage a more decentralized distribution of production locations at the global level by dividing production into small units that are closer to the market and densely networked via ICT (distributed or redistributed manufacturing; Freeman et al., 2016; Moreno and Charnley, 2016; Rauch et al., 2015). However, for developing countries this tends to have a negative effect on international production based on the division of labour, for example when additive manufacturing transforms entire supplier networks and favours re-shoring back to high-wage countries, and when the discontinuation of component production streamlines value chains (Ferdinand et al., 2016; Gebler et al., 2014; Laplume et al., 2016; Rehnberg and Ponte, 2017).

5.2.1.4
Conclusions: What can digitalization do for the global transformation of industrial metabolism?

The sustainability effects of digitalization in the production of goods can ultimately only be assessed ambivalently; they also differ according to a country's level of development (Higon et al., 2017). The pollution and negative health effects associated with the material requirements of ICT hardware production primarily affect mining and electronics-industry sites in developing countries and emerging economies. On the other hand, the potential for an eco-industrial turnaround that the resource-saving coordination of material flows and the circular economy can achieve though ‚smart' product designs and Industry 4.0 still lies primarily in industrialized countries and their knowledge-intensive urban locations. It is therefore necessary, especially in

Box 5.2.1-1

Recommendations for action on the arena 'Industrial metabolism'

- *Monitor and limit the material and energy consumption of digitalization:* The trends in resource consumption for the production of digital devices and systems should be recorded at the international level and – similar to other components of production statistics – regularly documented and accounted for in life-cycle analyses. In conjunction with this monitoring, international (approval) standards, legal frameworks and environmental guidelines should be tightened up – e.g. rules that restrict the overexploitation of rare earths in mining and the use of critical metals and many composite materials – urging a product architecture that is conducive to recycling and the circular economy (EEA, 2017c). Similarly, standards and regulations must be developed for additive manufacturing that limit highly material- and energy-intensive production processes and/or rebound overproduction.
- *Expand additive manufacturing as a driver of a digitally enhanced circular economy:* In order to use the opportunities of new product designs and the production methods associated with additive manufacturing specifically for sustainability goals, this production method should in principle be placed under a 'circularity proviso' at the national and international level. Existing EU approaches to the circular economy can be specifically used as a model for additive manufacturing in order to lay down a 'circular-economy proviso' or 'sustainability proviso' on the use of materials and product design, above all relating to the recycling possibilities of the materials used.
- *Bolster sustainable digital production in developing countries and emerging economies:* Approaches of international development cooperation and technology-transfer promotion should increasingly integrate resource-saving modern production methods in Industry 4.0 and additive manufacturing. In this way, digitalization can also be used in developing countries and emerging economies specifically for sustainably designed value-added steps and production systems, resulting in eco-industrial, labour- and qualifications-related improvements. Moreover, these upgrading processes in developing countries can protect them against the expected toughening of an unequal international division of labour. While 'fab labs' and similar formats are already being used in some countries as breeding grounds for digitally enhanced innovation (Irie et al., 2018), they should be more widely disseminated and more focused on sustainability and/or environmental aspects. In developing countries that mine raw materials (e.g. rare earths) for industrial goods in the digital economy, measures should also be taken to allow larger sections of the local population to benefit from the activities, e.g. vocational training for work in mechanized mining, or benefit sharing of mining profits to enable public investment in social services and infrastructure (OECD, 2008). Starting points can be provided by contractual arrangements (e.g. mining contracts or mining codes) or the Extractive Industries Transparency Initiative (EITI), which supports public-private partnerships for greater transparency in payment and distribution.
- *Strengthen and reward corporate responsibility:* By means of concerted information and incentives, production and service companies at home and abroad should be made aware of their great responsibility for the sustainable design of digitalized goods production. A veritable responsibility culture should be established in large parts of the economy that takes into account the threat posed to the environment and the world of work by the use of digital technologies as a special factor in all business decisions. National and international industry associations can exert political and economic pressure as important information brokers and opinion formers. In addition, incentives should increase companies' willingness to take responsibility for sustainable production in the Digital Age. Approaches that have already been considered – e.g. further developing corporate social responsibility into corporate socio-environmental responsibility (CSER; Mazurkiewicz o. J.) – can be made effective, for example, by offering better terms in tenders to companies with high CSER quality values. Tax breaks can generally promote industrial 'greening', i.e. the adoption of environment-related business and management models (Demirel et al., 2017), or the formation of circular, digitally coordinated business ecosystems. Prizes should be extended internationally as incentives and be endowed with larger sums, e.g. according to the model of the German Raw Material Efficiency Award of the Federal Ministry of Economics and Energy, which, among other things, awards prizes for digital solutions to improve the recyclability of goods.
- *Set up or expand dialogue platforms that spread knowledge on the influence of digitalization on industrial material cycles:* The growing literature (and with it the acquired knowledge on sustainability and environmental aspects of Industry 4.0 and additive manufacturing) should be made more widely known among sponsors, business users and R&D actors to sensitize them to sustainability aspects. In order to achieve this, internationally oriented dialogue platforms specializing in these aspects can be established or expanded, e.g. 'Sustainable Industry 4.0' or 'Sustainable additive manufacturing' as a sub-topic of the Industry 4.0 platform.

developing countries and emerging economies, to increasingly integrate production activities into a digitally optimized and efficient value-creation system that is consistently geared to the circular economy; this helps to save material and energy inputs there, secures jobs and raises the value of work. The risks of job losses due to the relocation of production stages back to industrialized countries (Section 5.3.8) can be reduced in this way.

Additive manufacturing based on digitalization, too, offers not only opportunities for sustainable production, it also entails some risks. On the one hand, it promises advantages in material input and resource efficiency, although these are yet to be proven by analyses. The same applies to expectations that individualized production that can be co-designed by consumers promotes inclusion, self-efficacy and a solidarity-based quality of life. On the other hand, additive manufactu-

Box 5.2.1-2

Research recommendations on the arena 'Industrial metabolism'

- *Launch a research offensive on sustainability impacts of Industry 4.0 and additive manufacturing:* The expectations of resource- and energy-saving production using digital technologies have so far not been challenged by solid empirical analyses or data evaluations. Research activities funded by the BMBF or other organizations should therefore systematically record the concrete sustainability effects of the introduction of Industry 4.0 technologies. A separate priority within the Research for Sustainable Development (FONA) programme of the BMBF could be developed for this purpose. Similarly, additive manufacturing could, for example, be a building block in an overarching research programme on digital transformation that scientifically examines all the key technologies considered in this flagship report (Section 3.3) from a transdisciplinary sustainability perspective (analogous to programmes such as 'Zukunftsstadt': City of the Future). With regard to the normative compass (Section 2.2), empirical research should be conducted on various implementation options for Industry 4.0 and additive manufacturing, materials used, product types and sectors of industry, and on their impact on jobs in different parts of the world. Different location constellations should also be considered, from urban to rural, under- to highly developed. The focus should be on systemic effects and the entire life cycles of manufactured products, possibly based on approaches such as the ecological rucksack or footprint.
- *Research the potential of digital technologies for improved industrial metabolism and/or industrial symbiosis and establish them on markets:* While the dialogue platforms mentioned above promote the discourse on sustainable Industry 4.0, digital business and market platforms combined with other digital technologies can help make industrial metabolism more sustainable. Ongoing research on digitally enhanced 'industrial symbiosis' (Marconi et al., 2018) should therefore be expanded as an element of the research into the digitally enhanced circular economy, which should be developed on principle. It should be designed as applied, transformative research, integrate different sectors of industry, and identify the opportunities, barriers and risks of digitalization for industrial symbiosis. The electrical and electronics industry should be prioritized as a field of research because of the duality between the problem of e-waste and the solution potential offered by digital technologies (Section 5.2.5).
- *Carry out social-science studies on prosumer behaviour:* Since the sustainability effects of trends such as private 3D printing and fab labs depend to a large extent on the commitment of the population, prosumer behaviour in particular should be examined in detail. Social and behavioural analyses can, for example, take into account different societal milieus or local contexts in order to determine tendencies towards rebound effects and redundancy. In this way, the potential, e.g. of additive manufacturing in shaping the sustainability transformation, can also be researched in a targeted manner to seek promising starting points for actors and institutions (e.g. how can improvements in the life-cycle assessment of digitalized manufacturing be achieved and by whom?).
- *Create real-world laboratories for a digitally enhanced circular economy in an urban context:* The chances of developing a sustainability-oriented digital production and an associated circular economy supported by spatial proximity, specifically for urban locations, deserve in-depth studies. For concepts such as fab labs (Kohtala, 2016) can be interpreted as urban transformation initiatives which, in the course of social innovation, may offer good potential for sustainable additive manufacturing. Their potential impact at the level of companies, makers' collectives and individuals must be evaluated and, where appropriate, tested using experimental formats such as real-world laboratories and prepared for upscaling. This should explicitly include cities in developing countries, possibly integrated into international partnerships for sustainable urban production based on digital manufacturing technologies.

ring could also cause rebound effects and redundant manufacturing, which must be contained and overcome together with other technological and economic challenges. Despite the broad opportunities offered by domestic production, there are dangers of a widening digital divide and labour-market exclusions due to the redistribution of work between employees of different qualification levels or in different countries (Gebler et al., 2014; Rehnberg and Ponte, 2017). The integration of companies as spatially effective actors plays a special role in designing an eco-industrially sustainable form of goods production in the Digital Age.

5.2.2
New forms of digital economy: approaches to sustainable economic activity in the Digital Age

This arena takes a look at current community-oriented forms of economic organization (Figure 8.4.1-2). It gives examples of new or 'alternative' business models, corporate forms and forms of production, including sustainable digital entrepreneurship, platform cooperatives, prosumers, and commons-based peer production. A special focus lies on new forms of participatory value creation in the sharing economy, since they in particular clearly show the potential and limits of private-sector and community-oriented economic organization.

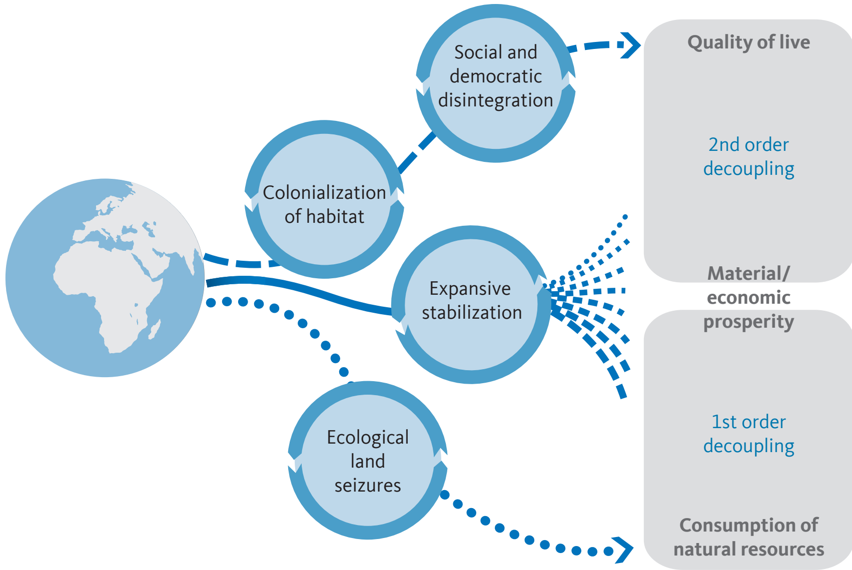


Figure 5.2.2-1
Disembedding mechanisms and their non-sustainable consequences, such as ecological land seizures, and possibilities for re-embedding the economy via 1st and 2nd order decoupling.
Source: Schneidewind, 2018:79

5.2.2.1 Re-embedding as a challenge of sustainable economic activity

The current form of global economic organization is closely linked to the breaching of planetary guardrails and ecological boundaries. The systemic causes of these developments are the 'disembedding mechanisms' of the modern economic order, which are analysed in detail by Polanyi (1944) in 'The Great Transformation': by removing economic processes from their immediate social and ecological contexts, there is an increased risk that they may have negative social and ecological consequences (externalities; Figure 5.2.2-1).

The great challenge of sustainable economic activity is to strengthen the 're-embedding' of the economy through "radical incremental change" (Göpel, 2016). By internalizing external effects, ecological and social consequences can be translated into existing economic control systems. This can be done, for example, by pricing resources or introducing minimum standards for working conditions. Environmental impacts and social consequences would thus be reflected in the economic costs and taken into account by market players in their economic actions. On the one hand, such control measures are currently difficult to implement in the short term, especially at the global level. On the other hand, there are chances that pioneers of change might be able to help us catch up with sustainability goals in the medium to long term. This could be the case, for example, with social and cooperative entrepreneurship, which combines entrepreneurial activity with ownership structures that allow a consistent orientation towards sustainability challenges (Dyllick and Muff, 2016). The following sections provide examples of how such approaches interact with digitalization.

5.2.2.2 Sustainable digital entrepreneurship

Sustainable entrepreneurship includes entrepreneurial activities that explicitly make aspects of sustainability an object of the business model and go well beyond conventional approaches such as efficiency measures or corporate social responsibility in the process (Demirel et al., 2017:2). Depending on the focus of the enterprise, other terms used here include 'common-good entrepreneurship' (Felber, 2018), 'social entrepreneurship', 'eco-entrepreneurship' or 'transformative entrepreneurship' (Burch et al., 2016; Santini, 2017). A sustainability orientation is particularly relevant during the start-up process, because here business models are institutionalized that can adopt sustainability goals in different ways (Behrendt et al., 2017). In addition to the transformation of established companies, business start-ups thus play an important role in the regeneration of the economic structure and the Transformation towards Sustainability (Borderstep Institut, 2017; Hörisch, 2015; Schneidewind, 2018:361ff.; Trautwein et al., 2018:8).

The category 'green digital start-ups' or 'sustainable digital entrepreneurship' needs to be defined more precisely in future, but it covers a broad field of activities, as the following examples show. It can include suppliers of sustainable hardware like Fairphone and Shift (Section 5.2.5), digital marketplaces for sustainable products like avocadostore.de (commercial) or fairmondo.de (cooperative), crowdfunding platforms such as betterplace.org or sharing sites like foodsharing.de, as well as greenapes.com, a "social network rewarding sustainable actions and ideas" (greenApes, 03.05.2019). Initiatives like wechange.de, which make software and communication solutions available for civil-society initiatives, are another example. The category should also include companies from the broad field of environmental technology ('clean tech') which use digitalization to contribute, for example, to the transition in agriculture, energy and mobility, as well as to the circular economy (BMU, 2018).

Despite their undisputed importance for the Transformation towards Sustainability, green start-ups are eclipsed by start-ups in digitalization and IT in public perception and in terms of funding (Borderstep Institut, 2017). Where they overlap is where the above-mentioned sustainable digital entrepreneurship forms. A key for its success, in addition to direct promotion, is the existence of supporting framework conditions in the form of sustainable business ecosystems – consisting of corresponding networks of actors made up of entrepreneurs, customers, suppliers and the public sector, as well as institutional, informal and socio-economic contexts (Volkmann et al., 2017).

5.2.2.3 Platform cooperatives as a special expression of collective entrepreneurship

Platform-based business models of digital companies could make important contributions to sustainability (e.g. climate-change mitigation). However, they are often criticized because organizational forms that focus on maximizing their return on equity can consciously or unconsciously evade regulation and thus open up 'parallel legal spaces' (e.g. Uber's penetration into the regulated taxi market). This involves the threat of ecological and, in particular, social externalization, such as the exploitation of workers and more difficult participation for people affected (Gegenhuber et al., 2018; Section 4.2.2). On the other hand, the number of platform cooperatives has increased in recent years. They are owned by stakeholders (e.g. employees, users, locally affected people) who jointly decide on the company's direction and profit intentions. From a technical point of view, they are similar to capital-market-oriented platforms, except that they are based on the cooperative model. They are embedded in the community and characterized by an orientation towards the common good, and thus towards more balanced value creation and value distribution (van Doorn, 2017a; Scholz and Schneider, 2016). Ideally, this prevents externalization effects, but cooperative forms of organization like platform cooperatives do not automatically guarantee an orientation towards sustainable development goals. Examples of platform cooperatives with a sustainability orientation that have already been mentioned here include the initiative wechange.de and the online marketplace fairmondo.de (van Doorn, 2017a).

Basically, this approach tries to combine the positive effects of platforms (economies of scale, network effects, accessibility) with the advantages of cooperatives. Cooperatives are particularly suitable for the prosumer economy (Section 5.2.2.5) because they explicitly aim to link the benefits for the members with those for the platform users. Some academics also regard platform cooperatives as highly promising because of their superiority in an expected 'zero marginal cost economy' (Rifkin, 2014), the potential for data autonomy and/or protection (VZBV, 2015:36), or their ability to provide digital commons in the sense of 'open cooperativism' (Kostakis et al., 2016).

Although platform cooperatives have societal advantages, they face a number of challenges that are currently hampering their dissemination. They rarely have the capital resources to quickly reach a critical mass of members. In digital markets with network effects and economies of scale, they thus have a structural disadvantage compared to investor-based platforms and are also at a disadvantage when it comes to the current public funding for start-ups, which is geared to the likelihood of economic success (Kagel et al., 2018). On the other hand, business ecosystems are formed around platform cooperatives which embed them in a conducive environment through (open-source) software, financing possibilities and legal advice. Examples include the Platform Co-op Development Kit (Platform Cooperativism Consortium, 2018), launched in 2018 and sponsored by Google with US$1 million, or the Internet of Ownership Project Council (ioo.coop).

5.2.2.4 Sharing economy between the classical and the collective economy

Modern sharing projects are also essentially based on digital platforms, which both promote the implementation of longer-existing concepts (e.g. car sharing) and open up new opportunities and perspectives. Currently, four basic fields of sharing can be distinguished in the sharing economy: (1) reuse of goods, (2) better use of existing objects, (3) exchange of services (e.g. time banks as presented below; Seyfang, 2004; Gregory, 2014; Diniz et al., 2018; Arcidiacono, 2018), and (4) sharing productive goods (Schor, 2016). Sharing approaches are distinguished not only according to

Table 5.2.2-1
Differentiation between sharing approaches according to their degree of commercialization.
Source: according to Gerwe and Silva, 2018, shortened

Sharing	Capital or good	Labour or time
Money-free	Couchsurfing (overnight stays)	Time-exchange circles (various activities)
Cost covering	BlablaCar (offering lifts)	Piggybee (transporting objects)
Profit-oriented	AirBnB (overnight stays)	Uber (taxi-like ride hailing)

their degree of commercialization (Theurl et al., 2015) between money-free, cost-covering and profit-oriented transactions (Gerwe and Silva, 2018; see Table 5.2.2-1), but also according to the actors involved: business-to-consumer approaches are similar to the traditional renting model, while in peer-to-peer sharing users lend goods to each other themselves (e.g. cars in peer-to-peer car sharing; Section 5.2.8).

Sharing economy for goods

Most activities in the heterogeneous field of the sharing economy (Behrendt et al., 2017) relate to goods. According to the sharing economy's basic principle of using instead of owning, value consists in access to goods, not in owning them (Behrendt et al., 2017). In the narrower sense, sharing goods is an intensification of use by hiring-out, co-use or lending; in the broader sense, it is also an extension of an object's service life by giving it away, exchanging it or reselling it (Scholl et al., 2015). This can refer to living space as in the case of airbnb.com or couchsurfing.com, but also, for example, to clothing (kleider-kreisel.de), food (foodsharing.de), or vehicles in the field of mobility (e.g. car and bike sharing). As a result, the sharing economy is credited with ecological potential (Sections 5.2.5, 5.2.8). Whether it can live up to this claim will depend, among other things, on whether there are rebound effects (Section 5.2.3) as a result of additional consumption. This could be the case, for example, if the money or time saved by sharing is channelled into additional activities or consumption (Buhl, 2014). Also relevant are the ecological costs of the possible increase in transactions (e.g. emissions from the multiple transport of goods) and the provision of overcapacity to cover peak demand. Both run counter to the goal of intensifying use and must be compared with 'conventional' consumption. Displacement effects must also be taken into account: in addition to social distortions, such as the conversion of residential space for short-term rentals, the spatial displacement of the local population also implies that they will probably have to travel further commuting distances, with corresponding environmental consequences. Sharing approaches are therefore by no means always socially and ecologically more advantageous. However, non-commercial sharing offers tend to be more environmentally friendly than commercial ones because they have more of an environmental and community orientation (Rückert-John et al., 2014; Behrendt et al., 2017).

Originally, the idea of the sharing economy grew out of a community-spirit perspective. It aims to re-embed forms of exchange into social relations (Arcidiacono, 2018). Digital technologies have strongly supported these economic practices in recent years. Through the rise of commercially oriented, mostly platform-based sharing approaches such as airbnb.com and uber.com, the currently dominant sharing economy has moved away from the original idea of community and reciprocity. There are therefore few signs that a "fundamental change towards a community-based consumer culture is taking place in the sense of a collaborative economy freed from the constraints of growth and profit" (Behrendt et al., 2017). The success of commercial sharing models lies only partly in the more efficient use of goods or more complete capacity utilization, for example by creating more marketable services with the same input (e.g. car sharing: more journeys per car instead of parking); it is also largely achieved by passing on costs and risks (Schor, 2017), i.e. avoiding taxes or ignoring labour standards (e.g. accident insurance, health insurance). Furthermore, their business models are often based on leveraging hitherto non-marketable goods or services as tradable goods (e.g. one's own home). This approach is problematic when the (in)ability of market participants to pay is exploited and people are forced to sell or rent their labour or goods out of financial necessity (Schor, 2017), or to market protected temporal and social spaces such as their own home or leisure time. This kind of sharing economy can be understood as an intensification of an on-demand economy, which tries to justify flexible and precarious work by an ambiguity of market-economy exchange processes on the one hand and altruistic values on the other (Cockayne, 2016). Consequently, it is not clear whether the commercial sharing economy contributes to an increase in the common good. Rather, in some areas, it is merely a commercialization and externalization strategy that passes on costs to the community.

Sharing economy for services: time banks

Parallel to the development of a sharing economy for goods, a sharing economy for the reciprocal exchange of services is also emerging. While this has so far mostly taken the form of neighbourly help in local time banks, barter circles and time-provision systems (Seyfang, 2004; Gregory, 2014; Diniz et al., 2018), the exchange of services can increasingly shift to virtual platforms through digitalization and thus overcome spatial restrictions (Arcidiacono, 2018). Via time banks, people can help each other and receive corresponding time credits in return, which they can redeem later to find help themselves. Unlike in voluntary work, the people involved have the prospect of receiving something that takes the same amount of time in return for their help. Thus, time banks help to diversify the sources of people's livelihood by using the 'currency of time', which puts a value on various forms of work, some of which today are not remunerated via labour markets (gainful employment, collaborative work, voluntary work, nursing care and supervision). In this way, time banks offer a good opportunity to strengthen the inclusion and integration of citizens (Behrendt et al., 2017), particularly in the event of impending losses of earned income through automation (Section 5.3.9), and to make them more independent of changes in the labour market

On the basis of new technologies, however, a new type of digital, non-profit time banks is emerging (Time Banking 2.0, e.g. Time Republik, Cronobank, Bliive; Arcidiacono, 2018). They – like some other commercial sharing-economy approaches – are not based on values like reciprocity and mutual help, but rather on a culture of self-entrepreneurship, i.e. marketing one's own abilities (Moral and Pais, 2015; Arcidiacono, 2018). By contrast, commercial time banking has the potential to aim at a more equal payment for different services, using the time spent on the work as the 'wage' or 'currency'. Above all, decentralized, e.g. blockchain-based time banks (Moral and Pais, 2015) – platform cooperatives supported by the users themselves or provided by such public actors as trade unions or social insurance funds (Section 5.2.2.4) – could contribute to a more balanced distribution of income by using 'time' as an alternative means of exchange to 'money'.

5.2.2.5 Collaborative forms of production: prosumers and commons-based peer production

Digital technologies have contributed to the development of alternative forms of decentralized collective/collaborative production, which are strongly based on the commons idea. Most prominently, 'commons-based peer production' emerged at the interface between the do-it-yourself (DIY) trend, Web 2.0 and digital production. In the context of digital goods production, the 'maker movement' can be counted among these forms (Kohtala, 2016: 28f.; Petschow et al., 2014: 15). This novel form of value creation differs considerably from conventional industrial production (Kostakis et al. 2016) in terms of its political/economic characteristics, and could initiate a change in economic processes away from competition towards more cooperation (Stengel, 2016). Already today, there are many collaborative projects that – especially in economically difficult times (Kummer et al., 2015) – deliver societal added value through the creation of digital commons (e.g. Wikipedia, OpenStreetMap), but whose services or goods experience considerable financing difficulties. Since these activities are not covered by market transactions, they are not included in macroeconomic accounts and only incompletely covered by existing economic indicators (Brynjolfsson et al., 2017).

The rise of commons-based peer production also means that the distinction between consumers and producers that has been typical for decades is disappearing. Consumers are increasingly (co-)designing and (co-)producing products themselves and thus becoming co-designers, makers or *prosumers*. Users themselves often also contribute to value creation when using digital products (Brousseau and Pénard 2007). Initially, commons-based peer production referred mainly to non-material products such as open-source software (Section 5.3.10). In the context of the maker movement, it is now expanding to include material goods, which, with the help of lower-cost 3D printers and other production technologies, can be developed and produced in places such as open workshops/makerspaces (Buxbaum-Conradi et al., 2016: 40; Erdmann and Dönitz, 2016: 15; Millard et al., 2018: 3). Open workshops are also important spaces for discourse and experimentation. Among the formats that advance experimentation with digital production technologies, fab labs (an abbreviation of fabrication laboratories) in particular are expected to make a contribution to the circular economy (Kohtala, 2016: 6, 24f.; Moreno and Charnley, 2016: 573; Petschow et al., 2014: 24; Prendeville et al., 2016: 578f.). The official Fab Lab Network includes approximately 1,000 fab labs in 78 countries, many of them in developing countries and emerging

Box 5.2.2-1

Recommendations for action on the arena 'New forms of digital economy'

- *Embed the digital economy in ecological and social framework conditions:* As an important basis, an ecological tax reform should be promoted which consequently also favours a sustainable digital economy. Its effect on pricing could provide incentives to reduce consumption and avoid rebound effects from sharing. From an ecological perspective, it is also important that sharing is embedded in a sustainable consumer culture, for example through improved search functions in online platforms that place more emphasis on environmentally friendly products (Section 5.2.3; Henseling et al., 2018). Furthermore, existing regulatory measures must be better enforced and gaps closed; a new framework for sharing and platform offers must be created wherever the regulatory framework is inadequate. Ultimately, a greening of the entire range of economic development instruments will also help ensure that digital key technologies (Section 3.3) and the digital economy are put at the service of sustainability to a greater extent than before. For example, the 'Economic Development 4.0' model (Kopatz, 2017) could provide orientation here; it proposes the systematic promotion of cooperative economic forms as a supplement to classical economic development promotion (e.g. marketing of commercial sites, location and maintenance of businesses, cluster promotion).
- *Change the orientation of start-up funding in the field of digitalization towards sustainable digital entrepreneurship:* Business start-ups play an important role in the renewal of the economic structure. Funding efforts should be directed towards sustainable digital entrepreneurship in order to embed sustainability firmly and permanently in the business models of companies from the outset. On the one hand, funding decisions should be more focused on the potential contribution to sustainability (e.g. on the SDGs). On the other hand, activities that run counter to these objectives should no longer be funded. Ecosystems of sustainable entrepreneurship (Volkmann et al., 2017) must be promoted to turn start-ups into transformation actors. During the often financially difficult initial start-up phases, special financing instruments are conceivable (e.g. special funds, sustainability bonuses such as tax or interest relief, exemptions), as are services in kind and consultation services, preferential treatment in the allocation of subsidies, and cheap, publicly-owned rented premises; they can also include access to green digital infrastructure, e.g. green computer centres, software and other benefits. Furthermore, the establishment of suitable formats and places (physical and virtual) should be supported where sustainable digital entrepreneurs can flourish, for example sustainable co-working spaces, hubs, platform cooperatives or open workshops, fab labs and repair cafés.
- *Strengthen sustainable platform cooperatives:* Platform cooperatives are a particularly interesting form of sustainable digital entrepreneurship that can be developed into effective instruments of socio-ecological entrepreneurship. For example, they could be boosted by common-good certification, confirming, among other things, that sustainability goals are already enshrined in their business purpose. Such a certification could be a prerequisite for access to certain forms of government support. Platform cooperatives need additional support from the establishment of model projects and the same opportunities as shareholder-oriented start-ups as regards access to state funding (Kagel et al., 2018). The above recommendations on start-up and business promotion apply correspondingly here.
- *Institutionalize commons-based peer production and provide it with enough freedom:* The activities of common-good-oriented commons-based peer production should be protected by a suitable (legal) framework which, for example, regulates the non-exclusivity of property rights to the products of prosumers and commons-based peer production, and supports professionalization. Experience with the environmental impacts and the functionality of commons-based peer production can be gained by realizing a programme for 1,000 open workshops. If successfully implemented, this will also promote the spread of commons-based peer production (fab labs, makerspaces, repair cafés, etc.). The hitherto insufficient consideration of environmental aspects can be addressed in this case by integrating environmental-management systems and joint benchmarking tools, which also provide important research data. Open workshops should also be increasingly used in development cooperation to bridge the digital divide and make inclusion possible. In general, the visibility of these activities should be strengthened with more users and contributors and expanded through public-relations work. Places and events for exchange between existing initiatives can stimulate mutual learning across borders. In order to enable people to participate in the collaborative economy, free spaces need to be created, for example by making working hours more flexible and creating new forms of social security.
- *Build democratic platforms via institutionalized actors such as municipalities or trade unions:* In addition to private actors in the sharing and platform economy, public institutions such as cities or trade unions, and civil-society NGOs can promote the development of an ecologically sustainable and socially acceptable digital economy by acting as platform operators themselves. For example, basic services could also be contracted out as cooperative forms of organization or passed on to the public sector (e.g. mobility services, circular-economy services). If successfully implemented, this could promote the reinvestment of profits resulting from network effects in platforms oriented towards the common good and support data protection, while at the same time putting basic public services back into democratically legitimized hands (Sections 5.2.7, 5.3.5). The establishment of digital time banks with the participation of social partners can provide a good way to move forward when it comes to sharing services. Vouchers for free access to services issued via these platforms can create network effects and thus initiate the necessary participation in these platforms. Such a model can keep more economic value creation local and help contain negative side effects such as the misappropriation of housing. To make regional sharing services easier to find, a public-service search platform can be established as part of a broader platform ecosystem (Section 5.3.5). This should ensure that only reputable providers are accepted who adhere to socially acceptable working conditions and are financially reliable

Box 5.2.2-2

Research recommendations for the arena 'New forms of digital economy'

The WBGU recommends increased research at the interface between new forms of the digital economy and sustainability. These should address the following questions and topics, among others:

- How can *sustainable digital entrepreneurship* be defined and identified? What is its status quo and what opportunities or risks does digitalization offer in this area? Which economic ecosystems (e.g. legal frameworks, financing instruments) do sustainable digital enterprises need?
- Does sustainable digital entrepreneurship need its own legal form on the basis of which other forms of promotion can be provided? Against this background, how can cooperative legislation be transferred to digital spaces and further developed?
- Expansion of *sustainability-oriented platform research* and development of criteria, an evaluation scheme, guidelines and a seal/certificate for social-ecological platforms.
- How can the common-good-oriented approach of *time banks*, which has emerged independently of digitalization, be maintained and promoted in the Digital Age? What kind of regulation, institutionalization or funding is needed for this? What meaningful links between time banks and digitalization would be conceivable in the finance field (e.g. Bitcoin or Faircoin)?
- What risks and opportunities are involved in *sharing models* with regard to their incentives for consumption reduction, their social integration function and different dimensions of justice (income, time wealth, working conditions)? What possibilities do digital technologies have to offer to steer this in a positive direction and avoid negative effects?
- Under what conditions does *commons-based peer production* contribute to a comprehensive reduction of energy and resource consumption? What best-practice approaches can be identified in this area, and what role does re-location play? Are local or decentralized production patterns/value-creation systems more sustainable than others? What new forms of basic social-security cover might increase involvement in the collaborative economy (e.g. creation of experimental areas for a basic income)?
- How can *cultures of sustainable economic activity* in the field of the growing digital economy be identified and further disseminated via network-based diffusion processes?

economies (Fab Foundation, 2019). The focus is mainly on education and experimentation, but it is only when all environmental dimensions are taken more fully into account that fab labs and similar formats can realize their full sustainability potential (Kohtala, 2016:100; Millard et al., 2018:27). Other forms of open workshops are design centres, sewing combines or repair cafés (Erdmann and Dönitz, 2016:15). The latter are playing an increasing role in the repair of electrical appliances, for example, and thus in the prevention of e-waste (Section 5.2.5; Charter and Keiller, 2016). Such collaborative formats often regard themselves as an alternative model to the usual combination of mass production and consumption, consequently also to the 'large-scale project' called Industry 4.0 and its main goal of individualized and/or personalized mass production (Baier et al., 2016; Buxbaum-Conradi et al., 2016:41f.; Kohtala, 2016:5; Petschow et al., 2014). In order for commons-based peer production to be possible on a larger scale and to offer appropriate incentives for collaborative project work, prosumers must be provided with enough free time, and the non-commercialization of the products manufactured must be guaranteed (Sassower, 2013:54).

5.2.2.6
Conclusions

Digitalization is having a significant impact on the emergence of collective/community-oriented forms of sustainable economic activity. Their potential for re-embedding the economy into societal and ecological boundaries depends not only on the business strategy chosen, but also on the company's organizational form. Most of these are currently still niche approaches. In order to open up enough creative space and scalability potential for these pioneers of change (WBGU, 2011:242ff.), it is necessary to enlarge the experimental scope available to these new forms of economic activity and thus improve their action options (Boxes 5.2.2-1, 5.2.2-2).

5.2.3
Digitalization of consumption and sustainable consumer behaviour: promotion of solidarity-based lifestyles

The term 'digitalization of consumption' used here refers to a broad range of changes in individual consumption involving digital support: from the consumption of digital and digitalized goods (e.g. products networked on the Internet of Things) to orders via online commerce and digitally supported, ecologically informed consumption, 'going without', and sharing (sharing economy: Section 5.2.2.4). The focus is not on the means of production but on consumer goods, i.e. material goods that directly serve to satisfy human needs (Morato Polzin et al., 2016). Individual consumer behaviour includes the use and consumption of these goods as well as their selection, purchase, utilization, repair, exchange and disposal (Defila et al., 2011; Reisch and Scherhorn, 2005). Changes in the supply landscape and the disposal

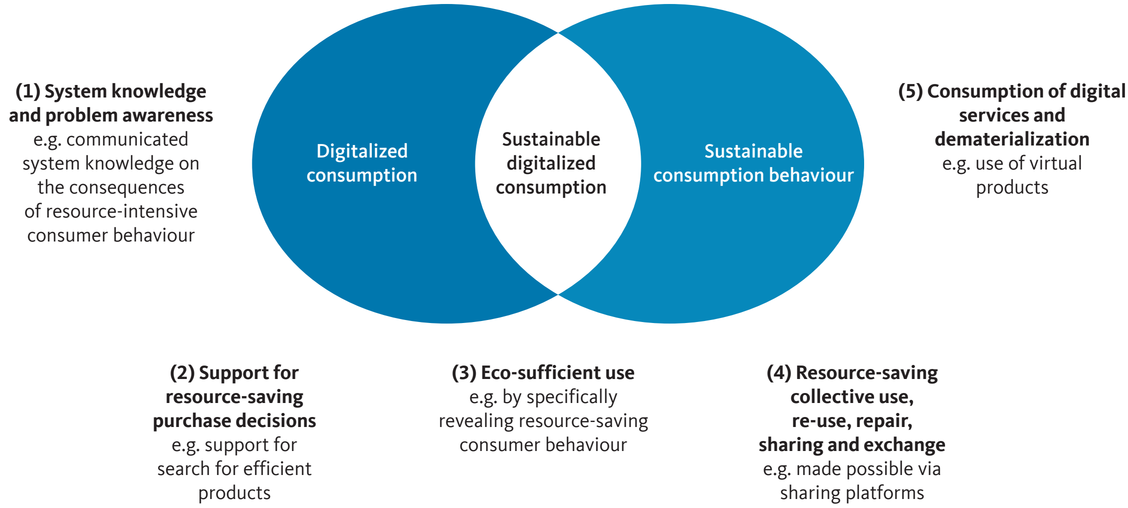


Figure 5.2.3-1
Digitalized consumption and sustainable consumer behaviour: systematic diagram showing the areas of digitalized and sustainable consumption to be investigated. The WBGU sees possible opportunities of digitalization for sustainable consumption in the way that digitalization can serve as a tool for (1) *system knowledge and problem awareness* on sustainable products and services and their (worldwide) consumption, (2) *an individual or/and collective preference for resource-saving products by consumers,* (3) an individual *reduction in consumption (eco-sufficient use),* (4) a collective reduction in consumption through *collective use, re-use, repair, sharing and exchanging.* It is not yet clear how much potential for sustainability lies in (5) the *consumption of new digital services*, such as social networks or streaming services, and the *dematerialization* and/or virtualization of certain consumer goods, e.g. experiencing virtual worlds instead of travelling.
Source: WBGU

of products are taken up elsewhere in this report (Sections 5.2.4, 5.2.5). This arena aims to show how the deployment of digital technologies can help consumers today and in the future to gear individual consumer decisions on the choice, type, quantity and use of products towards the concept of a solidarity-based quality of life. The WBGU defines 'solidarity-based quality of life' as a quality of life that is not only oriented towards one's own needs and those of one's immediate environment (e.g. family environment), but also takes into account the principles of intra- and intergenerational fairness (WBGU, 2016a: 133ff.). Furthermore, it is assumed that digitally supported consumption will increase (e.g. Section 5.2.4) and also generate new forms of consumption (e.g. sharing). Due to a lack of quantitative studies, this section does not provide a comprehensive quantification of digitalized consumption in relation to sustainability and the effects of digital innovations on consumer behaviour. Reliable statements cannot yet be made here.

5.2.3.1
Digitalized consumption for sustaining natural life-support systems

The WBGU has repeatedly shown that the natural life-support systems can only be sustained if consumer behaviour as a whole becomes less resource-intensive and more environmentally friendly (WBGU, 2014a; 2016a). Individual consumption has significant potential here.

There are numerous examples that show that digitalization can in principle be used to improve the resource and energy efficiency of consumer goods and services over a product's life cycle (Sections 5.2.1, 5.2.2, 5.2.6, 5.2.9). In the digitalization field, the WBGU regards five areas as especially relevant when examining the potential of individual consumption in the Transformation towards Sustainability (Figure 5.2.3-1).

1. *Strengthen system knowledge and create problem awareness:* Digital media can provide information on global consumption and environmental trends, as well as on the basic availability of alternative, sustainable products and services (creation of problem awareness; arena of 'Global environmental awareness' (Section 5.3.1). System knowledge on the consequences of resource-intensive consumer behaviour can be widely disseminated via trustworthy digital information sources.
2. *Support for resource-conserving purchasing decisions*: However, digitalization can also directly influence consumers' choice of goods and purchase decisions by providing knowledge for concrete behaviour choices, and in this way support a preference *for* resource-efficient and socially compatible products. Since products can be compared better online, impulsive or mispurchases could be reduced. Studies

Box 5.2.3-1

Recommendations for action on the arena 'Digitalization of consumption and sustainable consumer behaviour'

Digital solutions should be used specifically to increase system knowledge and problem awareness relating to the sustainability of products and services. Digital platforms should be used to make information available on the (worldwide) individual and collective consumption of resource-saving products, on how to reduce consumption (eco-sufficient use), and on the collective reduction of consumption through collective use, re-use, repair, sharing and exchange. In this context, the potential of new digital services, such as social networks or streaming services and dematerialization or virtualization, should also be used specifically to enable consumers to judge the sustainability potential of consumer goods (Figure 5.2.3-1). The WBGU recommends the following:

- *Improve the online provision of system knowledge and problem awareness about sustainable consumption patterns:* Credible and reliable information sources about resource intensity and the long-distance effects of products should above all also be made available online to enable resource-saving purchasing decisions and eco-sufficient use. Distributors and traders could be legally obliged to provide digital information, so that, for example, the CO_2 emissions generated during the manufacture and transport of the product, the resources used and the social implications of production – also in online commerce – are made transparent. For example, data collected by manufacturers for their business reports should be made easily accessible to consumers or consumer organizations using digital platforms, e.g. via links to sales platforms or codes on products. The provision of socio-ecological product information on online-trading platforms should be encouraged, since online traders currently provide very little information on sustainability aspects of their product ranges (Hagemann, 2017). Companies that differ from traditional distribution methods in that they assume societal responsibility should use digital distribution and marketing strategies to spread information about the eco-sufficient use of their products, and thus contribute to the dissemination of methods of eco-sufficient use (Gossen and Schrader, 2018). This also includes digital information about products that is accessible to consumers and third parties and makes repairs possible (Kurz and Rieger, 2018b).
- *Encourage resource-efficient collective use, re-use, repairs, sharing and exchange of products using reliable digital solutions:* For example, the spread of collective use could be accelerated by positive tax incentives for concepts of 'using instead of owning', or by resource-taxation schemes that give privileged status to less resource-intensive collective use. A supportive societal and legal environment should be created for digital tools such as peer-to-peer sharing platforms, in particular by avoiding legal uncertainty (Leismann et al., 2012; Section 5.2.2). Consumer protection, competition (particularly the prevention of monopolies), and the protection of privacy must also be guaranteed for community sharing (Meller-Hannich, 2014; Peuckert and Pentzien, 2018). In particular, commercial platform operators should not be able to evade this responsibility (Peuckert and Pentzien, 2018: 53). In addition, the public sector could also provide practical support for sharing concepts by refraining from acquiring ownership and purchasing services instead. Public sharing infrastructures could also be created by the public sector or public-private partnerships (Peuckert and Pentzien, 2018: 56; Section 5.3.5). Sharing platforms should make use of ecologization potential by improving the labelling of sustainable sharing services (Henseling et al., 2018).
- *Ensure the Eigenart of consumption and analogous inclusion in sustainable consumption:* Transparency obligations and rights of objection can also strengthen the sovereignty of consumers in the field of digital consumption (SVRV, 2016: 28). For people who consume primarily via the internet, for example, it must be ensured that the trend towards personalized or profile-based offer and price structures in online commerce does not restrict the scope for individual sustainability-oriented consumer behaviour. For people who do not participate in online commerce, alternative consumption structures should be created or maintained that make differentiated – i.e. also sustainable – consumption decisions possible.
- *Ensure the representation of consumers' interests:* This is key to enforcing consumer and environmental interests and to enabling the *Eigenart* of consumption and inclusion in sustainable consumption in algorithmicized online commerce (SVRV, 2016: 28). Consumer-protection organizations should be supported financially and institutionally so that they can exercise their control function – e.g. in the form of the right to issue warnings and the right of associations to initiate legal proceedings 8also for new forms of digitalized consumption) – and can reveal abuses at an early stage.

on online shopping, for example, indicate that the wide range of choices available in the online context leads to more rational, informed and less impulsive shopping (Chan et al., 2017b). For example, portals aiming to promote sustainable consumption, such as EcoTopTen for white goods (large electrical appliances such as refrigerators), can reduce search and comparison costs and increase consumers' freedom of choice and flexibility (SVRV, 2016: 17). However, the provision of sustainability-relevant product information is not well-developed on the most important German online shops to date; only the 'eco online shops' offer comprehensive information about the environmental quality of the products on offer (Hagemann, 2017).

3. *Eco-sufficient use:* Consciously reducing consumption is an expression of a modest, i.e. 'eco-sufficient' lifestyle. This too can be supported by the provision of easily accessible information on the internet. For example, ICT can reveal the specific consequences of individual consumer behaviour and point to alternatives (e.g. online platforms like

Box 5.2.3-2

Research recommendations on the arena 'Digitalization of consumption and sustainable consumer behaviour'

Research should be stepped up on quantifying the impact of digitalized consumption on the sustainability of consumer behaviour. Following the WBGU's systematic classification (Figure 5.2.3-1) a study is needed to determine whether and how digital tools can be used (1) to broaden system knowledge and problem awareness of sustainable products and services and whether the (worldwide) consumption of such products can be increased, (2) to support individual and/or collective consumer preference for resource-saving products via digital technologies, (3) to promote individual reductions in consumption (eco-sufficient use), and (4) to achieve a reduction in consumption through collective use, re-use, repair, sharing and exchange. Furthermore, it is as yet unclear how much potential for sustainability lies in (5) the consumption of new digital services, such as social networks or streaming services, and the dematerialization/virtualization of certain consumer goods, e.g. experiencing virtual worlds instead of travelling. This raises the following questions for research:

- How do digital applications influence the resource intensity of aggregated consumer behaviour? For example, hitherto it is unclear by how much and in which fields the resource intensity of aggregated consumer behaviour is rising overall as a result of online commerce. In the area of collective consumption, scientific research should be conducted to determine how and to what extent resource-efficiency potential along value chains really can be realized by practising 'using instead of owning' (Peuckert and Pentzien, 2018).
- How can people's willingness to develop and maintain a style of consumption based on solidarity be supported? How can networking with others and collective use in particular be promoted for this purpose? Can (and, if so, how can) identity and cohesion be promoted by making it possible for people to network and to consciously shape solidarity-based consumption styles.
- Can motives, norms and emotions that play a role in e.g. non-digitalized consumption (e.g. recreation, fascination when travelling) be satisfied in dematerialized forms of consumption, and how do these motives, norms and emotions influence consumer choices between material and non-material consumption?
- Do rising levels of networking lead to a loss of regional identity, to a quasi-standardization of preferences and thus of demand-related behaviour? This is a reference to the global availability of the same goods, which can force local suppliers out of business, since consumers can switch online to globally available, 'perfect' and cheap goods.

https://klimaohnegrenzen.de/english). A number of platforms also provide information on how materials are re-used. However, this depends on the longevity and reparability of consumer goods. Obsolescence, i.e. premature product ageing, is nowadays not only the result of producers' policies; it can also be a result of consumer behaviour (Box 5.2.5-1).

4. In some cases, the *collective use, re-use, repair, sharing and exchange* of products among consumers (peer-to-peer sharing) is only made possible by digitalized consumption and can help reduce resource consumption (Ludmann, 2018; Reisch et al., 2016). The use of individual products can be intensified or their useful life extended if products are given away, sold, exchanged, lent out, rented out or shared (Scholl et al., 2015), or if services, e.g. repairs, are exchanged. However, not every form of sharing contributes to resource efficiency (Ludmann, 2018), which is why distinctions should be made between different forms, e.g. between commercial sharing services and non-commercial sharing (Section 5.2.2).
5. *Consumption of new digital services and dematerialization:* The term dematerialization was first used in this context in the 1990s (Herman et al., 1990) to describe the reduction in the material weight of functionally similar end-devices over time (e.g. from room-filling computers to smartphones). More concrete definitions link dematerialization with the need to develop new processes, equipment and products that are designed from the outset to minimize material flows (Schmidt-Bleek, 1994). The idea is that the demand for new (digitalized, virtual) products such as music or film streaming, visits to social networks or the use of virtual realities could replace the demand for more material-intensive analogue products, distribution channels or services. Frequently discussed fields of consumption include media consumption via ICT (streaming to smartphones, replacing DVDs or CDs, e.g. Lange and Santarius, 2018,) and the replacement of travel by video conferences or virtual experience (e.g. Beck et al., 2018).

However, in addition to digitalization's foreseeable potential for sustainability mentioned above (Figure 5.2.3-1: (1)-(4), the discussion also looks at challenges. For example, a switch to more resource-efficient or shared products may lead to rebound effects: if a more resource-efficient production method or the shared use of goods leads to lower costs for the consumer, this may increase demand for these goods. Resource consumption will then decrease less than expected (direct rebound effect) or even increase in extreme cases. Empirical studies show that direct rebound effects vary in strength depending on the area of consumption and the country, and can cut the effect of increased efficiency on resource consumption by 10–30% (estimate of 'direct rebound effects': Sorell,

Topic box 5.2-1

FinTech in the context of sustainable financing

New financial technologies based on digital technologies called FinTechs are increasingly changing the market for financial services and the financial system as a whole (WEF, 2017a). FinTechs are also increasingly a topic of climate and sustainability policy. The term FinTech usually covers both digital financial technologies and the new services and business models based on them. In some cases, the term is also used solely as a synonym for new, innovative participants in the financial services market (Paul et al., 2016). Often, but not exclusively, these are start-ups. FinTechs also open up the market for financial services to established, non-sector-specific companies, especially technology groups (FSB, 2019). FinTechs affect almost all functions and services in today's financial system. They challenge the business models of established private actors in the financial system essentially by opening up alternatives to the current role of market intermediaries (He et al., 2017; Box 4.2.2-1), for example, mediating between savers and investors or in handling payments/transactions. This applies to banks in particular. The general view is that the changes in customer contact and branch structures caused by the increasing spread of online banking are only the first signs of major upheavals in the business models of banks (Paul et al., 2016; Mayer-Schönberger and Ramge, 2017; Anagnostopoulos, 2018). FinTechs open up new, more direct payment channels and systems; automated trading and decision-making systems offer new opportunities for asset management; and platforms such as peer-to-peer lending or crowdfunding offer new possibilities for financing (Paul et al., 2016; He et al., 2017). In the insurance sector, FinTechs are creating new ways of risk spreading and risk identification, for example through more individualized insurance products (OECD, 2018b). Compared to today's financial system, FinTechs promise above all lower transaction costs (which are still surprisingly high, e.g. in international payment transactions), a significant increase in market transparency through increasing data diversity and availability, and generally a broader access to and variety of financial services. In addition to these performance-related competitive advantages and digital technological progress, FinTechs are currently also benefiting from the fact that, in the wake of the 2007/2008 financial crisis, established financial market players are in some cases subject to stricter regulatory requirements, and that FinTechs have so far only been covered by financial market regulation to a limited extent, if at all (Philippon, 2016; Buchak et al., 2018).

The appropriate further development of financial market regulation to fill these gaps and avoid possible problems from new digital shadow banks is currently a major challenge (Paul et al., 2016; Anagnostopoulos, 2018). For example, the systemic implications of FinTechs are still largely unclear. One fear is that, despite initially more intense competition in the financial services market, in the longer term there will be an increase in market concentration and new risks to financial market stability, such as new and more networked players in the financial services market who also often elude existing regulation (FSB, 2019). At the same time, FinTechs raise questions about the future role of central banks and the effectiveness of monetary policy, as illustrated not least by the development of digital currencies (Brühl, 2017; Raskin and Yermack, 2016). However, some of the approaches of FinTechs must also be viewed critically for reasons of data protection, for instance when the range of digitalized financial services is linked with other business divisions (Section 9.2.3.3), or when behavioural data are collected for increasingly individualized insurance solutions (OECD, 2018b). The latter also threaten to further link access to insurance solutions with individual economic performance, thereby ultimately losing the societal balance of individual risks achieved through insurance.

The sometimes very far-reaching structural effects of FinTechs in the financial system also raise the question of the importance of FinTechs for sustainable financing. The risks associated with FinTechs mentioned above demonstrate that they do not contribute in principle and from the outset to creating a more comprehensively sustainable financial system. At the same time, however, almost all the promises made to the current financial system by FinTechs today point to the possibilities that FinTechs could remove key obstacles to sustainable financing and thus bring the financial system as a whole more into line with the goals of sustainable development. The fact that the financial system is of great importance for the implementation of climate-change-mitigation goals and general sustainable development goals has in the meantime been widely acknowledged by many actors and institutions within the financial system and also at the political level. For example, the Paris Climate Agreement prominently enshrined the goal of "making financial flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (UNFCC, 2015: Article 2(1)). Not least for this reason, 'sustainable finance' is now a topic in the banking sector (EBF, 2018), as well as in central banks and supervisory authorities. Examples include the 'Network for Greening the Financial System' (Banque de France, 2019) founded in 2018, and the Task Force on Climate-related Financial Disclosure set up by the International Financial Stability Board (fsb-tcfd.org). Germany's Federal Government is pursuing this issue as a strategic goal for Germany as a financial centre (Bundesregierung, 2019). On the basis of the final report of the EU's High-level Expert Group on Sustainable Finance published in 2018, the European Commission has developed its own action plan on sustainable finance (European Commission, 2018b). The G20 has set up a Sustainable Finance Study Group (G20 Sustainable Finance Study Group, 2018). However, the potential benefits and risks of FinTechs have only recently been finding their way into these initiatives and discussions on sustainable financing. One expression of this is the establishment in 2018 of a separate UN Task Force on the Digital Financing of the SDGs (digitalfinancing-taskforce.org).

In terms of content, 'sustainable financing' basically means not only mobilizing sufficient financial resources for the objectives of sustainable development, but also strengthening the resilience of the financial system to the stability risks of unsustainable developments, and promoting access to financial services. For example, in the EU alone, the additional annual investment needed to reduce CO_2 emissions across all sectors by 40 % by 2030 amounts to some €180 billion (EU High-Level Expert Group on Sustainable Finance, 2018). At the global level, estimates assume, for example, that the financing gap for the necessary investments for the implementation of the SDGs is currently around 4 billion US dollars, mainly in developing countries and emerging economies (UNEP Finance Initiative, 2018). Even today, substantial sections of the world's population still lack access to basic financial services, which are often basic prerequisites for independent economic development or an insurance against economic or health risks. More than 1.7 billion adults worldwide do not have a bank account of their own (World Bank, 2018a). At the same time, there is a growing awareness that both ecologically and societally unsustainable developments can endanger the stability of the financial system, at least in the longer term (EU High-Level Expert Group on Sustainable Finance, 2018).

Overall, the aim of the discussion on sustainable financing is to bring financial flows more into line with the objectives of sustainable development and to embed sustainability objectives more firmly in the decisions and assessments of the actors and institutions of the financial system (TCFD, 2017). At present, there are still several problems hampering a sustainable design of the financial system (G20 Sustainable Finance Study Group, 2018). In the absence of any consistent regulation of the external, social costs of private-sector action, there is still little awareness of the relevance of sustainable development issues. Moreover, there is often a lack of sufficient or sufficiently verifiable information on sustainable investment or general decision-making alternatives. One major obstacle is the discrepancy between the long-term returns on sustainable investments and the more short-term decision-making horizons of many actors, which is closely related to the aforementioned obstacles. In developing countries especially, broader access to financial services is hindered by high payment-transaction costs or a lack of economic biographies on the part of many people, e.g. needed for calculating credit default risks.

FinTechs have the potential to reduce these barriers through improved and more comprehensive possibilities for data compilation and processing and a greater accessibility of information (UNEP, 2016; SDFA, 2018). This applies both with regard to the availability and evaluation of sustainable investment projects and returns, and with a view to the relevance of sustainable development issues, especially for long-term financial returns and the stability of business models and financial markets. Increasing data availability and transparency can at the same time help to identify risks earlier, quantify them more precisely and, on this basis, find solutions for spreading and reducing the risks of unsustainable developments. Digital payment systems also offer new ways to track and monitor financial flows, so that funds really are used for sustainable investment (SDFA, 2018). All this can serve to generally embed sustainability criteria more firmly in financial-market decisions and also help to reduce apparent lower returns or conflicts between short-term return expectations and the long-term advantages of sustainable investments.

Finally, FinTechs can also significantly improve access to financial services, not only in industrialized countries but also in developing countries and emerging economies (World Bank and IMF, 2018). Improving access to the financial system is in itself an important step towards a more sustainable financial system in a broader sense by promoting economic autonomy and inclusion. It can also be used to mobilize the financial resources needed to implement the SDGs (UN Environment Inquiry, 2018). The spread of digital payment systems and online banking via mobile phones, for example in African countries (e.g. Kenya) already illustrates the potential of FinTechs today (World Bank, 2016; Björkegren and Grissen, 2018; Maino et al., 2019): Thanks to lower (transaction) costs, poorer people can also use these systems to make quite small payments. Digital networking via the mobile internet also considerably reduces the costs of providing services to people, even in more remote regions, and represents a form of leapfrogging, since the more capital-intensive expansion of cable-based infrastructures can be dispensed with (Section 5.3.8). By the end of 2013, 219 companies were already offering mobile payment services in 84 countries worldwide (GSMA, 2014). Crowdfunding and peer-to-peer lending platforms (World Bank, 2016) offer new possibilities for financing that are independent of the data-intensive calculation of credit scores and, in part, of expectations on short-term returns. At the same time, the data collected via digital devices and applications can help reduce information problems in determining credit default risks (Björkegren and Grissen, 2018; FICO blog, 2019).

In some cases, however, the sustainability risks and potential of FinTechs are closely related. The use of mobile-phone data, for example, allows the development and expansion of markets for credit and microfinance in developing countries, but it also highlights the critical data-protection implications of some FinTech approaches. The WBGU also has similar concerns about ideas and projects to collect sustainability-relevant data at the individual level and use them with the help of FinTechs to influence individual behaviour towards more sustainable decisions (GDFA, 2017; SDFA, 2018). In addition to the general risks to financial-market stability from FinTechs already mentioned, the World Bank also points out that broader access means that many people who are largely inexperienced in dealing with financial services are integrated into the financial system; appropriate information services and regulation of FinTechs are therefore necessary for their protection. Finally, the World Bank also sees the danger that, despite the fundamental increase in market transparency, digital payment services or currencies may be misused for illegal transactions such as money laundering and tax evasion (World Bank, 2016).

Further systematic analysis of the potential and risks of FinTechs for sustainable finance is desirable. This should include more studies on how the disruptive potential attributed to FinTechs can be used to improve the financial architecture and mobilize sufficient investment for sustainable development. Only with a framework that consistently takes into account external effects of private-sector action, short-term incentive structures and sustainability-relevant risks can FinTechs be expected to change the rules of the game of the global financial architecture in the interests of sustainability. Initial approaches are currently being developed in the context of the sustainable finance debate.

2007; Semmling et al., 2016).

If the cost of using goods falls, consumers can spend the money saved on consuming other (potentially also resource-consuming) goods ('indirect rebound effect'). Time saved by shopping online can, for example, be used for other resource-consuming activities (Dost and Maier, 2017). However, fewer direct and indirect rebound effects are to be expected when sustainability-conscious people are involved (Friedrichsmeier and Matthies, 2015).

In a discourse similar to that on efficiency and rebound effects, it is sometimes claimed that the impact of dematerialization (Figure 5.2.3-1: (5)) is nullified by an intensification of consumption, or even that new additional consumption domains are created (Lange and Santarius, 2018). The key issue here is whether the 'substitution' of old ways by new ways of satisfying needs really works at all. This relates, for example, to the question of whether needs associated with the consumption of products (e.g. media consumption for entertainment) can be satisfied just as well or even better or more easily by using online media (e.g. streaming or virtual reality). There is no reliable scientific evidence to back such assumptions (Trepte and Reinecke, 2018), so that a lot of research is needed here. For example, it is unclear whether motives and emotions that are satisfied by spending time in natural environments (e.g. recreation, fascination, 'being away'; Kaplan and Kaplan, 1989) can also be experienced in virtual realities.

Finally, there is the question of whether the personalized advertising often used on the internet (e.g. Pappas et al., 2014), i.e. advertising that has been adapted to the respective user on the basis of their online behaviour, might strengthen incentives to buy and thus raise the overall level of consumption. Although the function of advertising is rather to increase market shares, and therefore does not necessarily lead to a general increase in consumption, it is possible that individualized offers coupled with individualized pricing might ultimately lead to an increase in consumption (SVRV, 2016:21). At present there are no studies that might consolidate these speculations.

5.2.3.2
From sustaining the natural life-support systems to the concept of solidarity-based quality of life

The WBGU sees the spread of an extended concept of quality of life, prosperity and community – the solidarity-based quality of life – as key to making the most of the transformation potential that lies in individual consumption. A prerequisite and important aspect for the development of solidarity-based quality of life is conscious reflection on one's own lifestyle, understanding its impact, and a conscious acceptance of consumption's limits in society as a whole.

Initial successes in promoting sustainable consumption made possible by digitalization can already be observed. For years now, there have been approaches to revealing the consequences of individual consumer behaviour using digitalization, for example platforms for calculating one's personal CO_2 footprint (KlimAktiv, 2018; Carbon Footprint, 2018). These information platforms can create an understanding of the problem and strengthen people's motivation to engage in solidarity-based consumption by favouring resource-saving products, eco-sufficient product use, and collective consumer action (Figure 5.2.3-1). In order for such motivation to be turned into corresponding behaviour, information about alternatives must be available in the purchase setting, i.e. perhaps in the shop itself. Here, too, the first apps are being developed, for example for the purchase of fish, or for checking whether products are ecologically recommendable (e.g. Seafood Watch, codecheck, NABU seal check, Utopia). In the future, more products and services could be evaluated by manufacturers and consumers with the help of apps. This could mean information being available for every consumer decision on the consequences of consumption and the alternatives, thus helping to develop solidarity-based quality of life.

In addition to the provision of problem awareness and action knowledge via forums or apps, networking with others is also conducive to the realization of solidarity-based quality of life. A sense of community can contribute to accepting limits and jointly developing new sustainable modes of behaviour (e.g. Reese and Junge, 2017), for example by participating in networks reflecting on the local and global consequences of consumption, jointly testing sustainable lifestyles, or offering local and global support to others (donations, knowledge sharing, etc.). Ground-breaking examples are networks organized via peer-to-peer-sharing platforms which organize various joint actions to avoid food waste with the help of suitable apps (Foodwaste.ch, 2018), or applications that show the amount of CO_2 emissions that can be (collectively) saved by linking individual and joint sustainable activities (New Earth Handprinter, 2018). Jointly giving preference to resource-saving products, and using products in an eco-sufficient manner increase the perceived self-efficacy of a person's own actions (Reese and Junge, 2017).

5.2.3.3
Opportunities and risks of digitalized consumption for inclusion and *Eigenart*

Digitalization can enable – or restrict – the substantive, economic and political inclusion (Section 2.2.2) of previously disadvantaged groups. For example, people on low incomes in particular can make greater use of free sources of information and education on the internet (OECD, 2017b) and thus also access knowledge about sustainable consumption. ICT gives groups that can otherwise only participate in consumption with the support of other people (e.g. people who are not mobile) new opportunities for inclusion. However, a lack of suitable media literacy can make access to information and consumer goods more difficult. This applies, for example, to older people who do not use the internet when local shopping opportunities disappear.

The digitalization of consumption can also have both a positive and a limiting influence on *Eigenart*. On the one hand, creative autonomy and self-efficacy can potentially be increased through digitalization, since individuals can make more targeted online choices and, in some cases, themselves influence which products they consume. Identity and cohesion could be supported by enabling people to consciously shape their solidarity-based styles of consumption and networking. On the other hand, where internet literacy is low, legal guarantees of consumer protection are insufficient, and technology design is consumer-unfriendly, there is a risk that freedom of choice, self-determination, self-control and security – as components of consumer sovereignty – cannot be realized in digital consumer activities (SVRV, 2017). Here too, the potential of digitalization could lie in creating greater transparency and strengthening the chances of individuals to exert influence, for example by enabling them to determine for themselves which advertising, if any, they wish to receive. A kind of sustainability filter, used voluntarily, would also be conceivable here.

5.2.4
Sustainability in online commerce: status quo and prospects

SDG 9 of the 2030 Agenda refers to innovation, markets and value chains, while SDG 12 aims at sustainable consumer behaviour. The pursuit of both goals is rapidly changing as a result of digitalization. More and more consumers are choosing digital distribution channels to purchase goods and services. What are the consequences of digital commerce for sustainability? How does online commerce affect the environment and society? How does online commerce influence consumer behaviour?

5.2.4.1
Role and growth of online commerce

Online commerce, also known as e-commerce or online trading, describes the purchase and sale of products on the internet (HDE, Association of German Retailers). It can be divided into three categories: (1) between businesses (business-to-business – B2B), (2) between businesses and consumers (business-to-consumer – B2C), and (3) between consumers (consumer-to-consumer – C2C). This arena focuses on B2C online commerce, e.g. consumer shopping on Amazon, Alibaba and eBay, which, due to the increasing proportion of retailers (75%), has developed from a C2C into a B2C platform (Behrendt, 2017). Companies use online commerce particularly because they can reduce transaction costs, increase efficiency, and achieve economies of scale (Lang and Ebneter, 2012). In this way, formerly bricks-and-mortar companies become online traders or multi-channel providers.

According to the 'online market attractiveness score', the top countries in online commerce are the USA (79.3), China (77.8), the UK (74.4), Japan (70.1) and Germany (66.6). The 'online market attractiveness score' was developed by the consulting firm A.T. Kearney (2015) and measures online-commerce potential on a scale from 0 to 100. In several of these countries, more than 70% of the population already buy products and services online, while the ratio in most developing countries is less than 2% (UNCTAD, 2017; Kwarteng and Pilik, 2016). However, online commerce is also growing rapidly in developing countries, as shown by the examples of online mail-order companies such as Lazada, Tiki and Sendo in Vietnam (Choi and Mai, 2018), MercadoLibre in Latin America (WTO, 2018), or Bidorbuy, Takealot, Konga, Kaymu and Zando in South Africa and Nigeria (Enders, 2018).

In China and the USA, online commerce has been growing at an annual rate of about 20% for a decade. It is dominated by the companies Alibaba in China and Amazon in the USA (The Economist, 2017a). In China, Alibaba generated an estimated daily turnover of US$14 billion in 2015 on discount days like the 'Singles Day'. This corresponds to about 20 million parcels in one day. In 2017 Alibaba's turnover on that day already amounted to US$22 billion (Hua, 2017) and in 2018 to over US$30 billion (Cazzoli, 2018).

The clothing sector is the product group with the highest turnover in B2C e-commerce, although ICT (e.g. smartphones) and electrical goods (e.g. electrical household appliances), books and e-books are also very frequently sold via the internet. In addition, the food trade is increasingly moving to the digital world. More and more grocery chains are offering a range of durable and fresh foods online (Kolf, 2017b). In addition, exclusively online providers (e.g. DHL, Amazon) have established themselves in the food sector in the meantime. The online share of the total food trade is expected to grow – in Germany at an estimated rate of 10% – by 2020 (Ernst & Young, 2014; Kolf, 2017a).

The turnover of online commerce is strongly concentrated on a few companies such as Amazon, Alibaba or eBay, and products in online commerce are largely purchased internationally (WTO, 2018). Online commerce has therefore also become an important topic in the international negotiations of the World Trade Organization (Berger and Brandi, 2018).

In addition to the strong concentration of power among a few companies, there is also strong competition for new sub-sectors. Companies like Amazon and Alibaba are increasingly diversifying their range of products and services from online commerce to other areas of the digital economy, such as online payments, video streaming, search engines and social media. This diversification into new areas is also being pushed by competitors. Tencent, a rival of Alibaba's, is diversifying from the video-streaming and messaging business into online commerce, the payment sector and gaming (The Economist, 2017b). Companies are also increasingly trying to expand into other countries. Alibaba has announced that it is increasing its investment in India, while Amazon has been investing more in Germany, Japan and the UK (The Economist, 2017c).

5.2.4.2
Environmental impact of online commerce

Increasing online commerce has a number of negative environmental impacts. Packaging waste is generated especially when sensitive, perishable or fragile products are sent, and they are often packed with polystyrene or plastic cushioning in packages that are far too large. Although the proportion of recycled cardboard material is relatively high at around 75%, costs and emissions are nevertheless caused by the collection of cardboard and the use of other raw materials, including water and energy, in its manufacture (Nestler, 2016). In addition, marketing aspects play a role in packaging, as consumers often attach a higher value to an elaborately packaged product (Bertram and Chi, 2018). Fresh food, refrigerated and deep-frozen goods pose particular challenges for packaging and logistics (Ernst & Young, 2014).

The Packaging Act has been in force in Germany since January 2019 and includes new deposit regulations, higher recycling quotas, and a central body for registering packaging and paying licence fees, which also apply to online retailers. It aims to take the first step in reducing packaging waste (FAZ, 2018). However, it is estimated that "tens of thousands of companies (mainly internet retailers) have, illegally, not licensed their packaging at all so far" (Bethge et al., 2019: 15).

With regard to the volume of traffic, the environmental impact in the form of air pollution, noise, vibration, road wear and particle emissions has not yet been clearly determined (Sühlmann-Faul and Rammler, 2018). In the USA, it has been found that online commerce in the city of Newark has led to an increase in traffic volume and emissions of greenhouse gases and air pollutants (Laghaei et al., 2016; Sections 5.2.6, 5.2.8). A comparison of energy consumption between B2C online commerce and the traditional retail trade in the book sector in densely populated areas of Japan shows that online commerce consumes much more energy per book than the traditional retail trade. This is caused mainly by additional packaging, but also depends on how well courier vehicles are loaded and on the number of journeys required per delivery (Williams and Tagami, 2003). In rural and peri-urban areas, however, energy consumption is comparable, which is attributed in particular to the multipurpose use of private vehicles. In the USA, too, the environmental impact of the online book trade has proved to be comparable to that of using a private vehicle for shopping (Matthews and Hendrickson, 2001).

Not only the transport sector is responsible for the poor energy balance of online commerce, but also changes in customers' leisure and shopping behaviour. It is estimated, for example, that doubling online commerce's share of total retail sales to 20% in Germany would push up energy consumption by 5.6% as a result of increased leisure activities on the part of customers (Dost and Maier, 2017). Similarly, consumer behaviour (Section 5.2.3) has changed considerably over the last 20 years as a result of online commerce, and this has had negative effects on the environment (Bertram and Chi, 2018). In the clothing sector, for example, 'fast-fashion' companies have emerged as a result of simplified communication and the chance to quickly collect information on fashion trends. These companies offer cheap clothing with the result that consumers buy more clothes, which in turn are soon thrown away, resulting in considerable negative environmental externalities (Bertram and Chi, 2018).

At the same time, digital solutions can significantly reduce the ecological footprint of online deliveries by optimizing transport logistics. However, the shorter the delivery time, the more difficult it is to optimize the routes, which is why delivery vehicles are often only loaded half full (Kontio, 2013). A positive environmental balance can only be achieved if online shopping replaces 3.5 traditional shopping trips, if 25 orders are delivered at the same time, or if the driving distance is further than 50 km (Plepys, 2002; Newcastle University, 2010). Another study claims it is worthwhile for clothing buyers to switch from stationary to online retailing from as little as 14 km driving distance (Wiese et al., 2012). Due to the strong competitive pressure in online commerce, however, more and more online traders are offering delivery on the same day or within a few hours as express delivery.

Considerable journeys into cities can also be saved if online consumers drive or go to town to shop less frequently. In a survey in Germany, 40% of over 1,000 online consumers surveyed stated that this was the case (Bolz et al., 2017). However, it is also conceivable that they often first go to bricks-and-mortar shops to examine the products, and then order them online more cheaply.

Consideration must also be given to the frequent unsuccessful deliveries of orders to customers (Bertram

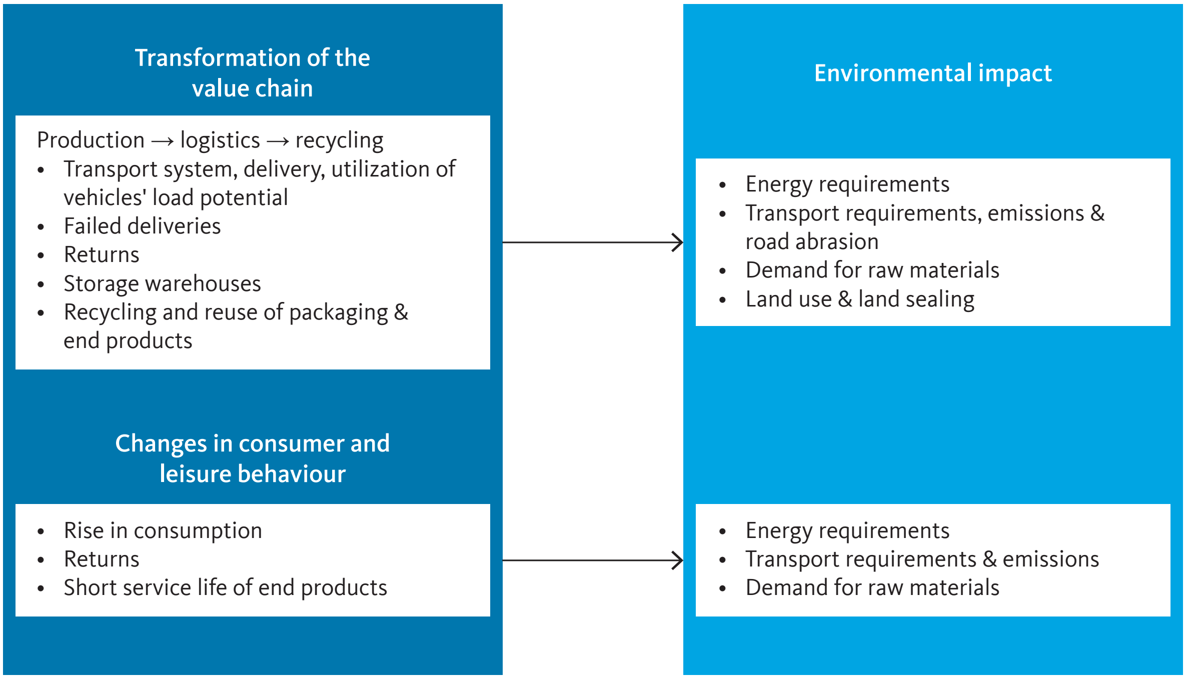


Figure 5.2.4-1
Environmental effects of B2C online commerce.
Source: WBGU based on Fichter (2003) and Tiwari and Singh (2011)

and Chi, 2018) and the many returns (Kontio, 2013). It is estimated that in Germany, on average, every tenth order goes back to the supplier, in the case of clothing as many as every second parcel (Kontio, 2013). A representative survey of 1,054 online consumers in Germany (Kontio, 2013) shows that the return rate has actually increased slightly over time. According to this survey, one in eight items purchased online is returned. This trend is especially pronounced among younger online customers. In addition, about half of all online consumers indicated that they make online purchases with the firm intention of returning them (e.g. clothing in different sizes; Kontio, 2013). In order to avoid returns and the associated costs, providers offer live chat sessions to advise customers or try to describe their articles as precisely as possible and present them visually. 360° shots and virtual changing rooms are being developed depicting clothes with the help of mannequins with the consumers' measurements (Kontio, 2013).

Further damage to the environment is caused by the construction of access roads, large storage warehouses for online commerce companies, and by sealing the soil. In many places, goods centres or hubs are created for the interim storage of ordered parcels. Amazon and Zalando alone currently have a total storage area of almost a million square metres in Germany (Morganti et al., 2014). However, digital solutions can help reduce storage space by better adapting production volumes to demand and avoiding overproduction. In addition, storage in interim storage facilities is usually more energy-efficient, as less heating and lighting is used than in bricks-and-mortar stores (Mottschall, 2015).

The role of customer loyalty is also becoming increasingly important in online commerce; it is measured by the Customer Lifetime Value (Ernst & Young, 2014). Increasingly, marketing strategies are being developed to boost consumption via online retailers' internet platforms, thus leading to an increase in production and consequently in transport and the associated emissions (Weth, 2016). However, apps, information platforms and online shopping guides may also make it easier for customers to search for sustainable offers, so that positive environmental effects can be achieved via the product effects. Global trading platforms for used goods such as eBay even aim directly at changing consumer behaviour away from a disposable culture towards a resale culture. Furthermore, eBay regards itself as an important building block for a circular economy (Behrendt, 2017) due to its subsequent orientation towards sustainability.

Environmental pollution is also generated by the increasing transport of goods over long distances in global online commerce. Since certain goods are only available in some countries, or because prices are lower, consumers are increasingly ordering products abroad.

Box 5.2.4-1

Recommendations for action on the arena 'Sustainability in online commerce'

To ensure that online commerce creates more opportunities than risks for sustainable development, the WBGU makes the following recommendations for action:

- *Strengthen consumer awareness of the impact of online commerce on sustainability:* In order to avoid negative effects in online commerce, consumers should be better informed about the impact of their purchasing decisions on sustainability, so that they are more aware while shopping. This could be achieved, for example, by including information on the product's environmental and/or social footprint with each purchase. For example, a footprint account could be introduced for each citizen to increase transparency about their own footprint and avoid unnecessary returns. The introduction of an explicit return fee should also be discussed in order to individualize (and not socialize) the costs.
- *Improved monitoring of environmental, social and health standards for online commerce; mandatory labelling and traceability:* Guaranteeing the quality of the merchandise, environmentally friendly packaging materials, climate-friendly shipping (e.g. using e-vehicles), and fair wages for employees in the delivery services can increase the sustainability of online commerce while at the same time creating more transparency for consumers. This also applies in particular to international online commerce, because here there are no checks or guarantees of product quality – unlike in bricks-and-mortar commerce. State quality controls of imported products should therefore be stepped up and legislation adapted if necessary. In addition, online retailers should be encouraged to develop and implement sustainability strategies (e.g. corporate social responsibility). Initiatives like the United Nations Global Compact should become more visible and be implemented at a decentralized level.
- *Reduction of packaging waste:* Targets should be set for waste reduction, and compliance with these targets (including recycling) should be monitored more closely. One possibility might be to introduce a deposit system for packaging. In addition, ideas should be developed for the reuse of packaging material. Plastic and polystyrene must be replaced by easily degradable bio-based materials (Bertram and Chi, 2018). Packaging avoidance and the effects of packaging waste must be made a global issue with the aim of changing consumers' environmental awareness and purchasing behaviour in the long term. Licensing of packaging in online commerce must be monitored, whereby cross-border regulations seem sensible. Exports of packaging waste to developing countries should be effectively prevented.
- *Cities and municipalities need support* in the development and implementation of strategies to create alternative offers for the urban population and to maintain or revive the traditional retail trade (e.g. with mobile retailers). In addition, cities and municipalities should inform consumers on public platforms about what is on offer from sustainably producing companies and/or shopping facilities in the region. This can be promoted by active marketing.
- *Further develop concepts of city and crowd logistics*: Centrally located parcel collection points with long opening hours are already being established in empty shop buildings to reduce the number of deliveries. The logistics sector is also being used as a testing ground for electromobility. These ideas should be further developed towards zero emissions and climate neutrality. Rail transport should be promoted as an alternative to fuel-based transport using trucks.
- *Avoid trips with low capacity utilization and reduce multiple trips:* To protect the environment, transport companies should only make deliveries when a certain degree of their vehicles' load potential has been reached; multiple journeys to deliver online goods should be reduced or, if possible, avoided. For this purpose, the already known options (parcel stations, delivery at a desired time, e-mobility) should be exploited and further advanced.

Of more than 1,000 online consumers surveyed in Germany, 40% stated that they had ordered from a foreign retailer in the last 12 months, particularly from China (35%) and the USA (20%; Bolz et al., 2017). As a rule, consumers cannot precisely check the extent to which environmental, health and social standards are complied with in the production and processing of such products. Unlike bricks-and-mortar trading companies, Amazon or Alibaba, which act as internet platforms, do not assume any responsibility if the goods offered do not meet certain standards – and checks by state authorities are only carried out very irregularly.

Figure 5.2.4-1 summarizes the various environmental effects of B2C online commerce.

New ideas for online deliveries have been developed to address sustainability goals in online commerce (Hegmann, 2016; Schlautmann, 2016). Amazon, for example, has filed a patent for a hovering department-store blimp positioned in the sky over areas of high demand from which unmanned drones could deliver their goods. In China, Alibaba already uses drones for customer deliveries. In Iceland, food orders are also delivered by drones, and the company Uber plans to enter the food-delivery service with drones in the USA (The Economist, 2018). The idea of using cooling boxes as collection stations for food ordered online is under consideration, e.g. at filling stations (Nitsche and Figiel, 2016). Delivery robots have been tested that transport parcels weighing up to 15 kg. Deutsche Post already has electric utility vehicles and street scooters as well as pedelec cargo bikes in operation. In 2018, the number of street scooters totalled 8,000; with over 35 million kilometres driven, this meant an estimated annual CO_2 saving of 23,000 t (Sebastian, 2018).

Major changes are expected from the development of concepts for city and crowd logistics, with 'people in

Box 5.2.4-2

Research recommendations on the arena 'Sustainability in online commerce'

There are only a small number of scientific studies that measure or evaluate the impact of online commerce on sustainability. Since the empirical evidence on this impact is far from clear, the WBGU proposes that the Federal Government provide funding support for research into the following concrete issues:

- *What short-, medium- and long-term ecological and social effects does online commerce have? What concepts or strategies are conceivable to promote the sustainability of online commerce?* Knowledge about the impact of online commerce on sustainability is still very limited, and results to date are inconclusive. Furthermore, there is a lack of the primary data needed to understand the relationship between online commerce and sustainability (Bertram and Chi, 2018). The latest developments and innovations must be taken into account in studies (including real-world laboratories for urban logistics) on the sustainability of online commerce.
- *How can packaging waste be drastically reduced or recycled?* The aim should be to achieve a circular economy. Can the goal be achieved at all in global online commerce, and if so, how?
- *Plastic packaging waste: what consequences does microplastic intake have for the health of humans and animals?* It is already known that plastic particles are absorbed by humans and animals through food, water and the air and that these particles can be detected in the human body (e.g. the liver and brain), yet little is known about the health effects (Waring et al., 2018).
- *What effects do online retailers' marketing strategies to increase consumption (immediate delivery or personalized prices and offers) have on consumer behaviour?* Digitalization influences consumer behaviour with direct consequences for the environment. Is consumption increasing as a result? How are consumption patterns changing?
- *Which urban concepts should be promoted that counteract the cultural loss of the inner cities and allow for some kind of dovetailing with online commerce and other online offerings?* In order to keep up with the fast-moving development in countries like Germany, changes will be necessary in the municipalities that are struggling most with the loss of the bricks-and-mortar retail trade. By developing alternative urban development concepts, it might be possible to counteract the cultural loss of inner cities in time.
- *What sustainability measures are companies taking in view of increasing online commerce?* Research in this area includes the analysis of sustainability concepts within value chains, how to deal with returns, and the optimization of logistics in order to internalize negative environmental externalities. The use of digital solutions, such as 3D simulations or computer-aided augmented reality, could be included in the analysis.
- *What impact does online commerce have on sustainability in developing countries? Which factors hinder or promote sustainable online commerce? What data should be collected in order to adequately reflect the impacts?* Data availability in this area is still very low. This applies in particular to developing countries, where little data on online commerce is available. This makes it difficult for politicians and companies to make strategic investment decisions.
- *What role does online commerce play in the World Trade Organization (WTO)? What impact is digitalization having on world trade? Will the discussion on online commerce lead to a new block formation of country groups?* Increasing online commerce has become an important and much discussed topic in the international negotiations of the WTO and the World Economic Forum. The WTO sees AI, the IoT, 3D printing and blockchain technology as the key technologies of digitalization in commerce and the ones that will have a significant effect on it (WTO, 2018). The 2018 World Trade Report highlights not only the benefits, but also a number of dangers, such as the increasing concentration of power and the loss of privacy and security (WTO, 2018), which need to be further explored.

a crowd' ordering or providing a service (Mehmann et al., 2015; Ernst & Young, 2014; Hausladen et al., 2015). For example, parcels to be delivered are placed in the boot of a vehicle located via GPS. 'Crowdshipping' links dealers, suppliers and customers via (mobile) software. Anyone who is already on the road can take parcels with them for others – for a fee. It is expected that environmental pollution caused by emissions from delivery traffic can be at least partially reduced in this way in the future. Sustainability solutions for online delivery already exist today. At the beginning of the millennium, DHL introduced parcel stations where customers can pick up their parcels, thus avoiding multiple deliveries. According to a study conducted in 2006, such parcel stations in Cologne, most of which are within walking distance for the customers, can save more than 35,000 km a year in car trips (Folkert and Eichhorn, 2007).

5.2.4.3 Social effects

Consumers benefit from online commerce because prices are lower and comparable, the range of products is more varied, and the act of buying is both independent of business opening hours (Berg, 2015) and much more convenient (Lang and Ebneter, 2012). Inclusion of elderly and handicapped people in particular increases because of the possibility of home delivery.

However, the growth of online commerce in general and pure online retailers in particular is also upping the economic pressure on bricks-and-mortar retailers, especially small and medium-sized enterprises (SMEs) and those based in smaller towns. As a result, more and more retail stores are closing in towns and villages, but also in major shopping centres (which are becoming 'dead malls'). For society, this can mean a cultural loss if urban flair and popular places for meeting and discussion are lost (Weth, 2016). In addition, there is a danger that people who predominantly shop online will become isolated and no longer maintain external contacts, leading to loneliness in society.

Structurally, city centres and the retail trade are closely linked. Shopping opportunities determine the attractiveness of an inner city for about 66% of the population (Mensing, 2010). Furthermore, the municipalities benefit from trade tax revenues (Stepper, 2016). Many municipalities find it difficult to optimally counteract fast-moving developments by making alternative offers in their city, since infrastructural planning is more geared towards the medium and long term and the bureaucratic hurdles are often difficult to overcome (Stepper, 2016).

At the same time, jobs are being lost in the retail trade (in Germany alone, more than three million people are employed in the bricks-and-mortar retail trade; HDE, 2015), jobs that are considered more attractive than in the logistics sector. However, it must be borne in mind that online commerce also opens up new sales markets for SMEs. In China, for example, thousands of new producers have emerged in the horticultural sector, marketing their fresh products via the Alibaba online platform (Weise and Reindl, 2017). It is also becoming easier for small booksellers and second-hand bookshops to find customers for their niche products via online platforms like Amazon or eBay. Likewise, innovative niche providers of sustainably produced products find it easier to find and advertise to a larger number of customers in online commerce.

5.2.4.4
Conclusions

Online commerce is growing rapidly. It not only raises efficiency and generates economies of scale, but also causes negative environmental externalities through increased delivery traffic, packaging waste, the numerous returns and the increasingly cross-border, international exchange of goods. On the other hand, there are positive effects from optimized logistics systems, people making fewer private trips to town, and improved control options, product and process labelling according to sustainability criteria, and traceability along supply chains. The empirical evidence of the overall effects on the environment is not yet unequivocal.

Negative social impacts in cities and municipalities can be observed in the displacement of bricks-and-mortar commerce. Furthermore, the turnover of online commerce, and thus its market power, is concentrated on a few companies; a not insignificant proportion of product purchases in online commerce are international and cross borders – with little chance to monitor compliance with environmental, health and social standards in the country of origin.

5.2.5
Digitalization: from the electronic waste problem to a solution for the circular economy?

5.2.5.1
Electronic waste in the context of the circular economy

This arena illustrates the potential, but also the challenges, of digitalization for the circular economy using the example of a more sustainable approach to electronic waste (e-waste). Digitalization is leading to a sharp increase in the production of electrical and electronic equipment, in the corresponding demand for strategic metals, and to growing amounts of toxic e-waste (Section 5.2.5.2; Baldé et al., 2017). At the same time, however, it also offers valuable potential and a set of tools for improving the circular economy (Section 5.2.5.3). The circular-economy approach is taken up by SDG 12 'Ensuring sustainable consumption and production patterns' (UNGA, 2015). An overarching view of industrial material flows is provided by the arena 'Sustainable industry 4.0 and circular economy' (Section 5.2.1).

For the WBGU, the rapid transition to a circular economy that is as complete as possible is seen as a central building block in the Transformation towards Sustainability (WBGU, 2016a: 21). The circular economy offers alternatives to the dominant form of 'linear' value chains, in which mineral raw materials are extracted from the Earth's crust by mining, processed into products, and incinerated at the end of their useful life or disposed of as waste (EMF, 2014). Especially the beginning (mining) and end (waste management) of this chain create considerable sustainability problems for the environment, health and development (UNEP, 2010). Furthermore, mineral deposits of metals and other technical raw materials are limited, requiring strategies such as the reduced and efficient use of resources, a circular economy and substitution, and sustainable consumption (UNEP IRP, 2017: 150ff.; Section 5.2.3).

The '3Rs strategy' (reduce, reuse, recycle) called for by the UN, among others (e.g. UN, 2016a: 47; UNEP IRP, 2017: 150ff.), is regarded as a guiding principle of the circular economy. Products should remain in use for as long as possible, keeping resource consumption per utilization unit low, and unnecessary production should be avoided by eco-sufficiency strategies (*reduce*). This can be achieved, among other things, by the joint use of goods by several persons (sharing economy:

Section 5.2.2.4). Afterwards, the devices should be repaired or their components refurbished and *reused*, which should already be provided for in the products' design. At the end of the longest possible lifespan, the technical raw materials (e.g. metals) in the product should be *recycled* as far as possible and used for the production of new goods (EEA, 2016a; Geissdoerfer et al., 2017). However, a completely closed cycle cannot be achieved because of the impossibility of both completely loss-free production and a 100% recovery of all technical raw materials (Korhonen et al., 2018). In addition, the diversity of technical materials used (e.g. alloys) is constantly increasing, making recycling considerably more difficult and further increasing the loss of strategic, rare resources (Reller and Diessenbacher, 2014).

Nevertheless, this '3Rs strategy' can reduce raw-material requirements and the quantity of waste generated, as well as the related damage to health and the environment (EMF, 2015). The return of biological materials to ecosystems (e.g. by composting; EMF, 2013) should be made possible by avoiding contamination.

5.2.5.2
Digital technologies as a cause of the global e-waste problem

E-waste is an issue at all stages of the product life cycle of electrical and electronic equipment. Many problems arise at the beginning of this cycle. The rapidly increasing demand for digital devices such as computers, tablets and smartphones, and the electronics and batteries integrated into everyday objects, together with inadequate recycling (e.g. the strategic metal lithium is not currently recycled in Germany), is leading to an increasing consumption of metals like gold, cobalt and tantalum. The extraction of these raw materials causes considerable environmental and health damage in the countries of origin (mostly developing countries or emerging economies) and is also a major cause of conflicts, violence and even military disputes (UNEP, 2012: 24; WBGU, 2016a: 182f.).

The main problem driver is the interplay between a growing number of electronic devices with shortening service lives and the fact that most devices cannot be repaired due to 'obsolescence', i.e. because they are intentionally or unintentionally designed in such a way that they do not last long (Box 5.2.5-1). As a result, e-waste (end-of-life electrical and electronic devices) is one of the fastest growing waste streams in the world (Kumar et al., 2017; Cucchiella et al., 2015). In 2016, the volume of e-waste worldwide totalled 44.7 million tonnes, and is expected to rise to 52.2 million tonnes in 2021 (Baldé et al., 2017). The growth rates of 3–5% per year correlate with GDP (Kumar et al., 2017). Only 20% of global e-waste was collected and recycled via official take-back programmes in 2016. 4% ended up in household waste, and the whereabouts of the remaining three quarters are unknown (Baldé et al., 2017). They were probably dumped in landfills, exported, or recycled under poor working, health and environmental conditions. Even in Europe, the e-waste recycling rate was only about one third in 2012 (Huisman et al., 2015). Despite a mature framework, the EU still has major difficulties in implementing the circular economy. However, the EU is increasingly recognizing waste as a strategic source of raw materials and attaching greater importance to reparability and pollutant reduction (e.g. in the action plan on the circular economy; European Commission, 2019d).

After the often illegal export to emerging economies and developing countries (e.g. China, Ghana, India), devices are frequently recycled in informal workshops with low efficiency levels and insufficient compliance with environmental and health standards, leading to considerable human exposure to, and environmental pollution with, toxic substances and heavy metals (UNEP, 2012: 182; Heacock et al., 2016). The e-waste dump in the Agbogbloshie slum in Ghana's capital Accra – one of the ten worst contaminated slums in the world – is often cited as a drastic example of intolerable conditions (Heacock et al., 2016; Daum et al., 2017).

The provisions of the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal are circumvented in the case of illegal exports (BAN, 2018). National regulations in this field are often inadequate or absent (e.g. in China, India and African countries; Wang et al., 2016b). China, the largest importer of e-waste, appears to be gradually changing its policy and, for environmental reasons, is increasingly preventing waste imports (Wang et al., 2016b; Mathews and Tan, 2016; Larson, 2014; Xiao and Zhao, 2017).

E-waste (including batteries and accumulators) does contain valuable metals such as gold, silver, copper, cobalt, tantalum and rare earths, but recycling is costly and, given the current incentive structures, of little economic interest in industrialized countries. E-waste holds great, largely untapped potential for the circular economy – the raw materials it contains alone were worth €55 billion in 2016 (Baldé et al., 2017: 54ff.).

The insufficient degree of implementation of the circular economy is mainly due to a lack of the right economic framework (Box 5.2.5-1), but also to information deficits. The latter could be eliminated by the (real-time) provision of the necessary data – which has often been lacking in the past – about location, condition, availability and material composition in a digitalized circular economy; electronic devices are particularly suitable for this (EMF, 2016: 19, 30f.; WEF, 2019; Wilts

Box 5.2.5-1

Obsolescence as a cause of the short lifespans of electrical appliances in the Digital Age

The causes of the ever-shorter product cycles of electronic devices are discussed under the term 'obsolescence' (Prakash et al., 2016). Not every case of obsolescence is intended by the manufacturer ('planned obsolescence'). The service life of electrical devices can also be limited by the wear and tear of the hardware ('mechanical obsolescence'). In addition, electrical devices are replaced for economic reasons when the use of product-related resources, necessary repairs and other maintenance are no longer worthwhile ('economic obsolescence'; Prakash et al., 2016:64). For example, permanently installed batteries make smartphones more difficult to repair (Primus, 2015:44). Laws have already been proposed in Germany and the EU to promote the material longevity and reparability of all products (Brönneke, 2015; Schlacke et al., 2015), as well as for environmental requirements laying down minimum service lives for digital products and services (Kurz and Rieger, 2018b).

Even apart from the lifespan of the hardware, e-waste is also generated by the shortened service life of electronic devices. Perfectly functioning devices are increasingly replaced for reasons of status, fashion or a desire to be up-to-date ('psychological obsolescence'). For example, 40% of users in Germany buy a new smartphone every two years at least (Primus, 2015:45). A return to the product loop is regularly prevented by the lack of proper disposal and collection systems for old devices (Primus, 2015). Although many consumers desire a longer service life, many devices become obsolete because they no longer meet the requirements of innovative services and products ('functional obsolescence'). This includes, for example, incompatibility with the latest soft- and hardware of other electronic devices (Prakash et al., 2016:64). If a smartphone is upgraded to the latest operating system (a prerequisite for using the latest apps and security standards), the processes can slow down because of the greater strain placed on hardware capacity ('software obsolescence'). When the hardware is older, upgrades are no longer possible, so that an (unavoidably) obsolete operating system leads to a lack of data security and incompatibility with new software (Ax et al., 2018).

In order to counter obsolescence, the WBGU believes not only that the minimum service life and reparability of the hardware should be legally guaranteed, but also that operating systems and software should remain upwardly compatible in the longer term and updates made available (Kurz and Rieger, 2018b). Corresponding obligations on the manufacturers should be introduced. Software should be designed in a modular and maintainable way during the development phase, designed to be resource- and energy-efficient and abstracted as far as possible from hardware in order to be compatible with both old and new devices for a longer period of time (Ax et al., 2018; Hilty et al., 2017; Kurz and Rieger, 2018b). In addition, manufacturers of obsolete equipment should make the manufacturer-specific design tools, software frameworks, documentations and software source codes available to third parties to ensure their further reparability and use (Kurz and Rieger, 2018b). Software must be incorporated into an integrated product policy like that promoted by the EU (Ax et al., 2018).

and Berg, 2017). Digital technologies offer new opportunities for an intelligently supported, integrated circular economy (e.g. BMU, 2018; Wilts and Berg, 2017) along the entire product life cycle. In particular, the Internet of Things (IoT), which allows an unequivocal assignment of identity and networking also for electrical appliances (Section 3.3.1), is considered to have a key role to play here (Baumgartner, 2016 70; EEA, 2017a:28; EMF, 2016:30). However, there are only a few cases where this has been done and correspondingly little knowledge about how digital technologies can actually be used in the circular economy or whether they might even have negative effects (EEA, 2017a:28; Pagoropoulos et al., 2017:20; RNE, 2017:29). Furthermore, the established recycling companies are as yet inadequately positioned for digitalization, while some ICT start-ups such as Rubicon are discovering the business potential for themselves, creating opportunities for a digitally supported circular economy (Büchele and Andrä, 2016; Rajala et al., 2018; Wilts and Berg, 2017. The digitalized circular economy is thus still in its infancy. Most of the solutions described below along the lines of the 3Rs strategy are therefore pilot projects and include equally important 'analogue' approaches.

Reduce

A central strategy for reducing e-waste – insofar as virtualization does not reduce the number of devices – is ecodesign ('design out waste': EMF, 2013:22, 2016:39). Decisions on a product's 'circularity' and its consumption of energy and resources are already made at the beginning of the life cycle or at the product-development stage (RNE, 2017:14), i.e. including sustainable product features like longevity or reparability. Digitalization can offer solutions here, e.g. if a design optimized using digital tools takes into account several circular-economy loops such as reuse, remanufacturing and recycling (EMF, 2016:37ff.). Today, IoT-generated data already flow back into *design processes*, so that new or further developed products can be optimized at an early stage with regard to the circular economy. The replacement of strategic metals with nano-carbons (Arvidsson and Sandén, 2017) or the use of biodegradable or transient electronics should also be already taken into account during design (Irimia-Vladu, 2014; Homrich et al., 2018; Tan et al., 2016).

Closely linked to waste avoidance and ecodesign is the movement for an 'open-source circular economy'. With its "[...] common vision of a collaborative economy of networked cycles and open information" (Majewski, 2016:97), it transfers the open source idea to the circular economy (Section 5.3.10) and pursues strategies against obsolescence (Box 5.2.5-1). A successful example of this is the Fairphone, which is doing pioneering work with its ecodesign and circular-economy-oriented business model (Fairphone, 2019; Majewski, 2016; Wiens, 2016) and has imitators like the German company SHIFT (SHIFT, 2016).

A key *reduce* strategy is the transition from product to user orientation. Based on the IoT, some companies have begun converting their business models into product-service systems, i.e. they sell the use of a product instead of its physical existence – in an analogous way to the sharing-economy idea (EEA, 2017a:24: Pagoropoulos et al., 2017:19). Although product-service systems seem to make important stimuli for the circular economy possible, they cannot guarantee success either (EEA, 2017a:26ff.; Tukker, 2015:87f.). In the commercial field, digitalization could drive concepts such as result-oriented contracts (Tukker, 2015:81), predictive maintenance or remanufacturing (here, the product is restored to its original condition and a guarantee given, e.g. toner for a laser printer; ERN, 2015:4). Such ideas are already in use for high quality vehicles, office communications, equipment or machinery (EMF, 2016:37ff.). An example for private customers is 'Washing as a service'. Digital monitoring of machine use ensures an extended service life through preventive and predictive maintenance as well as software upgrades, including (energy-) use optimization and estimating the remaining service life of the washing machine and its components (Bressanelli et al., 2018). Yet even simpler approaches have great potential. For example, it is estimated that a circular-economy-based rental model for routers could avoid up to 80% of raw-material losses and 45% of CO_2 emissions, while suppliers would save about a third of the costs (RNE, 2017:14f.). In some cases, however, the question arises as to whether a purchased product that has a long service life and is finally returned to a suitable collection point makes more sense for private customers and the environment. In addition, a compromise must be found between data protection and a circular economy that is coordinated via data (Bressanelli et al., 2018:220). Product service systems also frequently promote closed systems, such as subscriptions for printer cartridges, which bind customers to individual manufacturers instead of enabling them to refill at low cost (ERN, 2015:70f.). The aim here should be to create more system openness, also with a view to repairs.

Reuse

E-waste should no longer be treated as waste, but considered as a source of potentially useful products where reuse and recycling can be effectively integrated (Cole et al., 2017:156; Parajuly and Wenzel, 2017:279). Pioneering work is being carried out by the eReuse.org initiative, which uses digitalization primarily to increase reuse rates (Franquesa et al., 2016:8). Linked to an app, the system provides tools for device inventory and diagnostics, device management, and matching supply and demand; it also supplies data for device tracking and urban collection points.

Facilitated repair is a key promotional factor for the circular economy. Demands for a 'right to repair', a 'repair culture' or a 'repair society' should be seen, inter alia, as a reaction to the obsolescence of electrical appliances (Baier et al., 2016; Bertling and Leggewie, 2016; Charter and Keiller, 2016; Kurz and Rieger, 2018b; Wiens, 2016; Box 5.2.5-1). Worldwide, around 1,000 repair cafés in 25 countries (approx. 300–400 in Germany; Charter and Keiller, 2016:1) are making a contribution to increasing repairs of electrical appliances, avoiding e-waste and to the associated discourse. Online information (videos, manufacturers' manuals, social media) and platforms such as ifixit.com, which provide self-created repair information and sell spare parts and tools, also make a key contribution and support the work of the repair cafés (Charter and Keiller, 2016:9; Wiens, 2016).

Recycle

In order to avoid the most environmentally harmful solutions – landfills and incineration – when dealing with e-waste at the end of the product cycle, as many materials as possible should be recycled. In this context reverse logistics (i.e. logistics from the customer back to manufacturer/disposer) and waste management are crucial, but should ideally be digitally networked with earlier usage loops (EMF, 2016:47ff.). In reverse logistics, for example, sensors (satellite technology, RFID, mobile devices) and IoT or blockchain solutions can be used for process tracking, as is already standard practice in other areas of logistics. This helps to overcome problems of waste-mixing and to optimize resource utilization in real time. In waste management and recycling, more precise sorting is facilitated by sensor technology and real-time route optimization of waste collection by mobile communication, and intelligent waste containers provide incentives for better waste behaviour (EMF, 2016:47ff.). Earlier ideas of a purely RFID-based 'e-waste recycling passport' could now be extended to include the IoT (Löhle et al., 2009:68ff.; Schneider and Steinwender, 2009:167). A product passport on the device, in the cloud or via blockchain

Box 5.2.5-2

Recommendations for action on the arena 'Electronic waste and the circular economy'

The WBGU recommends that a clear course be set for the e-waste problem in the direction of a circular economy that is as complete as possible, as well as a cautious digitalization offensive and its embedding in legal framework conditions and economic incentives.

- *Promote environmentally friendly design and the circular economy:* A sustainable circular economy should become an explicit innovation goal of digitalization. Compatibility with the circular economy is already determined when a product is designed, so that sustainability and 'circularity' criteria must be integrated early on in the design phase. Longevity, substitution of toxic substances, the reparability and recyclability of devices, as well as the promotion of a sharing economy (Section 5.2.2.4), are essential points which are already largely determined at the design stage. New technologies (e.g. IoT, AI) and approaches (e.g. predictive maintenance, reverse logistics, remanufacturing) should be examined to determine their effects on the circular economy system before they are introduced.
- *Framework, rules and incentives:* Government frameworks should include rules and incentives on resource efficiency to avoid or substitute toxic and environmentally hazardous substances, and on the use of rare or non-recyclable resources. Another goal should be to create a repair culture and train repairing skills so that consumers can repair products and use them for longer (Kurz and Rieger, 2018b; Bertling and Leggewie, 2016). To do this, they need easily understandable information about the service life of electronic products (e.g. reparability) in order to take this into account when making a purchase decision. Extended producer responsibility for the circular economy should be enshrined in law, including an obligation of electronic-equipment manufacturers to ensure sustainable product design, taking into account energy consumption, longevity, reparability, and proper take-back and recycling. This also includes the publication of data and information (such as manuals, construction plans, functionality, components, constituents) as well as the long-term supply of spare parts and tools for repair and recycling. Software should be designed in a modular and maintainable way during the development phase, designed to be resource- and energy-efficient and abstracted as far as possible from hardware in order to be compatible with both old and new devices for a longer period of time. Authorized and independent repair workshops, repair cafés and individuals should be treated equally from a legal point of view. The 'right to repair' during the warranty period and a reduced tax rate on repair services should be examined and repair cafés promoted. In the field of electronic products, the mandatory open-source publication of product designs and source code after the end of commercial support is particularly important. Long warranty periods for devices and software (updates) create incentives for sustainable product innovations. Public procurement should also be consistently geared towards corresponding sustainable criteria.
- *Ensure transparent material flows*: Transparency regarding the resource use of ICT-based products and services should be improved (e.g. availability of market statistics, studies on the material inventory of digital hardware, life-cycle assessments; Köhler et al., 2018). The collection and recycling rates of e-waste should be made transparent and significantly extended, inter alia to reduce the extraction of raw materials and the associated environmental and health problems. Improved monitoring of material flows (e.g. digital product passports) can make it easier to avoid conflict minerals, curb illegal export flows of e-waste from industrialized countries, and help identify and combat imminent shortages and harmful environmental impacts at an early stage. The long-term goal should be to establish a global monitoring system for e-waste, including the documentation and control of the recycling chain for old devices.
- *Stop exports of e-waste:* E-waste generated in Europe must be recycled as effectively as possible in Europe itself and reused locally. The implementation gaps in the European export ban on e-waste from Europe should be closed as far as possible. Strict monitoring of exports of old electronic devices is crucial to prevent illegal export flows of e-waste. The mandatory certification of the functionality of old devices should be examined as a prerequisite for exports.
- *Support developing countries and emerging economies:* Within the framework of development cooperation, informal, non-governmental collection systems should be used, formalized and improved, particularly with regard to occupational health and safety and local environmental pollution. Improvements in the implementation of the import ban on defective and non-repairable electrical equipment should be promoted.

solutions could provide information on origin, constituents and condition, as well as disassembly and repair instructions throughout the life-cycle, e.g. fluorescence, RFID or DNA markers that make unequivocal labelling and identification possible (WEF, 2019:11). In addition, the use of AI is being tested in on-demand e-waste collection systems (Król et al., 2016). NGOs and telecommunications companies are jointly involved in the collection of old devices (Teqcycle Solutions, 2018). A simple existing solution is the free return option for e-waste by post (Deutsche Post, 2018).

In addition to sorting, a major challenge in recycling is the dismantling of products consisting of several components. In the case of highly standardized devices such as smartphones, this can be technically done entirely by robots, as Apple's pilot projects Liam and Daisy show (Alvarez-de-los-Mozos and Renteria, 2017:59; Becker, 2018; WEF, 2019:15). In the most common case of very different compositions of electrical waste, research is being carried out into the use of collaborative, adaptive robots that support humans in the identification and sorting of materials and components, but, above all, take over physically strenuous or hazardous dismantling work (Alvarez-de-los-Mozos and Renteria, 2017:61). A product passport can make this much easier (WEF, 2019:15). For both forms of

Box 5.2.5-3

Research recommendations on the arena 'Electronic waste and the circular economy'

The WBGU recommends a broad-based, transformative research offensive on e-waste in the context of the digitally enhanced circular economy.

- *Demand for materials and material flows:* There should be more research into the causes of the rising demand for materials in the ICT sector – e.g. accelerated product cycles, (not intended) obsolescence due to software and over-functionality. Globally oriented research on material flows in the context of e-waste is also recommended.
- *Material substitution:* Materials research should increasingly focus on promoting substitution by less rare, less toxic and less environmentally hazardous materials and by biodegradable electronics. For example, there are indications that some strategic metals could be substituted by carbon-based nanomaterials (Arvidsson and Sandén, 2017). Corresponding materials research should be accompanied by the investigation of possible environmental and health effects of novel substitutes.
- *Recycling technologies:* There should be more research and development on technical solutions for the use of robotics and machine learning and/or AI in the circular economy, as well as for recycling strategic metals and rare earths from e-waste and batteries (e.g. bioleaching).
- *Strategic approaches:* The theoretical and practical limits of the circular economy should be sounded out to assess the need for further accompanying measures, such as efficiency and eco-sufficiency strategies. Research projects in the field of waste prevention (particularly on rebound effects) – and on the influence of product information on longevity, reparability and recyclability on consumer decisions – should be initiated or intensified. The development of an indicator of ecological obsolescence should be examined.
- *Effectiveness of regulation:* Studies on economic incentives for reducing demand at the beginning of the design phase and for extending product life could help to increase recycling rates in the long term. The results could lead to improved urban and national regulations in the field of waste governance (e.g. collection systems, levies to control waste generation).
- *Criteria and standards:* There should be increased promotion of applied research and corporate research in the areas of green ICT, (open) source for product designs, and digitally supported recycling with regard to sustainability criteria and standards, including sustainable and long-lasting (open) software and hardware.
- *Access to data and information:* Publicly accessible data and information on resources, material flows and e-waste are important prerequisites for research work (Section 5.3.10). One example is the quantitative analysis of material flows in the electronics industry. How much potential is there for reuse in the highly diverse waste streams? What information is or should be available on the existing data platforms (materials used, construction plans)? At what cost and by whom can the information be used?
- *Participation and actors:* The opportunities for inclusion and the effects of different options for shaping the circular economy on different groups of actors such as civil-society initiatives (e.g. repair cafés), manufacturers and independent repair workshops and individuals should be examined, especially with regard to the impact potential of social innovations.

robotics use, problems of economic efficiency in particular still represent a barrier compared to existing practices. Innovative approaches from bio- and material science, e.g. microbiological processes to recover rare earths and metals, could be used to recycle raw materials (Bohnet, 2018).

In future, extracted raw materials and 'waste' could be traded (regionally) via digital platforms between companies at different stages of the value chain and in different sectors, thus promoting an 'industrial symbiosis' in the field of e-waste (Marconi et al., 2018; Section 5.2.1). Some people even suggest automated market and logistics platforms for secondary raw materials or intelligent products that virtually generate their own market; distributed-ledger technologies (Section 3.3.5.5) could provide the necessary anonymization of company and customer data (Wilts, 2018: 11; Rajala et al., 2018).

5.2.5.4
Conclusions

A clear course should be set in the direction of a circular economy that is as complete as possible and has as much target-oriented digital support as possible. This should be a fundamental component of the pathway towards future-proof sustainability. Digital technologies can help to make circular options more recognizable and traceable, support better coordination, and close process gaps. Policies should pursue a systemic and transformative strategy that looks at the whole life cycle of products and services – outlined here using the example of electronic and electrical products. Where appropriate, these policies should use digital technologies as tools. Starting points for this can be found in intelligent product design geared towards saving energy and resources and towards recyclability (Reller et al., 2013), in the coordination of an extended service life, and at the end of the life cycle, when digital solutions can also help ensure that toxic, environmentally hazardous substances do not pollute the environment and endanger health during recycling or disposal.

The handling of e-waste is still predominantly oriented towards the end-of-life phase of the product cycle, but this does not adequately address the e-waste problem. A digitally supported circular economy should be increasingly geared to the early phase of a product's life cycle with strategies such as eco-sufficiency, eco-design, repair and reuse. Not only technical and legal solutions, but also new business models, consumer education, social innovations and changes in cultural practices are needed, e.g. changes in behaviour and sustainable consumption (Sections 5.2.2, 5.2.3). The circular economy will not be successful without accompanying strategies for eco-sufficiency and changed consumption patterns (Schneidewind, 2018).

The WBGU recommends making timely political and economic decisions: clear regulation and incentives (national, European and international) to move away from toxic substances in product design and towards resource efficiency and modular products; a new, also digitally supported sharing economy and product-service systems; setting trends away from the throwaway mentality towards durable products and repair, and moving away from illegal exports of e-waste to emerging economies and developing countries towards effective recycling at the locations of consumption. Legal and fiscal incentives will play an important role in this change of direction. Among the prerequisites for such a fundamental change are a cautious *digitalization offensive* to leverage the positive potential of digitalization along the entire product life cycle and to counter rebound effects (Box 5.2.5-2), as well as a *research offensive* that looks at options for improved information accessibility, product reparability and solutions such as the development of biodegradable electronics (Box 5.2.5-3).

5.2.6 Digitalization for climate-change mitigation and the energy transformation

SDG 7 aims to provide all people with access to affordable, reliable, sustainable and modern energy; SDG 13 aims to combat climate change and its impacts. Both goals can only be achieved in combination, and digital technologies such as smart grids, smart meters and digitally supported energy storage can play an important role.

Successful implementation of the Paris Agreement requires a transformation of energy systems and changes in land use, urban infrastructure and industrial production (IPCC, 2018; WBGU, 2011). In the case of relatively short-lived greenhouse gases like CH_4 and N_2O, which are produced in agriculture for example, it is sufficient to stabilize emissions at a low level. However, anthropogenic CO_2 emissions must be reduced to zero to stop further global warming (IPCC, 2018: 14f). The main sources of anthropogenic CO_2 emissions are the use of fossil fuels such as coal, crude oil and natural gas and, to a lesser extent (12%), emissions from changes in land use (Le Quéré et al., 2018). Depending on how quickly greenhouse-gas emissions decrease, it will be necessary in addition to remove CO_2 from the atmosphere in the medium term to achieve the Agreement's objectives (IPCC, 2018; Box 5.2.6-1). The WBGU believes that the need for such 'negative emissions' should be kept to a minimum (WBGU, 2016b). The extensive decarbonization of global energy systems by the middle of the 21st century is therefore crucial, and this will only be possible if demand for energy does not rise too sharply in the same period (WBGU, 2016b). Just under 80% of global energy demand is still met by fossil fuels and only about 10% by modern renewable energies (hydropower, wind, sun, biomass/biofuels, geothermal energy, ocean energy; REN21, 2018a: 34). At the same time, access to sustainable and modern energy for all by 2030 must be ensured in order to meet SDG 7. Almost a billion people worldwide still have no access to electricity, and about three billion people depend on harmful forms of energy such as traditional biomass or coal for cooking (UN, 2018c). Scientists have developed various scenarios of how all sectors could be 100% supplied with renewable energy by 2050 (WBGU, 2016b; Jacobson et al., 2017). Core elements of such scenarios are electricity generation based on renewable energies, the integration of electricity with other sectors such as mobility, heating and industry ('sector coupling'), and technologies and instruments to reduce energy demand. Such a global energy revolution could also prevent millions of deaths from air pollution (Jacobson et al., 2017).

Digital technologies play a key role in enabling such a global transformation of energy systems. They can set the course for the decarbonization of energy systems (Section 5.2.6.1) and contribute to a reliable energy supply in off-grid regions (Section 5.2.6.2). At the same time, however, digitalization can also jeopardize the energy transformation if it leads to a sharp increase in energy demand (Section 5.2.6.3). Digital technologies and applications can also contribute to climate-change mitigation outside the energy sector, although possible rebound effects must also be critically examined in other sectors. For example, sustainable intensification in agriculture with the help of digital technologies could reduce the pressure on changes in land use and thus avoid emissions (Section 5.2.9). Integrated smart-city concepts (Section 5.2.7) could reduce urban emissions. There is also considerable efficiency potential in industry which could serve climate-change mitigation, for example in the field of goods production (Section 5.2.1). There is further potential in logistics in buildings and in the transport sector (Section 5.2.8; de Coninck et al., 2018: 370). Furthermore, digital technologies are not only relevant for climate-change mitigation, but can also play an important role in providing information for climate adaptation and disaster preparedness, e.g. through improved weather forecasting and early warning systems (Lourenço et al., 2015).

5.2.6.1 Use digital technologies for the energy transformation

The digitalization of energy systems is already in full swing. Global investment in digital electricity infrastructure and software has increased by 20% per year in recent years (IEA, 2017a: 21). Digital technologies influence almost all aspects of energy systems (IEA, 2017c, 2017) and are considered to have considerable transformative potential for the entire energy system (IEA, 2017a).

In the past, the electricity sector was dominated by large power plants supplying electricity on demand. In the meantime, more than 26% of the world's electricity is already generated from renewable energy sources (REN21, 2018b: 41), and the trend is rising. Due to the decentralized and fluctuating availability of renewable energies, their large-scale integration into existing grid-connected electricity systems poses increasing challenges to existing infrastructures and regulations. The management of system integration is a prerequisite, for example, for tapping the potential of photovoltaics, which is underestimated in many scenarios (Creutzig et al., 2017). Conceptually, the problem can be met with 'virtual power plants', i.e. intelligent interconnection and joint control of different decentralized power generators and storage facilities. Virtual power plants can react flexibly to changes in the grid and contribute significantly to a stable energy supply by joint control of decentralized energy plants. By bundling and combining them with storage facilities, volatile energy flows can balance each other out and provide electrical power reliably. Another purpose of integration is the joint marketing of electricity and flexibility as well as the provision of system services such as the operating reserve. Solutions for digital networking and intelligent control are supporting the paradigm shift in energy-supply flexibility (Farhangi, 2010).

Moreover, the electricity sector today is still largely isolated from the other energy sectors like heating/refrigeration and transport, and accounts for only about 20% of global final-energy demand (REN21, 2018a). In the future, a much more complex, decentralized system is conceivable, in which supply is no longer exclusively adjusted to demand, but demand can simultaneously follow supply via 'smart' systems. Furthermore, sector boundaries are becoming more permeable as a result of sector coupling: heat and mobility are increasingly coupled with electricity, and provide new storage capacity at the same time (e.g. batteries of electric cars). In such a system, the digitally supported transmission networks are expected to play a central balancing role in stabilizing the overall system (IEA, 2017a: 86).

These developments could pave the way for a fully renewable and largely emissions-free energy future, provided that the appropriate incentives and framework conditions are put in place. It is also important to consider systemic linking with other sectors that are relevant for climate-change mitigation, as well as the impacts on other aspects of sustainability. For example, not only electrification but also the substitution of fossil fuels by biomass or synthetic fuels based on renewable energies is being discussed as a possibility for sector coupling. The WBGU recommends maintaining a holistic view of the requirements of climate-change mitigation, biodiversity protection and the SDGs. The use of bioenergy must be assessed in the context of competition for land use (food production, ecosystem services, species protection; Smith, 2018; WBGU, 2009b). The potential of carbon-based synthetic fuels should be assessed in the context of the long-term challenges of climate-change mitigation (Box 5.2-1).

5.2.6.2 Use digital technologies to overcome energy poverty in developing countries

The combination of renewable energy sources and digital solutions can make an important contribution to overcoming energy poverty (Hafner et al., 2019; UNIDO, 2017). Although the percentage of the global population with access to electricity is steadily increasing (from 79% in 2000 to 87% in 2016; IEA, 2017b), current efforts will not be sufficient to ensure access to affordable, reliable and sustainable energy for all people by 2030 (SDG 7) (UN, 2018c). As recently as 2016, more than 65% of the population in the UN group of least developed countries (LDCs) had no access to electricity (World Bank, 2017b). Rural areas are clearly at a disadvantage in this context: 80% of those who have been given access since 2010 live in cities, and the rural population accounts for 87% of the access deficit (UN, 2018c).

Box 5.2.6-1

The conflicting priorities between 'negative emissions' and synthetic fuels

Digital technologies play an important role in climate-change mitigation in transport, for example by enabling new mobility concepts that potentially reduce the volume of traffic. They should also be used to make new forms of propulsion possible in the context of sector coupling, while avoiding path dependencies that could make long-term climate-change mitigation more difficult.

Hardly any climate-change mitigation scenario that meets the objectives of the Paris Agreement will be able to do without 'negative emissions', i.e. removing CO_2 from the atmosphere, in the second half of this century (IPCC, 2018). This involves hundreds of billions of tonnes of CO_2 that would have to be removed from the atmosphere in the course of the 21st century. By way of comparison, current global annual emissions from the combustion of fossil fuels amount to around 36 billion tonnes of CO_2. At present it is as yet unclear which technologies can actually be used to remove CO_2 from the atmosphere in the long term. On the one hand, the combination of bioenergy with carbon capture and storage (BECCS) is being discussed; on the other hand, large-scale afforestation is being considered. These two options are almost the only ones that are considered in model studies on climate-change mitigation (Fuss et al., 2014). Both methods compete with other land uses, such as food and biodiversity. Other technologies, such as the direct technical capture of CO_2 from the atmosphere (Direct Air Capture, DAC) are currently not economically feasible; they are also extremely energy-intensive and only capture tiny amounts (e.g. climeworks.com: 900 t of CO_2 per year). Corresponding projects usually aim to use the captured CO_2 (de Coninck et al., 2018:346; Wilcox et al., 2017). It will therefore be difficult to remove the required quantities of CO_2 from the atmosphere permanently.

At the same time, the use of synthetic fuels based on renewable energies is increasingly being discussed in the framework of the energy transformation as an option for a climate-friendly transport sector (WEC 2018). This could be hydrogen produced by hydrogen electrolysis, or carbon-based synthetic fuels such as methane, methanol, diesel, petrol or kerosene. The latter require CO_2 during production and then release it again during use. To keep these fuels CO_2-neutral, the CO_2 used must therefore come from the atmosphere, i.e. from biomass or DAC. This CO_2 from the atmosphere is thus no longer available for generating the necessary 'negative emissions', but is released back into the atmosphere when the corresponding synthetic fuels are used. The World Energy Council expects global demand for synthetic fuels to reach between 10,000 to 20,000 TWh per year by 2050. If these are carbon-based fuels, this corresponds to a considerable amount of CO_2 that would not be available for long-term storage: assuming, for example, that it is exclusively synthetic methane (this releases approx. 500g of CO_2 per KWh; WBGU, 2011), this would correspond to approx. 5–10 billion tonnes of CO_2 per year.

The WBGU therefore recommends that the focus for sector coupling in the transport sector should not be on carbon-based synthetic fuels, but primarily on other solutions (e.g. batteries, hydrogen). However, aviation, long-distance transport and shipping (Davis et al., 2018) present particular challenges. To this end, more research should be done into the contribution that digital technologies can make to minimizing the need for carbon-based synthetic fuels, for example in material or battery research.

Reliable power supplies in off-grid regions: solar home systems and mini-grids

Much of the above-mentioned potential of digitalized technology for the energy transformation can enable regions with an underdeveloped network infrastructure to 'leapfrog' in the technical expansion of their networks, reducing not only CO_2 emissions, but also power outages and losses (IEA, 2017a; IRENA, 2019). However, the nationwide expansion of the network in non-electrified areas is economically and technically difficult, which is why off-grid rural regions are increasingly turning to a decentralized energy supply with digital support (Alstone et al., 2015). The focus is on two approaches: the expansion of relatively small local networks, mini-grids, and household-based stand-alone solutions such as solar home systems (Nerini et al., 2016).

ICT is key to the provision and financing of solar home systems (SHSs), which usually consist of a solar module and a battery. SHSs often use the already widespread infrastructure for mobile phones. Typical business models are pay-to-own systems (where off-grid devices are paid off in instalments via mobile phone) and solar-as-a-service systems (electricity is paid for as a service via mobile phone, but the device is never owned; IEA, 2017b). These systems are suitable for regions with a low population density and can provide basic services at the household level relatively quickly. Except in regions with a very low population density, however, they are seen only as a short-term measure due to their cost intensity and the relatively low electricity volumes per household (Chattopadhyhay et al., 2015; Nerini et al., 2016).

More reliable long-term energy access is provided by mini-grids, i.e. local energy networks that can operate independently of a main grid and are based on modular power-generation technologies, e.g. photovoltaics, wind turbines, small hydroelectric power plants and, currently, often diesel or gas generators. To enable a stable flow of electricity, they use either these emissions-intensive generators or, increasingly, battery systems as storage facilities (IEA, 2017b). In 2016, 133 million people were already supplied with off-grid renewable energy, including 2.1 million from solar photovoltaic mini-grids. The market for this innovation is growing: in just eight years, the number of people supplied via mini-grids tripled in Asia and grew sixfold in Africa (IRENA, 2016).

Mini-grids based on renewable energy offer some advantages compared to solar home systems. They can provide high quality power to multiple households at the same time and are less expensive. They also provide basic services such as street lighting; the electricity is stable enough for industrial purposes and can be integrated into the national grid in the medium term. Even in areas with a grid connection, they offer a reliable replacement system for supply disruptions and increase resilience (IRENA, 2016; IEA, 2017b).

Digital innovations can make an important contribution to regionally expanding and accelerating the transformation to such systems. Similar to the main grid, ICT can improve the performance standards of mini-grids (e.g. flexible load control, smart meters) and, similar to SHSs, consumers can become more actively involved and informed via the mobile network (IEA, 2017a). Current research efforts are aimed at refining short-term control systems with intelligent control and more accurate performance forecasts for solar and wind energy, at adapting meter technologies, improving ICT and interoperability standards, and simplifying the linking of different technologies (IRENA 2016). In conjunction with the falling costs of photovoltaic and battery systems, there is great potential here for achieving SDG 7. However, here too, emerging 'digital' risks to network resilience and privacy should also be researched and addressed more intensively.

Although the technological foundations largely exist, a favourable political framework and investments are needed for mini-grids to achieve market maturity and market penetration. The regulation of mini-grids is still in its infancy. The International Renewable Energy Agency (IRENA) recommends that newly introduced standards should be sufficiently flexible to enable further development and innovation (IRENA 2016). Governments should boost capacity building and the dissemination of expertise through international cooperation and industry promotion. The International Energy Agency (IEA) also emphasizes that mini-grid systems should be linked to long-term plans for strategic grid expansion by the respective state government (IEA, 2017b). The dynamic development of the energy markets and digital innovations pose a challenge for political decision-makers that should not be underestimated.

5.2.6.3
Contain the demand for energy generated by digitalization

Too great an increase in global energy demand can undermine the energy transformation by making it more difficult to fully decarbonize energy systems in good time. There is no global estimate of how digitalization, with its direct and indirect effects, will influence global energy demand (Köhler et al., 2018). Various studies show potentially significant positive and negative effects of digitalization on energy demand in different sectors, and there is great uncertainty. The possible higher efficiency thanks to intelligent control and electrification is offset by increases in energy demand caused by new devices, software applications and changes in behaviour (Köhler et al., 2018). The future development of energy demand will therefore greatly depend on the framework conditions.

Change in energy demand in selected sectors caused by digital technologies

The effects of digital technologies on energy use in the transport sector, which currently accounts for 28% of global demand for final energy (IEA. 2017a), stem, for example, from expected automation, networking and electrification, as well as the possibilities of sharing. They could be considerable, but it is not clear whether they will increase or decrease demand. Scenarios developed by Wadud et al. (2016) show, for example, that in the US transport sector, energy demand could halve or even more than double as a result of vehicle automation, depending on what assumptions are made about technological and societal developments. For example, partial automation could reduce energy demand as a result of efficiency effects, while fully autonomous vehicles offer increased incentives to travel. Urban mobility is discussed in greater detail in Section 5.2.8.

Buildings currently account for about a third of global final-energy demand and 55% of electricity consumption. If full use is made of the efficiency potential made possible by digital technologies (e.g. smart control, use of real-time data for heating, cooling and lighting), according to an IEA calculation the total energy demand in this sector could be reduced by 10% in the period 2017–2040 compared to a reference scenario in which this potential is not used. This presupposes, however, that there is only a small rebound effect. According to the IEA, these savings could equally be offset by new digital services and rising standby consumption (IEA, 2017a: 29).

A third important sector is industry, which currently accounts for 38% of global final-energy demand. Automation has a long history in this sector, and there are numerous examples of how efficiency gains can be

Box 5.2.6-2

Recommendations for action for the arena 'Digitalization for climate-change mitigation and the energy transformation'

- *Strengthen climate- and energy-policy framework conditions:* Without clear framework conditions, digitalization can act as a fire accelerant, driving both the increase in greenhouse-gas emissions and in the demand for energy and resources. Strong framework conditions for climate and energy policies, as already outlined by the WBGU in previous reports (WBGU, 2011, 2016b), are therefore the basic prerequisite for exploiting the potential of digitalization for the energy transformation and climate-change mitigation. Among other things, this involves a long-term political, economic and regulatory framework for a complete decarbonization of energy systems, which should be largely completed by the middle of the century. An appropriate innovation policy should also be used to push ahead with targeted technological developments that address sectors which are currently difficult to decarbonize. Timely infrastructure investments are also necessary to enable an energy transformation towards sustainability.
- *Establish energy and resource efficiency as innovation targets for digital technologies and applications:* In view of the exponential increase in the use of digital technologies and applications, which are encompassing more and more areas of everyday life, limiting the respective ecological footprint must be given a high priority. The WBGU therefore recommends explicitly establishing energy and resource efficiency as an innovation target for all digital technologies and applications. At the same time, appropriate, forward-looking regulatory framework conditions should be created, such as efficiency standards for digital solutions and digitalized infrastructures, as well as regulations on standby energy consumption. These should take into account the rapid pace of development in the digital field. New device types and applications are being produced in quick succession; this is inherently different from the situation with classic electrical appliances such as refrigerators or air conditioners (IEA 2017a). Certification, e.g. for particularly efficient data centres, could also play a role. With a view to the possible limits of current ICT efficiency trends resulting from the physical prerequisites of transistors (IEA, 2017a: 115) and the environmental impact of ICT beyond energy demand, a selective limitation of digital networking must also be discussed.
- *Contain the risks of digital energy systems – security by design, comprehensive data protection and data economy:* In order to contain the security risks of increasingly digitalized energy systems, security and resilience considerations should play an important role in the development of technologies and the design of new systems. Comprehensive safety standards should be established for devices, vehicles, etc. that are networked with the energy system (IEA, 2017a: 115). The stability of the energy system should not be based primarily on ICT. Users must be guaranteed comprehensive data protection and protection against surveillance. Access to energy must not be linked to the disclosure of data. The principle of data economy should be established as a model for future energy systems.
- *Use mini-grid systems for overcoming energy poverty:* Mini-grids based on renewable energies can provide people in rural and off-grid regions with access to modern energy services. They achieve higher levels of service performance than solar home systems, for example, and can thus lay the foundations for productive energy use that goes beyond a basic provision of light, for example (IRENA, 2016). Digital technologies are at the heart of such mini-grids, which in many cases currently still combine fossil fuels like diesel with renewable energies; in the future, however, they can be based 100% on renewable energies. Measures for developing such climate-friendly mini-grid systems should be linked by the respective state governments with long-term plans for strategic network expansion (IEA, 2017a: 115). Regulatory frameworks should also provide reliable incentives for innovation (IRENA, 2019). The WBGU recommends that the further development of such systems be accelerated in order to make a contribution to global energy-system transformation and SDG 7.
- *Appoint an expert commission to examine the digital potential for decarbonization:* In order to systematically measure the potential benefits and risks of digital change for climate-change mitigation, and to derive starting points for political action, the WBGU recommends that the Federal Government should establish a Commission of Experts to critically assess the potential of digital change for decarbonization. In particular, opportunities for accelerating the energy transformation should be examined.

realized, for example by optimizing process control (IEA, 2017a). Furthermore, digitalization can support targeted innovations, for example by transferring energy- and resource-intensive test series to a 'digital twin', i.e. conducting them virtually. Section 5.2.1 provides an overview of digitalization's potential for industrial production and the circular economy: production processes could be made more efficient by digitalization, but these improvements could also be offset by an increase in energy demand generated by computer use, data transmission and data storage, so that the net effects are unclear (European Parliament, 2016). In addition, much of the efficiency potential is associated with considerable initial investments and requires special technical expertise, which can be particularly challenging for small and medium-sized enterprises (IEA, 2017a).

The energy demand of the digital infrastructure

The digital solutions that hold the potential for rapid decarbonization themselves require energy. If billions of new devices are networked in the coming years, the demand for energy from data centres and network services will increase. The IEA quantified the global electricity demand of data centres alone at 194 TWh (1% of global demand) in 2014, that of network services at 185 TWh in 2015. Furthermore, more than 20 billion networked IoT devices are expected by 2020, all of which will need power. However, it is difficult to

Box 5.2.6-3

Research recommendations for the arena 'Digitalization for climate-change mitigation and the energy transformation'

The goals for climate-change mitigation agreed in the Paris Agreement will require not only the decarbonization of the global economy, but also, in the long term, the actual removal of CO_2 from the atmosphere (IPCC, 2018). Research on the contribution made by digitalization to the global energy transformation should therefore be organized in a systemic way, i.e. going beyond the sectors of energy, mobility and heating. The WBGU recommends consistently pursuing the vision of an energy system that is based 100% on renewable energies and enshrining it as a central research mission. Key issues to which digital technologies can contribute are sector coupling, energy and/or electricity storage, the integration of fluctuating energy sources into the electricity grids, and dealing with increasing fluctuations in demand when other sectors are electrified (e.g. electromobility). Furthermore, there is a lack of innovative solutions in the transport sector (e.g. for ships, aircraft or heavy-goods vehicles). Focusing on carbon-based synthetic fuels would not be adequate here, as the use of CO_2 for this purpose conflicts with the long-term need to permanently remove CO_2 from the atmosphere in order to meet the climate objectives of the Paris Agreement.

In addition to the targeted use of digital technologies to limit energy demand and for energy efficiency, research should also focus on cost-effective and robust solutions for a reliable power supply in off-grid regions in emerging economies and developing countries. A wide variety of digital technology applications is important here, e.g. for mini-grids based on renewable energies (IRENA, 2016).

Finally, in the course of digitalization, greater emphasis should be placed on the reliability and stability of the energy supply, as well as on the protection of privacy. Furthermore, smart grids, smart meters and other intelligent applications lead to new complexities in energy supply and use. The implications of increasing complexity represent a further research topic.

forecast future energy demand as a result of ICT over the next few years, since, on the one hand, there is great uncertainty about the strong growth in data volumes and, on the other hand, it is hardly foreseeable whether further improvements in efficiency will be possible (IEA, 2017a: 103). However, there are currently no signs of a trend reversal in the ICT sector, despite high efficiency gains. On the contrary, the direct energy demand of the ICT sector continues to rise rapidly (Köhler et al., 2018). Both energy efficiency and resource efficiency should therefore be established as a firm innovation goal of digitalized systems and applications, and flanked by a corresponding regulatory framework.

5.2.6.4
Risks of a digitalized energy system: resilience and privacy

How much digitalization does an effective 'intelligent' energy system need? The growing digitalization of energy systems in the course of the diversification and decentralization of energy technologies, the integration of millions of energy prosumers and billions of IoT devices into energy networks, and the ever more extensive use of digital monitoring and control elements are creating a complex 'energy internet' (IEA, 2017a). This highly ICT-dependent energy system poses new risks for resilience and privacy: 'smart grids' are not necessarily the more robust or efficient systems and can even represent an obstacle to strengthening individual decision-making power and literacy in the sense of sustainable action.

Resilience of the energy supply

Energy systems are among the most critical infrastructures, since not only the energy supply itself, but also all other critical infrastructures, such as the water supply or communication networks, depend on them. Increasing digitalization and networking of energy systems may lead to additional risks with regard to their reliability and stability (European Parliament, 2016). The expansion of the energy networks into an 'energy internet' in which, for example, end devices are also integrated, can increase the vulnerability of the networks to digital risks such as geomagnetic storms, hacker attacks and viruses (Jacobson et al., 2017; IEA, 2017a). In the context of the global WannaCry attack in 2017, for example, more than 20,000 petrol stations of the China National Petroleum Corporation were forced offline (IEA, 2017a). A second problem can arise from a higher susceptibility to errors and so-called emergent behaviour: if different systems are networked to form a 'system of systems', the interaction of the systems can lead to unexpected behaviour, for example through feedback loops. A dramatic example of this fragility of interdependent systems was the power outage in Italy on 28 September 2003, which affected over 50 million people. The failure of power plants led to the breakdown of network nodes on the internet, which in turn caused the failure of further power plants and triggered a large-scale cascade of failures (Buldyrev et al., 2010). In view of these new digital risks, the resilience of digitalized systems should be increasingly integrated into research and development.

Privacy and data protection

Comprehensive system integration in the sense of the 'energy internet', like the internet in general, involves possible violations of the right to privacy and data protection. In principle, data from smart meters can be used to monitor behaviour (Greveler et al., 2012); for example, they can be used to determine which films or television series users consume. Strict security requirements must therefore be laid down for these data (e.g. encrypted transmission, etc.; European Parliament, 2016), and possible privacy-protecting smart-meter data must be processed (Kalogridis, 2010). In addition, the principle of data economy should serve as a model for future energy systems. In order to enable individuals to be informed and act responsibly in the sense of a rapid energy transformation, priority should also be given to making information on local energy consumption accessible. "If 'smart' systems are perceived as instruments of surveillance, enforcing conformity and maximizing profit, they cannot have a resounding success in the sense of sustainability" but will inevitably be rejected (Kurz and Rieger, 2018b). Accordingly, digital instruments should not be promoted exclusively to set the course for decarbonization; rather, their potential for strengthening the individual literacy of users and for self-sufficient and semi-autonomous local energy systems should be examined.

5.2.6.5
Conclusions

Digital solutions can make positive contributions to climate-change mitigation and the energy transformation in many areas. Obstacles to effective climate-change mitigation, however, are predominantly not of a technological nature, but lie in the political, economic and institutional spheres (WBGU, 2011). Digitalization will therefore only promote decarbonization, the global energy transformation and access for all people to modern forms of energy if the corresponding political, regulatory and economic framework conditions are put into place. This involves well-known – but insufficiently used – climate-policy instruments such as CO_2 pricing and the abolition of subsidies for fossil fuels, but also targeted technology promotion. The concept of 'Mission-Oriented Innovation' (Edler and Fagerberg, 2017; UNEP, 2018; Section 10.2.1) is particularly suitable for technology promotion in order to overcome unresolved problems, e.g. in sector coupling (Box 5.2.6-1). In order to be able to exploit the potential of demand management in intelligent networks in the future, regulatory and market-related prerequisites must be fulfilled at the national level (Shen et al., 2014). Long-term targets must be clearly and reliably set in order to steer investment and innovation in the right direction. Timely infrastructure investments are also necessary. The danger for the global energy transformation is a potentially fast-growing demand for energy as a result of digitalization. Policies that aim to keep global energy demand from rising too sharply are therefore of great importance.

5.2.7
'Smart city': sustainable urban development with digitalization?

5.2.7.1
Sustainable urban development in the Digital Age: challenges

As urbanization progresses, it is estimated that new urban infrastructures will have to be built for some 2.5 billion people by 2050 (UN DESA, 2014). Unless wisely and sustainably designed, this will have a big impact on resource use, greenhouse-gas emissions and ecosystems. Proportionately, cities consume the most resources and are responsible for about 70% of both global energy demand and greenhouse-gas emissions (Seto et al., 2014). At the same time, sustainability measures with large leverage and scalability effects can be implemented in cities. Cities are therefore crucial for the Transformation towards Sustainability (WBGU, 2016a). Ignoring the concerns of cities and excluding urban actors would jeopardize the implementation not only of SDG 11 ('Making cities and settlements inclusive, safe, resilient and sustainable'), but also of many other SDGs (Misselwitz et al., 2015). How can digitalization be used to improve the living conditions of urban populations, ensure sustainable urban development, and avoid unsustainable path dependencies in view of the huge global impact of urbanization (WBGU, 2016a)? What opportunities and risks do concepts like 'smart cities' offer, and how can people-oriented urban development be ensured even in times of digitalization? Does the greatly increased use of labelling combinations with the word 'smart' stand up to critical scrutiny from the sustainability point of view?

5.2.7.2
Smart city: concept, application examples, distribution and drivers

Most applications of digital technologies aimed at meeting urban concerns have some reference to the guiding principle of the 'smart city' (Bauriedl and Strüver, 2018; de Jong et al., 2015:34; Schweitzer, 2015:7). Although the term does not have a standard definition (Albino et al., 2015:5ff.; Cocchia, 2014:18; Dameri, 2017b:7ff.), the systemic merging of approaches of 'digital' (e.g. dig-

Table 5.2.7-1
Typical dimensions of smart-city concepts and their possible links to the SDGs.
Source: Dimensions according to Fromhold-Eisebith, 2017; SDGs according to UN DESA, 2016

	Relating to...	Smart-city dimension	Relating to...
IT infrastructure	SDG 9	Industry	SDG 9
Energy	SDG 7	Economic structure	SDG 8
Mobility	SDG 11	Education	SDG 4
Building (urban districts)	SDG 9	Consumption	SDG 12
Security	SDG 11	Health	SDG 3
Material cycles	SDG 12	Administration and governance	SDG 16 & 11

ital city, intelligent city, virtual city, ubiquitous city; de Jong et al., 2015; Albino et al., 2015; Cocchia, 2014) and 'sustainable' urban development forms a common denominator for a wide range of variants, including different angles on the 'smart and sustainable city' (Angelidou, 2015 2018; de Jong et al., 2015; Marsal-Llacuna and Segal, 2016; Neirotti et al., 2014). Germany's Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) has developed a definition that combines different perspectives: "By 'smart cities' we mean equipping and upgrading cities and their infrastructures with digital technology, linking previously separate infrastructures or their subsystems. The term 'smart cities' also incorporates the modernization of municipal decision-making, planning and management processes by involving citizens and private capital, and making intensive use of data" (BBSR, 2018).

Dimensions and application examples

A characteristic feature of smart cities is that a large number of functional dimensions, such as mobility, security, administration, energy and water supply, logistics, etc., are digitally upgraded, labelled 'smart', and often linked to sustainability objectives (e.g. to the SDGs, (Table 5.2.7-1); Komeily and Srinivasan, 2017). What is special about these functional dimensions, some of which are summarized as 'smart everything' or 'smart X', is the systemic *networking* of many areas of urban life and work via cyber-physical systems (CPS) or the Internet of Things (IoT), urban platforms and e-government (Fromhold-Eisebith, 2017; Geisberger and Broy, 2012: 29).

Digital technologies can help to significantly improve the protection of the urban environment, specifically the use efficiency of many resources. However, other fundamental changes are also necessary in addition to technology deployment, for example in the organization of urban mobility systems (mobility behaviour), in waste generation (consumption behaviour) or thermal insulation (energy consumption). Digital technologies deployed in environmental protection can be integrated as projects into smart-city initiatives; some of them are treated as separate arenas in the report. Examples include digitally supported circular economy systems (Section 5.2.1 and 5.2.5) or more efficient urban energy and water use, which has already been virtualized in many cities, with distribution controlled by intelligent networks (e.g. by means of virtual power plants; Section 5.2.6). Different systems can interlock in the field of mobility: automated driving using GPS, networked vehicles and infrastructures; the networking of information on location, environment and traffic (e.g. with Google Maps); and traffic monitoring and control with cameras and sensors (Section 3.3). Housing, too, is increasingly becoming digitally controlled, with e.g. coordinated (remote) control of heating, blinds and doors, automated needs assessment by smart refrigerators, or energy-optimized control of electricity-consuming devices such as heat accumulators, batteries or washing machines. Surveillance of public spaces with cameras or drones (Section 3.2), in some cases using face recognition and data storage, is also becoming increasingly widespread with the aim of improving public security. Supermarket shopping, including payment and inventory management, is being fully automated; purchasing behaviour is recorded and analysed so that customers receive customized offers on their smartphones. Often unregulated private-sector online platforms are increasingly becoming established in cities as agencies for holiday accommodation (e.g. Airbnb), or offering mobility or sharing services (e.g. the Uber transport service, bicycle rentals, car sharing; Section 5.2.8). Furthermore, smart-city initiatives are being launched to improve the inclusion of the urban population, e.g. by making urban administration more accessible and efficient, both internally and externally, through e-government and by interacting with companies and the urban population.

Global distribution

At present, it is not possible to say exactly how many smart cities there are, but the upper limit of estimates

Box 5.2.7-1

Excursus: the Indian Smart Cities Mission – example of the challenges in a developing country

In 2015, the Indian government launched the Smart Cities Mission to create 100 'intelligent cities' in the country. In a case study, the Housing and Land Rights Network India (HLRN) investigated and evaluated the Indian Smart Cities Mission (99 cities). The report notes a blatant neglect of the interests of the urban poor and makes the following recommendations to the government (HLRN, 2018):

1. The Smart Cities Mission needs a human-rights-based framework to ensure sustainable development.
2. The mission must place a special focus on the needs, concerns and rights of the marginalized urban population.
3. Participation should be a priority in the selection and implementation of smart-city projects.
4. All projects within the Mission must undergo a human-rights-based social-impact assessment and an environmental impact assessment before being approved.
5. It must be ensured that the implementation of smart-city projects does not lead to violations of human rights, including evictions, forced relocations and displacement.
6. The provision of adequate, affordable housing in all smart-city proposals must be enhanced.

seems to be around 250 (Angelidou et al., 2018). Up to now, smart-city projects have developed primarily in cities in Asia (about half of all current projects worldwide), Europe (about one third) and North America (about one tenth) (Cocchia, 2014). Although their number is rising worldwide, by 2015 only 79 had reasonably comprehensive smart-city strategies – in other words, there is a lack of integrated approaches (own calculations based on Statista, 2018c; Roland Berger, 2017b; Dameri, 2017b: 3ff.). All in all, the development of smart cities is still in its infancy and is mainly limited to pilot projects or real-world-lab experiments in a few countries, pioneering cities or individual sectors (Schweitzer, 2015; Box 5.2.7-1 on India's ambitious, often critically commented '100 Smart Cities Mission'). During implementation, the digital infrastructure is usually integrated into the existing infrastructure (e.g. sensor installation in street lamps, digital modernization of existing traffic-control or energy systems). This applies both to developed cities (e.g. in Europe) and to newly planned ones such as Songdo (South Korea) or Masdar City (UAE/Abu Dhabi).

Drivers

On the one hand, smart-city strategies are often initiated by city governments themselves or by national authorities (Bauriedl and Strüver, 2018). In many cases, digital technologies are intended to help address the specific problems of growing or shrinking cities (e.g. creating good living and working conditions to encourage the influx of new inhabitants). On the other hand, global technology groups (e.g. IBM, Cisco, ABB, HP, Siemens, Ericsson, Google) are significant drivers of urban digitalization (Townsend, 2013; Cocchia, 2014; Schweitzer, 2015). They see smart cities as sales markets for digital and networking technologies and as a source of comprehensive data collections which they want to use for exclusively commercial purposes. Overall, the implementation of digital technologies in cities can increase dependence on individual (global) providers (Bauriedl and Strüver, 2018; Viitanen and Kingston, 2014). Therefore, the European Commission warns: "In particular, the concentration of power in the hands of a few companies, and the relative lack or abandon of control of citizens on their own personal data, [...] raise concerns." (European Commission, 2019e). A change in awareness can now also be observed in numerous municipalities, leading to a more critical approach to major technology providers. In addition to a data protection officer many city governments now have a chief technology officer, a chief digital officer or a digital innovation officer, in order to systematically drive and control their city's digital transformation (e.g. Rio de Janeiro, Barcelona, Berlin, Vienna). The aim is to strengthen the local authorities' ability to act and make them more efficient (e.g. by digitalizing administration and supply infrastructures) and to bolster the common good in the digital transformation (e.g. wider access for all citizens, participation in democratic processes; Bauriedl and Strüver, 2018).

5.2.7.3 Selected areas of tension in digitally supported urban development

City governments must ask themselves which digital technologies can make a substantive contribution to achieving goals of urban development and, above all, sustainability, and which technologies, system architectures and implementation strategies are unsuitable – or even restrict the autonomy and quality of life of urban societies. The main points of criticism of the smart city are (1) an often one-sided fixation of projects on technologies that (usually) cannot solve the key problems of urban development (e.g. affordable housing, segregation, lack of participation), (2) the potential danger posed by state and private surveillance and data storage, and (3) a growing dependence on – especially a small number of major, international – technology providers.

Box 5.2.7-2

Excursus: The right to the city

The term 'right to the city' goes back to Henri Lefebvre ('Le droit à la ville', 1968) and sees itself as an explicitly inclusive model of urban development (WBGU, 2016a: 143). Lefebvre addressed the situation of the marginalized urban population in the new large housing estates built on the outskirts of the metropolises in the post-war years. For about 20 years, the concept has been intensely discussed and further developed internationally; it has given rise to new social movements. In South Africa, for example, the shack-dwellers movement was created to fight evictions and promote public housing. Similar movements have emerged in Istanbul, New Orleans, Madrid and Hamburg. The US-based 'Right to the City Alliance' (since 2007) is a nationwide alliance against gentrification processes at the expense of the poorer urban population. The 'right to the city' concept was also discussed during the United Nations' 2016 Habitat III Conference and is embedded in the related New Urban Agenda. Seen from a digital angle, the right to the city means that "technologies are recognized in their ambivalence and used with an openness oriented towards digital common goods" (Dobusch, 2017b).

Based on experience gained up to now and critical reflections from science, people involved on the ground, and from civil society, the guiding principle of the smart city is constantly changing. This has at least partially led to a strengthening of social and environmental aspects compared to the focus on ICT implementation (Albino et al., 2015; Angelidou et al., 2018). One example is 'Barcelona Digital City', where the digital development of the city has been strongly focused on the interests of the common good, such as 'city data commons', 'digital empowerment', 'digital inclusion' and 'digital rights' (Ajuntament de Barcelona, undated).

Privacy and data protection

Through the networking of urban and digital infrastructures and the introduction of sensor systems (such as cameras, air pollution, noise and other environmental monitoring devices), as well as geo-localizable apps on private end-devices and in public spaces (e.g. navigation systems), more and more everyday actions, habits and movement patterns of the urban population are being digitally registered (WBGU, 2016a; Box 2.1-5). In a smart city, citizens can hardly avoid or control the generation of data because this is a condition for using urban services, utilities or public spaces (Bauriedl and Strüver, 2018). The right to informational self-determination is being challenged and must be continuously safeguarded in accordance with the basic data-protection regulations. The amount of available data also makes their anonymization difficult, since the exchange and merging of different data sets enables companies and public authorities to create personality profiles and, perhaps, make predictions about the behaviour of individual people (Kitchin, 2016). Public administrations should pay attention to transparency relating to how data are handled. On the other hand, extensive observation and measurement of the environment can encourage compliance with laws (e.g. protection against excessive particulate pollution; Balestrini et al., 2017; Box 5.3.1-2). The use of blockchain technologies (Section 3.3), for example, can also improve administrative procedures and reduce corruption, as well as facilitate co-determination by the urban population, for example in infrastructure projects.

Inclusion in the 'smart city'

Inclusion must be a central element of digital urban development (WBGU, 2016a); Normative Compass). The Smart City Charter, inspired by the WBGU report 'Humanity on the Move: the transformative power of cities' (WBGU, 2016a), also emphasizes that barrier-free digital urban development oriented towards the common good requires transparency and the inclusion of the urban population (BBSR and BMUB, 2017: 18). This requires overcoming the digital divide that exists primarily in developing countries and emerging economies. There, smart-city concepts of municipalities or national governments often fail to meet the basic needs of the majority of the population due to a lack of opportunities for inclusion. The Smart Cities Mission launched by the Indian central government, for example, was strongly criticized for its lack of inclusion, equal opportunities and distributive equity (Box 5.2.7-1). When properly applied, the digital transformation of cities can be used effectively to make decisions in local politics de facto transparent, i.e. to communicate and thus contribute to democratic opinion-forming. At the same time, no-one should be forced to use digital structures. This means that municipalities should continue to enable the urban population to use services by analogue ways of access (BBSR and BMUB, 2017).

Digital urban infrastructures

The predicted doubling of urban infrastructures over the next two to three decades (WBGU, 2016a) will also be marked by the expansion of digitalized infrastructures. The threat of a growing dependence on individual technology providers has already led many cities to set up decentralized digital facilities (e.g. storage for open data, bottom-up networking, free WLAN, collective clouds and decentralized data-management sys-

Box 5.2.7-3

Recommendations for action on the arena 'Smart city and sustainable urban development'

The digitalization of cities should not be understood just technocratically as an optimization task; rather, every use of technology should be explicitly embedded in ecologically sustainable urban development. Especially the control of traffic flows (Section 5.2.8) offers an opportunity to rethink urban transport in terms of sustainability and the reduction of emissions and congestion. Likewise, with the help of digital controls, resource and energy consumption could be reduced in the future and resources and energy used more efficiently and in a more climate-friendly way.

However, 'smart city' should certainly be prevented from degenerating into a 'surveillance city'. Accordingly, privacy issues must already be taken into account at the planning stage of such projects. The individual's freedom from surveillance must be embedded in the technologies used. In addition, preventive measures should be taken not only against unauthorized access to the personal data of the respective city dwellers and visitors, but also against future ideas on surveillance that could arise from the data collected after the implementation of smart-city schemes.

The following recommendations are addressed not only to city governments and urban civil society, but also to all actors in international cooperation in urban development processes (e.g. UN, World Bank, regional development banks, EU, BMZ).

- *Combine digitalization agendas with sustainability agendas:*The implementation of the New Urban Agenda and the SDGs (especially SDG 11) is strongly influenced by global digital change. Digitalization agendas should therefore be combined with sustainability agendas. In order to ensure that the digitalization of cities is used for the common good and that municipalities are capable of shaping the Transformation towards Sustainability, the principle of digital (technological) sovereignty must be firmly embedded in urban-development processes. The 'right to the city' approach, extended by a digital dimension, should be pursued, and the efficacy of corresponding civil-society and science-driven initiatives and/or movements should be promoted. In particular, sustainability targets should be an integral part of urban digitalization strategies.
- *Make an inventory of municipal data and ICT infrastructure and create urban data spaces:* Urban data spaces are the foundation of a participatory, scalable and future-oriented digitalization of the public space. The prerequisite for the development of an urban data space is an inventory of the municipal data pool and the local ICT infrastructure. Building on this, a strategy should be developed for the use of the urban data space based on identifying the strategic fields of action that are central to urban development. From a global perspective, such an approach is also recommended for urban development policy, as well as for the implementation of the New Urban Agenda and the SDGs.
- *Raise city governments' awareness of dependency risks:* If municipalities rely on individual manufacturers or operators to design their ICT infrastructures, a cost-intensive dependency can arise. As a general rule, openness in the sense of standards-based interfaces, formats and services that are accessible not only to manufacturers or operators but also to a wide range of actors should be demanded when purchasing systems and products or when outsourcing, in order to avoid 'vendor lock-ins' (Fraunhofer FOKUS et al., 2018). In the WBGU's view, private providers that collect data in the public domain should be required to report to local authorities and submit aggregations of the data.
- *Ensure openness of urban digital platforms:* In order to integrate all actors of urban development via urban digital platforms, the openness of the standards, architecture and components used is a compulsory prerequisite (Fraunhofer FOKUS et al., 2018). This can be achieved, for example, by ensuring that open interfaces and formats, as well as standard conformity for interoperable value-added offers, are mandatory requirements in the realization of components of the urban digital platform. Furthermore, every software component of an urban digital platform commissioned by the public sector should also be made available by the public sector as open-source software for use or further development by third parties. This is the only way to create a dynamic ecosystem of different products without ending up with a producer dependency that excludes potentially relevant actors from the urban digital platform (DIN, 2016).
- *Equip municipal administrations for digitalization in terms of personnel and institutions:*In order for municipal administrations to become, or remain, capable designers of urban digitalization, it is necessary to increase personnel and boost institutions in the digitalization field – something which has already been done by many municipalities. This applies in particular to cities in developing countries and emerging economies. Municipalities should make it a priority to create posts for data officers, data-protection officers and digital-innovation officers, as well as competence centres for digitalization in municipal administrations.

tems). Free WLAN under municipal or civil society control has been installed, for example, in Catalonia (guifi.net), Vienna (FunkFeuer), Berlin (Freifunk) and Athens (AWMN) (Morozov and Bria, 2017). Individual municipalities (e.g. Emden) have themselves become active in setting up digital infrastructures and are expanding the fibre-optic cable network themselves according to the so called municipal utility model. This business model has the advantage that municipalities themselves benefit from the value-added. In general, municipal procurement is an important field of action and a good way for municipal authorities to manage digitalization (e.g. in the EU the volume of this investment represents 14% of GDP; European Commission, 2017).

The European Commission promotes cooperatively organized digital platforms with a programme called 'Collective Awareness Platforms for Sustainability and Collective Action' (CAPS) (Section 5.2.2). Its topics are open democracy (participation of citizens in democratic processes, e.g. via online consultation), open policy-making (better decision-making on the basis of open data), collaborative economy (granting of loans,

Box 5.2.7-4

Research recommendations for the arena 'Smart city and sustainable urban development'

- *Expand Research and Development on ICT integration for urban sustainability:* While R&D activities aimed at mastering the technological challenges of networking ICT systems for smart cities have been strongly promoted nationally and abroad for some time now, the inclusion of sustainability goals must be emphasized in the future. Research on the appropriate linking and integration of various digital ICTs (hard- and software) should be directed towards reduced environmental impacts (e.g. material consumption, emissions), higher resource efficiency, broader usability for the urban population, and technological sustainability.
- *Support empirical analyses of the opportunities and risks of the smart city* The academic debate on smart cities and urban digitalization has recently been characterized primarily by a critical view of the urban development model. However, there are still too few empirical studies showing in detail not only the risks, but also the opportunities associated with such urban digital innovations. The WBGU therefore recommends placing the emphasis on promoting empirical studies that take a critical and constructive look at the economic, social and ecological implications of digital smart-city approaches and investigate them empirically in situ. Inter- and transdisciplinary approaches can also take account of the fragmentation of smart-city research (Mora et al., 2017).
- *Advance international learning processes for smart-city approaches:* The broad international spread of the smart-city concept suggests that international learning processes on sustainability issues in urban strategy and project development should be promoted even more strongly than in the past. These should be based on research activities, be highly inter- and transdisciplinary in orientation, and also take account of the special features of smart-city implementation in developing countries and emerging economies (Vu and Hartley, 2018). Crucial for this are internationally comparative studies on significant differences in the motivation, portfolios of measures, actor structures and implementation dynamics of smart-city approaches in different countries or regions. In this way, broad, reliable knowledge of factors for positive and negative developments in the sense of sustainability transformation can be gained and good-practice examples identified that can be incorporated into internationally oriented further-education initiatives.
- *Focus on people – acceptance research on the smart city:* In terms of acceptance and diffusion research, the extent to which large sections of the urban population are willing and able to adequately deal with the various ICT application fields of a smart city in their everyday lives in the future deserves special attention. Thus, the focus should be on studies on the acceptance of different ICT applications (e.g. for mobility, housing, work, security/safety, environmental monitoring) in order to be able to assess their broad enforceability across population strata. For only if the new digital possibilities are used widely can significant environmental effects be achieved (e.g. savings in energy and water requirements, more efficient use of many other material resources). Here, too, acceptance should be examined in different context situations and cultural areas in order to identify good-practice approaches and implement them in applications.

exchange economy), collaborative making (development of new production processes), collaborative consumption (rethinking consumer behaviour), environmental protection (acting together to save the planet) as well as new collaborative approaches for inclusion, agriculture, health and disaster management (see also section 5.2.2).

In addition to the development and use of digital infrastructures to serve the common good, the ongoing digital transformation is also concerned with the criticality and fragility of urban infrastructures. Since the number of possible security gaps and targets for attack increases with the size of the network, the danger of cyber-attacks on the highly networked infrastructures in cities will increase (Kitchin, 2016. This is particularly problematic when digital infrastructures form the principal basis of urban organization. In order to maintain the crisis resilience of cities and their creative sovereignty in shaping the future, the WBGU believes that both the digital (technology) sovereignty of municipalities, sovereignty over urban data, and open standards and interfaces must be defined and resolutely guaranteed, as laid down in the German Specification for Open Urban Platforms (DIN SPEC 91357: DIN, 2016).

5.2.7.4
Digital sovereignty and the 'right to the city'

In the course of the extensive digitalization of the cities, the list of requirements for 'people-oriented' sustainable urban development (WBGU, 2016a) is also growing. In the WBGU's view, the opportunities and risks described therefore require an additional framework in the sense of 'digital urban governance', in which the focus is not only on 'digital sovereignty' but also on the 'right to the city'. The discourse on the 'right to the city' (WBGU, 2016a: 143; Box 5.2.7-2) requires the addition of the topic 'digitalization', according to the WBGU. Apart from overcoming the 'digital divide', central components should be the design principles of digital, data, infrastructure and platform sovereignty, which focus on the management, monitoring and (in part) use of digital solutions by city governments, administrations and civil society. The focus should be on usability, accessibility, transparency with the aim of open data, decentralization, the application of cooperative structures in the use of digital technologies (e.g. cooperatively organized platforms such as sharing services; Section 5.2.2), participation, and the environmental compatibility of digital technologies. The first urban and civil-society initiatives on these issues have been formed and are developing concrete solutions for sustainable urban development (examples can be found in Morozov and Bria, 2017). Governments and municipalities are also increasingly devoting their attention to the socio-political controversy involved and the need for regulation on the subject of digitalization in cities. In Germany, the BMUB adopted a 'Smart City Charter' in 2017 as part of a long-term research and participation process (BBSR and BMUB, 2017). This serves as orientation for the design of digital change in the sense of integrated and sustainable people-oriented urban development, and contains numerous actor-specific recommendations for action.

Urban data commons – the right to data as a common good

As the importance of the platform economy grows, there is also a growing need for clarification as to who has access to data of any kind, who can exploit it, and how it is managed and secured. The digital ecosystems and the Internet of Things (Section 3.3.1) follow very different standards of (private-sector) data management. Municipalities, municipal companies and end users often cannot use their data in a self-determined way. One option for data acquisition and transmission is the promotion of decentralized data infrastructures and data accounts that rely on open architectures (open standards, open formats, open interfaces and sometimes open source; Section 5.3.10). There are many examples of cities that are actively moving in this direction: DECODE in Barcelona and Amsterdam, MyData in Helsinki, DataCités in Paris or Health Knowledge Commons in the UK.

The Code for Europe initiative aims to promote the use of open data and the sharing of existing codes through cooperation between technology experts and municipalities. The focus is on closed code-sharing platforms (repositories for program codes) which are then available to the participating cities. Up to now, Amsterdam, Berlin, Barcelona, Coburg, Helsinki, Manchester, Rome and cities in Scotland are involved. The British Government Digital Service initiative aims to introduce new service standards and codes of conduct that strengthen the use of open standards and open source.

Urban data spaces

The development of 'urban data spaces' (Fraunhofer FOKUS et al., 2018) is an essential prerequisite for the use of data for urban development for the common good. In most cities there is usually no overview of the possibilities and availability of municipal data. Information on open-source software, data-access standards and data portability is also lacking. Furthermore, existing data are hardly being used (Fraunhofer FOKUS et al., 2018). The idea of developing urban data spaces is to bundle all the data relevant for municipal politics, citizens, administration and business and make it available as a common database.

5.2.7.5
Conclusions

These examples illustrate that – apart from the opportunities offered by digitalization – a growing number of cities are also aware of the threat to their formative autonomy and are actively investing in decentralized digital urban platforms, open architectures and public-welfare orientation, in order to maintain their technological, data, infrastructure and platform sovereignty. If this trend prevails, there is justified hope that the digital revolution can be used for an urban development that strongly supports sustainability in many respects.

Digital technologies – when properly used – enable improved environmental protection, more efficient resource use, new business models, information and service opportunities, and new administrative control and optimization. The extent to which the various smart-city initiatives meet the objectives of inclusion, preservation of *Eigenart* and sustaining the natural life-support systems in practice depends in each case on a strategic objective, intelligent management and precise monitoring. Smart-city strategies differ greatly, for example, in their orientation, the 'smart services' they provide, and the participation of the urban population. The spectrum of digital urban development ranges from primarily private-sector driven to primarily municipally controlled and participatory co-creative variants (Cohen, 2015). However, not every urban digitalization measure is automatically 'smart' in the sense of serving the common good and being suited to local conditions. Risks exist in the areas of data security, data protection, data sovereignty and operational security, as well as in undesirable ecological effects (such as increased resource consumption due to digitalization and rebound effects; Sections 5.2.1, 5.2.5). Therefore, in order to ensure long-term sustainable urban development (housing quality, social development, inclusion, climate and environmental protection, etc.), it is necessary to constantly monitor the effects of urban digital transformation and, if necessary, to implement appropriate regulatory control. Whether smart-city strategies can be assessed as sustainable (in the sense of the WBGU's normative criteria) therefore depends on each individual case. Here, too, as in urban development in general, there can be no blueprints (WBGU, 2016a).

5.2.8
Sustainable urban mobility in the Digital Age

Sustainable mobility is an important aspect of the 2030 Agenda. It concerns not only SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities), but also, indirectly, goals such as health (SDG 3) or economic development (SDG 8). In the following, the WBGU concentrates on the aspect of urban personal mobility, which is particularly relevant for sustainability considerations, i.e. it only marginally addresses digital mobility concepts for rural areas. Aspects of urban logistics are also discussed in Section 5.2.4 'Online commerce'.

5.2.8.1
Guiding concept of a sustainable urban mobility turnaround

Problems caused by motorized private transport – high CO_2 and air-pollutant emissions (above all particulate matter and nitrogen dioxide), land consumption, noise pollution, rising travel and transport times – are more concentrated in cities due to high traffic density and accident risks. These problems can also be regarded as external costs and often affect poorer countries and population groups disproportionately. For example, more than 80% of people living in urban areas screened for air pollution are exposed to levels of pollution that exceed WHO limits, posing increased risks of stroke, heart disease, lung cancer and acute respiratory diseases (WHO, 2016). In low and middle-income countries, 98% of cities with more than 100,000 inhabitants do not meet WHO air quality guidelines. Poorer population groups are particularly affected, for example because they live on busy roads. They are more often dependent on inadequate public transport or non-motorized transport and are therefore exposed to higher accident risks. Worldwide, an estimated 1.25 million people die and 50 million are injured each year as a result of road accidents, with 90% of fatalities occurring in low- and middle-income countries (Sharpin et al., 2018).

Core elements of sustainable urban mobility are described similarly by many actors, for example in the New Urban Agenda (UN-Habitat, 2017). This agenda and related initiatives offer global stimuli, some relating to ICT, for the expansion of a safe, affordable infrastructure for pedestrian, bicycle and public transport. One aim of such an environmental network is to make inclusion in and via mobility possible, especially for poorer population groups, and to create attractive alternatives to motorized private transport and a better urban quality of life (BMZ, 2017; UN-Habitat, 2016a, 2017, 2019; WBGU, 2016a) After all, future mobility will have to meet the targets of the Paris Agreement and be decarbonized. Integrated traffic and land-use planning can make mobility (i.e. spatial accessibility) possible, while simultaneously reducing the volume of traffic (WBGU, 2016a; UN-Habitat, 2017).

Future mobility and transport systems in cities will differ considerably from today's. The disruptive potential of digital technologies encourages the discourse on the future of mobility; data-based business models of the digital economy open up options for sustainable mobility innovations (Flügge, 2016). A mobility turnaround accompanied by appropriate framework conditions can support all the sustainability objectives defined by the WBGU, i.e. sustaining the natural life-support systems, inclusion and *Eigenart* (Section 2.2). However, digitalization could also perpetuate or even reinforce existing unsustainable mobility patterns. The following section discusses the possibilities and risks of digital options for a sustainable urban mobility turnaround.

5.2.8.2
Elements of the digital mobility turnaround

Digital innovations affect all modes of transport that are also potential 'data suppliers'. The mobile internet and smartphones have brought about a breakthrough for new mobility concepts, as they often give people access to up-to-date information for the first time. Furthermore, they are the basis of many needs-based services (Jacoby and Wappelhorst, 2016; Lenz and Fraedrich, 2015: 177). So far, such services have been developed primarily to improve urban (personal) mobility, although some digital mobility concepts are also suitable for rural areas, as long as the often patchy broadband coverage allows this. The mobility problems in rural areas are very different from those in larger cities, for the low population density means less congestion and relatively low traffic-related air pollution. However, here too, especially the high motorization rates of rural regions and the problems of maintaining adequate public transport services require digitally enhanced mobility solutions for the benefit of greater sustainability (Gross-Fengels and Fromhold-Eisebith, 2018).

Smart mobility

Numerous digital mobility innovations are discussed under the term 'smart mobility' as part of the 'smart city' (Section 5.2.7; Papa and Lauwers, 2015: 543ff.; Dameri, 2017a: 105). Yet there is neither a uniform definition nor a uniform understanding of the concept of smart mobility, and the relationship to *sustainable mobility* is also sometimes questioned (Lyons, 2016). However, some common core elements or fields of

Box 5.2.8-1

London Congestion Charge

The London Congestion Charge (LCC) is an example of road pricing. Its introduction in 2003 sought to avoid congestion in the city centre by initially charging a static fee, which was collected and monitored by automatic licence-plate recognition (Flügge, 2016: 32). Because this simply moved the traffic jams to other parts of the city, the toll area had to be extended and the toll increased. A special feature of the LCC is the linking of the system to dynamic environmental data (Bauriedl, 2017: 23) from London's air-monitoring network, which now comprises 150 measuring stations. It records and evaluates numerous parameters, e.g. air pollutants, weather data (humidity, solar radiation, temperature) and traffic-relevant information (days of the week, major events, etc.). A key element is the prognosis software based on neural networks (Section 3.3.3), which links these data and automatically initiates the appropriate traffic-control measures. In addition to temporarily increasing the city toll, this also includes, for example, transit barriers for trucks, public transport options and warnings to citizens about air pollution. The acceptance and enforcement of such measures should be closely monitored. It should also be the responsibility of policy makers to determine which data are collected and processed by the system and what action is taken (Bauriedl, 2017: 23).

action can be identified (e.g. Janasz and Schneidewind, 2017: 253; EEA, 2015b: 60; Fulton et al., 2017: 1; Flügge, 2016: 92; Docherty et al., 2017: 5; Nikitas et al., 2017; Finger and Audouin, 2018): intelligent transport systems, shared mobility and mobility as a service, new drive technologies, autonomous driving, as well as cross-cutting issues such as data, information and digital business models. The different elements are discussed below.

Intelligent transport systems

Intelligent transport systems refer to the use of ICT to meet overarching mobility objectives and are already in wide use (Dameri, 2017a: 101ff.; Festag et al., 2016: 23, 144; BMVI, 2015; Flügge, 2016: 29; Behrendt, 2016: 158). They range from intelligent traffic-light control systems, parking guidance systems, electronic signs, traffic monitoring and traffic control to the creation of virtual vehicle groups (platooning) and electronic toll collection (e.g. e-tickets, electronic toll systems, usage-based invoicing systems, licence-plate recognition). Other elements include information systems, passenger information for local public transport or navigation systems, and driver-assistance and safety systems such as distance controllers, cruise controls and collision detectors (BMVI, 2015; Dameri, 2017a: 101; Grant-Muller and Usher, 2014: 162f.). Intelligent transport systems also include traffic data analysis, which produces traffic forecasts for dynamic traffic management on the basis of historical or real-time data (Flügge, 2016). With the new digital technologies, instruments are available that can also record and price negative external effects such as emissions, land consumption, loss of time, etc., in almost real-time by, for example, linking intelligent traffic-control systems with time- and congestion-dependent toll systems. The pricing of road use (e.g. 'city tolls' like the London Congestion Charge), which varies with the time spent in the 'zone' or with the volume of traffic, is exemplary (Cramton et al., 2018; Bauriedl, 2017: 23; Flügge, 2016: 32; Box 5.2.8-1). The further development of intelligent transport systems is regarded as an essential prerequisite for future mobility innovations. Autonomous driving, for example, requires communication, networking and cooperation both between individual vehicles and between vehicles and the transport infrastructure via sensor data and mobile communication technologies (Alam and Ferreira, 2017; Grant-Muller and Usher, 2014: 150f.; Festag et al., 2016: 6, 71).

Demand-oriented services and shared mobility

New forms of mobility which change the classic provision and use of the means of transport are developing primarily in the direction of shared mobility (Sharing Mobility; Santos, 2018: 2; Nikitas et al., 2017: 2; Baedeker et al., 2018). This involves using, instead of owning, a means of transport such as a car or a bicycle. Important forms, mostly mediated via internet platforms, are car sharing and similar systems for (electric) bicycles or electric scooters, which are offered either from fixed rental stations or on a non-stationary basis. In addition, there are systems for sharing private cars – online ride-sharing/car-pooling centres such as BlaBlaCar or Waze, and ride-hailing services like Uber, Lyft or Didi Chuxing. A more recent approach is flexible call or collection systems (ride splitting). These mobility concepts, whose operation greatly depends on the use of modern ICT, can in particular also make passenger transport in rural areas more sustainable because they make mobility possible that is spatially and temporally demand-oriented but nevertheless shared (Gross-Fengels and Fromhold-Eisebith, 2018).

Mobility as a service

Mobility as a service (MaaS) goes one step further (EEA, 2016b: 63; Flügge, 2016: 212; Nikitas et al., 2017: 14; Giesecke et al., 2016: 3, 8ff.). This approach, which integrates different modes of transport, includes

(1) the integration and simplification of previously fragmented ticket and payment systems, (2) the creation of mobility packages (comparable to data volume packages or flat rates in mobile communications), and (3) the centralization of traffic information on an ICT platform with the provision of an intermodal travel planner (Kamargianni et al., 2016: 3295; EEA, 2016b: 63; Nikitas et al., 2017: 14; Giesecke et al., 2016). 4; Flügge, 2016: 211ff.). Ideally, this happens close to real time, on demand, 'from a single source' and from 'door-to-door'. It enables seamless intermodal mobility, i.e. the use of several, possibly shared, means of transport on a single route. A well-known pioneer of mobility as a service is Ubigo, which emerged from a pilot project in Gothenburg (Sweden) and is now being relaunched in Stockholm. Via its platform, Ubigo offers households a mobility subscription that includes both public transport and car rental, car sharing, taxis and rental bikes (UbiGo, undated). Another example is Daimler AG's moovel platform. This combines services from Daimler and other partners including car sharing, taxi services, ride sharing, bike sharing and rail travel. The announcement by the BMW Group and Daimler AG that they were bundling their mobility services shows just how difficult it is to implement MaaS and how competitive the digital mobility market can be (moovel Group, 2019; Tatje, 2019).

Alternative drive systems: electromobility

Although electric mobility is not dependent on digitalization *per se*, it is nevertheless closely *linked to digital trends*. First, the shift towards electric drives is a key lever for decarbonizing transport and reducing emissions (Nikitas et al., 2017: 2; WBGU, 2016a) Second, electric vehicles can play an important role in the energy system transformation via the digitally enhanced sector-coupling of power generation and mobility (Section 5.2.6). Third, electromobility and new-vehicle and mobility concepts mutually promote each other: for example, in car- or bike sharing, users don't have to pay the purchase costs, so that electric vehicles become more easily accessible. New vehicles are also being developed, such as small electric vehicles in neighbourhood mobility and urban logistics (Section 5.2.4), which also blur the borderline between cars and bicycles (Jacoby and Braun, 2016: 44; Lenz and Fraedrich, 2015: 192; Nikitas et al., 2017: 6 f). Electric buses in local public transport can also make an important contribution to improving urban air quality. They are still produced and used almost exclusively in China, but other countries and manufacturers are gradually catching up (Manager Magazin, 2018; GIZ, 2018; Forst, 16.02.2018).

Autonomous driving

In a narrower view, digital mobility is often equated with autonomous driving and therefore dominates the discourse on smart mobility (Flügge, 2016: 113) and the future of mobility as a whole (Fraedrich et al., 2015: 4). The technological challenges and uncertainties suggest that autonomous driving will develop gradually. After the initial increase in the number of driver-assistance systems (e.g. ABS, lane assistants, parking aids), more and more tasks are being transferred from the driver to the vehicle (Festag et al., 2016: 71; Fraedrich et al., 2015: 10f.; Milakis et al., 2017: 325; VDA, 2015). New applications in car sharing such as delivering and fetching vehicles are also becoming possible; this can save costs and time and facilitate intermodality (e.g. in combination with rail transport). Local public transport offers the potential for flexible call and collect services that are independent of timetables and lines (Lenz and Fraedrich, 2015); this relates to both urban and rural needs. Flight taxis and drone taxis are a special form of autonomous (electric) mobility. They are about to be put into operation for the first time soon, and their benefits and effects are currently being discussed (Stüber and Schmiechen, 04.06.2018). The revolution in new drives, new forms of mobility, and the discourse on networked autonomous driving in road traffic are closely linked, because the engines of autonomous vehicles and their integration into mobility concepts such as car sharing play a decisive role in determining their sustainability (Lenz and Fraedrich, 2015; Milakis et al., 2017: 330; Fulton et al., 2017: 1).

5.2.8.3
Status quo and challenges of sustainable digital mobility in urban areas

Shared mobility holds the promise that fewer vehicles and thus less space will be used for transport, while at the same time vehicle utilization and thus the efficiency of resource use will increase (Lyons, 2016: 10). Despite the growing number of offers and a high user acceptance, however, shared mobility is still in its infancy because it is not yet regarded as a fully-fledged form of mobility, but only as a supplementary element (Santos, 2018: 5; Nikitas et al., 2017: 2f.). In Germany, for example, only about 3% of the population are members of a car-sharing organization, and the percentage of journeys and kilometres travelled is extremely low (BMVI, 2018b: 83ff.). The effects of car sharing on traffic are therefore still very local and individual, but will have to be taken into account if there is further growth. The environmental balance of car sharing is usually better in the case of station-based systems (e.g. no cars searching for parking spots, potential for e-charging stations) – and when combined (intermodally) with environment-friendly means of transport – than in the case of non-station-based systems. However, the balance generally depends largely on factors such as fuel consumption, emissions and the intensity of vehicle use, as well as on whether there is a shift away from eco-mobility (Baedeker et al., 2018).

On the one hand, the unplanned boom in non-stationary bike sharing shows the need for flexible, emission-free mobility; on the other hand, it has already caused resentment because of the uncontrolled parking of rental bikes in city centres and the corresponding countermeasures. Ride-sharing services are a typical example of the advantages and disadvantages of the platform economy (Section 4.2.2); they are criticized worldwide primarily because of competition with conventional taxi services and poor working conditions for drivers. Environmental and CO_2 effects are difficult to identify, because the growth of ride-sharing services corresponds to the decline in taxi rides, which often only account for a small proportion of traffic (Santos, 2018: 5). In some cities in developing countries, such as Mexico City, taxis are a mainstay of the transport system due to a lack of public transport services, and here too ride-sharing services compete with them (Puche, 2018: 42).

The effects of new services first have to be studied for a while, as does the development of mobility as a service, which is still highly fragmented and in a (dynamic) preliminary or early stage (Kamargianni et al., 2016). Therefore, the sustainability effects of the services offered have hardly been empirically researched and are therefore of a more theoretical nature (Giesecke et al., 2016: 4; Nikitas et al., 2017: 14ff.). The expansion and scaling-up of mobility as a service is made more difficult above all by a lack of cooperation between mobility actors, by obstructive legislation (e.g. tax incentives for driving) or a lack of financing (Nikitas et al., 2017: 15f.).

The market share of battery-electric vehicles is still small due to their relatively high purchase price, limited range and sparse charging infrastructure. However, innovations and cooperation in these areas are continuously making these vehicles more attractive. Subsidies and falling battery prices are driving sales up, and the global market share of such vehicles is now at about 1% (Canales et al., 2017: 13). Greater difficulties are posed at present by such sustainability risks as sourcing the raw materials for batteries, the stability of the energy network, or consequences for the automotive industry and its employees (Manthey-Kloppenburg, 2018: 105ff.; Nikitas et al., 2017: 7f.). The eco-balance also depends on how quickly the energy system transformation in power generation succeeds.

Autonomous driving in particular is still fraught with many open questions, challenges and uncertainties with regard to quantitative effects (Nikitas et al., 2017: 4f.; Festag et al., 2016; Maurer et al., 2015; Fraedrich et al., 2015: 11; Milakis et al., 2017). In the short term, significant improvements in traffic flow and the utilization of the transport infrastructure can save time and fuel (estimated at a reduction of up to 31–45% for vehicles with internal combustion engines and more than 90% for (hybrid) electric vehicles), so that emissions are avoided in this way; in addition, the technical systems improve the level of safety (Milakis et al., 2017). In the *long term*, however, autonomous driving seems to involve a particularly serious danger of rebound effects through changes in cost structures and time use (Wadud et al., 2016). It is estimated that the demand for transport in terms of distance travelled could increase by between 3% and 27% (Milakis et al., 2017). Ethical and safety issues, as well as legal implications (e.g. with regard to human-machine relationships, liability, decisions in critical accident situations, mixed traffic, especially with pedestrians and cyclists) are also increasingly coming into focus (Fraedrich et al., 2015: 5; Milakis et al., 2017: 339f.).

How data are handled is also a fundamental challenge of digitally enhanced mobility. In many cases, it is not clear to users which data are collected by providers under new business models and how they are used (e.g. Breitinger, 2018). Furthermore, positional and mobility data are particularly sensitive because, even after anonymization, they can in certain circumstances be used to identify the user and even to assign further unrelated data sets to a person (Kondor et al., 2018; Matheson, 2018). Solutions must be found and implemented here in order to preserve the privacy of the users.

Box 5.2.8-2 illustrates the options for digital mobility in developing countries and emerging economies, using China as an example.

5.2.8.4
Conclusions: Setting parameters for a sustainable digital mobility turnaround in the urban environment

The introduction of digitally enhanced forms of mobility is still in its infancy in many areas. In addition, many developments are running parallel. The driving forces behind this development include automobile manufacturers, ICT companies and ride-sharing services that simultaneously promote e-mobility, autonomous driving and mobility as a service (Box 5.2.8-2; Nikitas et al., 2017: 4). However, solutions to key urban transport problems (e.g. high CO_2 and air-pollutant emissions, land consumption, noise pollution, increasing travel and transport times and accident risks) are not a purely

Box 5.2.8-2

China's digital mobility turnaround – a model (not only) for developing countries and emerging economies?

Despite or perhaps even because of its relatively unfavourable environmental balance, China is increasingly establishing itself as an important global player in the ICT and mobility sector (Ibold and Retzer, 2018). The country is trying to curb the negative effects of the rapid growth of population, cities, the economy (with its own car industry) and transport – effects that are particularly noticeable in megacities like Beijing, Shanghai or Guangzhou (Gao and Kenworthy, 2017; Tyfield, 2014). Intelligent transport systems have been integrated since the beginning of the comprehensive development of transport infrastructure in the mid-1990s (Wang et al., 2017:38ff.). The two most recent Five-Year Plans for Economic and Social Development show a marked sustainability change in transport policy (Ibold and Retzer, 2018). The 12th Five-Year Plan (2011-2015) laid the foundation for more sustainable infrastructure development and a move away from car-focused policies (Gao and Kenworthy, 2017:40, 51). The 13th Five-Year Plan (2016–2020) and the 'Intended Nationally Determined Contributions' (INDC) to the Paris Climate Agreement, which were submitted in 2015, are currently important milestones. In particular, the item on 'smart transport' and the associated programme to promote smart transportation reflect the importance of digitalization for China's mobility turnaround and, at the same time, the country's ambitions for global innovation leadership in ICT, big data, smart mobility and smart-city technologies (Ibold and Retzer, 2018:3ff.; for further examples: Perez-Cerezo, 2018). China is regarded as a pioneer in shared mobility and mobility services because, on the one hand, it has a partially restrictive car policy (low level of car ownership) and, on the other, it is very open to digital technologies, and (sharing) apps like the 'all-in-one' platform WeChat are widely used (GIZ, 2018; Roland Berger, 2017a). For example, the boom in bike-sharing providers such as Mobike (3.65 million bikes), Ofo (10 million planned) or Bluegogo, as well as a stock of approx. 250 million electric bicycles, is seen as an opportunity for a renaissance of the bicycle – in both areas China is the global leader in terms of production and demand (Gao and Kenworthy, 2017:49ff.; Zuev et al., 2018:2; Tyfield, 2014:597; chinadialogue.net, 09/06/2017). However, for a long time, e-bikes were hardly promoted, and sometimes even restricted by measures such as removing wrongly parked rented bicycles. A similar situation can also be observed in Germany and Europe, where Asian and Chinese suppliers are entering the market (DW, 2018; GIZ, 2018). In the field of ride-sharing services, a similar development of boom and readjustment can be observed (Chong, 2018). The best-known company is Uber's competitor Didi Chuxing, which has been operating since 2012 and took over Uber's Chinese subsidiary in 2016 for US$35 billion (the following statements are based on Roland Berger, 2017and Gao and Kenworthy, 2017:51). Didi Chuxing also wants to expand internationally and is continuously extending its range of services beyond the provision of travel services. It includes repair services, charging stations, traffic-management solutions for cities, as well as research and development on autonomous electric vehicles and artificial intelligence. The two above-mentioned bike-sharing providers Ofo and Bluegogo already belong to the group. Didi Chuxing is thus an impressive example of the emergence of integrated 'mobility as a service'. At the same time, it is also an example of the risks that networked mobility creates with regard to data security and the formation of monopolies, not least against the background of comprehensive state scoring (Section 5.3.3).

technological matter; rather, they depend on how digital solutions are embedded into comprehensive concepts of sustainable urban mobility. What is needed first is a clarification of action competences: development should be guided by democratically legitimized institutions, not by technology companies. They should promote an urban mobility turnaround that focuses on people's well-being and the protection of natural life-support systems. Shared mobility can play an important role in reducing or limiting both urban and rural traffic. The necessary decarbonization of urban mobility can be achieved by prioritizing public transport, walking and cycling, and by electrifying motorized transport on the basis of renewable energies. In addition, a change in business models towards mobility as a service should be directed towards the goal of a sustainable urban mobility turnaround. In developing countries and emerging economies, the first priority must be the development of sustainable urban mobility systems and, in particular, access to mobility services also for the poor population, as well as the connection of informal urban neighbourhoods to local public transport. The safety of non-motorized traffic is also of key importance. Moreover, sustainable, digitally enhanced urban mobility will only emerge if the digitalization potential is fully harnessed in the service of integrated sustainable mobility concepts. Digitalized and networked urban passenger transport must be embedded in new work and leisure models that make use of digitalization opportunities to drastically reduce the volume of traffic, in integrated urban planning concepts that reduce distances and routes, and in transport planning that actively promotes forms of mobility that improve the ecological and urban quality of life (especially pedestrian and cycle traffic and innovative, emission-free vehicles). Only within the framework of such 'smart mobility governance' can digital and autonomous mobility lead to positive sustainability effects.

Box 5.2.8-3

Recommendations for action on the arena 'Sustainable urban mobility'

- *Set up models and transformation roadmaps for digitally enhanced, sustainable urban mobility:* The WBGU recommends developing guiding principles and implementation plans for digitally enhanced, sustainable urban mobility at the city level in cooperation with the national level. Such urban, spatial and transport planning focuses on health and quality of life. It avoids individual motorized traffic and puts eco-mobility (local public transport, cycling and pedestrian traffic) at the centre of attention. The focus should be on the reachability of the destinations and access to mobility in itself; motorized transport should become emissions-free (e.g. electric, based on renewable energies) in the long term. The planning should explicitly include the role of digital technologies and applications for the sustainable urban mobility turnaround. In smart mobility, much more attention should be paid to the financial and planned promotion of walking and cycling. Based on a forward-looking, reflexive 'transformation roadmap', capacity gains should be used to redeploy no-longer-needed road lanes and parking spaces for pedestrian and cycle traffic as well as other sustainable land uses. By setting up an intermodal traffic-management system that also includes pedestrian and cycle traffic, land uses can be flexibly adapted to suit demand and, for example, converted to space-saving means of transport at times when demand for mobility is high. Environmental, transport, societal and industrial-policy frameworks should be adapted in order to use digital technologies specifically for a sustainable mobility turnaround.
- *Create cost transparency, internalize external effects, abolish environmentally harmful subsidies*: The WBGU regards the creation of cost transparency in the transport sector as an essential lever for promoting sustainable mobility, together with a related reform of transport-system financing including the abolition of environmentally harmful subsidies. With the new digital technologies, instruments are available across the board to internalize – even close to real time – external effects such as emissions, land consumption, loss of time, etc., for example in the form of intelligent toll systems (Cramton et al., 2018) or by means of tariff structuring for mobility as a service. Distribution-policy effects must also be taken into account and alternatives created in the public sphere.
- *Ensure the municipal common good in data-based mobility business models, take into account the strategic role of mobility data*: In view of the dynamic development of new actors and business models, it is extremely important to incorporate and implement the objectives of sustainable mobility in the planning and design of the public sphere and infrastructure. In order to preserve the formative sovereignty of public decision-makers in shaping sustainable mobility, action should furthermore be taken to prevent and counteract data concentration and dominant market positions on the part of individual private-sector actors. In addition, public actors themselves must be enabled to collect and use digital data for specific purposes (Section 5.2.7). For example, city authorities should have access to, and sovereignty over, essential parts of mobility data. They should be able to oblige private mobility providers to make their data available to public planners or to provide citizens themselves with the possibility of a voluntary 'data donation'. In this way, new (digital) public-private partnership opportunities can be exploited and forces combined to promote sustainable mobility. One step in this direction is the joint efforts of municipalities, transport companies and mobility service providers to integrate shared mobility into local public transport season tickets. Particular attention must furthermore be paid to data protection and to protecting people from surveillance.
- *Develop decentralized, interoperable, standards-based* traffic databases and a data and *booking system* for local and long-distance public transport as the basis for a European mobility service system: Low-threshold mobility inclusion, especially in public transport, should also be possible without having to disclose sensitive personal data. Decentralized databases could guarantee this and, at the same time, reduce concentration tendencies in the data economy. The still-complex structure of fare, booking and information services in public transport currently makes it subjectively less attractive than individual transport. In order to counter this and increase the attractiveness of local and long-distance public transport, the WBGU recommends the establishment of a European data and booking system, which would form the basis for a European mobility service system.
- *Developing countries and emerging economies should develop or redesign their mobility systems at an early stage on the basis of the sustainable-mobility model:* Transport systems in developing countries and emerging economies are often unable to keep pace with rapid population and traffic growth, so that many problems are particularly pressing there. They should be guided by the sustainable-mobility model, introducing or further developing solutions tailored to their specific needs with the help of digital technologies such as shared mobility, intelligent transport systems and, above all, (electric) fast bus systems: (Bus Rapid Transit: Stead and Pojani, 2017:291; Nikitas et al., 2017:8). Ideally, they should develop these themselves with the involvement of (potential) users and adapt them to local conditions. A particular focus therefore lies on developing adapted technologies, acquiring specialist knowledge and developing monitoring and enforcement skills. Access to (public) mobility services, especially for poverty groups, should play a prominent role. International collaborations are supporting the countries along the road described. For example, the 'Initiative for Transformative Urban Mobility' with the participation of the BMZ, and other activities within the framework of the New Urban Agenda, can be used as a basis (BMZ, 2017; UN-Habitat, 2016a, 2017, 2019).

Box 5.2.8-4

Research recommendations on the arena 'Sustainable urban mobility'

The WBGU sees a great need for research, especially on the sustainability impact of 'digital' mobility:

- *Create data pools, set up monitoring:* Because digitally enhanced mobility is quite new, there is a lack of suitable data. Data pools should be created promptly by setting up a monitoring system for sustainable digital mobility; it should be differentiated according to urban and rural areas and countries with different levels of development. Valuable foundations for this are, for example, IoT and big data, e.g. from internet-based, mobile-communications or mobility service providers. The aim is to explore ways in which this can be done without the risk of exposing individuals to surveillance.
- *Expand research on sustainability impact:* (Empirical) research on the sustainability effects of digital mobility must be greatly expanded and networked. This applies, for example, to changes in the demand for mobility and should also take into account freight transport (new concepts of urban logistics, new production structures and value chains, shift from value creation to intangible assets). Environmental and resource implications, distribution-policy aspects and data-protection issues must be researched in particular.
- *Conduct research into obstacles, potential and effects for changes in mobility behaviour (e.g. rebound effects) through digitalization and examine change strategies in practice (real-world laboratories):* This also involves questions of acceptance, for example with regard to the technologies used, or questions of possible behavioural reactions to changed or newly created price signals.
- *Develop transdisciplinary development research and cooperation on sustainable digital mobility:* Especially in selected cities in developing countries and emerging economies, real-world laboratories for sustainable, digitally enhanced mobility should be set up and the foundations laid for integrated spatial and transport planning.
- *Promote research on 'smart mobility governance' and promptly put findings into practice:* The coordination and control requirements associated with the manifold systemic possibilities of smart mobility call for a high degree of both conceptual and empirical research. This can and should also be embedded in corresponding smart city research projects.

5.2.9
Precision agriculture: the next step towards industrialized agriculture?

5.2.9.1
The context: global, sustainable land use

The 'transformation field' of land use (WBGU, 2011: 234ff., 299ff.) will become one of the most important arenas for sustainability and securing the future in this century. Digitalization in agriculture, here called simply 'precision agriculture', promises to provide an important building block for the sustainable intensification of agricultural production and thus to achieve increases in yield while, at the same time, reducing environmental damage (Schrijver 2016: 30ff.).

Agriculturally usable soils are a scarce, indispensable and non-substitutable resource of the Earth system that is closely linked to water resources and on which the well-being of the entire human race depends. In principle, sufficient food can currently be produced for the world's population (Grote, 2014; SDG 2: 'Zero hunger'). This threatens to change in the future, as considerable increases in demand are predicted, among other things due to population growth and increasingly land-intensive dietary styles (above all through increasing consumption of animal products). The corresponding expansion of agricultural production required by the middle of the century is estimated at approximately 50–100% (FAO, 2018; Valin et al., 2014; Alexandratos and Bruinsma, 2012; Tilman et al., 2011; IAASTD, 2009). The demand for agricultural goods is also increasing due to the biomass requirements of the bio-economy (e.g. as a result of switch to bio-based products and the use of bioenergy), as well as the need for 'negative emissions' to help mitigate climate change (SDG 13: 'Climate action') through large-scale afforestation or the combination of bioenergy with carbon capture and storage (Bioenergy with Carbon Capture and Storage – BECCS; WBGU, 2016b: 11).

Irrespective of the rising demand, a decline in agricultural production can be expected as a result of soil degradation, water scarcity and unchecked climate change (WBGU, 1994; IPBES, 2018; UN-Water, 2018; Porter et al., 2014: 488). So far, part of the increasing demand has been met by expanding agricultural land into near-natural ecosystems (e.g. tropical forests, savannah). However, there is a broad international consensus that this option must be stopped to protect biodiversity and ecosystem services (SDG 15: 'Life on land'; Aichi targets 5 and 7: CBD, 2010; WBGU, 2014b: 29). Another option for increasing yields is to intensify production on existing agricultural land with the simultaneous aim of minimizing environmental damage ('sustainable intensification': The Royal Society, 2009; Tilman et al., 2011; FAO, 2018).

Studies on this second option offer hope that the increase in production on existing land can make a significant contribution to sustainable food security, so that the destruction of further near-natural ecosystems

Box 5.2.9-1

Precision animal husbandry

Digitalization has been making its way into livestock farming for several decades with the primary goal of increasing production efficiency. Electronic animal identification using radio frequency identification (RFID) makes it possible to monitor animal health and feed dosage. The quantity and quality of milk and meat can be optimized by dosing feed (including the ingredients and energy content of the feed) using feed and pasture robots. An increase in livestock output is achieved via factors such as comfortable surfaces to lie on, healthy surfaces to move on, mechanical aids for body care, and a health-promoting, stable climate. The animals' movement profiles, feeding times and amount of feed eaten are also taken into account. Digitalization also improves precision in the documentation of livestock population and traceability along the value chain, e.g. using origin-documentation and quality-assurance programmes. Marking farm animals with RFID chips also helps prevent livestock theft (Grote and Neubacher, 2016). In addition, the 'virtual fencing' of animals in open fields makes it easier to avoid overgrazing, control weeds and manage nutrients. Banhazi et. al. (2012) give an overview of many technical possibilities in precision animal husbandry.

On the other hand, digitalization and the associated economization in livestock farming also have some downsides:

- An increasing concentration can be observed in livestock farming worldwide; this is reflected in rising average herd sizes and a higher output per animal. In addition to successes in breeding, digitalization is a major driver of this regional and operational concentration. In Germany – especially in the southern Weser-Ems region – more than three quarters of all chickens are fattened on farms with more than 50,000 animals (BMEL, 2019). It is even estimated that, in future, several million broiler chickens, 25,000 dairy cows or 200,000 fattening pigs will be able to be kept on a single farm (Berckmans, 2017).
- Livestock concentration poses the risk of diseases spreading, so that antibiotics are sometimes administered as a preventive measure. However, the frequent administration of antibiotics in animal husbandry can result in multi-resistant germs, which can also be dangerous for humans (Cassini et al., 2019). In Germany, the German Antibiotics Resistance Strategy ('DART 2020') has been introduced to curb the spread of antibiotic resistance. However, despite a more-than-50% reduction in antibiotic doses given since 2011, the annual volume was still around 800 tonnes in 2015 (BMEL, 2019). In other important producing countries, such as the USA, the use of antibiotics is still permitted even to promote output (BMEL, 2019).
- Various forms of environmental damage are caused by the high concentrations of emissions. Over 90% of NH_3, 37% of CH_4 and 65% of N_2O in the atmosphere comes from animal husbandry, and up to 30% of all land, up to 70% of agricultural land and 8-15% of water resources are used for animal husbandry (Berckmans, 2017; Steinfeld et al., 2006; Sharma et al., 2018). Moreover, the quality of drinking water and groundwater suffers due to excessive nitrate pollution, particularly in regions with concentrated animal farming (Taube, 2018; Hermanowski et al., 2018).
- Concerns are also repeatedly expressed about data protection and data security, as well as farmers' high degree of dependence on a few large corporations, since all a farm's data are recorded digitally (Roosen, 2017). A company that develops an attractive platform combining the sale of various input factors with advisory services and in-house complex data has very good prospects of establishing a monopoly (A.T. Kearney, 2016).
- Critics also stress that digitalization and the concentration of livestock is changing the relationship between humans and animals. Digital skills are more important to farmers than knowledge of husbandry methods and animal health, which are increasingly being digitally controlled and monitored. The importance of a bioethical analysis of precision animal husbandry is seen against this background (Wathes et al., 2008).
- Ultimately, the massive concentration trend in animal husbandry means that meat is offered at relatively low prices and demand continues to rise. It is estimated that by 2050 an additional 200 million tonnes of meat and one billion tonnes of cereals for animal feed will have to be produced annually to meet global demand (FAO, 2009a). Consumption of animal protein increased by 69% between 2003 and 2013, compared to an increase in the population growth rate of around 29% over the same period (Behrens et al., 2017).

could be significantly reduced (Egli et al., 2017; Henry et al., 2018; Mauser et al., 2015; Foley et al., 2011). However, intensification is also a major factor in the rapid decline in terrestrial biodiversity and ecosystem services observed worldwide (IPBES, 2019; CBD, 2014: 10; WBGU, 2001: 3).

In industrial agriculture, precision agriculture can contribute to the sustainable intensification of agricultural production (Schrijver, 2016: 30ff.). The subsequent arena in this report (Section 5.2.10) discusses the different, but also interesting potential of digitalization in predominantly smallholder agriculture in developing countries.

5.2.9.2
Precision agriculture: methods, dissemination and potential

The term 'precision agriculture' was coined around the mid-1980s. It involves the precise application of seeds, water, fertilizers and pesticides via digital systems according to the needs of the plants and the soil quality (Gebbers and Adamchuk, 2010), and aims to facilitate harvesting. For this purpose, digital systems are used for the networking and intelligent control of agricultural machinery; these comprise sensors (e.g. instruments measuring soil moisture and nutrients, fruit recognition), monitoring (e.g. digital documentation and evaluation of meteorological data, use of drones for image recognition), and satellite-based positioning (e.g.

digital maps of fields, autonomous driving of agricultural machinery; Walter et al., 2017). Furthermore, precision agriculture also offers potential in animal husbandry (Box 5.2.9-1).

The degree of digitalization in agriculture varies widely, and very different definitions and indicators are used for its measurement, such as the percentage of areas used, the proportion of users, or the intensity of machine use. Precision agriculture, however, is used primarily in industrialized countries (USA, Canada, Australia, northern and central Europe; Reichardt 2010), but also has potential in emerging economies oriented towards the export of agricultural products (e.g. Brazil, Argentina; McBratney et al., 2005; Silva et al., 2007). In England, for example, around one fifth of farms were already using precision agriculture methods in 2012 (UK DEFRA, 2013); in the EU, the proportion was around a quarter in 2016 (Schrijver, 2016). Precision agriculture appears to be profitable in the majority of cases studied (Gebbers and Adamchuk, 2010).

Precision agriculture uses a number of approaches to make more efficient use of resources and to contribute to sustaining the natural life-support systems (Section 2.2.1). Digitally supported, targeted water management offers above all regions lacking water the prospect of higher yields, lower costs and sustainability (Monaghan et al., 2013). Soil cultivation, harvesting methods and timing can be optimized by precision agriculture, reducing harvest losses and improving food quality (King, 2017; Monaghan et al., 2013).

Fertilizers and pesticides can be dosed more precisely and thus more economically with the aid of digital technology (Robertson and Vitousek, 2009; Khoshnevisan et al., 2013), e.g. the targeted microdosing of herbicides using robotics can lead to potential savings of over 90%. The use of laser technology or mechanical systems can in some cases even make it possible to avoid using herbicides completely (King, 2017). According to a study commissioned by the BMEL, the savings are in the low single-digit percentage range (BMEL, 2017). These methods are already being used at the laboratory scale and, in some cases, are already available.

There is also potential for increasing efficiency and quality in fruit and vegetable cultivation (both outside and in greenhouses; Zude-Sasse et al., 2016), for example by mechanically harvesting the fruit at the optimum time (this is already possible e.g. with grapes, apples, tomatoes, strawberries and olives; King, 2017).

These methods of precision agriculture can reduce operating costs and increase yields per hectare (Bramley, 2009; Haboudane et al., 2002). In Brazil, for example, sugar-cane yields have been increased by an estimated 5–10% (Demattê et al., 2014). Furthermore, soils, energy and water resources, surrounding ecosystems and food are less polluted (CBD, 2014: 13).

5.2.9.3
Efficiency versus sustainability

For industrialized agriculture, this digital revolution could mean a new technological stage and trigger disruptive changes (Walter et al., 2017; Wolfert et al., 2017; BMEL, 2016). Precision agriculture offers potential in the cultivation of large-scale monocultures. The main incentive for farmers is more efficient management, since considerable costs can sometimes be saved on the input side (fertilizers, pesticides, fuel, labour costs; UK DEFRA, 2013). The development of technologies for precision agriculture is progressing rapidly in line with the progress of digitalization, but their application in practice is linked to capital-intensive investments. These can be carried out more easily by large farms than by small ones, and this can reinforce structural change (BMEL, 2017). A key question, therefore, is how all farms, regardless of their size, can benefit from digital technologies (Schrijver, 2016). Smaller farms, for example, can benefit from these technologies by merging into cooperatives and forming machinery pools.

The use of big data in agriculture aims to make it possible for production systems and value chains to network– also beyond the farm level (Wolfert et al., 2017; TAB, 2018). Discussions are currently ongoing on the risk of farms becoming increasingly dependent on major agricultural corporations (e.g. agricultural machinery manufacturers, agrochemical and seed companies), on questions of 'data sovereignty' (rights of access to, and rights to use, the growing amounts of valuable agricultural data accumulated on farms) and data security (DBV, 2019; BMEL, 2017; Kritikos, 2017; WD, 2018; TAB, 2018; FBI, 2018). The rising numbers of mergers of agricultural machinery manufacturers, and seed and agrochemical companies, with the inclusion of digital platforms, harbour the danger of new monopolies and positions of power that can create additional dependencies for agricultural operations. For example, methods of digital rights management (DRM) are increasingly also being used in the field of agricultural machinery; among other effects, this undermines the possibility of independent repair and adaptation (Kurz and Rieger, 2018b). Not least, the digitalization of agriculture, as in other sectors, is associated with rising electricity consumption and an increased volume of electronic waste (Section 5.2.5).

A particularly interesting approach from the perspective of sustainable development is a trend in the opposite direction to large-scale industrial agriculture: MacMillan and Benton (2014) say that the next wave

Box 5.2.9-2

Recommendations for action on the arena 'Precision agriculture'

At present, the opportunities offered by digitalization appear to be used primarily to further intensify industrial agriculture. The focus is on improving efficiency and cutting costs. Yet digitalization also offers potential for more sustainable agriculture; however, this is not a priority for many actors. The potential for increasing yields while at the same time reducing environmental damage (sustainable intensification) should be further investigated and comprehensively exploited. The aim should be to give preference to more small-scale, ecologically compatible farming methods, to promote animal welfare, and to use agrochemicals as sparingly as possible.

- *Make sustainability an explicit goal of precision agriculture:* Support should be given to forms of precision agriculture that are geared to the strategic goal of global sustainability and embedded in a systemic approach to sustainable land use. In particular, the focus should be on avoiding agrochemicals, using soil- and resource-conserving methods, and promoting agricultural diversity. The chances for re-diversification and a return to smaller scales should be explored. Precision agriculture technologies that can make a particular contribution to sustainability and are environmentally friendly should be promoted and widely used. To do so, the framework conditions and incentive structures should be restructured in the direction of sustainable agriculture; this applies in particular to EU agricultural subsidies.
- *Find solutions for handling agricultural data:* The protection of non-personal business data is not yet sufficiently regulated (TAB, 2018). The increasing amount of agricultural data being generated should remain in the hands of farmers, and they, like other businesses, should make data available for uses that are oriented towards the common good (Section 5.3.10). The data sovereignty and security of farms should be promoted and safeguarded. Agricultural corporations should be prevented from monopolizing data, as this involves the risk of farmers becoming more dependent on powerful agricultural companies. To this end, emphasis should be placed on international, open standards and platforms for the exchange of data and on the collaborative digital interoperability of different actors, software and machines (Schrijver, 2016; BMEL, 2017). The potential for common-good-oriented and cooperative solutions should also be explored and implemented (e.g. open data, open source).
- *Create the right conditions for digitalization in rural areas:* Broadband structures should be set up or expanded in rural areas in order to cope with the increased data flows associated with precision agriculture and the necessary communication and control requirements. In addition, the use of drones should be regulated.

of agricultural innovation should concentrate on the small scale. Precision agriculture offers a chance to return agriculture to more ecologically compatible, small-scale landscape design with greater diversity in cultivation (e.g. mixed cultivation, crop rotation; King, 2017; Walter et al., 2017), e.g. through the use of autonomous, intelligent, lightweight machinery. In view of the unchecked loss of biodiversity in the countryside (BfN, 2018: 50), including dramatic declines in the number of insects (Hallmann et al., 2017; Rada et al., 2018) and birds (Birdlife International, 2018; Gross, 2015), the conservation of biodiversity and ecosystem services should furthermore be at the focus of agriculture in the future.

Given the resources and potential of digitalization and robotics, it should therefore not be a question of adapting the landscape and agriculture to ever-larger machines (e.g. in the course of land consolidation), but, conversely, there is a chance that machines can adapt to a smaller-scale landscape and diversified agriculture in view of the increasingly urgent requirements of sustainability (King, 2017).

5.2.9.4
Conclusions

To prevent biodiversity loss, a global, systemic approach to sustainable intensification, as advocated by the FAO (2018: 10ff.) seems to promise the best results (The Royal Society, 2009; Egli et al., 2017; TEEB, 2018). However, there is a contradiction in the concept: agricultural intensification is usually also associated with an increase in environmental problems (e.g. soil degradation, water pollution, loss of biodiversity through pesticides) and is therefore not sustainable. Precision agriculture, which is only made possible by digitalization, offers a possible solution for this with the promise of a triple synergy: operating costs can be reduced e.g. by a more economical use of agrochemicals; yields and quality can be increased by more precise management; and, at the same time, environmental damage, e.g. from nutrient and pesticide inputs, can be reduced.

Agriculture is characterized by (1) very tight regulation at national and regional levels, (2) considerable environmental damage combined with massive subsidies, and (3) only a partly open world market. In view of this complexity, the question arises as to how plausible and comprehensive the hoped-for global potential benefits for sustainability really are, and what incentive structures can be used to implement them. The answer to this question depends not least on the objec-

Box 5.2.9-3

Research recommendations for the arena 'Precision agriculture'

Investment in research and development will be a key driver for the agriculture of the future and should be strengthened in the EU (Schrijver, 2016). The Federal Government should set up a research programme for the sustainability, resource conservation and re-diversification of agriculture using digital methods and machines. In particular, the focus should be on the following open questions:

- *Potential benefits and risks of digitalized industrial agriculture:* How big are the potential benefits and risks of precision agriculture if it is essentially designed (especially in industrialized countries and emerging economies) as a further development of industrial agriculture in large-scale monocultures? Does this reinforce the trend towards industrialized agriculture, which would mainly benefit large farms? How can technology (e.g. intelligent, autonomous, small, lightweight machines) be developed that focuses on a diversified, small-scale agricultural landscape with greater biodiversity and ecosystem services? Could precision agriculture of this kind make a significant contribution to world food security, given that the bulk of global food production is generated by small farms?
- *Potential benefits and risks of a decidedly sustainable precision agriculture:* How big are the potential benefits if the primary target of digitalization and autonomous machines is a biodiverse form of agriculture, focusing on mixed cultures, crop rotation, animal welfare, agroforestry, smaller scales and re-diversification? Can sustainable precision agriculture be a response to the biodiversity crisis and climate change, and to strengthened ecosystem services, better resilience and healthier nutrition? What opportunities and risks exist for small-scale, automated, functionally diverse and sustainable agricultural production? Which low-cost ICT solutions are suitable to help small farmers set up their own recycling chains? Can new opportunities for smallholder agriculture also be identified in this context?
- *Regulation, framework conditions and incentives:* In view of the unresolved questions concerning the handling and use of data – in this context especially agricultural data – the need for an adaptation of national, European and international regulations should be examined. Besides, the question should be asked as to how the incentive structures should be shaped in the context of strongly state-regulated agriculture so that decidedly sustainable, small-scale, diverse precision agriculture becomes competitive with large-scale, industrial precision agriculture (balancing the economies of scale)?

tives and priorities. At present, the focus seems to be primarily on increasing business efficiency; the environmental benefits are apparently seen mainly as positive 'collateral benefits'. There seems to be little prospect at present of a systemic approach with a form of precision agriculture that is primarily oriented towards the goal of global sustainability, with the result that the triple synergy promise has not been fulfilled (Box 5.2.9-2).

Other important questions remain (Box 5.2.9-3): How big is the sustainability potential of precision agriculture in industrialized countries and emerging economies if it is essentially regarded as a further development of industrial agriculture for large areas? To what extent does precision agriculture enable a return to smaller-scale landscape design and agriculture without yield losses but with more biodiversity? How should the framework conditions be designed so that small-scale, biodiverse agriculture becomes competitive vis-a-vis large-scale, industrial agriculture (balancing the economies of scale)? How can the EU's agricultural policy be changed so that the conservation of biodiversity and ecosystem services becomes an explicit objective of precision agriculture?

What potential emerges for developing countries? Smallholder agriculture in developing countries, which is the basis of more than 80% of food security there (IFAD and UNEP, 2013), will hardly be able to follow the capital-intensive, high-tech pathway of industrialized precision agriculture (Mondal and Basu, 2009). Relevant potential benefits are likely to be long term here. The next Section 5.2.10, on the arena 'Digitalization in agriculture in developing countries', provides some insight.

Attention should be concentrated on the many open questions concerning the safeguarding of data sovereignty and independence of farmers, as well as the risk of data-based innovations further increasing farmers' dependence on agricultural corporations (Schrijver, 2016; Kritikos, 2017; TAB, 2018). However, many solutions to the problems described at the beginning of this arena will lie outside the narrow areas of digitalization and mechanization (e.g. plant breeding, land management, soil restoration, adaptation to climate change).

Further very important potential lies beyond higher production in agriculture, above all in a reduction in demand, e.g. by avoiding the considerable food losses after harvesting, or by changing nutrition styles to fewer animal products (Springmann et al., 2018; Willett et al., 2019). In order to solve the pressing problems, these different proposed solutions should be combined in an integrated approach and embedded in the broader context of globally sustainable land use (Godfray et al., 2010; WBGU, 2011:234ff., 299ff.; Searchinger et al., 2018; Springmann et al., 2018).

5.2.10
Digitalization in agriculture in developing countries

Most of the world's farms are smallholdings and cultivate less than two hectares of land each (FAO, 2014a). Smallholders produce the largest amount of food (about 80% in Asia and Africa) and farm about 60% of the world's arable land. The main problems of smallholders in developing countries are the lack of access to land and difficulties in securing land titles, as well as a lack of access to water, energy, capital, fertilizers, seeds or markets. In addition, losses in harvesting, processing and storage, especially in Africa, are high at almost a third (Malabo Montpellier Panel, 2018). In view of the growing global demand for food and biomass, a challenge for small-scale agriculture in developing countries is the need to significantly increase yields – without colliding with sustainability requirements (e.g. avoiding soil degradation, using water sustainably and, in particular, conserving biodiversity and near-natural ecosystems). Non-sustainable agriculture, on the other hand, risks compromising the security of supply in the future.

Digitalization has the potential to increase market transparency via access to information and capital, to lower transaction costs, and to reduce information asymmetries. This would raise agricultural productivity (Ekekwe, 2017) and increase sustainability (Nwagwu and Soremi, 2015), which would contribute to the positive development of the agricultural sector in developing countries. In addition to improvements for large landowners, digitalization has the potential to increase the inclusion of many other, often marginalized population groups, especially smallholders, farm workers, but also the younger, more technology-oriented generation. This is particularly important in developing countries, where the agricultural sector has the greatest potential to reduce poverty and improve the living conditions of large population groups dependent on agriculture (FAO. 2014b). Thus, many new start-ups in Africa offer a variety of digital solutions for the smallholder agricultural sector and the food industry (Ekekwe, 2017; Rose, 2016; Mittal and Mehar, 2012). These innovations often focus on smallholders' access to information and finance. In this respect, opportunities for digitalization arise from a combination of access to information and improved microfinancing, e.g. in the conversion to microfertilization or microirrigation. Opportunities lie above all here because there is usually too little capital available to operate an industrialized form of agriculture, as is customary in many industrialized countries and emerging economies. The significance of digitalization in this context is discussed in the previous arena (Section 5.2.9).

5.2.10.1
Access to innovative digital technologies

Digitalization has the potential to supplement or promote the mechanization of the agricultural sector in a completely new way via drones, sensors, robotics, AI and the Internet of Things (Malabo Montpellier Panel, 2018). However, in Africa especially the degree of mechanization in agriculture is still very low; these digital technologies have not been accessible for the majority of smallholders in Africa up to now. Exceptions are countries such as Nigeria, Kenya and Tanzania, where IT applications are already being used to facilitate the joint use of agricultural machinery by networking machine owners with farmers (Malabo Montpellier Panel, 2018).

The deployment of improved technologies (e.g. soil sensors that measure and optimize fertilizer and water needs, or drip irrigation systems driven by solar pumps) is also a way to increase agricultural productivity. Precision agriculture is not necessarily dependent on high-tech solutions. In the cultivation of small areas, it can also consist of a combination of labour-intensive, manual technologies with digitally-supported advice. In Africa, increases in millet yield of 44–120% have been achieved through the manual microdosing of fertilizers (ICRISAT, 2016).

5.2.10.2
Access to production-related information and agricultural advisory services

Agricultural advisory services are one of the most important ways to increase the productivity of smallholder agriculture and thus the income of the rural population (Evenson and Pingali, 2007). The use of mobile phones, internet platforms and social networks makes it possible to reach poor and marginalized farmers in remote villages – and to do so at more regular intervals (Cole and Fernando, 2012; Aker, 2011). In India, the annual income of farmers has been increased by almost 40% through mobile-phone-based advice on new agricultural practices and better management (Grimshaw and Kala, 2011; Vashisth et al., 2013). Even uneducated farmers use mobile phones to access agricultural information (Islam, 2011; Nyamba and Mlozi, 2019). In Sudan, text-message-based advisory services have increased the efficiency of water use and increased agricultural productivity by 300% (CTA, 2015).

At present, lack of access to information is hampering the introduction of technologies (Baumüller, 2015). The rapidly increasing spread of mobile phones offers opportunities: if farmers have mobile phones, it is easier for them to exchange experience and also possible to organize targeted agricultural counselling (Fu and Akter, 2012). For example, the use of mobile phones

Box 5.2.10-1

Recommendations for action on the arena 'Agriculture in developing countries'

If the digitalization of agriculture is to have a broad-based effect on development, it must be embedded in a strategy for sustainable land use and geared to the needs and opportunities of smallholder agriculture (Cassman, 1999). In order to ensure that digitalization overall offers more opportunities than dangers for agriculture in developing countries, which is predominantly small-scale, the WBGU makes the following recommendations for action to the Federal Government:

- States – supported by digital enterprises and within the framework of international development cooperation, e.g. as public private partnerships (PPPs) – should expand their mobile communications infrastructure and make internet access possible on a large scale, so that farmers can gain digital access to information and advice. The promotion of local micro-grids for the energy supply based on renewable energies can generate synergies. Digital access to e.g. weather forecasts, advisory services and education enables efficiency gains and sustainable management in smallholder agriculture.
- In Africa, investment in mechanization and innovative technologies should be promoted as a priority along the agricultural value chain. Development cooperation can help governments to improve framework conditions and promote cooperation with the private sector, so that smallholders can also benefit from digital technologies.
- The WBGU recommends the promotion of cooperative associations of smallholders. Successful adaptation of digital solutions to smallholder structures would be facilitated by the formation of cooperative structures (e.g. producer groups). This expands the scope for area-based planning and design, enables economies of scale, and reduces implementation costs for individual smallholders (World Bank, 2007).
- It must be ensured that smallholders own the personal and technical data they generate when using digital devices.
- The WBGU recommends improving access to open-access data, as this has great potential for benefiting marginalized population groups in particular (IFPRI, 2018).
- The WBGU also recommends actively promoting women's access to digital networks, as they bear most of the workload in the agricultural sector in many developing countries and would thus benefit disproportionately from information of all kinds.

Box 5.2.10-2

Research recommendations on the arena 'Agriculture in developing countries'

Research on the digitalization of agriculture should be geared to the goals of globally sustainable land use and poverty reduction. The Federal Government's research programme should aim to overcome the digital divide in agriculture. In particular, the following open research questions should be at the focus of attention:

- Which factors promote or inhibit digitalization for sustainable development in agriculture in developing countries?
- Will digitalization make the workplace in the agricultural system more attractive in the future? Will digitalization in agriculture reduce the rural exodus and the trend towards urbanization in developing countries?
- What efficiency gains can be achieved in smallholder agriculture through precision agriculture?
- Should the priority in research and development in developing countries be given to precision agriculture in the future? Or are research investments in other areas of smallholder agriculture even more important? Opinions diverge here (Cassman, 1999 versus Chen et al., 2011).
- How can precision agriculture make a significant contribution to poverty reduction?
- What barriers hinder the adoption of digital innovations at the smallholder level?
- To what extent does digitalization promote or inhibit land grabbing (WBGU, 2011:61f.) in emerging economies and developing countries?

can mitigate or even prevent agricultural risks due to pests and disease outbreaks or soil erosion (Fu and Akter, 2012). Digital photographs of plants help to determine nutrient requirements and treat pests. In Mexico, consultants use equipment that measures the health status and nitrogen content of plants in order to fertilize and use pesticides as needed, thereby reducing groundwater pollution and protecting the environment (van Vark, 2014). Targeted advice via mobile phones can also be used to prevent the rapid spread of diseases, as in the case of Avian 'flu in Asia (FAO, 2009b).

5.2.10.3
Access to weather information and disaster preparedness

Crop losses often occur when rain falls after harvesting and before storage (in India, for example, 10–35% of total turnover). This can be avoided by improved access to weather information via mobile phones or the internet (Mittal et al., 2010). In Colombia, farmers receiving weekly weather information via text messages had 4–7% lower weather-related crop losses than a control group without weather information (Camacho and Conover, 2011). Early warnings of extreme weather events help farmers to take timely action (Klasen and Waibel, 2015). In Vietnam, villagers have been provided with mobile phones so that they can react more effectively to floods and, for example, protect their livestock and crops (Ospina and Heeks, 2010). In West Africa, too, weather forecasts via mobile phone have increased resilience to weather risks; in one third of cases, losses have been reduced and yields increased (Roudier et al., 2014). In the event of a disaster, crowd mapping can be used to make spatial information visible on a map, so that aid can be coordinated better and more efficiently (Sutter, 2010).

5.2.10.4
Access to market and price information

Mobile phones also make it easier and cheaper to use financial services in rural, often under-served areas and to compare different suppliers (Nair and Fissha, 2010), which in turn increases agricultural productivity (Duncombe, 2014; Maree et al., 2013). Mobile phones improve access to information along the entire value chain, from production to the marketing of the products (Mittal and Mehar, 2016). This saves time and money, reduces transaction costs and increases productivity (FAO, 2013). For example, a group of women in Bangladesh have been able to significantly increase their profits from marketing chickens (World Bank, 2011). In India, welfare increases for producers and consumers have been measured along the value chain in the fishing sector (Jensen, 2007).

Information asymmetries about current market prices often limit farmers' bargaining power (Ali and Kumar, 2011). The Southern African Confederation of Agricultural Unions has developed a digital aggregation platform that functions like a 'virtual cooperative'. This allows farmers to aggregate their products for sale and achieve higher prices with their trading partners (Sunga, 2017).

5.2.10.5
Access to land and capital

Blockchain technologies in developing countries make it possible to have reliable land registration in land registries, to fight against and improve control of corruption, and to provide people with a formal identity by means of e-identification. These technologies have the potential to provide secure access to land rights and thus to microcredits or microinsurance (Kshetri, 2017). Secured land rights for smallholders, e.g. via blockchain technology, would be an option to counteract the problems of large-scale land grabbing by foreign direct investors, which often involve the expulsion of smallholders (WBGU, 2011:61f.; Feist and Fuchs, 2013). However, avoiding land grabbing is a political rather than a technical issue.

Mobile payment systems, such as M-Pesa in Kenya, make it possible to pay for services and goods without a bank account. An M-Pesa customer can transfer money to the account of another M-Pesa user by mobile phone, and this credit can be paid out, for example, in supermarkets or kiosks. Access to capital in connection with other goods that remain limited in many developing countries, such as fertilizers, pesticides, water and energy, only leads to real efficiency gains in the context of digitalization (Deichmann et al., 2016).

5.2.10.6
Conclusions

Precision agriculture can achieve increases in efficiency through digitalization primarily in large, input-intensive enterprises, and these are found mainly in industrialized countries and emerging economies, only occasionally in developing countries (Section 5.2.9). Capital-intensive high-tech precision-agriculture solutions are not directly suitable for smallholder agriculture in developing countries (Chen et al., 2011). However, elements of digitally supported agriculture can still be used meaningfully in smallholder agriculture in these countries, especially when the smallholder farmers are organized as cooperatives.

Overall, it can be seen that the use of digital innovation can increase the efficiency, productivity and sustainability of small businesses, particularly through improved access to information and advice (Nwagwu and Soremi, 2015). Access to mobile telephones plays a key role here. It is difficult to assess the significance of these innovations in the light of the urgent need to increase yields in smallholder agriculture in developing countries. However, it can be observed that the number of medium-sized agricultural enterprises is also increasing in Africa and that the demand for processed food is rising in the growing cities (Malabo Montpellier Panel, 2018) so that the use of components of precision agriculture could also rise more strongly there in the future.

5.2.11
Digitally enhanced monitoring of ecosystems and biodiversity

5.2.11.1
The biodiversity crisis

Digitalization changes nature conservation in a fundamental, transformative way (Arts et al., 2015; Joppa, 2015). The digital revolution in nature conservation is taking place against the background of a global, highly dynamic, anthropogenic loss of biological diversity, which is being compared with the great extinction events of the Earth's history (Ceballos et al., 2017; Barnosky et al., 2011). The rate of species extinction today is approx. 1,000 times the Earth's geological average and still accelerating (Pimm et al., 2014; De Vos et al., 2015). The planetary network of ecosystems as a whole is undergoing radical and unpredictable change (Barnosky et al., 2012). Half of the world's most biodiverse regions have lost 90% of their vegetation (Sloan et al., 2014). This has led to significant restrictions in the distribution range of wildlife populations (Dirzo et al., 2014; Ceballos et al., 2017), which have been depleted by 60% over the last 40 years (WWF, 2018). Large-scale changes in land use for agriculture, infrastructure development and mining are leading to the disappearance of natural ecosystems and the fragmentation of habitats (IPBES, 2019; Marques et al., 2019). Overuse of biological resources by, for example, fishing (Worm, 2016), hunting and poaching (Ripple et al., 2019; Chase et al., 2016) or illegal logging (Brancalion et al., 2018), as well as the spread of invasive alien species, are further important causes of the biodiversity crisis (Early et al., 2016). Anthropogenic climate change alone could mean the extinction of a sixth of all species (Urban, 2015).

There is now a broad consensus in international environmental policy on the causes and effects of the biodiversity crisis. The Convention on Biological Diversity (CBD) has presented a clearly defined and quantified catalogue of political objectives in the Aichi Targets (CBD, 2010). The 2030 Agenda also sets clear goals with SDG 14 (Life below water) and SDG 15 (Life on land; UNGA, 2015; Box 2.1-1). Monitoring ecosystems and biodiversity is a global priority of the CBD, for it is a challenge to measure the status and trends of biodiversity and the degree to which policy objectives are achieved in a standardized and comprehensive way (Bush et al., 2017). Aichi Target 19 specifically addresses the knowledge base and technologies, e.g. for monitoring the status and trends of biodiversity (CBD, 2010).

5.2.11.2 Improved knowledge through digitally enhanced monitoring

The detailed processes of the biodiversity crisis are not sufficiently known, and this makes it difficult to assess their impacts on ecosystem services and human welfare (Dirzo et al., 2014). We know too little about ecosystems, their functioning and services, the composition of species, their population sizes and distribution, about environmental factors and threats (Pereira et al., 2013). This knowledge is crucial for effective and efficient nature conservation (Turner, 2014), e.g. in identifying threats, setting priorities in the selection of protected areas or the use of scarce financial resources (Joppa et al., 2016), or assessing the impact of interventions in the sense of adaptive management (Bush et al., 2017; WBGU, 2001: 135). This knowledge is also a strategic prerequisite for developing science-based rules for the sustainable use of biological resources (e.g. in fishing: ICES, 2018). This analysis of ecological processes and impacts requires huge amounts of data and therefore a considerable amount of data acquisition, storage, processing and modelling (Kelling et al., 2009). The skilful use of information technology and the networking of data records can bring considerable advantages here (Joppa et al., 2016).

Environmental monitoring (abbreviated to 'monitoring' here) makes valuable contributions to this knowledge and is therefore an essential part of nature conservation (Section 3.3.5.1; Secades et al., 2014). Monitoring helps us when taking stock of ecosystems and populations, when supervising management regulations and bans to prevent overuse. Monitoring also contributes to the prevention of environmental crime, e.g. the trade in endangered species (Box 5.2.11-1). Digitally enhanced, continuous monitoring is, for example, also very valuable in identifying and certifying the origin of biological resources (Bush et al., 2017). Comprehensive scientific advisory services for policy-makers and assessments (e.g. by IPBES, ICES) are also dependent on digitally enhanced monitoring, so that political objectives can be set and verified on a sound scientific basis (Secades et al., 2014). Last but not least, knowledge about nature inspires and motivates many people and creates an incentive for political commitment or participation in citizen science projects (Section 5.3.1.1).

The aim is that successful nature conservation should no longer be hindered in the future by a lack of knowledge about biological diversity and its management (Pimm et al., 2014). The vision of a continuous and comprehensive global system for the monitoring of biodiversity and ecosystem services, as well as for the aggregation, storage and evaluation of large amounts of biological data, is becoming more and more feasible through digitalization and international cooperation (Bush et al., 2017; Pereira et al., 2013).

5.2.11.3 Techniques and examples

Digitally enhanced technology for nature conservation has made tremendous progress in recent years. Electronic devices have become more powerful, smaller, lighter and cheaper by several orders of magnitude, generating new, efficient technologies for biodiversity monitoring (Bush et al., 2017; Snaddon et al., 2013). Digitally enhanced monitoring systems linking remote sensing (e.g. satellites, aircraft, drones; Box 3.3.5-2)

Box 5.2.11-1

Environmental crime and its prevention using digital technologies

ICT has made environmental crime easier and more global – with negative impacts on biodiversity. This applies, for example, to the illegal trade in endangered animal and plant species. Europe has become not only one of the largest transshipment centres, but also one of the biggest consumers worldwide (Siepe, 2017; Sina et al., 2016). Police crime statistics for Germany for 2015 show just under 7,500 registered crimes under Germany's Nature Conservation, Animal Welfare, Federal Hunting and Plant Protection Acts (BKA, 2015). Having remained more or less constant for several years, the figures on the trade in endangered animal and plant species published by the Customs Service have recently shown an alarming increase. For example, the number of confiscations in the field of protected species rose from 63,000 in 2013 to around 580,000 in 2015 (Zollverwaltung, 2015). The trade in endangered animal species on the internet is also booming (Section 5.2.4). In a survey of 280 internet platforms in 16 countries, around 33,000 threatened wild animals or animal parts or products were discovered – and more than half of them were alive (IFAW, 2014). It is estimated that the illegal trade in wild animals turns over more than €13.8 billion a year (IFAW, 2014).

However, digitalization can also be used to prevent environmental crime. Just as perpetrators make use of digital technologies, authorities or owners can do so too. To protect plants such as cacti against theft in the USA's national parks, they are equipped with RFID microchips (Ziegler, 2008). In Germany's forestry sector, GPS transmitters are installed in felled tree trunks (HAZ, 2018). These examples show that digital solutions can help better monitor biodiversity conservation regulations.

with *in-situ* sensors (e.g. camera traps, GPS trackers, acoustic recorders, smartphones, DNA barcoding) are making new and valuable contributions to knowledge about biodiversity and ecosystems (Turner, 2014). In the following, some examples are given that illustrate how digital technology is enabling progress to be made in nature conservation (Figure 5.2.11-1).

Remote sensing by satellites, aircraft and drones

Satellites have long provided photographs and remote sensing data that make large-scale, repeated and cost-effective information available on, for example, land cover, land use, the dimensions and clearing of forests, and ecosystem types. This valuable information helps analyse threats to nature conservation and improve the surveillance of progress towards international policy objectives (Secades et al., 2014; O'Connor et al., 2015). Although data are increasingly made available free of charge by public authorities (Joppa et al., 2016), generally free access to satellite data would be an important prerequisite for better exploitation of their potential (Secades et al., 2014; Turner et al., 2015).

Satellite data are particularly informative if they are linked to environmental sensors in the air, on the ground or on water (cameras, acoustic sensors, tags; Turner, 2014). Combined with high-resolution images from aircraft or drones, it is possible, for example, to analyse species of vegetation right down to individual trees and large animals (Turner et al., 2015).

Aircraft and unmanned drones are used, inter alia, to monitor illegal activities (poaching, illegal logging), for mapping terrain and taking stock of populations (Wich and Koh, 2018; Dandois and Ellis, 2013; Schiffman, 2014). Last but not least, they provide great images for nature films ('virtual experience of nature': Section 5.3.1.1).

Digital photography

Camera technology has experienced a revolution in recent years as a result of digitalization. In parallel, this has revolutionized the possibilities of monitoring individuals, populations and species. Statically installed camera traps produce large quantities of individual images of wild animals, which can be aggregated into very interesting data sets to provide, for example, information on population sizes and migration. Steenweg et al. (2016) imagine a network of camera traps that would allow globally coordinated monitoring of large areas and different habitats and populations.

Current developments include the networking of actors and projects, the organization of data management and the automation of image analysis using artificial intelligence (e.g. Wäldchen and Mäder, 2018). The WWF is currently testing infrared cameras in Kenyan national parks to track down poachers at night. The application of artificial intelligence makes it possible to automatically distinguish between humans and animals and to recognize vehicles (WWF, 2019; MacDougall, 2018). One example from Germany is Flora Incognita, which enables the classification of thousands of plant species using a smartphone app (Flora Incognita, 2019).

Acoustic recorders

Calls and songs are characteristic features of many animal species. Automatic acoustic recorders for recognizing animals are already in use today, e.g. for bats (O'Farrell et al., 1999), whales (Vester et al., 2016; Johnson et al., 2009), birds (Oliver et al., 2018), fish (Bolgan et al., 2018) and even for monitoring entire ecosystems (e.g.

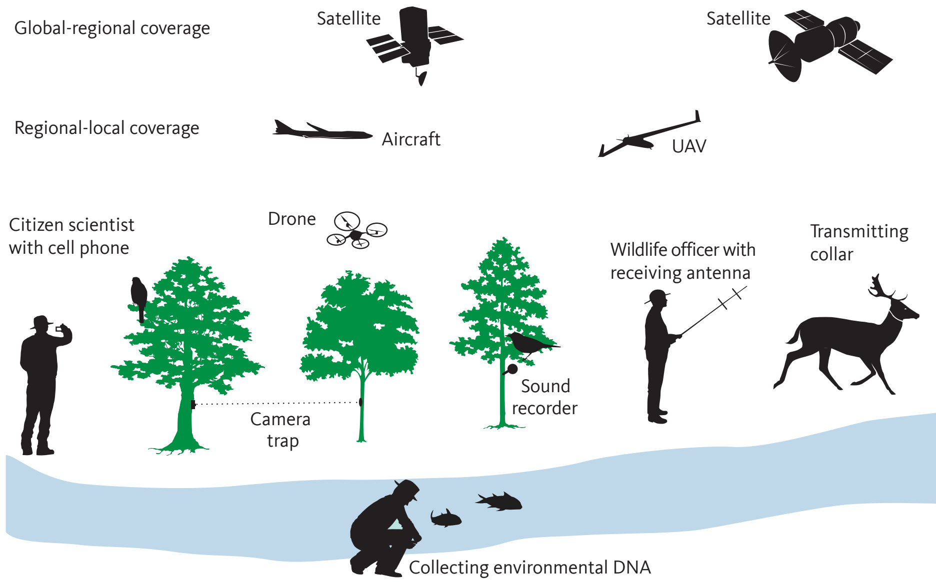


Figure 5.2.11-1
Overview of digitally enhanced techniques for monitoring ecosystems and biodiversity.
Source: P. Huey/Science from W. Turner, Science 346:301,(2014). Reproduced with the permission of the AAAS

coral reefs: Bertucci et al., 2016). The acoustic recorders are now so small that they can even be used for behavioural research in individual animals (Couchoux et al., 2015). The large amounts of bioacoustic data are suitable for the application of artificial intelligence, opening up possibilities for automated monitoring and species recognition (Oliver et al., 2018; Aide et al., 2013). However, it is also possible to detect noises from poachers and wood thieves (e.g. shots, chainsaws); here, too, automation and networking make it possible to monitor large areas (Hill et al., 2018).

Tracking individual wild animals

The automatic tracking of animals by GPS has revolutionized the study of the behaviour and migratory movements of individuals and populations of endangered species (Joppa, 2017; Turner, 2014). In the meantime, miniaturization has progressed to the extent that even very small animals, e.g. insects, can be traced (Arts et al., 2015). The international ICARUS initiative aims to provide real-time satellite-based observations from the International Space Station (ISS) of the location and migration of small animals (e.g. birds, bats or turtles) tagged with radio chips (ICARUS-Initiative, 2019; Curry, 2018).

DNA barcoding and digital sequence information

Genetic analyses and evaluations of digital sequence information have become so inexpensive and fast that they are suitable for large-scale application in making inventories (Hebert et al., 2003; Pimm et al., 2014). DNA barcoding, a method for determining species by individual genes (e.g. in mitochondria), can be used to identify species simultaneously – individually or in thousands – to detect the presence of protected species and monitor the spread of invasive alien species (Creer et al., 2016; Bush et al., 2017). This technique also offers valuable potential in the fight against the trade in endangered species (e.g. sharks: Steinke et al., 2017) and for many other scientific questions (Hebert et al., 2016). The International Barcode of Life Initiative maintains an international, freely accessible database of DNA barcodes and aims to cover all species by 2040 (Hebert et al., 2016).

Digital data management

The digital techniques described have led to an exponential growth in the amount of data available worldwide in the field of biodiversity research (Nelson and Ellis, 2018). Big data approaches are becoming increasingly important for addressing the high complexity of ecosystems and the threats they face (Joppa et al., 2016; Kelling et al., 2009). Accordingly, networked data-management systems that bring together decentralized data collections from institutions, projects or researchers and integrate them into global, publicly accessible databases are also gaining in importance (Pimm et al., 2014; Hampton et al., 2013). The aggregation and management of data by internationally coordinated projects brings significant benefits for biodiversity research (James et al., 2018).

The international Global Biodiversity Information Facility (GBIF) is one of these initiatives that aim to provide access to extensive biodiversity information in

Box 5.2.11-2

Recommendations for action on the arena 'Monitoring ecosystems and biodiversity'

Digital solutions should be rapidly and widely deployed in order to contribute to the protection of endangered species and ecosystems and arouse the interest of societal actors, particularly the public, in the biodiversity crisis.

- *Strategic approach to remote sensing:* A strategic research-policy approach can help to improve the networking of communities in the fields of remote sensing, biodiversity and AI, in order to move towards the overarching goal of a continuous and comprehensive global system for monitoring biodiversity and ecosystem services. The rapid continuation of efforts to improve access to valuable satellite data and make it free of charge is an important building block in this context. An important product would be a long-term, consistent and regularly updated global database on land use and land-use change, which should be used to monitor success and also provide interfaces for AI applications. The initial costs for global biodiversity monitoring and the corresponding products and data centres should continue to be borne by the public sector. Close networking with international scientific advisers (e.g. IPBES, WCMC) and multilateral policy processes (e.g. CBD, CITES) is key.
- *Development cooperation for nature conservation:* The biggest share of biological diversity is found in developing countries, but the drivers of its loss come mainly from industrialized countries and emerging economies. Industrialized countries have a special responsibility to jointly develop the technological and organizational knowledge that is needed and to provide appropriate financial support within the framework of development cooperation. Developing countries have the greatest need for monitoring, as the biggest gaps in inventories and practical conservation solutions are to be found there. Priority should be given to the active involvement of actors from developing countries in development-cooperation projects and to private nature-conservation projects for monitoring and data exchange.
- *Promotion of citizen science:* Citizen science will become even easier and more interesting for the participants thanks to the digital possibilities in monitoring and, above all, networking, and will become even more valuable for research due to the increasing amounts of data collected. This trend should be further supported, not only in industrialized but also in developing countries. The promotion of coordinated participatory monitoring projects should be intensified and the collections of data made available worldwide as digital commons (Section 5.3.10).
- *Protect privacy:* The risks described in Section 3.5.3 with regard to invasions of privacy and surveillance may also apply to some of the monitoring instruments described here. For example, the vision of a total surveillance of nature parks can also affect the people living there or in the surrounding area. Therefore, when implementing digital surveillance technologies outdoors (e.g. drones, camera traps; Section 5.2.11.4), it should be ensured that those affected are involved in the projects and their privacy protected (e.g. through privacy by design; Sections 3.5.3, 8.3.1, 8.4.2.2).

natural-history collections (Nelson and Ellis, 2018). The complete digitalization of the collections is in progress, and they will be made digitally available (James et al., 2018). The Group on Earth Observations, an association of states, with its Biodiversity Observation Networks (GEO BON), is building up a global biodiversity-monitoring system that will integrate existing regional monitoring projects to create a coordinated and harmonized system based on standardized 'essential biodiversity variables' (EBV; Pereira et al., 2013; Navarro et al., 2017).

5.2.11.4 Risks

Digitally enhanced monitoring is not good or bad *per se*, but certainly a transformative development that requires shaping and controlling. The above-mentioned digitally enabled technical methods (e.g. camera traps, drones, GPS navigation) for locating and tracking biological diversity, as well as the use of open-source biodiversity data are, of course, not only available to nature conservationists but also to those who make a profit from biological resources and wish to carry out resource extraction (Arts et al., 2015). A further problem with the increased use of sensors could be electronic waste. A solution currently under discussion is the use of biodegradable electronics that decompose after a predefined period of use (Section 5.2.5).

Digital techniques facilitate the identification – for legal and illegal actors alike – of valuable natural resources such as shoals of fish, high-grade woods, or populations that would be of great value for poachers (e.g. rhinoceros or ivory). Data protection is therefore also a relevant issue when it comes to data from monitoring; for example, information from the real-time tracking of endangered species, rare plant populations or nesting sites of endangered birds should not fall into the wrong hands (Berger-Wolf et al., 2017; Pimm et al., 2015). There are doubts as to whether drones are effective in combating poaching (Humle et al., 2014).

The availability of the described digital solutions could be used as an argument for the loss of professional taxonomic expertise that has been going on for decades (Hopkins and Freckleton, 2002), despite the fact that taxonomic expertise remains indispensable for building, training, developing and applying monitoring technology (Arts et al., 2015).

Respect for the privacy of the local human population is essential in all monitoring and surveillance activities (Sandbrook, 2015). When planning and imple-

Box 5.2.11-3

Research recommendations on the arena 'Monitoring ecosystems and biodiversity'

Given the rapid pace of technological development, there is still insufficient research on the medium- to long-term potential benefits and risks of digitally supported nature conservation (Arts et al., 2015). The race between digitally enhanced overexploitation and the sustainable use of biological diversity must also be kept in mind. The following points deserve special attention:

- *Building blocks for global monitoring:* The WBGU recommends the promotion of concrete research projects as building blocks for global and comprehensive biodiversity monitoring. This includes the development and application of new technologies, e.g. for remote sensing, tracking, image recognition and analysis. Remote sensing of vegetation types and land use should remain a priority (Secades et al., 2014).
- *Data acquisition and management:* Strategic, longer-term promotion of the standardization (e.g. metadata and data formats) and international networking of existing collection and storage projects (e.g. GBIF, GEO BON) is recommended. In general, the use of open, international standards to promote interoperability and re-usability, and free access to data (e.g. satellite data) should be promoted (Turner et al., 2015; Secades et al., 2014). However, possible risks related to threatening scenarios such as resource extraction or poaching should be taken into account.
- *Digital instruments for nature conservation:* The research, development and testing of digital tools for practical nature conservation in the rapid assessment and management of threatened species and ecosystems deserve further support. Particular attention should be paid to new methods of combating poaching (e.g. use of algorithms from the field of AI to optimize patrols by gamekeepers; Nguyen et al., 2016). Pattern recognition via machine learning also offers great potential for digitally enhanced monitoring for other applications (Section 5.2.11.3; Kwok, 2019). This opens up an interesting and dynamic field of research that deserves increased support.
- *Taxonomy:* Despite all the enthusiasm for new digital technologies, biological taxonomy as a science must not be neglected. It remains an indispensable scientific basis in the digital context, and the application of taxonomic knowledge will become much more efficient (e.g. 'digital field guide'). The WBGU recommends the expansion of taxonomic institutes and professorships, with a focus on digital methods.

menting digital monitoring, concepts such as privacy 'by design' and 'by default' should therefore be applied (Sections 3.5.3, 8.3.1, 8.4.2.2). Due to concerns about private monitoring, African governments (e.g. in Namibia) have already stopped some drone conservation projects (WWF, 2019; MacDougall, 2018).

Last but not least, it is important to note that the richest biodiversity is found in developing countries; hence, the advantages of more expensive digital solutions are most difficult to implement in those areas where they would be most beneficial.

5.2.11.5 Conclusions

New technologies alone will not save threatened species or ecosystems (Pimm et al., 2015). The political will to conserve and sustain ecosystems and biological diversity and to implement the agreed objectives remains a prerequisite for the success of the CBD and the 2030 Agenda.

Digitally enhanced monitoring opens up completely new possibilities for helping us understand biodiversity. The new techniques promise more data in real time, faster processing, better access to information and networking, new visualizations, and support for decisions via machine learning (Kwok, 2019; Joppa, 2017; Arts et al., 2015). These do not replace traditional methods, e.g. manual inventories made by observation, but they can powerfully support and complement them. Digitalization already provides valuable tools for management strategies and decision-making, as well as for improved ecosystem modelling (Secades et al., 2014). A global monitoring system with automated inventories of species using image recognition, acoustics and DNA barcoding is now considered possible (Section 5.2.4.2; Bush et al., 2017; Snaddon et al., 2013).

The knowledge gained in this way can be used, among other things, to develop scientifically better substantiated rules for the sustainable use of biological diversity. In addition, digitally enhanced monitoring offers completely new potential in the enforcement and supervision of these management regulations and bans.

A decisive starting point is to win people over to nature conservation. Here, too, digitalization offers valuable opportunities (Section 5.3.1.1). The increasingly visible commitment of citizens can strengthen the motivation of political decision-makers to place the biodiversity crisis higher up on the political agenda and thus trigger positive feedback with the urgently needed improved implementation of the politically set goals. Without a much stronger political will to conserve biological diversity, better monitoring would merely improve our knowledge of the biodiversity crisis without preventing it.

5.3
People and society

5.3.1
Digitalization as an opportunity to promote a collective global awareness of sustainable development

This arena looks at the potential of a global and/or environmental awareness newly generated or strengthened by digitalization to stimulate action to conserve the Earth system and to develop a solidarity-based lifestyle. The connection between awareness and action is an old topic in social psychology and, in relation to environmental protection and sustainability, also a well-researched field of environmental psychology. The large number of empirical studies shows that problem awareness only leads to appropriate action under certain circumstances, e.g. by knowing how to act, and that many distinctions need to be made here. In this context, the WBGU takes into account the state of knowledge based on studies of environmental and intervention psychology on the motivation to act in a way that conserves the Earth system. It also outlines which new digital opportunities could contribute to environmental awareness, such as rapid interactivity and/or gaming, virtually experiencing nature, and citizen-science projects. The WBGU poses the overarching question of whether networking can facilitate a new social awareness and willingness to cooperate (global citizenship).

5.3.1.1
Raising awareness through digitalization

Since the 1970s, environmental psychologists have considered the cognitive preconditions of ecological action to conserve the Earth system, and under what circumstances knowledge is beneficial here (e.g. Maloney and Ward, 1973; Hines et al., 1987).

How can knowledge change environment-related action and where does the potential of digitalization lie?

Meta-analyses (Bamberg and Möser, 2007; Hines et al., 1987) show that simply knowing about the threat to natural life-support systems usually has only a weak influence on everyday action to conserve the Earth system (researched predominantly under terms like environment-friendly action, private-sphere behaviour, according to Stern, 2000). Just hearing in the media about the threat of environmental problems, e.g. disaster images of floods or hurricanes, can even lead to people distancing themselves (Klöckner, 2015; O'Neill and Nicholson-Cole, 2009). On the basis of these studies on environmental problems and knowledge, the WBGU asks how digitalization might be able to support environment-friendly action.

Against this background one can assume that – if at all – only concrete action knowledge (i.e. knowledge about what actions can be taken to counter the problems) is relevant for everyday actions, but that simply knowing about the problems is hardly enough. However, being aware of a problem is an important prerequisite for people to feel morally obliged to act in an environment-friendly way, to develop a 'personal norm' (e.g. Schwartz, 1977; Schwartz and Howard, 1981). Personal moral obligations (personal norms) for 'political actions' in the broadest sense are clearly very relevant for taking action (Stern, 2000) and for the acceptance of political measures (Steg and Vlek, 2009). It would therefore be important – together with making it possible for people to experience problems via depictions of them – to directly point out solution areas (political and everyday actions) and to make it possible to experience them as concretely as possible (Rogers, 1975). The WBGU sees this as a possible (enabling) potential of digitalization for a global environmental awareness. Let us imagine that we could experience future worlds – virtually and interactively – in such a way that decarbonization, comprehensive inclusion and the recognition of diversity are already (virtual) 'reality' and where the roads leading there can be experienced – and preferably selected and explored. People learn best when they are actively involved and receive immediate feedback on newly learned behaviour, i.e. when they are self-effective. In the health sector, initial meta-studies point to the positive benefits of digital educational games (e.g. 'serious digital games': DeSmet et al., 2014). In the environmental field, however, there are few games so far – and a lack of research on their effectiveness (Fjællingsdal and Klöckner, 2017). Examples include the game collection called Strange Loop Games (2018), the use of the cult computer game Minecraft for participative urban planning in cooperation with UN-Habitat (Block by Block Foundation, 2019), or explaining the global e-waste problem in political youth education (Evangelische Akademie Sachsen-Anhalt, 2018; Section 5.2.5).

In the WBGU's view, the potential of the digitally enhanced acquisition of environmental knowledge lies above all in making political action possible, in understanding the need to take measures, and in accepting those measures. Digital applications that reliably point out resource-conserving alternatives for action can support individual everyday actions.

Can virtually experiencing nature act as a motivation for environmental protection?

Experiencing nature (e.g. combined with positive emotions) seems – like knowledge – to have little influence on environment-friendly actions in everyday life (e.g. Kals et al., 1999; Nisbet et al., 2009; Sparks et al., 2014). However, experiencing nature could be relevant for indirect, i.e. political action (e.g. for nature conservation; Nisbet et al., 2009). In this respect, the WBGU asks whether *spending time* in a digitalized natural environment or in digitally mediated *interaction with* natural environments (e.g. IPGarten (online garden): Box 5.3.1-1) can promote an awareness of nature and thus encourage direct or indirect environment-friendly action.

Up to now it is not clear whether nature can be simulated in such a way that environmental awareness is also promoted in virtual environments. There are initial indications that experiences of nature made possible with ICT (images or films) increase a closeness to nature and promote behaviour to conserve national nature (particularly attractive national parks, Arendt and Matthes, 2016), but reduce the perceived attractiveness of local nature (Levi and Kocher, 1999). Initial studies also report that watching nature films, images or simulations is associated with positive feelings. Naturalness and the feeling of being in a continuous space, and elements such as immersion (i.e. how completely or vividly a reality is depicted) and larger viewing surfaces (Cummings and Bailenson, 2016) seem to be relevant elements for virtual realities to be valued positively (e.g. De Kort et al., 2006). Virtually experiencing nature with positive emotions could thus awaken personal norms and a willingness to act. Examples would be virtual experiences with otherwise inaccessible and impressive natural landscapes and creatures, which, in such a virtual encounter, trigger empathy and feelings such as pride and majesty, e.g. the image of the planet, swimming with dolphins, or flying over a waterfall from a bird's perspective.

Citizen science – raising problem awareness and strengthening collective effectiveness by participating in knowledge building

When non-professional 'scientists' independently get involved in – or are incorporated into – science, this is often referred to as citizen science. Prominent examples include the mostly very successful calls for bird surveys. Digital platforms (e.g. Buergerschaffenwissen.de, 2019; SciStarter.org, 2019) offer a whole range of citizens' research projects where interested people can participate and report (e.g. Bonney et al., 2015).

On the one hand, such experience-based, involved learning has the potential to give people a knowledge boost and a fascination for system knowledge. However, here too the newly acquired knowledge can only be expected to be directly converted into *sustainable action relevant to everyday life* if knowledge of how to act is imparted at the same time (Section 5.3.1.1). Since citizen science presumably supports the idea of experiencing collective effectiveness, one would expect *political action* in particular to be promoted by such forms of scientific environmental experience. One such transformative force of digitalization for environmental protection or global environmental awareness can currently be seen in the area of air-quality monitoring in public spaces (Box 5.3.1-2).

5.3.1.2
The individual and the cosmopolitan society: can digitalization promote empathy and solidarity?

The WBGU assumes that networking and virtuality can create a proximity to problem areas (situations, individuals, groups, life situations) that are far away in terms of space and time, i.e. the 'psychological distance' (Uzzell, 2000) is reduced. The question arises whether this new form of proximity can promote collaborative and environment-friendly behaviour or, in a broader sense, solidarity (Gifford, 2014)?

Does the expansion of social networks promote international cooperation?

Social and neuropsychological studies (Dunbar, 2018) indicate that social networks do not increase in size as a result of digitalization (e.g. through social media), but are likely to become more heterogeneous (Haerter et al., 2012). Digitalization can facilitate contact with people from different groups, because, among other things, passport controls do not play a role online, ethnicities and other group affiliations can be deliberately concealed, and physical contact, which may be fear-laden as a result of prejudices or simply costly, no longer takes place (spatial distance). In the following, the WBGU discusses whether this expansion of social networks promotes international cooperation.

Since the 1950s, psychological studies (in particular Allport, 1954) have shown that intergroup contacts reduce prejudices, especially under ideal conditions such as equal status in the contact situation and common goals. Recent overview studies confirm that contact alone between individuals of different groups reduces prejudice and promotes affection (meta-analyses: Pettigrew and Tropp, 2006; Lemmer and Wagner, 2015). Studies on intergroup contact, however, almost exclusively relate to personal (face to face) contacts or 'indirect contact'; for example, the knowledge that a person close to us is in close contact with people of other ethnicities also promotes a positive attitude

Box 5.3.1-1

Digitalization to enable virtual contact with nature – IPGarten: "your own garden just a mouse click away"

A practical example where virtual technology is used to enable a new way of experiencing nature is the Berlin-based IPGarten Project (ipgarten.de, 2019). IP gardeners gain digital knowledge about sustainable agriculture and implement it directly by cultivating their own piece of land from home, planting, watering and harvesting their garden 'digitally'. The digital IPGarten owners' instructions are implemented by 'analogue' (i.e. real) gardeners 'on the spot'. The harvest can be collected from a central location (and surpluses are donated to needy people via the *Berliner Tafel* charity). Plant growth can be observed live via cameras and drones, and a wide variety of data, e.g. on soil, water and air, are transmitted in real time. Anyone can purchase an IPGarten, although the project is advertised particularly intensely in the educational context, e.g. in schools. Applicants currently have to wait for a garden for up to four years.

IP gardening uses a virtual world to pass on knowledge for solving environmental problems, such as the sustainable use of soils. Apart from acquiring knowledge, concrete options for action can be tried out: indirect, environment-friendly action is made possible by digital interaction. It is certainly conceivable that the knowledge acquired in the IPGarten project (e.g. on soil protection) could also lead to IP gardeners becoming more politically committed to such goals (e.g. sustainable soil management).

Practical examples such as the IPGarten need evaluations to assess whether forms of virtually experiencing nature offers potential for environmental protection, e.g. whether *digitally* acquired knowledge and action on environmental protection issues is transferred to actual political or environment-friendly action.

towards this group (Lemmer and Wagner, 2015). Little research has been conducted on virtual forms of contact, but initial studies indicate that virtual contact with individuals from other groups has little or no effect on prejudice reduction, affection or positive attitudes (Lemmer and Wagner, 2015).

The WBGU believes that digitalization has potential in the development of solidarity, particularly at the level where people with the same interests network directly and experience common ground at the civil-society level. Examples of such networking potential include campaigns such as Standing Rock (standwithstandingrock.net), where people show global solidarity with others for a certain purpose (in this case with the Sioux for nature and water protection) and take joint political action. Such political options are broadened by digitalization and range from direct participation to the dissemination of content via social networks, online or crowd-funding and petitions. The constant possibility of exchange, together with direct insights via video messages, probably strengthens the feeling of collectively having an impact (strengthening collective self-efficacy: Bamberg et al., 2015) and enable 'pioneers of change' (WBGU, 2011:242ff.) to make their feelings and ideas digitally comprehensible for others more quickly and more directly.

Should digitalization promote empathy?

In the following, the WBGU takes up the key concept of 'empathy expansion' (Rifkin, 2009), which is associated primarily with positive effects in public discourse: it is imagined that empathy with other people's joy and suffering drives one to behave altruistically and/or show solidarity (Batson and Shaw, 1991).

From the point of view of cognitive psychology, the discussion should include the fact that the promotion of empathy, e.g. via stronger networking via social media, also entails risks at the individual and societal level. Hence, 'empathizing with other people', the core of empathy, is often also associated with negative stress (empathic distress; Singer and Klimecki, 2014), especially when negative emotions are involved (e.g. pity for climate-change victims). For example, the emphasis, especially in social media, seems to be on exchanging negative emotions and thus negative feelings of stress. Initial studies show that texts on climate change shared on social media are often emotionally charged (Veltri and Atanasova, 2017). Here there is a risk of feelings of helplessness, for example when others share the negative emotions (fear, anger, grief, disgust) of a climate-change victim who is currently losing their home. This can result in people distancing themselves psychologically in order to protect themselves (Hart, 2011).

Solidarity, as defined by the WGBU (WBGU, 2016a), is more likely to be strengthened by a rational experience of 'compassion' rather than by such an emotional experience. Compassion describes a feeling that arises when other people's suffering is witnessed, and this motivates the desire to help (Goetz et al., 2010; Lazarus, 1991; Singer and Klimecki, 2014). First studies show a positive influence of compassion on actions to conserve the Earth system (Pfattheicher et al., 2016).

The WBGU asks where and how digitalization can try to have an effect here. Compassion requires recognizing one's own feelings, separating them from those of others, while allowing positive feelings for others. These skills can be promoted e.g. by mindfulness meditation techniques (Singer and Klimecki, 2014), which could be learned with the support of appropriate digital applications.

Box 5.3.1-2

Digitalization for citizen sensing

'Citizen sensing' is an exciting trend at the interface between digitalization, the environment and citizen science. Above all, the availability of ever cheaper, smaller and more powerful sensors enables ever denser and better networked monitoring of air quality (Jiang, 2017; Gabrys et al., 2016). The associated empowerment of more and more actors to carry out air measurements themselves releases a potential for societal transformation that should not be underestimated. In addition to, or together with, 'professionals' such as environmental authorities, companies, environmental organizations or scientists, more and more private individuals are becoming 'measurement actors' in citizen sensing.

In the context of digitalization, measurements in microsensor networks and networking in the IoT are expected to contribute to better air quality and consequently sustainable urban development (Lambrechts and Sinha, 2016; Sections 5.2.7, 5.2.8). A well-known German example of citizen sensing is a project called luftdaten.info (2018) organized by the OK Lab Stuttgart. The project encourages people to build and operate their own particulatematter sensors and to share the measured values on an open internet map platform, which now extends beyond Germany's borders. It thus embodies many characteristics of the bottom-up digitalization movement, from the collaborative production of open knowledge to 3D printing of casing parts (Fröschle, 2017:515f.; Sections 3.3, 5.2.2, 5.3.10).

As already mentioned, citizen sensing currently offers above all the potential for societal transformation. From a metrological point of view, the disruptive potential of cost-effective sensors can still be classified as rather low due to the fundamental conflict of objectives between quality and costs, but it could increase with rising quality (Jiang, 2017:728ff., JRC, 2017:1; for sensors from luftdaten.info: LUBW, 2017). However, low-cost sensor technology, especially in developing countries and emerging economies, could help to set up or expand (citizen) air-measurement networks and to monitor measurements made by the authorities (Lambrechts and Sinha, 2016:11ff.). The required energy and resource consumption should be taken into account here (e.g. electricity for sensors and WLANs, e-waste).

A combination with indoor air-quality measurements also offers the potential to measure people's actual total exposure and to derive suitable options for action (Jiang, 2017:727). Citizen sensing can also be used for environmental education in schools, e.g. smartphones as air sensors in the SusMobil project (SUSmobil, 2018).

5.3.1.3
Digital participation and networking to make changes in consumption styles possible in everyday life

Taking into account the often reported success of group-based intervention techniques (e.g. targeted diffusion in social marketing measures; Abrahamse and Matthies, 2012), or interventions that encourage groups to commit themselves collectively or individually (e.g. Energy Neighbourhoods initiated by the EU: European Commission, 2019b), the WBGU identifies considerable potential in digitalization for promoting sustainable consumption and a solidarity-based quality of life.

Digitalization can enable participation, dissemination and rapid social interaction in different ways. Social interaction via ICT can enable in particular sustainable consumption based on shared use, reuse, repair, sharing and exchange (Sections 5.2.2, 5.2.3, 5.2.5). In addition, digitalization can make a wide range of different measures possible: from interactive counselling programmes adapted to one's own life situation (tailoring of interventions: Abrahamse et al., 2007) and feedback systems on one's own lifestyle (behaviour feedback: Klöckner, 2015) to applications that reveal CO_2 emissions associated with consumer goods and identify sustainable alternatives (Section 5.2.3).

5.3.1.4
Conclusions

In the WBGU's view, the potential of the digitally enhanced acquisition of environmental knowledge lies above all in making political action possible, understanding the need to take measures, and accepting those measures. Digital applications that reliably point out resource-conserving action alternatives can support individual everyday actions. Overall, it can be seen that involved learning through digitalization is possible and, if well designed, can in particular promote political action and the acceptance of measures. It is important here to use digitalization's potential to increase knowledge of problems and systems – e.g. fast interactivity, direct feedback possibilities, and virtually experiencing natural environments and living creatures worthy of protection, which creates positive emotions. Funding for involved education and research formats such as citizen science (e.g. Box 5.3.1-2) can improve system knowledge and lead to more civil participation (self-efficacy).

Box 5.3.1-3

Recommendations for action on the arena 'Promotion of a collective global awareness'

- Direct effects of digitalization (in the sense of networking, enabling a virtual online experience, etc.) can be expected in particular to promote an enhanced and enriched knowledge and understanding of problems. New forms of providing and experiencing information can therefore be expected to have positive effects on people's motivation for political action and the acceptability of measures. The WBGU therefore recommends using digitalization to impart background knowledge and to reveal political action options.
- In the field of individual everyday actions, fewer direct effects can be expected from new forms of knowledge transfer; here, however, existing behaviour-changing techniques (such as tailored intervention, implementation intentions, feedback) can be further developed and improved through digital implementation, and this should be promoted.
- In the 1990s, the possibility of determining one's individual ecological footprint strongly motivated people to take individual action. Digitalization makes the step from footprint to handprint possible: today, it is possible to focus on the positive effects of one's own sustainable consumer behaviour and on joint effects, such as reductions in CO2 emissions if recommendations for action are implemented alone or jointly (e.g. handprinter.org). This should receive funding, and existing instruments should be further developed and disseminated on the basis of evidence.
- Credible and reliable action knowledge and information in the sense of transformative education should be made widely available via the internet. This digitally available action knowledge should be used to develop applications that provide information on sustainable action alternatives tailored to a person's individual life situation.

Box 5.3.1-4

Research recommendations for the arena 'Promotion of a collective global awareness'

- There is a particular need for research on the impact that educational games, simulations of complex problem solving, and virtual experiences of nature have on environment-friendly everyday actions and political activity. Up to now it has been unclear (even in the health field) which digital technologies and elements (e.g. increasing immersion and entertainment value, feedback) are particularly suitable for promoting knowledge of problems and for supporting action.
- Research is especially needed into the extent to which the effectiveness of measures (such as recommendations for action and feedback) can be transferred when they are carried out digitally. Studies have long since shown, for example, that particularly a combination of knowledge and action promotes changes in behaviour (Hungerford and Volk, 1990): whether digitally acquired knowledge and digital action (e.g. IP gardens: Box 5.3.1-1) also promote changes in behaviour is yet to be researched.
- Especially in everyday life, the ability to directly experience and directly test new sustainable modes of behaviour are drivers of behavioural changes. Intensive research should therefore continue into new strategies for promoting knowledge for action and environmentally relevant norms and values in ways that are not digital.
- One overarching research question on the topic of networking concerns the possible promotion of empathy and/or compassion. According to the current state of knowledge, empathy can also lead to negative stress reactions – and thus to denial. Since compassion holds greater potential for positive reactions and commitment here, it is urgently necessary to clarify which are the best measures for digitally promoting compassion and, building on this, solidarity-based action.

5.3.2 Digitalization and public discourse: the end of rational argumentation or the chance of a global agora?

'Digital structural change of the public sphere' – what at first might sound academic and complex describes a transformation that is very evident for many people: digital technologies are changing the way we communicate, how we perceive societal debates, and how we can take part in them (Fraser, 2010; Imhof, 2011; Ullrich, 2017). Worldwide, but by no means globally, many people use social media such as Facebook, Twitter or Instagram to privately and professionally communicate, receive and transfer information and messages. One third of Germans, almost half of Americans and two thirds of Brazilians used social media as a source of news in 2018 (Newman et al., 2018). In many cases, information is also provided by end users themselves (Dolata and Schrape, 2017). The media landscape is changing: a small number of successful digital platforms are gaining importance as new intermediaries (mediators) via new media and sales formats, while print circulations are declining and traditional business models are being eroded. Print media have increasingly come under economic pressure since the turn of the millennium (Figure 5.3.2-1).

To put it bluntly, the reader's letter as a format for

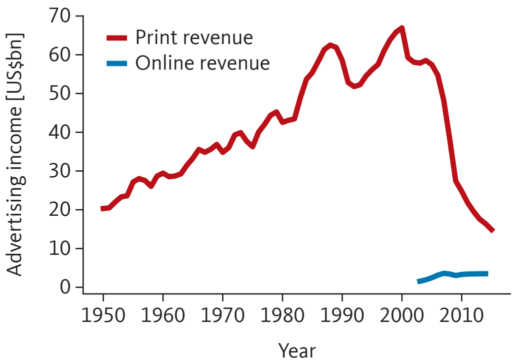


Figure 5.3.2-1
Inflation-adjusted advertising revenues of US newspapers since 1950 in US$ billions (print and online).
Source: Wikimedia, 2018

discourse is becoming a relic of bygone times, and Mr Smith now comments on the internet as purplediamond72 – this change has communicative potential, but also risks. But what exactly is the digital public sphere of blogposts, comment columns, likes and retweets? Is all this a remake of what we are already familiar with in a new digital guise, or is it a fundamental upheaval – emancipation, regression, or both at the same time? The question as to what are the new 'leading media' – especially in the sense of common, widely shared forums of authentic societal exchange – has remained unanswered up to now. Can the digital public sphere fulfil the important societal function of representing and aggregating the diversity of opinions in order to facilitate political decision-making and democracy? Can societally relevant problems be revealed and substantive interests articulated there in such a way that areas where action needs to be taken can be identified and dealt with in the context of politics and society?

In order to approach some of these fundamental changes, this arena is dedicated to public discourse in the Digital Age. What multiple structural changes is the 'digitalized agora' undergoing (Section 5.3.2.1), e.g. through the blurring of boundaries and through fragmentation, while at the same time enormously increasing the quantity of public communication? What does this structural change mean for people in terms of dignity, *Eigenart* and inclusion, speakers' freedom of information, opinion and speech, and the need for an authentic interlocutor (Section 5.3.2.2)? What significance does the transformation in the media landscape have (Section 5.3.2.3)? What decisions are necessary to realize the democratic potential of digital change and to ensure a shared and reliable, digitally enhanced societal space for discourse in the long term (Section 5.3.2.4)?

5.3.2.1
The digitalized agora – structural changes in public discourse in the digital space

The transformation of the public discourse space is often reflected in the changed intermediaries of this space. All media, from classic daily newspapers to online platforms, are intermediaries, i.e. service providers and places of provision, aggregation, selection and mediation of content. However, classic media – both offline and online – usually have long-established practices and stable procedures involving internal quality standards, voluntary self-regulation and a pronounced professional ethic imparted in the course of training and practice. Especially in its initial heyday, the internet and digital space were seen as an alternative to this structured form of public exchange. However, the early euphoria of the 1990s and 2000s about a great democratization and transnationalization of largely user-organized public opinion-forming and decision-making today faces a much more critical assessment (Lovink, 2017; Jacob and Thiel, 2017). Sheer quantity is not to be equated with the quality of participation. A simple increase in the possibilities of digital communication could come to nothing unless they are connected – in a (media-)mediated and editorially structured way – to (e.g. parliamentary) fora of genuine political decision-making (Ullrich, 2017). In addition, differences in usage skills and access to the possibilities of the digital public sphere – together with the parcelling out of communication into filter bubbles or echo chambers with like-minded people in the social media – have promoted a fragmentation and trivialization of public digital communication (Pariser, 2011; Bedford-Strohm, 2017). Although the public sphere was already locally and thematically fragmented in the past, the monopoly of reach and the influence of mass and leading media on the media agenda have been broken by digitalization – in this way, "the idea of a uniform national public sphere has been revised once and for all" (Hillje, 2019:69). The assumption is that "the decreasing orientation function of the mass media [meets] an increasing disorientation ability of the social media", i.e. that using the media today creates *less* instead of *more* orientation and overview (Hillje, 2019:69). The extent of this fragmentation, however, has only been partly clarified by empirical research up to now, and it can vary by international comparison (Schünemann, 2019). However, a tendency for people to be less politically informed and capable of discourse, while polarization is on the increase, "can be confirmed quite well on the basis of communication theories, empirical findings and plausible considerations" (Schweiger, 2017:182). Accordingly, people "today must be equipped with much more sophisticated information skills to be able to

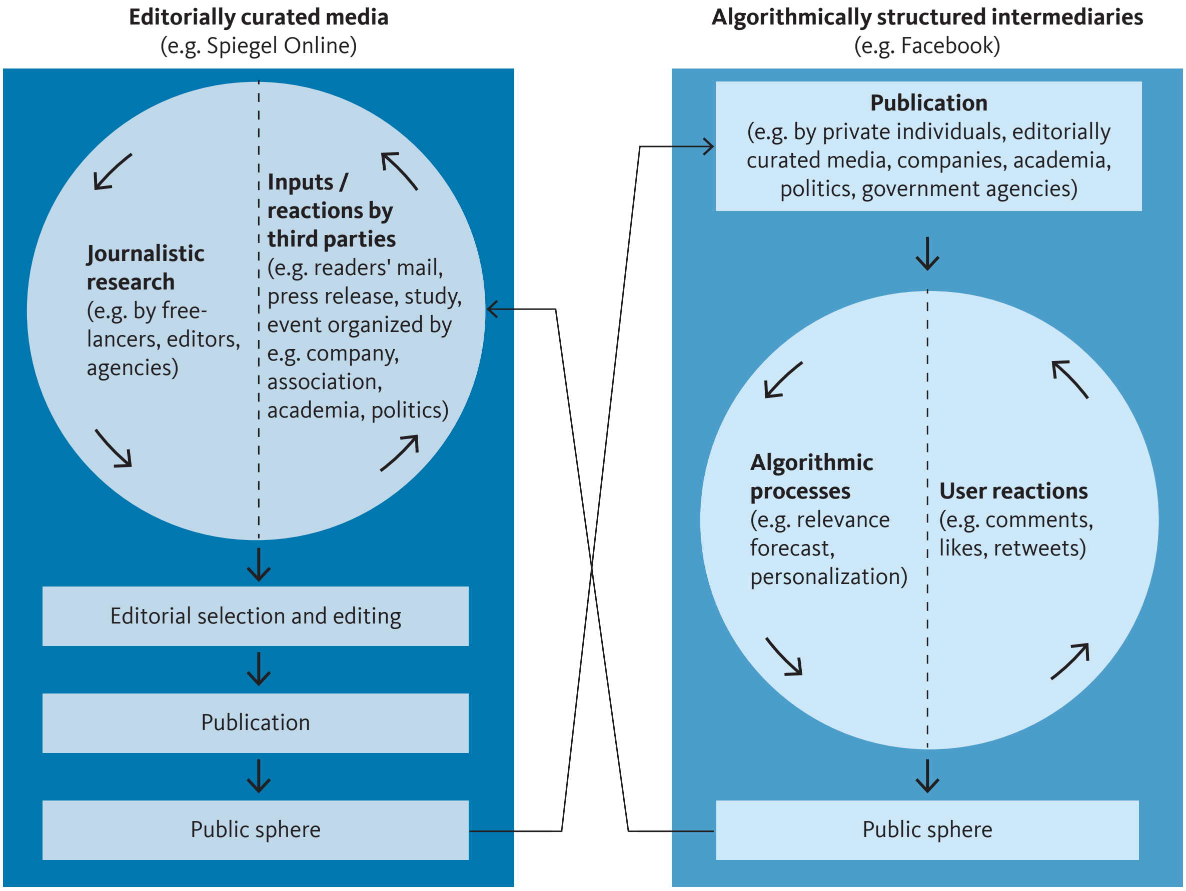


Figure 5.3.2-2
Comparison of the processes of two types of media intermediaries. Left, classic editorially curated media with editorial processing and indirect influence of user reactions. Right, algorithmically structured intermediaries with algorithmic sorting and a direct influence of user reactions.
Source: Lischka and Stöcker, 2017

navigate the jungle of facts and fakes and not to constantly run the risk of being manipulated instead of informed" (Hillje, 2019: 123).

Despite a huge amount of available information and knowledge that is unsurpassed in human history, there are therefore also risks for public discourse, for example when conspiracy theories can generate a similar amount of media attention as serious news. Although disinformation already existed in earlier forms of the public sphere, there has been a qualitative and quantitative change in view of new forms, infrastructures and incentives for digital communication. This concerns both the supply side of the media and their reception by individuals. On the supply side, the algorithmic pre-structuring and channelling of content plays a particularly important role, whether in social networks or in the listing of search results (Figure 5.3.2-2).

As a result, intermediaries such as Google, Facebook and Apple, which process and offer content using algorithms, are now offering their platforms and services as a solution to the very media industry they challenged (Schmidt, 2018). They want to become "publishers of the publishers", so to speak, without themselves assuming responsibility for the content, which in the end "will undoubtedly increase the power gap between digital corporations and news media" (Fanta and Dachwitz, 2019). This variant of the Silicon Valley "solutionism" (Morozov, 2013) – i.e. the motivation to counter every (societal) difficulty with a rapid technological solution without considering possible problematic consequences – is risky for a democratic pluralistic public sphere as a basis of an open society. It further strengthens the power position of these corporations, undermines efforts at transparency and the democratic potential of a common-good-oriented form of public-service ICT (Section 5.3.5), and is susceptible to abuses of power – even for totalitarian purposes.

An important and hotly contested basis for a largely non-discriminatory infrastructure of public deliberation is the transmission of information in the web on equal terms. Compliance with this principle of net neutrality (Cheng et al., 2011; Pil Choi and Kim, 2010; Verständig, 2016) is therefore a prerequisite for freedom of information and public opinion forming. It could be ensured particularly well in a public-service-based ICT (Section 5.3.5). Close networking and an increasing number of communication channels available at all times have been the technical drivers of structural change in recent decades. However, other systemic technical innovations that fundamentally challenge the structure of the public sphere as we know it are becoming increasingly important. For example, their already not unproblematic "economy of attention" (Franck, 1998) has become a data-driven "attention bazaar" (Dueck, 2017). Ultimately, algorithm-based systems that predict the relevance of content and personalize new media offerings decide whether and which content is communicated with what kind of reach (Hillje, 2019: 122). In addition, there is disinformation – the extent and effect of which has as yet been insufficiently clarified by empirical research – via programmed accounts in social networks (social bots; Klinger, 2019; Kind et al., 2017), as well as manipulation of existing image, video and sound material using neural networks (deep fakes; Box 3.3.3-2).

The first approaches to solving new problems of the digitalized public sphere have recently been implemented, but some of them are producing new challenges. The German Network Enforcement Act (Box 4.3.6-2), for example, seeks to have hate content removed by platform operators – to protect personal rights and the debate culture and to stop criminal content. However, this involves risks associated with privatized law enforcement, such as a lack of transparency, especially in the case of unjustly removed content, or ethical issues associated with automated content moderation. This can conflict with normative principles such as enabling individual inclusion or protecting human dignity (Chapter 2). For example, the documentary film 'The Cleaners' (bpb, 2018) clearly shows how clickworkers in the Philippines (Section 5.3.8) sort problematic social media content in precarious working conditions and under psychological stress according to rules that are not subject to any external scrutiny. Yet in Germany, too, the work of content moderators of individual Facebook service providers – at least according to the few available sources – is constantly monitored with a scoring system (Section 5.3.3), in which up to now speed seems to prevail over quality (Reuter et al., 2019). Training data for AI procedures arising from such working practices create foreseeable new problems, e.g. when they are used to create increasingly automated filters. Critics of upload filters for platform content see them as a "close-meshed censorship infrastructure" (Dachwitz and Rudel, 2019) that potentially runs counter to freedom of expression and democracy.

5.3.2.2 Empowerment of, and threats to, individual inclusion in public communication

The core of the internet's promise of democratization was the immediacy of communication participation at the individual level (Zipfel, 1998; Siedschlag et al., 2002; Vowe, 2014): each participant can be a potential speaker in many different formats in digitally enabled public exchange. Weblogs, podcasts, social media and the general possibilities of participation discussed under the catchword Web 2.0 (Schmidt, 2007; Constantinides and Fountain, 2008; MacDougall, 2011) mark the transition from mere access to information (perceived till then by the general population as the main benefit of the internet) to a fusion of the roles of recipient and speaker. Indeed, the internet offers not only immediacy in the public communication of organizations, i.e. without mediation by media operators, but also in particular direct interaction. Individuals can therefore not only access large amounts of information more directly, they themselves can be speakers in the communication process. This has the potential to emancipate societal debates from the gatekeeper function of traditional media and thus allow for more plurality (Neuberger and Quandt, 2010).

Even individuals who lack the necessary attention resources such as prominence can, in principle, make their voices heard in the discourse with little technical effort. However, it has been shown that the potential for strengthening a societal discourse in the Habermasian sense, in which everyone would strive to reach a consensus (Habermas, 1981) through the sincere exchange of arguments, remains largely untapped. Obstacles to the full development of this potential can be identified from the perspective of the speakers. On the one hand, the loss of the press's intermediary function is both liberating and a challenge at the same time. In reception, there is no such curator to help select and classify content and without whom the recipient might be overtaxed both qualitatively and quantitatively (Neuberger and Quandt, 2010; Busch, 2017). Despite the generally lower technical requirements for participation, sections of the population who lack access to or an understanding of digital technology can also remain unheard in public debates if the latter shift primarily to the virtual sphere (hence the need for the right to evade digital spaces; Box 9.3.1-1).

On the other hand, the new opportunities for participation do not necessarily overcome existing power structures. The large number of participating companies and users on the internet do not in themselves guarantee that there will be no concentration of power (Sassen, 1999). Two developments are essential in this context. First, the reduction of technical barriers to access has by no means led to an unlimited pluralization of voices in digitalized public discourse. Established actors have taken over the discourse space opened up by the internet. The initial understanding of Web 2.0 as a public space that enables sincere discourse in the Habermasian sense has proved to be naive (Chadwick, 2008). After an exploratory phase in which the freely accessible internet was mainly used by research institutions and technophiles, contents have become commercialized, partially concealing diversity in the discourse. YouTube is an example that illustrates the opportunities for emancipation and plurality as well as their counter-trends. The video platform made it easier to appear in digital communication not just passively as a recipient – like a television viewer – but also to be a 'broadcaster' oneself (Burgess and Green, 2018). Following an initial, pioneering phase of broadcasting from home using simple technical means, many producers have now become more professional and commercialized their content; established media groups have joined as high-profile providers and signed up many of the supposedly independent producers within the framework of multi-channel networks (Döring, 2014; Cunningham et al., 2016). As a result, a discussion about the essence of YouTube has flared up: is it "a social network site produced by communities of practice; a chaotic archive of weird, wonderful, and trashy vernacular videos; or a distribution platform for branded and big media entertainment" (Burgess and Green, 2018: 91)? Platforms like YouTube can certainly generate attention for individuals and enable them to participate in public discourse. However, the example urges us to consider the limitations of this potential. In view of the tendencies towards commercialization, the hoped-for emancipatory, authenticity and diversity effects may sometimes be drowned out, as is also the case in offline media.

Second, other participants in public communication cannot be unequivocally identified by individuals as authentic (human) speakers (Box 9.3.1-1). Automated computer programs now also act as speakers. Although such bots on platforms like Twitter can also serve benign purposes, such as pointing out genuine news from established agencies or (online) newspapers (Lokot and Diakopoulos, 2016), social bots are increasingly being used for political propaganda, imitating human speakers (Ferrara et al., 2016; Kollanyi et al., 2016; Ehrenberg-Silies and Thiele, 2016; Haller, 2017; Kaufhold et al., 2017; Graber and Lindemann, 2018). Although the extent to which social bots are currently used is as yet insufficiently empirically clarified (Klinger, 2019; Kind et al., 2017), nevertheless, individuals cannot be sure whether the virtual counterpart is a sincere person or a machine with a programmed agenda and less sincere people behind it. The contextual prerequisites for communicative action are not given in this case. Against this background, competence in dealing with digital media and an understanding of the underlying technology are prerequisites for the consolidation of public debating culture (Graber and Lindemann, 2018).

5.3.2.3
The digital agora between concentration of power and the public interest

Even before digitalization, mass media were characterized by a fundamental contradiction between societal and individual interestsTheir role as societal institutions for a living democracy contrasts with their commercial role: "On the one hand – as creatures of the Enlightenment – they are committed to values such as freedom, autonomy, reason and knowledge. On the other hand, the mass media and their actors are oriented towards practical, pragmatic requirements and goals such as reach, competition, editorial deadlines, professionalism and careers. This situation leads to conflicts between expectations expressed towards the media and what the media and their journalists are capable of" (Weischenberg, 2018: 55).

While Weischenberg (2018: 55) regards media quality as threatened when it is "unilaterally dissolved in favour of profits and to the detriment of social responsibility," media corporations are now confronted with structural problems threatening their existence on both levels in the Digital Age. The circulation of print media sold in Germany has been declining continuously in recent years (IVW, 2018: 10), although the situation on the German press market has stabilized somewhat recently with slowing loss rates and double-digit growth rates in electronic editions of newspapers and magazines (IVW, 2019). As a result of the longer-term trend, however, editorial resources have been continuously thinned out, which has also worsened the working conditions for journalists in terms of working hours, pay and (for freelancers hardly accessible) permanent employment opportunities. Figure 5.3.2-2 has already shown how dangerous – in view of a further increase in the concentration of power – it can be for the democratic public sphere if this problem is 'solved' by digital corporations which are partly responsible for it. On the other hand, however, the first prototypical pioneers of a media change oriented towards individual autonomy and freedom of the press are emerging; the WBGU believes they should be strengthened, as should new potential for using digitalization to research the democratic public sphere. For some time now, high expectations have also been made of journalists under the heading of constructive journalism. Against a background of positive psychology, it is argued here that in addition to addressing problems, journalists also have the function of drawing attention to possible solutions and to actors working on solutions, in order to strengthen the collective self-efficacy of the recipients and to avoid a journalistic "negative bias" (Gyldensted, 2018). Transparently operating research networks such as correctiv.org also make a cooperative form of investigative journalism possible offering a quality that is becoming increasingly difficult in times of cost pressure and thinly staffed editorial offices. In addition, the infrastructure basis can be designed by means of public-service ICT (Section 5.3.5) in such a way that it promotes both this kind of change in the media and the realization of corresponding potential in both private and public-service media companies.

5.3.2.4
Conclusions: the impact of the digital structural change in the public sphere on democratic processes

The described structural change in the public sphere, including its individual and media-economic characteristics, has significant effects on public communication in democratic processes. Transparency in political affairs is a prerequisite for discourse and diversity of opinion (Sarcinelli, 2011); it is thus essential for the functioning of a democratic political system. As explained in the course of this section, digitalization enables the multiple provision of information and more direct forms of political inclusion, and promotes plurality and visibility of opinion through simpler, faster and more direct public communication. Emancipation from established media companies as conventional gatekeepers enables a more pluralistic, empathic and integrative discourse. Through global interconnectedness, this could even have an effect at the transnational level and thus create a post-national public sphere and deliberative structures beyond individual nation states through the formation of cross-border communities and a global environmental awareness (Sections 4.2.7, 5.3.1).

However, as explained in the course of this arena, there are a number of limitations and counter developments. In general, the actual reach of an individual is only small (Section 4.2.3). Against the background of the sheer quantity of contributions, individuals still have little chance of visibly contributing their own opinion to the discourse without the corresponding institutional resources. Furthermore, as explained with the example of filter bubbles and echo chambers, there is a risk of the discourse becoming fragmented and polarized (Del Vicario et al., 2016; Boutyline and Willer, 2016). Due to the lack of *editorial* pre-sorting and classification (Neuberger and Quandt, 2010; Busch, 2017) – unlike automated selection – on many platforms, the rationalization and filtering function of plural societal or media organizations is missing. These organizations have an important mediating role in the democratic public sphere as rationalizing sluices and amplifiers (Habermas, 1992). Instead of editors, algorithms trimmed to click counts determine what is placed in a prominent position (Newman et al., 2018). This can be a breeding ground for propaganda as well as for politically motivated misinformation and agitation – often discussed under the buzzword 'fake news' (Lazer et al., 2018), especially in connection with the presidential election in the United States in 2016 (Allcott and Gentzkow, 2017). In their selection criteria, editors too can focus more on sensation and the potential for attention – and thus sales – rather than on an orientation towards solutions and strengthening the self-efficacy of the recipients; however, automated and accelerated dissemination in social networks speeds up and intensifies the associated effects of negative bias and demoralization. In fake news, the characteristics of public online communication that could basically strengthen democracy are turned into challenges for democracy.

In addition, the extent to which the opportunities for participation on the internet are actually taken up is also particularly relevant for democratic processes. Although the number of users of social networks today is drastically higher (Chadwick, 2008; Busemann and Gscheidle, 2011), there are still large sections of the population who do not participate in the digitally enabled public discourse. Even though it is an easy and quick way for journalists to get an impression of opinions, a mood in social media cannot be understood as the will of the people. The privatization and oligopolization of the digital public space and thus also of the "infrastructure on which the democratic public sphere is constituted on the web" (Hillje, 2019: 15) is far advanced. For example, there is currently just one quasi-monopoly consisting of four search engine operators, all located outside the EU: Google and Bing from the USA, Yandex from Russia and Baidu from China (Tangens and Ude, 2019). But whoever, as is the case with Google, "processes three-quarters of all search queries on the internet has the power to direct users to very specific paths on the network and to make other paths less accessible" (Hillje, 2019: 120). The extent to which the sometimes massive private concentration of power advances the democratic public sphere is questionable, not least because "first and foremost the platforms naturally always pursue an economic interest – in case of doubt to the detriment of the common good" (Hillje, 2019: 128). Against this background, the WBGU

Box 5.3.2-1

Recommendations for action on the arena 'Digitalization and public discourse'

Due to the concentration of power among the intermediaries who currently provide key services for the digital public, and the observable deficits in their regulation (e.g. by the German Network Enforcement Act, NetzDG, Box 4.2.6-2) and this regulation's enforcement (e.g. the European General Basic Data Protection Regulation, GDPR, Box 4.2.6-1), the WBGU sees the creation of adequate alternatives as an important lever for securing a functioning digital public sphere. In order to be able to implement the following recommendations as quickly and successfully as possible, there is also an urgent need for research across disciplinary boundaries in all areas.

- *Establish a European public-service platform infrastructure*: The WBGU recommends the timely creation of a European platform infrastructure for digital media and communication. Realized via public-service ICT (Section 5.3.5), this should serve as a potentially powerful European alternative plan to counter the concentration of power by US American platforms, with an open, cross-border communication space guided by democratic values (Box 5.3.5-1) instead of being driven primarily by private-sector business models. In the WBGU's view, private-sector interests and an orientation towards the common good are not mutually exclusive on principle; however, in a core societal area such as the public sphere, the former should be answerable to the latter, i.e. subordinate in case of doubt. An interoperable infrastructure of diverse platforms should in principle be open to both public-service and private media from different European countries and should enable a joint communication of content and its AI-supported translation. In a similar way to public-service broadcasting, the coordination of this project should be independent from the outset and democratically supported by societal groups. As a first step, the WBGU recommends networking existing initiatives (Box 5.3.5-1; Hillje, 2019:130f.) and providing start-up funding for the first lighthouse project of a European public-service media platform. This can then be successively extended in the sense of a later platform ecosystem that should be as diverse as possible. The vision is that this diverse infrastructure will also promote a global digital democratic public sphere beyond Europe.
- *Build up a European search index*: As an accompanying measure, and in order to use the central resource of a database of all searchable websites and their contents for the public good, the WBGU also recommends the establishment of a European search index as a "public library of the internet" (Huss et al., 2019) and a "basis for diversity" (Lewandowski, 2016:15). Since this concentrated power plays a key role in the digital public sphere, public funds should be made available to prevent information flows that are distorted by business interests. A corresponding "open web index" (Huss et al., 2019:7) would also help secure a critical infrastructure, restore Europe's digital informational sovereignty, and stimulate search engines and the European start-up and internet economies. It would be available globally to all companies, public institutions and civil-society actors as a further central part of a future European public-service ICT infrastructure. On that basis, a new pluralism in access to and the dissemination of digitalized information would be possible, as would data-protection-friendly business models.

In addition, states should support actors who provide quality-checked information online and enable individuals to express their opinions on the web.

- *Guarantee journalistic quality and freedom of the press:* The WBGU recommends broad media-policy support and the expansion of quality journalistic initiatives. Investigative, transparent and collaborative research networks and news portals (e.g. correctiv.org, uebermedien.de or netzpolitik.org) and constructive journalism that also looks for possible solutions should be strengthened. On a national level, this could be achieved through increased cooperation with the public-service sector, for example by mutually supporting (counter-)research, and by supporting and expanding corresponding collaborative projects. Internationally, the establishment of a decentralized agency and information portal could contribute to greater pluralism and more transparent reporting. The WBGU also strongly recommends that the protection of sources and whistleblowers be legally safeguarded in order to strengthen investigative journalism as an essential part of journalistic practice relevant for democracy.
- *Ensure anonymity in internet communication and protect fundamental rights:* The WBGU advocates both the general necessity of anonymous online communication to ensure privacy and the possibility for citizens to consciously communicate in a non-anonymous way in designated secure digital spaces. A general and comprehensive obligation to use real names is not necessary. In view of a risk of advanced censorship by the private sector in order to comply with the German Network Enforcement Act (Box 4.2.6-2) or copyright regulations through upload filters, the WBGU similarly shares the critical assessment of the UN Special Rapporteur's opinion on freedom of expression, the right to privacy and the protection of fundamental rights in the fight against terrorism (Kaye et al., 2018). In the WBGU's view, only independent institutions committed exclusively to the rule of law can guarantee the regulation of online communication in conformity with fundamental rights.
- *Promote media and information literacy and embed it more firmly in the education system:* In the WBGU's view, the promotion of individual autonomy is another important strategy against current crisis phenomena in the public sphere, particularly with regard to the dissemination of disinformation. Accordingly, it is important to embed media competence and confident information interpretation more firmly in the education system. Ideally, in a modern democracy, all citizens would have sufficient journalistic competence to reflect on and classify content, but also to compose content themselves and discuss it critically within the digital agora.

considers it important to counter any threat to the fundamental democratic functions of the public sphere decisively and in good time.

Box 5.3.2-2

Research recommendations on the arena 'Digitalization and public discourse'

- *Develop new infrastructure to secure and enforce the law:* Instead of the current practice of delegating the securing and enforcement of legal rights to private corporations, with the risk of content (pre-)censorship, the WBGU recommends increased interdisciplinary and international research into options for securing fundamental rights in order to moderate legally problematic online content.
- *Promote research on media and information literacy*: In media sciences, especially in media psychology, there are research approaches that empirically investigate initial measures for promoting internet literacy (e.g. the recognition of fake news; Roozenbeek and van der Linden, 2019a, b). In view of the great importance of media literacy, the WBGU recommends strengthening research activities on the effectiveness of measures to promote media and information literacy.
- *Research and establish new mechanisms for the quality assurance of online media and content:* The WBGU recommends that the current practice of online platforms moderating content (e.g. for the purpose of removing problematic content such as depictions of violence, but also other content that contradicts the corporate guidelines) should not be maintained in this form. Psychologically burdensome outsourcing is incompatible with human dignity, and at the same time there is a risk that unclear guidelines may significantly affect freedom of expression. The alternative is not laissez-faire, but research into and the establishment of quality assurance institutions compatible with fundamental rights in conjunction with the development of autonomy-promoting information services and education (e.g. correctiv.org, reporterfabrik.de), individual media competence and ethical reflection.
- *Research and establish transparency-focused media ethics:* In view of the fundamental upheavals described above, the WBGU recommends the development and implementation of ethical codes, particularly to balance journalistic and commercial interests, to maintain or promote expectations of self-efficacy, and for transparent ownership and data protection (Puppis et al., 2017; Heesen, 2016). These should be developed and implemented by the media industry with interdisciplinary scientific support.

5.3.3 Challenges of the scoring society

Scoring methods that describe human behaviour with a numerical value (Box 5.3.3-1) are being used as a basis for decision-making in more and more core areas of society. They represent an enormous abstraction and simplification of complex contexts. This is both the strength and weakness of these methods. Simplification and standardization initially facilitate decision-making in specific areas. Scoring methods that use a mathematical-statistical approach of analysis are an example of algorithm-based decision-making systems. The informative value of a score, however, must always be viewed with great caution and seen in the context of the specific field of application, even if the selection of data, analytical methods and application areas is criteria-based.

In addition to the field of economic-risk assessment, where scoring has been common practice for many decades (primarily in the banking and insurance sectors), the use of scoring methods to assess 'social risks', e.g. calculating recidivism predictions in criminal prosecution, is currently spreading (Brayne, 2017). As a result, individuals are no longer only evaluated in their role as consumers, but also in other key areas of life. This social categorization and evaluation of individuals using scoring methods is referred to as 'social scoring'. With more and more behavioural data accruing in social media and in increasingly digitalized areas like health, education and mobility systems (Section 3.2), a new quality is emerging in the scope and complexity of scoring techniques. The use of female consumer data for predicting pregnancies in order to place advertising (Dixon and Gellman, 2014) or social-media data in loan approvals (Hurley and Adebayo, 2016) illustrates the depth and intensity of intrusions into the privacy of individuals that is already possible in business today. Experiments with social credit systems by Chinese central and local governments in turn show how scores can be used as an instrument for wielding state power (Box 4.2.6-2).

Global trends include the use of alternative data sources for the worldwide dissemination of credit scores, the use of a score outside its original area of application, and, increasingly, the use of scores to influence behaviour or as an instrument of state societal control. In view of the currently ongoing expansion of scoring methods in many areas of application where the underlying cause-and-effect relations are only insufficiently reflected and there is inadequate regulation to prevent violations of the rights to freedom and equality, the sustainability potential of scoring methods in defined areas of application is not addressed in this chapter. Instead, the focus is on a systemic and societal perspective.

Although the use of scoring methods aims to enable more objective decision-making in a specific area, the systemic effect of these applications can contribute – unnoticed by the individual – to an undermining both of self-determination and privacy, which are protected by fundamental rights, and of human decision-making sovereignty (Section 8.3.3). The social and legal embed-

Box 5.3.3-1

Definitions of scoring and distinctions between terms

The term 'scoring' is generally used to assign a numerical value to a natural person in his or her role as a consumer, citizen, employee, etc. Scoring can also refer to the aggregation of different characteristic values to form a single value – often using a statistical procedure. In profiling, by contrast, categories are formed to which certain measures are linked. The individuals are allocated to the categories; the allocation can also be based on a score. The term scoring is relatively rarely used in the evaluation of e.g. companies, organizations or states. Examples of scoring definitions include:

- "awarding a number of points in a finely graded classification that allows the person to be ranked according to values" (Mau, 2017: 104).
- "assigning a numerical value (score) to a person for the purpose of predicting or controlling behaviour. This numerical value is usually determined on the basis of a broad pool of data using an algorithmic process" (SVRV, 2018; 15).
- the "use of a probability value relating to a particular future action by a natural person for the purpose of deciding on the creation, execution or termination of a contractual relationship with that person" (Section 31(1) of the Federal Data Protection Act of 30 July 2017: Federal Data Protection Act (BGBl.) I S. 2097).

In credit scoring, the best-known and most widespread application of scoring (Figure 5.3.3-1), several people's payment or credit histories are combined with other personal data (name, gender, age, current and previous addresses, etc.) in a database. On the basis of the payment histories of all the people in the database and other personal characteristics, weights for each variable available in the database are calculated using a statistical process, usually a logit regression, which serves to predict the individual probability of repayment. The individual probability of repayment forms the credit score and serves as the basis for deciding whether to grant a loan or for determining the loan conditions.

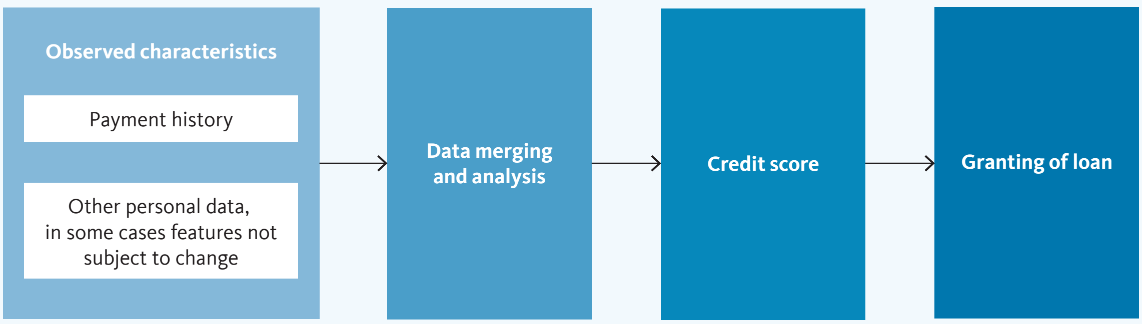


Figure 5.3.3-1
Credit-score-based decision-making.
Source: WBGU

ding of these procedures is key to avoiding such violations of fundamental rights; however, at present this is currently inadequate. Similarly, in some cases the potential for more objective decision-making in specific areas of application cannot currently be exploited due to a lack of transparency about areas of deployment, methods and data, and a lack of supervision (SVRV, 2018). The WBGU therefore suggests holding debates on scoring focusing on key issues in order to prevent violations of the rights to freedom and equality (Box 5.3.3-3). A central research topic here should be how the increasing use of scoring methods is shifting societal norms and moral standards.

5.3.3.1
Global trends in the application of scoring methods

On the one hand, scoring methods are being spread by private-sector actors whose business models are based on the analysis of new data sources. On the other hand, state actors, authorities and international organizations are also involved, some of whom collect their own data or enter into collaborations.

Use of alternative data sources for the worldwide dissemination of credit scores

Especially in the case of credit scoring (Box 5.3.3-1, Figure 5.3.3-1), one current focus of application is the scoring of people for whom there are no financial data, but for whom alternative data sources exist. Knowledge of payment-default risks is crucial for building stable credit markets. Scores consolidate this information and thus enable a standardized and rapid decision-making process on individual lending. From an economic perspective, credit scores thus have the function of establishing trust between economic actors, which is a fundamental building block of functioning credit markets. Partly in cooperation with international organizations such as the ITU or the World Bank, private-sector and state actors are therefore planning to calculate

Box 5.3.3-2

Expansion of data availability and the data trade

Data are sometimes collected for a specific purpose, for example by statistical offices, research institutes or market analysis institutes, to enable an analysis of an existing issue or state of affairs. However, when digital applications are used, behaviour-generated data such as social graphs, communication patterns, purchase histories or streaming data are generated as a 'by-product'. In addition to the specific application, companies are interested in obtaining structured information from these basic data which can be used for their business purposes and offer immediate added or novelty value. Data brokers specialize in collecting and reselling these data. The US data trader Oracle links information from online and offline sources about payment histories, social-media activities, magazine subscriptions, and religious or political affiliations. According to its own information, this data trader owns an average of 30,000 characteristics of over 2 billion customers worldwide (Federal Trade Commission, 2014). This data generation and valorization process is currently taking place without sufficient regulation to exclude violations of the rights to freedom and equality (Fezer, 2017); the structure and scale of data trading vary according to the requirements of national data protection law (Christl und Spiekermann, 2016). Having given their consent to data processing once in the context of a specific application, users are no longer involved in the further data processing. As a result, companies have access to personal information that is denied to users as data subjects (Jentzsch, 2017). Although the GDPR contains regulations that restrict data trading, it remains to be seen whether these regulations can be enforced. The first lawsuits have been filed against the data brokers Acxiom and Oracle (Privacy International, 2019). In the WBGU's view, it is necessary to create transparency over what, where and how personal information is used. However, transparency alone is not enough. Each individual should have sovereignty over his or her data, including the behaviour-generated data created when using digital applications. This can be achieved, for example, using Personal Information Management Systems, i.e. systems that allow users to manage their personal data in secure, local or online storage systems and to distribute usage consent to different digital applications and withdraw it when necessary. In addition, individuals should be appropriately involved in the valorization of their data.

credit scores for the approximately 3 billion people worldwide without bank accounts or payment histories, most of whom live in developing countries and emerging economies. Alternative data sources such as psychometric data (World Bank, 2017a; FICO blog, 2019) or data obtained from online tracking are to be used on a large scale for this purpose. Facebook, for example, had a process patented in 2015 that also takes into account an applicant's social network when deciding on creditworthiness (SVRV, 2018). Other providers use information such as shopping habits or information about how quickly e-mails are answered – information that would not intuitively be associated with creditworthiness – to determine the score (Hurley and Adebayo, 2016). Data brokers such as Acxiom or Oracle specialize in collecting and reselling these data (Box 5.3.3-2).

Use of a score outside the original area of application

Almost universally available scores are not limited to one area of life, but are also used as a basis for decision-making outside their specific area of application. For example, the scores generated by the German credit investigation company 'Schufa' (Schutzgemeinschaft für allgemeine Kreditsicherung), which are calculated for more than 66.3 million private individuals in Germany, are requested not only in the financial sector but also for apartment rentals, the conclusion of mobile-phone and internet contracts, and online purchases. Schufa generates annual sales of €123 million with this business model (Christl, 2014). Furthermore, US credit scores are taken into account in staff recruitment decisions. A single indicator can thus be decisive for several key areas of life as well as for such individual basic needs as communication or housing and therefore have a fundamental influence on inclusion in societal life (Figure 5.3.3-2).

The influence of scoring on behaviour

Knowledge of individual preferences and behaviour patterns enable not only probability statements about individual behaviour and subsequently fast decision-making processes based on objective criteria, it can also exert targeted influence to bring about behavioural changes in its own interests. These possibilities are particularly interesting for insurance and advertising companies. For example, individualized insurance offers and premiums (telematics-based tariffs) and the associated financial advantages and disadvantages can lead to changes in behaviour, such as a more prudent approach to one's own health (Schumacher, 2016:48) or more responsible driving. Targeting specific customers with advertising, as illustrated by the example of pregnancy scoring, can influence consumer behaviour (Korczak und Wilken, 2008).

Scores as an instrument of state societal control

China's original plan to introduce scoring methods to promote credit markets, which was similar to those in other developed economies, was expanded in 2012 to include the idea of establishing a 'trust-based' society (Kostka, 2018). Not only payment histories, but also social behaviour is to be evaluated (Box 4.2.6-2). The

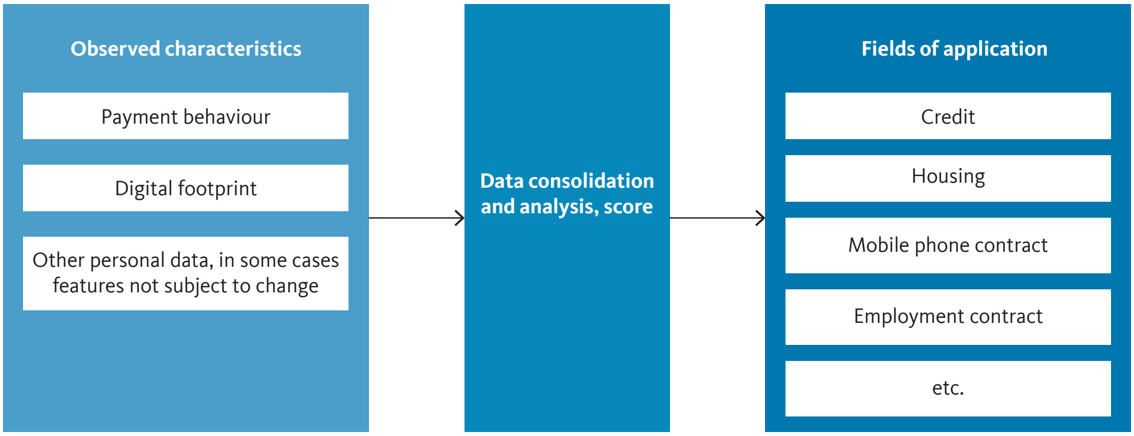


Figure 5.3.3-2
Schematic diagram showing the application of credit scores using information that would not intuitively be associated with creditworthiness.
Source: WBGU

Chinese scoring process is designed as an instrument of governance operating on various levels. In addition to the economic advantages of scoring that are also emphasized in other countries, it is intended to remedy social grievances such as corruption, crime and a lack of trust in public institutions (Kostka, 2018). As from 2020, the score, which thus functions as social credit, is to be calculated at the central state level for individuals, companies, social organizations and state authorities. This would basically make the (digital) surveillance of the entire Chinese population possible.

5.3.3.2
Necessary debates

What are the implications of the development outlined above for society as a whole? What key questions in the application of scoring methods need to be solved so that they can be used for the common good without having to accept long-term violations of the rights to freedom and equality? Approaches that should be discussed in the context of scoring are outlined below.

The mantra of more transparency: who attributes which values to whom using which data and procedures?

The current scoring practice exhibits numerous problems which, although widely known, have not yet been countered by appropriate regulatory measures. In contrast to self-chosen scoring services such as fitness trackers (Section 5.3.7), individuals can rarely evade scoring services used by third parties. Since in many countries it is ultimately unknown how many such scores are calculated, where they are applied, which calculation methods are used and what information is included in the calculation, it is currently difficult to assess to what extent individual rights such as equal treatment or informational self-determination are being violated (Dixon und Gellman, 2014; Korczak und Wilken, 2008). The latest report by the German Advisory Council for Consumer Affairs (Sachverständigenrat für Verbraucherschutz) for the German judicial area contains detailed proposals on how grievances in the field of consumer scoring can be countered (SVRV, 2018). The WBGU supports their swift implementation. The proposals include greater transparency regarding areas of application, the methods and underlying data used by scoring methods, improved consumer education, and supervision by the state and civil society.

Communitization or individualization of risks within society

The distribution of risks within a society is a normative issue. In the global banking and insurance industry, the contractual conditions are determined by the individual risk of default, so that each borrower usually pays for his or her own risk. This is considered fair by large sections of society, even though it may restrict financial inclusion for some individuals. In many countries, by contrast, the principle of solidarity is applied in the health sector; existing risks are redistributed according to defined distribution ratios that do not correspond to the individual risk. In its many different areas of application, scoring brings a new quality to the individualized calculation of risks on a large scale. The question as to which risks are individualized and which are communitized therefore needs to be reassessed in those areas where the principle of solidarity is applied. For example, the introduction of telematics-based tariffs, which use scoring techniques to determine tariffs depending on individual behaviour, has led to individual people

Box 5.3.3-3

Recommendations for action on the arena 'Scoring society'

Scoring methods are currently being applied in more and more core areas of society without an appropriate legal framework to ensure that the aim of scoring – a more objective, transparent and efficient decision-making process – will be achieved and to avoid violations of the rights to freedom and equality. The systemic effects of these applications can impair an individual's self-determination and privacy, which are protected by fundamental rights, as well as human sovereignty over decision making – without even being noticed by the individual concerned. The social and legal embedding of these procedures is therefore essential:

- The WBGU recommends the rapid implementation of the proposals for 'consumer-friendly scoring' that have been put forward for the German judicial area (SVRV, 2018). These proposals include greater transparency on the areas of application, the methods and underlying data used by scoring methods, improved consumer education, and supervision by the state and civil society. In addition, the WBGU recommends that a 'right to reasonable inferences' be established at European level (Wachter and Mittelstadt, 2018a).
- Although many democratic societies (still) vehemently reject state-applied holistic scoring systems– like the Chinese social credit system – scoring approaches that also include social behaviour in their calculations are gradually creeping into society via the private sector as a result of the current lack of transparency and a legal framework. In this way, they develop considerable societal steering effects. At the international level, discourse spaces should therefore be opened up and guard rails and targets introduced on the use of scoring methods.
- At the international level, processes should be set up to observe, discuss and regulate the cross-border effects of different scoring systems similar to those that are in part being implemented in China.
- In the WBGU's view, it is necessary to create transparency over what happens – where and how – to personal information. However, transparency alone is not enough. At the international level, processes should be set up to regulate the global data trade. Each individual should have sovereignty over his or her data, including the behaviour-generated data created when using digital applications. Greater use should therefore be made of systems that enable usage consent to be distributed to different digital applications – and withdrawn when necessary.

Box 5.3.3-4

Research recommendations on the arena 'Scoring society'

Key research topics should include how the increasing use of scoring methods can be embedded in the law and the ways in which scoring methods shift societal norms and moral standards.

- There is a considerable need for research on the effects of scoring on the fields of privacy law, self-determination and private autonomy. Scoring can have discriminatory effects. A distinction must be made here between whether scoring is used in a private-law relationship or by the state. One of the key research questions is whether and how the current legal system is in a position to counter the violation of rights by scoring adequately.
- Similarly, there is a need for research on the social impact of increasing quantification of decision-making processes and emerging shifts in values and norms. Work should also be done on any objectification tendencies that may arise as a result of the evaluation of an individual by a third party, e.g. the 'worthlessness' of a consumer with small financial resources.

being excluded from – or charged more for – health services due to certain characteristics such as lifestyle, alcohol consumption, participation in screening programmes, genetic disposition or illness (Weichert, 2018). Particularly in the healthcare sector, therefore, the discussion on the normative question of risk distribution must be reopened.

Changes in norms and moral standards

Scoring methods themselves can gradually shift norms and moral standards as the areas of application expand (Fourcade and Healy, 2016). However, to date there has been little research on the social consequences of the comprehensive use of scoring methods. In the Chinese context, some of the small number of available studies point to initial changes in behaviour and further effects such as the influence of the score on the choice of a partner (Kostka, 2018). Initial representative survey results show high approval rates of up to 80% for the scores commonly used there (Alpermann and Thünken, 2018; Kostka, 2018). As scoring methods are used more broadly, therefore, there is a considerable need for research into the social effects of the increasing quantification of decision-making processes and emerging shifts in values and norms.

State scoring approaches for the control and monitoring of societies

According to many experts, a centralized state scoring system aimed at controlling and monitoring society as a whole, like the social credit system planned in China, has the potential to reshape entire social systems (Ohlberg et al., 2017). If the social credit system is successfully implemented, it cannot be ruled out that other countries will also follow China's example. Parallels have already been drawn in the media between the Venezuelan ID card programme and the Chinese social credit system (there is evidence that the Venezuelan system uses Chinese technology; Berwick, 2019). In addition, an initial case study points to the cross-border effects of the Chinese social credit system. China's civil aviation authority has accused international airlines of 'grave dishonesty in trade' because they listed Taiwan, Hong Kong and Macau as travel destinations on their websites, which violates guidelines laid down in the social credit system (Hoffman, 2018). Although holistic scoring approaches like the Chinese social credit system are (still) vehemently rejected in many democratic societies, scoring approaches that also include the social behaviour of societal groups in their calculations are gradually creeping into society as a result of both intransparency and the lack of a legal framework. At the international level, discourse spaces should therefore be opened up and guard rails and targets introduced on the use of scoring methods.

Overarching legal framework for scoring methods based on statistical inference

When statistical methods are used to determine a score, that score is always a probability statement. The legal handling of probability statements is not explicitly regulated in many countries. For example, a court in Finland recently ruled that credit decisions may not be based solely on models founded on probability calculations derived from statistics on the behaviour and characteristics of others (National Non-Discrimination and Equality Tribunal of Finland, 2018). The individual payment histories should also have been considered separately in addition to the score. This argumentation has far-reaching consequences for current practice. For example, what should be done if there is no payment history? Should the use of psychometric data obtained from online tracking, as promoted by the World Bank and private providers, be considered illegal? This example illustrates the fundamental problems of how the law should handle algorithmic decision-making systems, of which scoring methods are a subset. The collective dimension of statistical models ('collective' because an individual score cannot be calculated without the data of many other individuals) conflicts with individual rights, such as the right to equal treatment. In certain cases, unequal treatment does not constitute discrimination. This is the case, for example, where there is a legal basis, the objective pursued is justified, and unequal treatment is a proportionate way to achieve that objective. However, a review of this kind hardly ever takes place in practice. The question of whether and how the current legal system is able to deal with this situation, or whether existing ethical and legal criteria need to be further developed, should be a key issue for research (Jaume-Palasí and Spielkamp, 2018).

5.3.3.3
Conclusions

The use of scoring methods is already normal procedure today and has a fundamental influence on societal inclusion. This often happens without the knowledge of the affected individuals or without reflection on the underlying cause-and-effect context of the methods used. In addition to obvious regulatory steps, such as creating more transparency or giving the state and civil society supervisory responsibilities and capacities, debates of a fundamental nature should be initiated, for example on the distribution of risks in the banking and health systems and the overarching legal framework for algorithmic systems that support decision making. It should be assessed on a case-by-case basis to what extent scoring methods are a proportionate means of achieving an objective and to what extent they infringe on people's rights to freedom and equality. Changes in norms and moral standards within society can already be seen where state scoring approaches of societal control are used, e.g. in the case of the social credit system implemented in China. However, they can also take place insidiously. There is still a lack of public awareness of this perspective. Here, educational and research work must be carried out to preserve societies capable of long-term action in the Digital Age and to prevent losses of freedom.

5.3.4
From education for digitalization and sustainable development to future-proof education

This arena shows that the conceptual combination of digitalization and sustainability requires a wide variety of initiatives in the context of education. After a brief assessment of the current situation, some examples are given below of ideas on how education could be shaped in the sense of 'transformation education' or 'future-proof education', and how risks connected with digitalization can be contained and positive potential leveraged.

Topic box 5.3-1

Digitalization: risk or opportunity for the enforcement of environmental law?

Although many states have established comprehensive regimes of criminal and regulatory law to protect environmental goods, enforcement is nevertheless inadequate (World Bank, 2017c: 259). The main reasons for this *shortcoming* are insufficient financial and human resources coupled with a lack of professionally and technically trained staff in the responsible authorities, insufficient information, and little willingness to enforce the laws effectively (Ziekow et al., 2018: 78ff.). In addition, there is a lack of scientific and technical expertise and local knowledge among government employees (SRU, 2007: 176). The constantly growing number of laws often contain very detailed regulations that are sometimes inconsistent with other (environmental) laws, which are difficult to understand and problematic in their application (Bogumil et al., 2016: 10). The enforcement of environmental law is typically the responsibility of the state authorities that punish violations of environmental regulations. These state authorities for environmental law enforcement are listed under SDG 16 'Peace, justice and strong institutions'.

Digitalization to combat enforcement deficits

Just as digital technologies facilitate violations of environmental law, they also provide new instruments to prevent violations of environmental regulations. To counteract the *lack of human and financial resources* for environmental law enforcement, digitalization can be useful to an environmental administration if it is successfully used to make work processes more *efficient*. For example, digitalized files (e-files) can be used to improve knowledge management by making existing findings and experience available and making it easier to access comparable procedures, thus reducing workloads (Adelhard, 2017). In order to improve the clarity and accessibility of environmental law, regulations are already being compiled on digitally searchable platforms (e.g. ECOLEX by FAO, IUCN, UNEP and InforMEA by the UN). At the same time, digital methods require experts who are familiar with the technical infrastructures used, which creates a need for ICT competence among all participating government employees.

Digital technology can counteract *information deficits in environmental management* in various ways: digitally supported opportunities for citizens to send reports to the administration cut administrative employee costs and give authorities access to private knowledge regarding violations of environmental law. They also enable citizens to take responsibility for the natural environment that directly affects them, and to improve their own quality of life. Citizens in Maputo (Mozambique), for example, have become involved in official monitoring activities; they use text messaging, apps and websites to report undisposed waste, illegal landfills and unauthorized waste incineration to the responsible environmental authorities (UN DESA, 2016a: 52). Between 2014 and 2016, 43 countries introduced mobile applications or text messaging services in the environmental field (UN DESA, 2016a: 89). While simpler communication between citizens and public authorities can promote the enforcement of environmental law, digital technologies also involve the risk of people being denounced as 'polluters' on social media, thus violating their personal rights. Environmental law enforcement should therefore be understood and carried out as a state task. Electronic microchips inserted into plants are increasingly being used to protect plants such as cacti in US national parks from theft (Ziegler, 2008). Automatic scanning systems are then used to detect thefts when people leave a national park. The origin of the plants or animals can also be traced later from dealers and future owners.

Linking and openly publishing environmental data is particularly effective. The collection and publishing of environmental data on freely accessible, state-run digital platforms creates a common, quickly available database for different authorities. They can improve the pool of data on which administrative decisions are based. This can reduce the transaction costs of communicating information on the state of the environment. Potential sources include manual entries and automated recordings by sensors, e.g. measuring the concentration of pollutants in the air (World Bank, 2016: 322). Such information portals have an impact on an internal and also on an external level and can promote the cooperation between authorities required by environmental law. When open-data portals make private data from companies, the scientific community and environmental organizations available and useable, the information platforms are doing more than making work easier within the administration; information and data are also made available to the general public, business enterprises, the scientific community and environmental organizations, thus making the administration more transparent (UN DESA, 2018: 104, 107). This helps build up pressure on authorities and decision-makers, increasing the *will to enforce* environmental regulations.

Prerequisites for the successful use of digital tools for environmental law enforcement

However, the successful use of data platforms also faces challenges. The quality and topicality of the data provided must always be guaranteed. Although the quality of data in particular and the technical methods of collection and dissemination have improved considerably since the early 1990s (World Bank, 2016: 323), e.g. the 'Open Data Barometer 2018' shows that there is still room for improvement in the quality of open environmental-data provision. Only 20% of environmental data are openly accessible, and only 41% of these are updated (World Wide Web Foundation, 2018: 17, 23). Therefore, an important new role for the administration is to set standards for data collection, reporting and sharing to ensure data quality and topicality (World Bank, 2016: 324). Quality control of publicly supplied data in turn ties up human resources and requires technical knowledge, which can be a challenge for environmental administrations and cause new resource shortages.

Incorporating digital technologies into communication and cooperation between public authorities, businesses and civil society for environmental law enforcement involves the need to make portals, services and apps user-friendly and attractive, for example by providing support in local languages (UN DESA, 2016a: 52). The high costs of setting up and maintaining monitoring systems are significant barriers (World Bank, 2016: 322; Section 5.2.11).

Moreover, the accessibility of data alone is not sufficient to ensure that laws are enforced. It is also necessary to disseminate information to potentially interested parties and to enforce accountability (World Bank, 2017c: 248). As administrations become more transparent and public, and private participation increases (digitalization is an essential multiplier here), this must always involve the realization of effective legal protection. Only if decisions are judicially verifiable are authorities and the political decision-makers and governments behind them forced to implement existing environmental laws. Effective legal protection in the environmental field is promoted, for example, by the use of judicial control instruments, such as class actions by citizens and associations, to enforce environmental law. One treaty that establishes the three pillars of access to information, public participation and legal protection is the Aarhus Convention, which all states should ratify.

5.3.4.1
Assessment – today's education for digitalization

Up to now, a rapid digitalization has taken place in many areas of society without this technological development being systematically integrated into formal education courses in schools, colleges, universities and educational institutions. In Germany, most digitally-supported learning is informal, self-organized, and takes place online or at home (for example via Google and YouTube; WBGU, 2016a). Teaching staff do not seem to be well-enough trained to use digital teaching materials (e.g. open educational resources, digital journals) and platforms that are firmly established in everyday learning (e.g. Wikipedia) for didactic purposes (Brinkmann and Müller, 2018; Schmid et al., 2017). Inadequate advanced training for teachers, a shortage of teachers, a lack of infrastructure, and material access restrictions are regarded as barriers to successful learning with digital media in both industrialized and developing countries. This means that there is often a lack of protected learning locations for trying out digital media, promoting potential and containing risks.

There is therefore national and international political discussion on how to better embed and use digitalization in the education system. Ideas include creating easier access to high-quality education (see SDG 4) and preparing for the use of digital infrastructures (e.g. Hochschulforum Digitalisierung, 2019; KMK, 2017; UNESCO, 2018; WSIS, 2018; OECD, 2018a,b,c). There is a consensus that educational goals such as the self-determined use of digital media (digital literacy) pose major challenges, especially for formal educational institutions like kindergartens and schools (e.g. OECD, 2018b). In the WBGU's view, the promotion of digital skills is a necessary but insufficient prerequisite for 'transformation education' or 'future-proof education'.

5.3.4.2
Future-proof education as a driver of the Great Transformation

According to the WBGU's humanist understanding, education should enable people to be proactive players in shaping society (see also the OECD Learning Framework 2030 and the UNESCO Global Action Programme for Education for Sustainable Development, Alliance for Future Education in Germany). Individuals face challenges in handling digital technology as citizens, users and consumers. These changes must be addressed by education (Chapter 4). Problem awareness, systemic thinking, responsible action, individual and collective creativity and innovation (WBGU, 2016a: 23, 425) are just as crucial in the networked and complex societies of the 21st century as personality development, cooperation skills and the courage to act (UNESCO, 2014; John et al., 2017; Brundiers and Wiek, 2017; Rasfeld and Breidenbach, 2014; Amsler and Facer, 2017; OECD, 2018).

In the sense of the Great Transformation, the WBGU distinguishes between transformation education and transformative education or transformative learning. Transformation education provides research findings on sustainability transformation and critically reflects on the basic knowledge and skills needed by the actors of sustainability. This includes a well-founded understanding of the pressure to act to create environmentally friendly development paths, a global sense of responsibility, and a systemic understanding of the interrelated issues involved (WBGU, 2011; 2016a). Transformative education also plays an important role, especially in times of profound upheaval. It promotes an understanding of diverse options for action and solution approaches, of the dynamics of societal change, and of one's own self-efficacy in shaping life contexts and societal changes. By using the term 'future-proof education', the WBGU combines the requirements discussed in the field of sustainable development with digital literacy (Figure 5.3.4-1). It aims to make individuals and societies 'fit for the future', i.e. to enable the continuous shaping of changing circumstances in a meaningful, anticipatory and target-oriented way. Future-proof education in the Digital Age requires a new quality of technological understanding, since key relationships between people and their environment are increasingly mediated digitally (digital curtain).

In order for digitalization to be shaped in the sense of a sustainable society that is fit for future, individuals need both digital and sustainability skills (Engagement Global, 2018). Skills in technical design, privacy skills, equal opportunities, data protection and the use of open educational resources are important secondary objectives, as formulated in the *DigitalPakt Schule* ('DigitalPact for Schools') of the Federal Government and the Länder. In order to participate in the Great

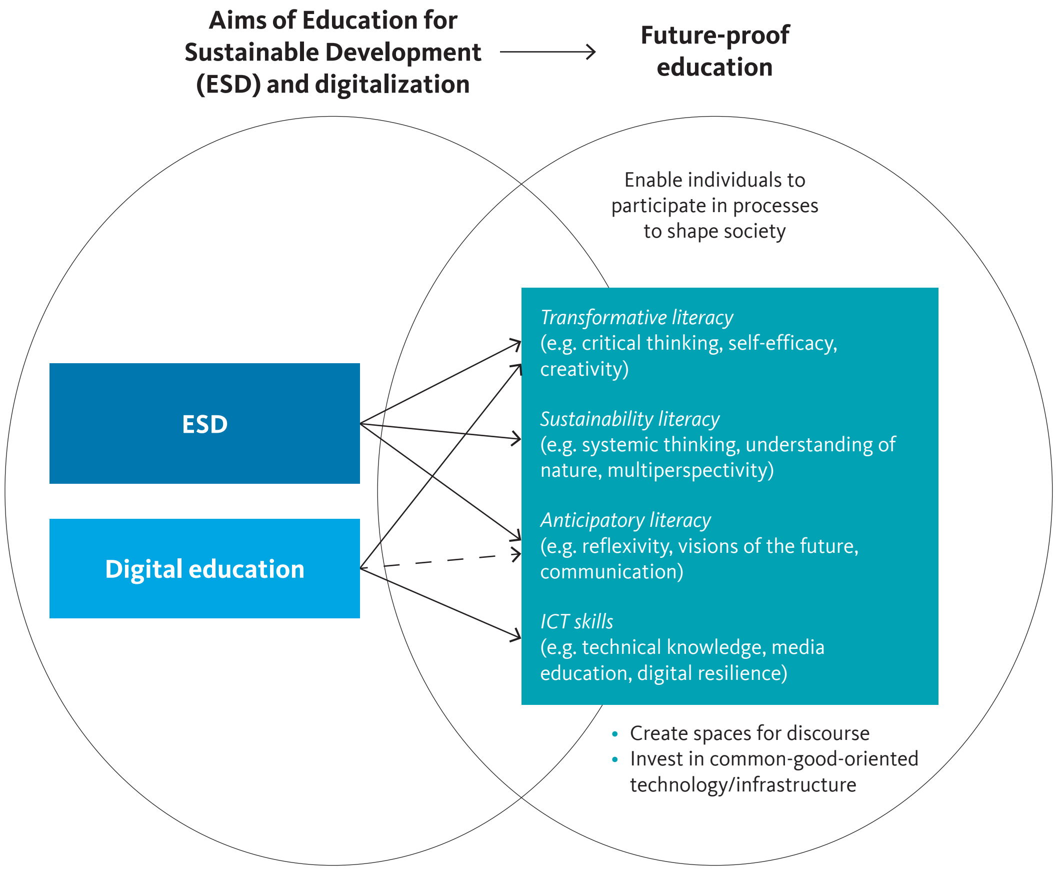


Figure 5.3.4-1
From Education for Sustainable Development and Digitalization.
The skills required in each case overlap considerably. Taken together, they should enable individuals to actively participate in shaping the Great Transformation, including its digital components (Chapter 8). Transformative literacy means the ability to understand information on societal change processes and to contribute one's own actions to these processes (WBGU, 2014a: 103); it is thus similar to formative skills (de Haan, 2008). Sustainability literacy combines systemic thinking, planning and self-competence, but also in particular environmentally relevant knowledge, attitudes, standards, a sense of responsibility, taking action and being involved (Wiek et al., 2011; Roth, 1992). Anticipation skills include a critical-constructive discourse with human ideas and notions and their effect on how society is shaped over time. ICT skills comprise media education and technical knowledge in order to use, understand and shape digital media critically, autonomously and responsibly, and to negotiate privacy (Trepte, 2016b; SFIA Foundation, 2019).
Source: WBGU

Transformation, individuals also need *skills in Education for Sustainable Development* in order to be able to place their own activities into the context of global environmental change, for example to think and plan systemically and develop environmentally relevant attitudes and behaviours (Roth, 1992; Scholz, 2002). Dealing with change and uncertainty also requires *transformative literacy skills* such as innovativeness and *anticipation skills* in order to develop a desirable vision of the future for oneself and others.

The objectives of future-proof education and the skills proposed for it are described in more detail in the Recommendations for action (Section 9.1.4). The following are examples of the challenges that should be offset by education.

5.3.4.3
Use education to offset negative effects in the Digital Age

Among other things, education should create sensitivity and compensation strategies for risks and requirements arising from the use of digital technology, ranging from social media and digital applications (apps) to the Internet of Things (e.g. smart homes). These requirements include, for example, control over one's personal data and self-presentations in social media, e.g. posting such information about oneself as hobbies, professional life, friends and interests. Identity conflicts (privacy vs. self-revelation), phenomena such as 'social scoring' (Section 5.3.3) and the 'chilling' effect (self-censorship for fear of negative consequences of publishing on the internet), and filter bubbles are new challenges facing the education system. The rapid and cooperative provision and dissemination of information via online media and social platforms involves both potential and uncertainties – such as whether information is generated by people or avatars (e.g. social bots that simulate human identities). Furthermore, it is difficult to distinguish verified general knowledge from private beliefs or opinions.

One particularly frequently discussed example is the distribution of incorrect information ('fake news') via online platforms, social media and online magazines, for example that man-made climate change is a lie. It is still unclear how such false information affects people's attitudes and behaviour (e.g. electoral behaviour in the USA: Allcott and Gentzkow, 2017). Research has shown that people selectively prefer and trust information that resembles their attitudes and thought patterns (Leiserowitz, 2006) and those of family and friends (Metzger et al., 2010). Phenomena such as echo chambers or filter bubbles are also discussed in this context.

Strategies of source checking and balanced opinion formation, as well as quality-assured sources, should help expose false information, for example by providing trustworthy and vetted information options or lists on the internet, or clear rules and checks, as for example in Wikipedia (Van der Linden et al., 2017; Chan et al., 2017a; Lewandowsky et al., 2017; SVRV, 2017). Much more comprehensive measures are needed to ensure that people develop the knowledge and skills to reflect on their own opinions and attitudes and those of their social environment in the long term (Lewandowsky et al., 2017). These measures include the promotion of sustainability and environmental literacy and the creation of discourse spaces (Figure 5.3.4-1; Section 9.1.4).

5.3.4.4
Use digitalization to promote a solidarity-based quality of life, inclusion and *Eigenart*

Education should aim to enable people, both individually and collectively, to use and shape digital technologies in a way that helps them generate quality of life for themselves without restricting other people and future generations (WBGU, 2016a). Key prerequisites for this are sustaining natural life-support systems, inclusion, *Eigenart* and dignity (Normative Compass; Section 2.2). The WBGU uses examples to show how solidarity-based quality of life can be made possible by providing educational opportunities.

Sustaining natural life-support systems: actively involve people in resource conservation

Digital educational opportunities can be used to raise awareness of global environmental contexts (Section 5.3.1) and actively involve people themselves in resource-saving measures (experiential learning).

People can actively participate in knowledge building via citizen-science approaches (e.g. air measurements in their city). At the same time, opportunities open up for transformative education, for example through knowledge provided by apps about a product's CO_2 footprint or by drawing attention to resource-saving product alternatives (Sections 5.2.3, 5.3.1).

Online applications, platforms and games make it possible not only to communicate theoretical educational content, but also to test and develop sustainable options for action through educational games (experimental learning). Knowledge about the problems of the Earth system and climate change can thus be directly linked in simulations to knowledge about action. Digital educational opportunities can offer support where practical learning experience would otherwise not (yet) be technically possible, or else be costly. One idea might be to make it possible to digitally experience climate protection by testing new mobility concepts or eating habits (Sections 5.2.3, 5.2.8).

Inclusion: reduce financial, temporal and spatial educational barriers

Digitalization is cited by many actors as the key to inclusion in education (e.g. KMK, 2017:8; UNESCO, 2017b:13). In particular, financial and spatial barriers to the use of educational opportunities can be overcome with digital media. Examples include free software and educational opportunities such as online courses and teaching materials that can be used in class, or independently outside educational institutions. Particularly in poorer countries, digitalization is seen as a great opportunity to boost education and as an essential prerequisite for successful sustainable development (World Bank, 2016). Here, online learning and web-based training courses, virtual universities or classrooms, and distance learning are being promoted in an active and target-oriented way.

Particularly in emerging economies and developing countries, teacher shortages and insufficient digital literacy among teachers and students jeopardize the success of such measures (UNESCO, 2016). Language barriers (van Dijk, 2006), poor ICT infrastructure, lack of electricity or financial resources (UN, 2018a; Andersson et al., 2009) make access to digital technology more difficult. It is the case in all countries that active participation in shaping digital technology requires a range of abilities (e.g. programming skills) in which disadvan-

Box 5.3.4-1

Recommendations for action on the arena 'Future-proof education'

- *Develop integration mechanisms between processes, institutions and funding programmes for digital education and education for sustainable development (ESD):* Both of these funding programmes call for significant extensions to the current canon of education, teaching formats and teacher training, although up to now their efforts have been largely implemented in parallel and without any coordination (Figure 5.3.4-1). On the one hand, there is much synergy potential; on the other, integration would prevent either technical knowledge (in the case of ESD) or environmental knowledge (in the case of digital education) from being neglected, despite considerable adjustment measures.
- *Align educational content and formats to active efforts to shape the future:* The traditional understanding of education is rather instrumental and reactive, the aim being to make people fit to fulfil certain tasks which are prescribed to them. In times of profound upheaval like today, however, it is neither easy to foresee the jobs of the future, nor does a reactive understanding of one's own role in society enable people to shape transformation and innovation processes proactively and participatively. Topics such as human dignity, systemic knowledge, the ability to reflect, moral thinking, the ability to change one's own behaviour and to be aware of one's own self-efficacy should be further quality features of education content. The OECD 2030 Learning Compass plays an interesting role here due to the OECD's standard-setting role.
- *Measures to contain (already existing) disadvantages (gender, age, origin):* Education should counteract the aggravation of existing areas of discrimination, and new digital opportunities should enable and improve in particular participation in education for groups of people who facing major challenges (e.g. as a result of physical or mental characteristics, cultural differences, geographical distances). New digital and non-digital educational opportunities should be (further) developed in a targeted manner, involve discriminated groups and be geared to their needs.
- *Conduct evaluations to document the implementation of new educational content, as well as the effects of digital teaching and its connection with analogue formats:* Regular and relevant evaluations are necessary for the further development and improvement of educational opportunities (Michelsen and Wells, 2017). They should be differentiated enough to reflect qualitative and quantitative aspects and local differences such as *Eigenart*, and to avoid tendencies towards uniformity.
- *Develop educational formats for the competent use of digital technology and media literacy:* People should be enabled to critically question and assess digital information, knowledge and sources (e.g. knowledge about climate change, political news) and to take a responsible part in shaping them. The basis for this is also the communication of knowledge about rights in the digital space (e.g. data protection), as well as education about the risks of a public life and addictive potential (privacy skills and digital resilience).
- *Expand qualification measures for teaching staff in all educational institutions:* Teaching staff worldwide should be given further training, and personnel and infrastructures should be significantly improved. The US$39 billion per year funding gap estimated by UNESCO (projection for 2019) for achieving just the educational goals that are stipulated in SDG 4 should trigger a special programme of international cooperation (UNESCO, 2015).
- *Create digitally available, trustworthy knowledge and supervisory bodies for content on the Great Transformation:* In the WBGU's view, trustworthy knowledge sources and information are a prerequisite for all measures designed to promote the dissemination of transformation-relevant knowledge and action. This includes a wide range of knowledge fields: information on environmental problems (e.g. climate change) and sustainable consumption alternatives, as well as on social justice and human rights (e.g. flight and migration). Similar recommendations have already been made in the field of digital health (e.g. the proposal made by the German Advisory Council for Consumer Affairs (SVRV) for a 'positive list of evidence-based and understandable [digital] sources'; SVRV, 2017). In this context, offering a central platform for the provision of scientifically sound knowledge on intensely discussed political demands and content can counteract the dissemination of fake news (see e.g. the ideas of the Science Media Lab). It would be important in this context to also clarify the origins of different statements by scientific studies: methodological and disciplinary data selection, variables and derivations, or even time periods etc. can be reasons here; understanding them restores confidence in the credibility of evidence.

taged groups (such as women) tend to be less proficient. Restrictions on time (e.g. women do more unpaid work worldwide than men) and differences in predominant participation behaviour are also examples of barriers to participation with regard to common goods available online. For example, less than 10% of authors at Wikipedia are female (Dobusch, 2017a; Ford and Wajcman, 2017). Overall, digital-education measures should counteract existing forms of discrimination and barriers, i.e. enable equal access to high-quality education and thus often also to societal inclusion.

The WBGU therefore recommends the (further) development of new digital and non-digital educational opportunities involving all groups, especially those who are discriminated against; the opportunities should be geared to their needs. This includes, for example, offering educational opportunities in diverse local languages (OECD, 2018) and/or in a culturally sensitive way for each target region using local staff (Lotz-Sisitka et al., 2017). A potentially global dissemination of knowledge and educational content must not come at the expense of diversity and cultural heterogeneity (Amsler and Facer, 2017).

Box 5.3.4-2

Research recommendations on the arena 'Future-proof education'

- *Transformation knowledge and action:* The WBGU recommends creating a broader empirical knowledge base in order to specifically investigate how digital and non-digital educational measures can promote knowledge and action for the Great Transformation.
- *Research on the systematic substantiation of the new education pact and the evaluation programmes:* Both the pooling of competencies and their implementation in pioneering institutions should be accompanied intensively. One priority is new capabilities such as digital resilience or futures literacy.
- *Research into which digital elements and techniques promote problem knowledge and action:* For example, research should be conducted on what effect educational games, simulations of complex problem solving, and virtual experience of nature have on environmentally friendly everyday actions and political activity. Research should also be conducted into which digital technologies and elements (e.g. increases in immersion and entertainment value, feedback) are particularly suitable for promoting knowledge of problems and for supporting action. Context dependencies should also be taken into account in this context.

Eigenart: enable targeted advancement, cooperation and creativity

Since the 1980s (Benjamin, 1988), it has been argued that digital media can enable individualized and self-regulated knowledge acquisition and targeted advancement (Heinen and Kerres, 2015). It is said, for example, that, through individualized feedback and exchange, digital technology guarantees a self-regulated learning process that is adapted to the strengths and weaknesses of the learners (e.g. digital learning portfolios, vocabulary training according to learning status). One hope is, for example, that digital technologies promote networking and that digitalization increases the importance of creative skills (BMBF, 2016; Heinen and Kerres, 2015; OECD, 2018: 40). Initial studies show that digital media encourage particularly problem-based and cooperative learning with a wide range of materials (Herzig, 2014). It is said that the use of digital media particularly promotes creative freedom and prevents personalized monitoring and the quantitative recording of performance from leading to excessive standardization and restrictions on imaginativeness (Williamson, 2018).

An additional aspect relating to safeguarding *Eigenart* concerns privacy skills, i.e. the ability to decide and negotiate (with individuals, companies and other institutions) which personal contents may be disclosed to whom and in which form (Masur et al., 2017). Digital resilience (UNESCO, 2018) is another term that encompasses not only the cautious use of online services in terms of time and scope, but also the socio-psychological effects of extreme exposure and changes in forms of behaviour in social networks. Research is only beginning here.

5.3.4.5
Future-proof education: protect human dignity and master societal challenges collectively

With its three Dynamics of the Digital Age (Chapter 7), the WBGU addresses the societal potential and risks that a new humanist vision of the 21st century must master. Compliance with planetary guard rails, safeguarding social inclusion and cohesion, and securing *Eigenart* are always prerequisites for a successful technological revolution that respects human dignity. The Digital Age is therefore about much more than the technical and digital literacy of individuals; it is equally about individual and societal skills in using new technologies as aids in shaping structural upheavals and transitions for desirable futures, and in containing negative and unintended consequences at an early stage.

Education for the societal challenges of the coming decades should therefore include a paradigm shift that enables each individual to actively participate in shaping his or her (digital) environment (WBGU, 2011: 351–352). Future-proof education enables people to hold discussions and dialogues, to reflect on their own and other people's behaviour, and to act in such a way that their own interests and motives are protected – without restricting those of others. Human rights and human dignity, the ability to reflect, moral thinking (i.e. adopting perspectives and orienting oneself towards ethical principles) and the ability to change one's behaviour in a self-determined way are already key issues in transformative education, peace-building and education for sustainable development (UNESCO; Orr 1991; Ibisch et. al., 2018); they are also discussed in psychology as personality development.

So, instead of developing and promoting a separate strand of digital education and technological literacy, the aim should be to bring the leading educational concepts of sustainability and media education together with the approaches of futures literacy and anticipation, and to formulate a 'pact for future education' for active participation in shaping the 21st century. This can be based on the processes mentioned above, and resources and competencies can be combined in such a way that educational offers are supplemented accordingly in all contexts, especially in regions with high transformation dynamics. To this end, funding should be significantly topped up as a systematic 'investment in the future' (Section 9.1.4.3); internationally, too, measures to achieve SDG 4 on 'Education' should be expedited accordingly (Section 9.1.4.4). The UNESCO programme on 'Education for Sustainable Development Beyond 2019' is moving in the right direction and makes it clear that good education for all people is not only a goal pursued by the international community, but that educational content corresponding to the challenges of the future also lays the foundation for the implementation of the SDG agenda (UNESCO, 2019). In the WBGU's view, this includes an explicitly reflective and anticipatory approach to knowledge and assumptions about possible, realistic and desirable futures (Section 9.1.4.5).

5.3.5 Public-service ICT as part of basic public services

For some years now, basic internet access has been the subject of public debate as a fundamental or human right, for example within the framework of the UN Resolution of 2016 (UN, 2016a: 3), the judgement of Germany's Federal Court of Justice in 2012 (BGH, 2013), the signing of the principles of the Contract for the Web (Webfoundation.org, 2019) by the German and French governments among others in 2018 (Bundesregierung, 2018a), the Charter of Digital Fundamental Rights of the European Union initiated under the auspices of the Zeit-Stiftung (Zeit-Stiftung, 2018), and the Internet Rights Charter of the Association for Progressive Communications (APC, 2006). For example, the Charter of Digital Fundamental Rights of the European Union provides for a fundamental right to information and communication (Article 2), and in Estonia, citizens have had a constitutional right to internet access since 2000 (Hartleb, 2017: 39).

In Germany, the Federation has an obligation to provide a constitutionally guaranteed infrastructure of basic services, including appropriate and nationwide telecommunications services (Article 87f. of the Basic Law; Deutscher Bundestag, 2011: 7). However, this does not apply to information technology services, e.g. the internet or social platforms that make data and educational offerings available, which are of particular importance in the Digital Age. In the WBGU's view, every state should have an obligation to guarantee such IT services as part of basic public services, as it is apparent that the market has failed to create general and secure access to ICT infrastructures and services up to now. This can be seen, for example, in the inadequate provision of high-speed internet of at least 50 Mbit/s in rural areas, and in the market dominance of commercial social platforms, which inadequately safeguard the data protection and privacy of their users. There is evidently a lack of incentives for the private sector to adequately embed an orientation towards the common good into services of infrastructural relevance – such as platforms – from the outset.

The WBGU therefore considers the realization of a form of public-service ICT that pursues the interests of the common good from the outset to be a sensible option for meeting these challenges (Section 4.3.2). Problems related to a digitalized public (Section 5.3.2), e.g. concentration of power, could also be solved by public-service ICT. Based on the definition of public IT by Fromm et al. (2013: 17), the WBGU defines public-service ICT as information and communication technologies that are of key importance to society as a whole and where the state has a special responsibility for their realization. In the WBGU's view, public-service ICT infrastructures are made up of a public-service part of the internet, including social platforms, via which public data, information, knowledge and educational and citizens' services are accessible and subject to key principles such as net neutrality (which is increasingly threatened), inclusivity and accessibility (Section 5.3.5.4).

Information and communication are regarded as basic human needs (Sen, 2015: 2813); public-service ICT can ensure that they are met. Moreover, inclusion and *Eigenart*, as overarching sustainability goals (Chapter 2), can be achieved via public-service ICT. The provision of public-service digital services is an important precondition of inclusion in societal and economic life in the Digital Age (Deutscher Bundestag, 2012: 4). Public-service ICT is also an important prerequisite for the provision of, and access to, digital public goods (Section 5.3.10) and a location factor for innovation, competition, employment and sustainable economic growth. The public sector is therefore responsible for ensuring affordable access (as part of basic services) for public institutions (schools, museums, etc.), public spaces (squares, traffic areas, etc.) and businesses.

Although it is possible in principle to involve the private sector in the provision of infrastructure, it is necessary for provision to be the state's responsibility and thus under state supervision. If the infrastructure is not provided by private actors, the state has a duty to realize it in some other way. The concrete design of public-service ICT infrastructures is in the hands of the responsible public administrations (in Germany, for example, the municipalities and other federal structures), in order to make it possible for public-service ICT to be tailored to local and regional needs. A public-service ICT in cities and regions created on the basis of universally accessible international standards makes the necessary diversification of the required subsystems and their components possible. This creates space for resilient and inclusive infrastructures. With regard to the UN's sustainability goals, there are close links to SDG 9, 'Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation' (in particular targets 9.1 and 9.C), and SDG 11 'Make cities and human settlements inclusive, safe, resilient and sustainable' (in particular target 11.7; Section 5.2.7). The focus here should be, inter alia, on creating and extending universal and affordable access to ICT services worldwide. Against the background of the increasing digital divide, the public sector's obligation to guarantee further information-technology services, such as information and education services, as part of basic public services should also be addressed.

5.3.5.1
Public-service ICT to reduce the digital divide

In Germany, the concept of basic public services includes, among other things, state-organized water and energy supply, postal and telecommunications services, a basic school and education system, and guaranteeing external and internal security (Deutscher Bundestag, 2006: 2f.). The WBGU calls for a broader understanding of the concept of basic public services, where the public sector is not only responsible for traditional basic services, but must also acknowledge the growing importance of ICT and be obliged to guarantee general access to further information-technology services in line with the needs of the Digital Age (Deutscher Bundestag, 2012: 5f.).

The provision of information-technology infrastructures and services is central to reducing the digital divide worldwide. For example, there are major differences in the provision of, and access to, ICT infrastructures both within countries (e.g. according to geographical location) and between countries at different stages of development (World Bank, 2016: 7). Over four billion people worldwide have no access to the internet (World Bank, 2016: 4, 6). Whereas in 2014 only 31% of the population in developing countries were connected to the internet, in high-income countries the figure was 80% (World Bank, 2016: 6). In developing countries, mobile phones are the most important form of internet access. But although more than 70% of the poorest fifth of the world's population have a mobile phone, almost 60% of the world's population have no access to the internet (World Bank, 2016: 6). Overall, there is a significant correlation between a country's gross domestic product and ICT penetration (Nipo and Bujang, 2014). The reasons for the continuing digital divide between industrialized and developing countries are diverse and range from unfavourable market conditions (e.g. lack of competition and the formation of monopolies, which impacts on the cost of hardware and internet access), low institutional efficiency levels (e.g. caused by political, economic and social instabilities that prevent investment), to a lack of education (e.g. in ICT management; Fong, 2009; Cruz-Jesus et al., 2018: 14f.).

In addition to the digital divide between industrialized and developing countries, there is also a digital divide between individual social groups (e.g. between the sexes, young and old, etc.). Geographical factors also play an important role, as demonstrated, for example, by the insufficient provision of broadband in rural areas. Digital divides within countries can be as large as the divide between countries (World Bank, 2016: 6). It is therefore necessary to ensure universal access to public-service ICT infrastructures as part of basic public services both between and within industrialized and developing countries and emerging economies.

5.3.5.2
Options for the realization of public-service ICT

Broadband connections are regarded as key infrastructures for the internet. They thus represent a basis for digitalization (Eskelinen et al., 2008: 412). By international comparison, however, Germany only holds a medium-ranking position in terms of broadband provision (Opiela et al., 2019: 10). In rural areas especially, services are inadequate (Beckert, 2017: 12), when it comes to high-speed internet access of 50 Mbit/s or more, especially as broadband meanwhile denotes speeds of 100 Mbit/s or more. In Germany, only 50.5% of households had access to fast internet at 50 Mbit/s or more by mid-2018 (BMVI, 2018a: 6). Compared to other EU countries, Germany was thus below the EU average in 2017 (EU-Commission, 2018a: 97).

Not only in Germany have market failures led to insufficient broadband availability, especially in rural areas, and the dominance of a small number of technology corporations that pay inadequate attention to public welfare, data security, privacy and data protection. These dominant digital corporations include such tech giants as Apple, Alphabet (Google), Microsoft, Amazon and Facebook (GAFAM, also known as the 'Big Five'), which are among the five most valuable corporations in the world in terms of market value (Barwise and Watkins, 2018: 21; Section 3.1). Their handling of user data repeatedly gives rise to negative headlines.

Box 5.3.5-1

Public-service platforms – approaches for a European and global digital public sphere

A functioning democracy needs an enlightened public sphere and lively societal discourse based on trustworthy sources of information. On this basis, the 'Public Open Space' project aims to develop a digital platform oriented towards the common good. The intention is to facilitate intensive cooperation between the media, education, culture and society, to master the challenges of digital structural change in the public sphere (Section 5.3.2), and to unleash its potential. It is "an initiative that is transnational, European and open to development; it consists of representatives from science, the public-service and non-commercial media, as well as civil-society organizations from Austria, Germany and Switzerland. The initiative currently sees itself as a project that synergetically, cooperatively and participatively develops a public-civic partnership that provides the foundation for such a #PublicOpenSpace" (POS, 2019). Beyond the current concentration of power and economization on the internet, digital technologies could thus open up "opportunities for more freedom of expression and diversity, independence, credibility and participation in the national, European and global context" and turn corresponding visions into reality (POS, 2019):

The 'Public Open Space' initiative urges the development of a new digital, non-commercial platform (#PublicOpenSpace), which makes content and services accessible while taking societal diversity into account, as well as offering a public discourse space for the entire population. In order to do justice to an increasingly fragmented society, particularly the media with a public mandate have the function of facilitating links between individual societal groups. Here, the traditional inclusion mandate of public-service media is given a new, urgent topicality. This requires new collaborations and alliances between media with a public-service mandate and public institutions in the fields of science and education, civil society, art and culture.

This initiative, which is characterized by a broad interdisciplinary team of researchers and media professionals, began as a project called 'European Public Open Spaces', launched in 2017, which initially existed primarily in the European context (EPOS, 2018). In addition, a working paper entitled 'Ideas for a contemporary public-service media platform' was recently put forward under the term 'internet directorship' calling for a "new understanding of a public-service approach to interactive and/or audiovisual media" (Bieber et al., 2019): "In order to do justice to the digital potential for generating and distributing specific and general public-service content, we call for the endowment of a separate internet directorship using funds from the broadcasting licence fee. The five main tasks of the internet directorship comprise (1) the development and operation of a public-service platform, (2) the allocation of funds for the creation of specific public-service online content, (3) curating and cooperating with third-party providers, also beyond classic content productions, (4) the promotion of innovation, and (5) the establishment of a supervisory body, especially with regard to the protection of minors from harmful media".

Irrespective of questions about concrete design – e.g. on the de-/centrality or plurality of an internet directorship, an ecosystem of networked platforms, or the possible integration of both poles – a global reach is essential. In view of the global nature of the internet and the global challenges of the digitalized public sphere, these ideas should be thought about and realized not only in European terms but also globally (POS, 2019). The development of a 'Platform Europe' (Hillje, 2019) or a corresponding ecosystem for a European communication space in the Digital Age is, however, initially focusing on urgent democratic challenges in Europe, because: "as yet there is no European public sphere; up to now there has been no success in creating one either by Europeanizing national public spheres or via digital channels. The member states talk about the EU and about each other, but not with each other. Europe negotiates European topics in national filter bubbles, instead of in a European communication space" (Hillje, 2019: 14) By contrast, the "decentralized, nationally-independent structures of the internet could at last be used for European integration" and bring about "a democratization of the digital space in Europe, and thus create a digital public sphere based on European values that serves the common good and European democracy" (Hillje, 2019): 15).

The creation of a public-service ICT makes sense – and not only in Germany – in three respects: first, in view of the lack of nationwide broadband internet coverage; second, in view of the power of a small number of private digital corporations that pay little or no attention to their users' privacy when realizing their business models; and third, because public digital services are often lacking or only limited.

Suitable state intervention could be meaningful to ensure that countries, regions or individual social groups are not digitally left behind and that, for lack of alternatives, individual users are dependent on social media platforms which do not properly meet requirements such as privacy protection or an orientation towards the common good. TThe WBGU proposes that key ICT services such as public-service communications access, information services, citizen accounts and services, and digital commons (Section 5.3.10) should be implemented under state responsibility. Public communication and information services are of crucial importance for democratic decision-making in the Digital Age, which is why common-good-oriented platforms should be created for both public-service and private-sector media formats (Section 5.3.2). There are many initiatives of this kind (Box 5.3.5-1), and the WBGU believes they should be expanded. In this context, it should be pointed out that the public-service media in Europe as a whole already have comparatively large budgets, and it does not seem rational that their cooperative and long-term-oriented activities in the digital sector should be restricted by regulation (e.g. by only being able to offer fragmented media libraries),

Box 5.3.5-2

Broadband coverage by international comparison – examples

Sweden

Sweden was the first European country to implement an active broadband policy and is seen as a pioneer in the availability of broadband connections (Eskelinen et al., 2008: 413). In 2017, the country achieved very good levels of broadband availability and was above the EU average, also in terms of rural broadband coverage (European Commission, 2018a: 182). A key role in broadband provision with fibre-optic networks in Sweden is played by local actors, such as city and municipal administrations, public utilities and local network operators, who "early on regarded high-speed internet lines as part of basic public services" (Beckert, 2017: 41) and laid their own cables, which are operated as open access networks. Municipal networks account for around 60% of Swedish fibre-optic cables. The remainder are run by telecommunications and cable-TV operators (Beckert, 2017: 42). The largest telecommunications company TeliaSonera, which is more than 37% state-owned, has set up its own fibre-optic networks outside the coverage areas of the city networks, which it also makes available to other providers in an open-access model (Beckert, 2017: 43). State funding of around €400 million was made available between 2000 and 2005 to promote the expansion of broadband infrastructure. In Sweden, this model works because "the city networks have been demonstrating for many years how a competition of services can work on a common technical platform, and the success of the city networks has led to expectations that make copper-based expansion strategies seem unsuitable" (Beckert, 2017: 43).

The Swedish government also set ambitious targets with its 2016 broadband strategy. The aim is to provide 95% of all households and businesses with broadband internet access at a minimum speed of 100 Mbit/s by 2020. Access to high-speed broadband should be available throughout Sweden by 2025 (European Commission, undated).

New York and San Francisco

Major US cities have launched a broadband initiative to ensure broadband coverage for the population at more than 100 Mbit/s. New York City and San Francisco are considered pioneers (Morozov and Bria, 2017: 82). To close the digital divide in New York City, the strategy followed by mayor Bill de Blasio, 'One New York: The Plan for a Strong and Just City', will provide access to affordable, reliable and fast broadband services by 2025 for the entire urban population, as well as for urban enterprises (Shorris, 2015; DoITT, 2019). San Francisco aims to bridge the digital divide, create more competition in internet-access services, and make access to high-speed internet available at affordable prices across the board. The aim is to connect all households and businesses in the city to a fibre-optic network and to create fast and affordable internet access for both citizens and businesses (San Francisco Department of Technology, o.J.). To this end, a city-wide fibre-optic network is to be put into operation that gives priority to network neutrality and the protection of privacy. In order to provide higher-quality internet services at more affordable prices, the city has opted for a PPP model (Crawford, 2017).

Box 5.3.5-3

Further development of public-service ICT in the EU: Next Generation Internet programme

The Next Generation Internet (NGI) programme supports the creation of European internet platforms to counter the dominant internet platforms operated by US companies with monopoly-like market positions (Morozov and Bria, 2017: 82). The NGI programme was launched by the European Commission in 2016 and aims to develop and promote new internet technologies, together with various stakeholders, and to advance research (Smart Data Forum, 2017). The aim is to create an internet that serves people and society, addresses current problems (e.g. monopolization and aspects of data security and privacy) and follows the 'internet for the people' principle in terms of development and design. The internet of the future is to be developed within the framework of an inclusive and multidisciplinary approach (Fatelnig and Müssigmann, 2017). It focuses on values such as openness, cross-border cooperation, decentralization (e.g. through decentralized data systems), transparency, the protection of privacy, and the prevention of exclusion (BMWi, 2017a). The programme is still in its infancy, so it remains to be seen what impact it will have and whether the objectives associated with the programme will actually be achieved.

thus at least indirectly supporting the market power of commercial platforms. Going beyond the orientation of 'Public Open Space' – and based on it – it would also be conceivable to open up such a platform providing public-service resources to private media, thus guaranteeing pluralism of content and making it more attractive for users.

In Germany, as in other countries, ICT infrastructures such as broadband networks are often implemented via *public-private partnerships* (PPPs). Country studies have "shown that it is often municipal involvement that triggers competition and drives technical innovation" (Beckert, 2017: 9). The involvement of third parties (e.g. with PPPs) has had a positive effect in many countries, e.g. with regard to broadband expansion in the interaction between state and private-sector actors. In

Box 5.3.5-4

Recommendations for action on the arena 'Public-service ICT'

The WBGU recommends guaranteeing free and equal access to public-service information and communication services for all, made available as part of basic public services by, or on behalf of, the public authorities themselves. ICT should be enshrined as an integral part of national development strategies and plans (Ericsson, 2016: 69ff.), thus closing the digital divide and ensuring access to the internet for all (OECD, 2017b: 145). According to this list of requirements and in line with the aims of the EU's Next Generation Internet programme (Box 5.3.5-3), the WBGU recommends defining public-service ICT as a core area of public tasks. On this basis, anything that is politically desirable but not (adequately) achieved by market forces could be implemented (Lenk, 2018: 241).

In this context, the WBGU advocates, on the one hand, ensuring net neutrality in the public-service part of the internet. On the other hand, the creation of plurality and competition is key, and this includes promoting and applying open international standards and designing modular and exchangeable technical components, in order to avoid dependencies on individual manufacturers and infrastructure providers. Furthermore, open source software should be used and developed, and principles such as interoperability, reusability, security and scalability should be fulfilled (Zeit-Stiftung, 2018; Schieferdecker et al., 2018). In addition, increased private-sector investment in the digital infrastructure and services that takes the common good into account should be made possible by improving the framework conditions for its funding and for implementing new business models (OECD, 2017b: 146).

The aim should be to (re-)establish public ICT infrastructure-planning structures that are oriented towards the common good and not towards commercial gain (Meerkamp et al., 2008). The establishment, expansion and operation of ICT infrastructures and services should also be ecologically focused, using energy-, resource- and data-optimized technologies. The components of public-service ICT should be adapted to local circumstances and policy objectives (UNCTAD, 2018). To this end, open dialogue and cooperation between different stakeholders (local authorities, business, science, civil society) to promote a rapid, user-centred introduction and improvement of ICT services are recommended (Ericsson, 2016: 96ff.).

Digital competence should be promoted, especially in public administration and politics, in order to fulfil the tasks related to public-service ICT. This can be done through targeted training and further-education modules to develop or update ICT skills in administrative careers. New policy areas that have emerged as a result of digitalization should be given greater consideration. The focus on ICT infrastructures and services in network policy should be complemented by content-related questions such as "whether and to what extent many societal problems can be solved with a constantly refined database and its evaluation" (Lenk, 2018: 241).

Box 5.3.5-5

Research recommendations on the arena 'Public-service ICT'

Accompanying research in the humanities and social sciences is essential in view of the societal relevance and urgency of this subject area (Section 10). Possible topics include trust in data or services (Rieder and Simon, 2018), the limits of a development tending towards technocratic 'governance by numbers', the potential and limits of predictability, and the (partial) automation of the (social) world (Mainzer, 2018; Królikowski et al., 2017).

Public-service ICT itself should therefore become the subject of research. Possible research questions include:

- How should public-service ICT be designed?
- Which services are fundamental components of public-service ICT, which are optional, and which belong outside?
- How can it be financed, regulated and operated?
- What technical solutions are needed to establish public-service ICT on the one hand as a driving force for innovation in business, public administration and science, and on the other as an anchor for open, democratic and multilateral opinion-forming?
- How will the social fabric change with the availability and use of public-service ICT?
- How can the general pace of ICT innovation be matched with that of public-service ICT?
- How will inclusion be promoted in public-service ICT?

view of the criticism of existing PPPs on infrastructure provision, for example on responsibility or the restriction of democratic control and design (Mattert et al., 2017), the WBGU calls for a precise allocation and review of responsibilities. The development and operation of public-service ICT must focus on the common good.

Despite known problems with PPPs, this form of cooperation between public authorities and private individuals continues in Germany (Mattert et al., 2017), and the state is increasingly withdrawing from responsibility for the infrastructure (Luch and Schulz, 2009). On the other hand, in countries regarded as leaders in broadband expansion, government intervention has increased to ensure nationwide fibre-optic coverage. In 2016, for example, the Icelandic government launched the 'Ísland ljóstengt' initiative, coordinated by the Telecommunications Fund, which aims to provide 99.9% of Icelandic households and businesses with wired high-speed internet at ≥100 Mbit/s by the end of 2020 (Government of Iceland, 2018). This initiative has put Iceland at the forefront of general broadband access in the world (PTA, 2017: 5 f.). However, other countries are also playing a pioneering role (Box 5.3.5-2).

5.3.5.3
Approaches to the further development of public-service ICT

The WBGU believes that the public sector has a responsibility to create, protect and ensure the functioning of public-service ICT-supported spaces, thus achieving the corresponding sustainable development goals (in particular SDGs 4, 5, 9, 10 and 11, also as a technical instrument for the other SDGs). The following requirements need to be met by public-service ICT (Fromm et al., 2013: 9f.; Fromm et al., 2014; Schieferdecker et al., 2018: 209ff.):

1. It needs to operate its own communication networks and services (effectiveness and efficiency) in the public sector, also to ensure technological and data sovereignty.
2. Public-service ICT systems should be characterized by clear decision-making processes and traceable functions (transparency).
3. A holistic approach to security is also key. Data protection, data security, as well as IT and functional security should already be taken into account at the planning stage (security).
4. Because of the increasing networking of public ICT systems, which are often organized in a decentralized way, it is important that they can cooperate across levels and domains (interoperability).
5. To create inclusiveness and promote the use of public-service ICT, involving users in the planning of the ICT and user-friendly operability are key elements. In addition, inclusive, non-discriminatory and barrier-free access must be guaranteed in order to open up new possibilities of societal, economic and political inclusion for everyone (inclusiveness and usability).
6. In order for public-service ICT to adequately fulfil its societal functions, an equitable balance of interests among all actors (civil society, business, science, public administration) should also be established (Fromm et al., 2014). The involvement (cooperation, coordination, information) of as many actor groups as possible is needed to ensure the functioning of public-service ICT infrastructures and services (participation).
7. Technical components should be designed to be standards-based, modular and exchangeable, in order to avoid dependencies on individual manufacturers and infrastructure providers. In addition, open-source components should be used wherever possible and be financed with public money. The principle of net neutrality must also be guaranteed and strengthened using regulatory measures (competition and plurality).
8. The protection and sustaining of the natural life-support systems should also be ensured when establishing, expanding and operating ICT infrastructures and services.

5.3.6
Digital technology as a gender bender?

Despite growing political attention, gender equality has still not been achieved in any country in the world (Köhler, 2017). The UN member states have agreed on an important conceptual framework for gender equality in the 2030 Agenda. SDG 5 formulates the goal for the global community of overcoming all gender inequalities by 2030. These include, for example, lower educational opportunities (SDG 4.5), legal and economic inequality, harmful socio-cultural practices (e.g. forced marriage, etc.) and (sexualized) violence and discrimination (SDG 5.1–5.6). Furthermore, SDG 5.b stipulates that enabling technology, in particular information and communications technology (ICT), should be used to promote the empowerment of women (UNGA, 2015). How exactly can this emancipatory potential be leveraged without reinforcing inequalities? Can digital technology be used as a 'gender bender' – as indicated in the title of this arena – to break down existing gender boundaries and clichés and contribute to more gender justice?

On the one hand, interactions in virtual space offer in principle the possibility of overcoming inequalities due to physical differences like gender characteristics and age, as well as racial discrimination. In addition, when precisely targeted, digital technology can also have an emancipatory effect. On the other hand, digital systems are not created in a technical vacuum. They are developed by human beings within a socio-cultural context, which is why their development and use run the risk of reproducing societal inequalities and discrimination of all kinds (Box 5.3.6-1; Garcia et al., 2018; Hargittai and Hsieh, 2013; Nakamura, 2014). Active political and societal shaping is therefore still indispensable in the Digital Age if progress is to be made on gender equality, also beyond a two-gender understanding (Box 5.3.6-2). This section addresses urgent needs for action: dismantling gender-specific access barriers, strengthening gender diversity and awareness-raising within the tech community, the

Box 5.3.6-1

Digital divides and online discrimination

According to the UN Charter of Human Rights (1948), all persons are entitled to equal protection against all forms of discrimination. The WBGU underpins this general ban on discrimination by explicitly naming the inviolability of human dignity as an orientation aid for shaping digitalization and as a foundation for the normative compass (Section 2.2). Inclusion and *Eigenart* are particularly relevant dimensions of this compass in the gender context. Tim Berners-Lee designed the internet with the idea of creating a universally accessible and open network (Berners-Lee, 2010). As a great equalizer, it promised equal opportunities in terms of access to information and services (Hargittai and Hsieh, 2013). However, discrimination is widespread in both the analogue and digital realms. Disadvantages based on diverse identity characteristics often interact (intersectionality) and sometimes lead to multiple discrimination, both online and offline (Hill Collins and Bilge, 2016). In order to do justice to this diversity of digital marginalization dynamics, and going beyond purely technical barriers to access, some people use the plural and speak of digital divides and inequalities (Hargittai and Hsieh, 2013; Nakamura, 2014).

Digital divides exist both geographically, for example between the city and the country or between countries and between population groups (e.g. according to age and income) (Zillien and Haufs-Brusberg, 2014). For example, the World Bank estimates that the probability of having internet access in African countries is almost three times higher for the 60% that are better-off than for the poorer 40% (World Bank, 2016). In addition to physical access to ICT, the decisive factor is in particular skill-based and use-related access: i.e. language barriers must be overcome, teachers must be enabled to teach ICT-based knowledge, and enough teachers should be available in general in the education sector. At the same time, digitalization also offers enormous potential for reducing socio-economic disparities. One obstacle is the relatively high cost of internet use in developing countries compared to richer countries. While internet access in rich countries costs around 1.7% of annual net income, relative access costs can amount to as much as 40% of annual net income in developing countries (Weingarten, 2013).

anti-discriminatory use of algorithms, and designing digital experimental spaces for equality and gender diversity.

5.3.6.1 Exclusion from the digital sphere: gender-specific access barriers

Although access to information and communication systems has improved in general, the gender gap has remained unchanged globally. Between 2013 and 2017, the proportion of women among people using the internet worldwide rose from 37% to 45% and the proportion of men from 41% to 51% (data are not collected for other gender groups). While women and men are similarly well connected to the internet in industrialized countries (80% of women and 82% of men have access), the gender gap remains large in emerging economies and developing countries. In emerging economies, 38% of women and 45% of men, and in developing countries 14% of women and 21% of men have access to the internet (Sanou, 2013; ITU, 2017a).

Disadvantageous cultural contexts and norms create access barriers, especially for women and gender minorities (IGF, 2017 and 2018a). These can also limit participation in creative and decision-making processes within the internet and tech sector, or have a negative influence on user experience, perpetuating or even exacerbating existing inequalities. For example, the proportion of female authors in Wikipedia, the world's largest online encyclopaedia, is below 10% (Ford and Wajcman, 2017). Not surprisingly, therefore, persistent gender stereotypes and inequalities have been identified on Wikipedia (Graells-Garrido et al., 2015; Wagner et al., 2015). The user experience of women and gender minorities is also marked by violence in the digital realm. Although digital violence is on the increase, particularly affecting people with transgender identities (Levitt and Ippolito, 2013), it is not yet recognized in many countries as a 'real' form of violence (Šimonovic, 2018).

Above all in emerging economies and developing countries, however, the unequal availability of financial resources is also relevant for the acquisition of end devices or network connections (A4AI, 2016; GSMA, 2018). For example, low-income households in the Asia-Pacific region often have only one mobile phone, if any, between them; here, the male family members often feel entitled to use it exclusively themselves (IGF, 2017, 2018a). The danger of a digital divide in society is especially great in developing countries and emerging economies. The reasons for gender-specific barriers to access, leading to discrimination or the exclusion of women and gender minorities from digital life, therefore lie primarily in existing patterns of discrimination.

5.3.6.2 Still a male domain: gender aspects in the design of technical systems

Much of the power to shape the digitalization process lies with people with technical expertise, e.g. programmers, IT experts or scientists (Section 4.2.4). How prevailing gender attitudes shape technology development and use has been researched since the 1990s by feminist cyber- and technoscience in the social-sciences

Box 5.3.6-2

Overcoming the binary understanding of biological and social gender as a global challenge

Overcoming the binary understanding of biological and social gender is a global challenge, despite the progress that has been made in recent decades. Some countries already have a third legal gender category, stating that the person is not classified according to the two-gender understanding (Shardlow, 2017; UN, 2015a). Since December 2018, it has been possible for intersexual people to be registered as 'diverse' in the birth register in Germany. Some cultures also historically recognize more than two or dynamic gender categories (Nanda, 1999; Roscoe, 1991; Kulick, 1998). However, the two-gender understanding, in which the social gender (gender identity and gender roles) conforms to one of two biological sexes (male or female), continues to be the norm worldwide (Köhler, 2017). This marginalizes diverse gender minorities, such as intersexual people, whose biological gender cannot be classified in binary form, and transgender persons, whose gender identity does not correspond to the gender assigned to them at birth. In addition, it restricts cis-gender men and women because of its rigid role attributions (Butler, 1991; OHCHR, 2013; Wippermann, 2016). The global two-gender norm is also reflected in the fact that SDG 5 implicitly has a two-gender perspective on reducing gender inequality (Dorey, 2016). Action still needs to be taken, therefore, both nationally and internationally, to do justice to the diversity and dynamics of gender roles.

Little attention is currently being paid to the question of whether digital technology can be consciously used to cross existing gender boundaries, or as an experimental space for gender diversity, i.e. as an emancipatory 'gender bender'. Yet this debate is urgently needed: in Germany, for example, an initial survey shows that 3.3% of the population do not recognize themselves in the binary male-female model (Allmendinger, 2017) and only 17% of German men have a gender role model that is consistent with gender equality (Wippermann, 2016). In Section 5.3.6.4, the WBGU presents some initial ideas on how greater equality and gender diversity can be achieved with the help of digital experimental spaces and how restrictive role allocations can be broken down.

(Haraway, 1991; Hawthorne and Klein, 1999; Faulkner, 2001; Wajcman, 1991, 2010). However, its suggestions for critically examining gender-related aspects of technology development have so far met with little response outside the field of gender studies and have not been systematically integrated into technical training.

Since women and gender minorities remain under-represented among creative technical actors, gender-related aspects in the design of technical systems are primarily decided by men. This is a circumstance that becomes more relevant in society as digital solutions become more widespread, for example with the increasing use of virtual assistants. Although a test has shown that language assistants were able to refer callers speaking of suicidal intentions or health emergencies (e.g. heart attacks) to suitable emergency numbers, when other callers mentioned domestic violence or rape, these situations were not recognized as emergencies (Miner et al., 2016). Furthermore, when personalities or human-like attributes are assigned to robots and autonomous systems, there is also a danger that female stereotypes will be used and existing role understandings reinforced (Ferrando, 2014). Virtual assistants have already been criticized for reacting very reticently to ambiguous questions, insults and sexual advances, thus propagating a passive image of women (Fessler, 2017). Technical systems are thus not neutral, as is often assumed, but reflect existing gender attitudes. The gender-specific effects of the design of digital technologies on individual users and society should be consistently studied and a sensitive approach to diversity within the tech community promoted in order to make technology design inclusive.

It is still the case in almost every country in the world that, at present, fewer women than men complete courses of study in engineering and computer science. Exceptions are Oman (where 53% of engineering graduates are female) and Malaysia (where there is parity in the IT sector). In Germany, the proportion of female graduates was 19.5% in computer science and 23.1% in engineering in 2017 (Kompetenzzentrum Technik-Diversity-Chancengleichheit, 2018). Similar ratios also apply in most countries in the natural sciences, although the proportion of female graduates is much higher. In Europe and North America it varies between 26% and 55%. Some developing and emerging countries have higher female shares by comparison. Female graduates are in the majority in eleven of 18 Arab states, and in Guatemala the figure is as high as 75% (UN, 2015b). Since the societal significance of these subject groups will continue to increase (Grabka, 2016; OECD, 2017a; Sorgner et al., 2017; WEF, 2016b), the persisting differences should be seen as a wake-up call. This applies particularly to the not insignificant number of countries where the proportion of female graduates in tech-relevant courses of study is falling, not rising (UN, 2015b). In addition, the disproportionately high share of men in technical occupations is accompanied by a low level of awareness of gender equality. In Germany, a supposedly progressive country in terms of gender attitudes, only 17% of men have a role model that is consistent with gender equality (Wippermann, 2016). In order to reduce unevenly distributed creative power, therefore, diversity in particular within the tech community should be promoted.

Box 5.3.6-3

Recommendations for action on the arena 'Digital technology as a gender bender?'

Despite growing political attention, gender equality has still not been achieved anywhere in the world (Köhler, 2017). Equality policies such as legal harmonization, an equal distribution of unpaid work, and dismantling discriminatory socio-cultural practices are therefore still indispensable. However, new digital instruments or measures to reduce inequalities in the digital realm should be seen as a complement to existing equality policies, not as a replacement for them.

- *Take gender-specific access barriers into account when expanding the net:* The global expansion of the net reached a milestone in 2018: more than 50% of the world's population now have access to the internet. However, women and gender minorities are disproportionately confronted with access barriers. As the net continues to expand, more attention should be paid to ensuring meaningful access for these groups and to identifying and removing context-specific access barriers. The UN Internet Governance Forum has identified barriers such as unaffordability, lack of infrastructure, language (lack of local languages), insufficient digital literacy, social stigma and cultural factors (IGF, 2017).
- *Digitally advance disengagement from the binary gender model and rigid gender roles in all countries:* Additional categories that take gender diversity into account should be introduced for digital identities that require gender assignment. AI personalities and humanoid robots should also be designed in a gender-sensitive way to prevent the direct reproduction of existing stereotypes. In this context, the labelling obligation for interactions with machines in cyberspace should also be regulated, or else new machine categories or 'machine genders' should be developed that clearly identify machines as machines.
- *Digital experimental spaces to raise awareness of equality and gender diversity:* Digital experimental spaces should be specifically created to enable individuals to experience their gender identity via games and to use changes of perspective to become more aware of other people's positions. These should be used for educational purposes in schools as well as in adult education.
- *Promote diversity in the tech community and bring about cultural change:* Programmes to empower women and gender minorities in STEM occupations (science, technology, engineering and mathematics – STEM) are becoming increasingly important as a result of rapid digitalization. Tech companies in particular should work towards an inclusive learning and working culture, raising general awareness of anti-discrimination issues and preventing structural discrimination. In view of these companies' increasing societal impact and the spread of digital products, professional ethics should be developed for this branch of industry – particularly for product managers and developers – and integrated into training.
- *Recognize digital violence for what it is:* In order to counter new forms of gender-specific discrimination and violence, technological and internet-based violence should be recognized as such by all states and taken into account in legislation.

Box 5.3.6-4

Research recommendations on the arena 'Digital technology as a gender bender?'

- *Set up an interdisciplinary research programme to reveal gender inequalities and develop a digital anti-discrimination agenda:* The European Commission and the BMBF should create a framework for an interdisciplinary research programme that combines expertise in the fields of gender and machine learning. The aim of the programme should be the systematic investigation of existing gender bias in media content, social processes and products in the digital environment. New analytical methods and qualitative social-science approaches offer especially promising prospects here. As a next step, an interdisciplinary task force should be set up to develop an anti-discrimination agenda for the Digital Age in the light of the research findings.
- *Set up a research agenda regarding the re-production of gender and gender inequality:* The WBGU recommends setting up a research agenda that specifically examines and analyses the gender concepts produced in virtual spaces and how they affect existing gender images.
- *Integrate critical gender perspectives into computer-science education:* A sensitive approach involving diversity is key to inclusive technology design. In order to specifically minimize the reproduction of unequal notions of gender by technical systems, a critical gender perspective should be integrated into computer-science studies and related training courses. The findings of gender studies conducted by feminist cyber- and technoscience in the social-sciences should be used in this context.

5.3.6.3 Anti-discrimination work using algorithm-based systems?

When deployed with deliberately emancipatory intentions, digital solutions can also help to raise awareness of existing inequalities and discrimination and to track the emergence of rigid role allocations. Social interactions (e.g. written communication in chats, the sharing of image material), which until now have not always been traceable in detail, leave behind data in digital space that can be strategically evaluated. The analysis of unstructured data, i.e. data lacking a formalized structure (e.g. videos, images or text) (Eckert et al. 2014: 7), can also be used today to improve our understanding of gender inequalities. Automated analysis of text corpora and film contents have already been used to identify discrimination patterns in language use (Caliskan et al., 2016) and to quantify the under-representation of women in terms of speaking time and screen presence in films (GDI, 2017).

The emergence of gender inequalities can also be tracked digitally, as shown, for example, by the analysis of comments in the chat room of an interactive computer game: although players are observed only via their actions within the computer game, players identified as females are more likely to receive comments on body aspects, whereas players identified as males are more likely to receive comments on technical or strategic aspects (Nakandala et al., 2016). On Github, a web-based online service that enables collaborative software development, in a collective decision-making process developers accepted 71.8% of the program codes written by women when their gender was unknown. When their gender was disclosed, the acceptance rate fell to 62% without any change in the quality of the program code (Terrell et al., 2017).

If algorithms are trained using such distorted data without reflection, they reproduce the discriminatory patterns. For example, software trained on distorted data concluded that 'computer programmer' relates to 'man' in the same way as 'housewife' relates to 'woman' (Bolukbasi et al, 2016). This makes it all the more important to also recognize and exploit the anti-discriminatory potential of new analytical methods. In this way, gender-based discrimination and decisions influenced by (un)conscious bias can be made visible and suitable measures for gender equality derived from the data.

5.3.6.4
Digital experimental spaces for gender equality and diversity

Flexible and diverse gender identities, which the WBGU reaffirms in the category of *Eigenart,* are lived out in virtual spaces (normative compass, Section 2.2; Cannon et al., 2017; Cipolletta et al., 2017). Facebook, for example, offers its users up to 73 gender categories to choose from (Haimson and Hoffmann, 2016). In addition, some disadvantaged gender minorities, e.g. transgender people, have an opportunity to develop a sense of belonging as well as welfare structures that are often denied them in dominant public discourse but represent central identity generators and necessary points of support in everyday life (Cavalcante, 2016). Digital spaces can also be used to put people in the 'digital shoes' of disadvantaged people by means of immersive virtual realities using avatars. This raises their awareness e.g. about gender-based exclusion, and negative social stereotypes are reduced (Yee and Bailenson, 2006). Experimentation in digital spaces can therefore contribute to softening rigid concepts of roles and to establishing new role models that do justice to the diversity and dynamics of gender roles.

5.3.7
Digital self-tracking: between empowerment and loss of control

The digitalization of more and more areas of life also involves the spread of ICT in the healthcare sector. Examples include the implantation of digitized devices that support physical functions (Topic box 5.3-2) by means of virtual consultations with a doctor via video chat, or apps and devices for tracking one's own body. Such devices are presented here as examples to illustrate the digitalization of the healthcare system and the possible implications of the comprehensive collection and availability of data. This topic seems particularly relevant since digital self-tracking can significantly influence three of the four dimensions of the WBGU's normative compass (Section 2.2): inclusion, *Eigenart* and human dignity. It also influences health and well-being, which are both goals (SDG 3) and resources of a Transformation towards Sustainability (WBGU, 2016a: 184).

5.3.7.1
Digital self-tracking and the data generated

A survey conducted in 2016 in 16 countries worldwide showed that one in three internet users use digital tools to observe, evaluate and, when appropriate, monitor their own health or fitness. Self-tracking is a form of continuous data recording where the initiative for recording the data originates from the individual her/himself. The methods of data collection vary. People can enter data (such as eating habits or medical examination results) in apps and other data carriers themselves. Furthermore, networked devices can transmit certain measured values (e.g. a person's weight measured using networked scales) directly to personal devices or central servers. Increasingly, health data are collected 'en passant' by computers worn directly on the body (wearables), e.g. smart watches and fitness trackers (Jülicher and Delisle, 2018). In addition to fitness and health data, metadata are also collected, i.e. data about the wearable itself, such as the duration and intensity of equipment use or connection data (Jülicher and Delisle, 2018). All the data collected, including the metadata, allow conclusions to be drawn on users' habits (Mau, 2017: 118) and are used for behavioural assessments and predictions by algorithm-based systems. The calculation methods are frequently considered by the manufacturers as trade secrets, so that it is incomprehensible for users how the results are obtained (Rey, 2018: 5–6).

Most of the data collected by self-tracking applications are legally classified as health data (Kampert, 2018). With regard to the European data-protection law, which offers a comparatively high level of protection (Box 4.2.6-3), health data are personal data relating to a natural person's physical or mental health and revealing information about that person's well-being (Article 4 no. 15 of the EU-GDPR). The data are classified as particularly sensitive because processing them poses considerable risks to a person's right to life and health (EU-GDPR, Article 9, EU-GDPR, recital 51) and could facilitate discrimination (Weichert, 2017). In addition to health data (in the narrow sense), however, numerous other forms of personal data can also allow conclusions to be drawn about a person's health (e.g. movement data or search behaviour on the internet; Deutscher Ethikrat, 2017), conclusions that can also be classified as relevant to health in related contexts.

5.3.7.2
Does digital self-tracking of health strengthen or weaken individual self-determination?

There is still a lack of comprehensive and representative empirical studies on the individual and societal effects of digital self-tracking. This section therefore examines selected implications of digital self-tracking that require further empirical review.

As a positive effect of digital self-tracking, the literature emphasizes that users of self-tracking services could gain a better understanding of, and more control over, their own bodies and state of health even without medical expertise (Jülicher and Delisle, 2018: 84; Sharon, 2017: 97). Users' self-determination can potentially be strengthened by encouraging them – in a low-threshold manner and without involving the health system – to use digital self-tracking to make health-promoting lifestyle changes (e.g. by increasing their physical activity) in the sense of prevention, therapy and aftercare (Charismha, 2016: 21). Medical staff treating patients can also use the data collected – in aggregated and visualized form and independently of place and time – in diagnostics and the treatment of diseases (Charismha, 2016; Heyen, 2016). Furthermore, improved knowledge on the part of patients could also break down the asymmetry of information in the relationship between healthcare professionals and patients, and possibly lead to greater transparency in healthcare. Potentially, it will enable patients to assume more responsibility for their own health and, for example, to better exercise their patient rights (Charismha, 2016: 2; Sharon, 2017: 97). Digital self-tracking could strengthen the inclusion and *Eigenart* of patients (normative compass; Section 2.2).

In practice, however, it can be seen that self-tracking apps sometimes have considerable deficits when it comes to data quality, data-collection methods and data processing (Heyen, 2016: 7; Lucht et al., undated: 22f.; Charismha, 2016: 197f.). This can lead to users being misled and making wrong health-related decisions, e.g. if diabetics make health-endangering adjustments to their insulin dose based on their own digitally measured blood-sugar level. Poor data quality can also cause problems in the subsequent use of data in medical research. It is emphasized that a positive side effect of individual self-tracking could be the creation of a comprehensive database, which, in aggregated form, could contribute to medical research. However, in order to meaningfully use aggregated and individual health data (e.g. for therapies or in research), both the database and the data-processing methods must meet scientific standards. Furthermore, studies from Germany and Europe point out that there is uncertainty, or a lack of competence, in the use of fitness-tracking services (Budzinski and Schneider, 2017; Adam and Micklitz, 2016), which could have a negative effect on patient sovereignty and thus on inclusion in the health system. However, a list of criteria and a web app called the APPKRI have been developed to address this problem and support users in evaluating and selecting health apps.

There is also a discussion that digital self-tracking technologies could lead to an (unnoticed) restriction of users' personal freedom and self-determination and thus have a negative impact on their *Eigenart* and human dignity. For example, self-tracking technologies could be used to monitor and discipline both the sick and the healthy (Deutscher Ethikrat, 2015; Sharon, 2017: 98). In some cases, employers use fitness trackers to promote the health of their workforce as part of occupational health and safety programmes, thus simultaneously gaining access to sensitive data that could be used as a basis for calculating a salary or granting promotions (Christl, 2014: 40; Röcke, 2015: 619). Health and life-insurance companies already use data from self-tracking services to offer individual insurance tariffs or premiums adapted to their policy-holder's lifestyle as part of bonus programmes (Schumacher, 2016: 48; AOK Plus, undated; Generali Vitality, 2019). The data could potentially be used to the detriment of users, for example by withdrawing benefits in the event of illness or not granting benefits at all if there are deviations from measurement parameters that are regarded

Box 5.3.7-1

Recommendations for action on the arena 'Digital self-tracking'

Various measures for maintaining self-determination and protecting the privacy of users of self-tracking services are discussed in scientific literature. This section presents recommendations considered worthy of support, complemented by the WBGU's own recommendations:

- *Secure privacy, enable sovereignty:* In order to ensure data protection and data security in self-tracking services and to protect their privacy, users must gain sovereignty and control over their own data and decide what may be done with them (Buck et al., 2015: 57; Deutscher Ethikrat, 2017: 268). To this end, incremental opt-in models are proposed that allow users to give their consent once, regularly or on a case-by-case basis (Deutscher Ethikrat, 2017a: 270). In addition, it is important that self-tracking devices and applications offer data-protection-compliant basic settings as standard, as stipulated in the European GDPR (privacy by design and/or privacy by default; Deutscher Ethikrat, 2017: 270). Audited or certified software tools in the form of data agents can help users to manage the collected data as they wish (Deutscher Ethikrat, 2017: 268). Selling products that are flawed in terms of data protection and data security should be illegal and sanctioned to ensure that only high-quality products are put on the market. Here, authorities, consumer-protection organizations and individuals can promote the further development of the law by filing corresponding lawsuits. The legal basis is not only rooted in data-protection law, but possibly also in medical-product law (which should be further developed), competition law, consumer-protection regulations and general liability law (Deutscher Ethikrat, 2017: 97ff.). A further development of the liability basis, e.g. by applying 'strict liability' for processing health-related big data analyses, might also be considered (Deutscher Ethikrat, 2017). The WBGU regards transparency and choice as key levers for more self-determination and data protection. Here, labelling requirements for data storage and a user-friendly administration of usage options (only private, also for friends, also for science, or for all) could help. Labelling should provide, among other things, answers to the following questions: are the data only stored locally on the users' own devices, or also (or even exclusively) centrally? To what extent are they stored centrally?
- *Ensure protection against discrimination and stigmatization, safeguard the solidarity principle:* The WBGU recommends encouraging a societal discourse on the relevance of the solidarity principle in healthcare in relation to the (self-)tracking of individuals. The following issues should also be discussed in this context: How can certain groups of people (e.g. addicts) be protected from discrimination and stigmatization (e.g. via complaints offices and arbitration bodies) in view of the societal trend towards digital self-tracking (Deutscher Ethikrat, 2017: 273)? To what extent can individuals be held responsible for their health? Should sanctions be imposed on 'unhealthy' behaviour, and from which point on can behaviour be classified as 'unhealthy' (Heyen, 2016: 12)? How can one ensure that appropriate measures are developed so that persons are not morally or contractually obliged to use self-tracking applications or devices (Röcke, 2015: 619f.), e.g. by employers or health insurance companies? The WBGU regards discourse arenas (Section 9.4.4) as a way of achieving a societal debate on this topic.
- *Promote health-data skills:* Another recommendation is that schools, other educational institutions and businesses should teach comprehensive knowledge on the importance of collecting personal data and on the value of this data (Deutscher Ethikrat, 2017: 271f.; Charismha, 2016: 23). This means creating the necessary prerequisites, e.g. by means of teacher training (Deutscher Ethikrat, 2017: 271f.). The literature also emphasizes the need for (further) training of medical staff in the potential of third-party health data and how to handle the data responsibly (Rey, 2018: 16; Deutscher Ethikrat, 2017: 280). In order to empower users, the WGBU recommends information campaigns on the consequences of disclosing one's health and fitness data. In addition, there should be more extensive enforcement of the transparency obligations of the operators of tracking applications and devices, e.g. on their purpose and methods of data collection and the creation of user profiles, or on changes to their general terms and conditions (Deutscher Ethikrat, 2017: 270f.; Rey, 2018).
- *Assure data quality and data security:* The prerequisites for the usability of health data collected by self-tracking for individual, medical and scientific purposes are high levels of data quality and data security. The WBGU therefore recommends creating uniform data and documentation standards, as these enable cross-system data exchange (interoperability) and traceability of the data back to their origin (Deutscher Ethikrat, 2017: 265). In addition, thresholds and/or data ranges for health data should be laid down and understandably described. Furthermore, checks on the data quality and data security of self-tracking applications should be carried out and published by independent bodies such as technical testing organizations, consumer-protection organizations or patient-protection organizations (Rey, 2018: 5, 16). In addition, internal data audits – analogous to invoice audits – can be introduced (Deutscher Ethikrat, 2017: 278). In particular, the WBGU recognizes a need for test seals or data-quality and data-security certificates for health apps. Since many devices are sold via app stores, a corresponding (self)obligation should be introduced, perhaps an obligation for app stores to test products (Charismha, 2016: 29). The list of criteria developed by Fraunhofer FOKUS for evaluating health apps could provide a starting point for tests.
- *Enable the use of self-tracking data for research purposes:* Provided that users have been fully informed about the further use of their data (and/or the data of people for whom they are responsible) and about the possible implications (e.g. for the rights of affected family members when disclosing genetic defects), the WBGU recommends making it easier for willing users of self-tracking services to make their data available for further use in clinical and medical research without a strict purpose limitation (Deutscher Ethikrat, 2017: 198, 266f.). In addition, standards of behaviour – preferably internationally agreed – should be established for researchers who wish to use highly sensitive health data (Deutscher Ethikrat, 2017: 279). The WBGU also sees the possibility of 'health accounts' with government-supervised intermediary institutions, similar to the citizen accounts planned under the Online Access Act (OZG), from which data from health apps could be released to doctors, hospitals or research institutions. Such a procedure should be considered. The highest security standards would have to be applied, permanently updated and further developed for such solutions. The concrete feasibility of the idea requires further examination.

Box 5.3.7-2

Research recommendations on the arena 'Digital self-tracking'

- *Research the implications of tracking health data:* On the one hand, there should be research into the societal potential (e.g. reducing health costs through self-tracking) and into the effectiveness of self-tracking for the individual as advertised by providers (e.g. to promote health or improve quality of life and one's own health competence; Rey, 2018:5, 16). On the other hand, it is also necessary to empirically show the dangers of tracking, e.g. possible loss of control or the danger that excessive digital self-tracking can cause an exaggerated fear of illness ('cyberchondria') (Heyen, 2016:13; Sharon, 2017:116; Charismha, 2016:22; Röcke, 2015:620; Rey, 2018:10).
- *Investigate data protection and data security in the field of health data during processing by self-tracking services:* There should be studies on whether and how data protection and data security can be ensured in self-tracking by digital tools, e.g. data agents. In particular, the effectiveness of the evolving legal framework for the further use of user data must be examined (Deutscher Ethikrat, 2017:269).
- *Research data quality in self-tracking services:* There should also be research to determine how a high level of scientific data quality can be ensured in self-tracking services, and what the minimum requirements concerning research with data from self-tracking services in view of fluctuating data quality are.
- *Research the importance of fitness and health tracking for universal healthcare:* There is also a need for research into the extent to which the tracking of fitness and vital data already plays a role in healthcare today (Charismha, 2016:23). It would be interesting to study to what extent fitness and health data tracking already has an influence on healthcare in different countries. In order to conduct scientifically based societal debates on the significance of the solidarity-based system in the health sector, the studies should focus on the relationship between the individualization of the insurance system and the solidarity principle.

as ideal (Rey, 2018:8). This could have an impact on the overall organization of health systems, especially health insurance, if they are organized according to the principle of solidarity. Where the solidarity principle applies, the insured person's insurance contribution is based on their economic capacity, but benefits are granted independently according to need (Brockhaus Enzyklopädie Online, 2018). An integration of self-tracking applications into the health-insurance system favours those who are physically fit and can (and want to) document the fact (Rey, 2018:15). Potentially, therefore, this could lead to restrictions on substantive and economic inclusion and to violations of human dignity for those less privileged in terms of health, or for all those who reject self-tracking of their fitness and health. The erosion of a health system based on the solidarity principle could also create or increase overall societal pressure to optimize oneself (Schumacher, 2016:48), thus threatening *Eigenart* in the sense of diversity. At present, at least in Germany and Switzerland, individualized conditions based on proven positive self-tracking data are only permitted in the case of supplementary insurance policies (Rey, 2018).

In the context of a possible loss of self-determination due to digital self-tracking, the concept of reducing physical functions and characteristics to numbers is also viewed critically (Buck et al., 2015:57). It is thought that users might increasingly determine their well-being on the basis of the measured data, thus reducing their ability to assess their own body or to notice signals (Buck et al., 2015:57; Sharon, 2017:107). Digital self-tracking carries the risk of undermining a person's autonomous, self-determined interaction with his or her own body. The possibility is also considered whether a permanent preoccupation with one's own fitness and health might contribute to increased pressure to perform and cause fears of illness ('cyberchondria'), or increase anxious people's proneness to hypochondria (Rey, 2018:8, 10f.). Some even see in the self-rationalization through the described tracking practices the risk that individuals might become objectified, thus threatening the core of human existence – and consequently also human dignity (Selke, 2016:967; Duttweiler and Passoth, 2016:10).

The key risk of digital self-tracking is the users' loss of control over their own data (Sharon, 2017:105; Röcke, 2015:619). For, in the case of self-tracking services using wearables or apps, these data are often available not only to the users, but also to the tracking providers, who pass the data on to third parties. This is problematic because users of digital fitness and health trackers fitted with a memory function do not have a clear picture of how their data are transmitted to and used by third parties. A study by the German Federation of Consumer Organizations (Verbraucherzentrale Bundesverband), for example, has shown that providers of self-tracking apps and self-tracking platforms grant themselves comprehensive rights in the use of user-generated data in their general terms and conditions and data-protection provisions (Koch, 2014). The data are forwarded to and merged with data from third-party sources (Gigerenzer et al., 2016). Although data-protection laws like the GDPR stipulate that consent given for the further use of personal data can be invalid, there is a lack of appropriate mechanisms to prevent such practices (Deutscher Ethikrat, 2017:17).

Topic box 5.3-2

The technologization of the human being

In the course of industrialization, and since the 1950s at the latest, the influence of human beings on the environment has reached such an extent that we must be regarded as a central, formative factor influencing the Earth system. Naming a new geological epoch the Anthropocene is an expression of this development (Crutzen, 2002; Rosol et al., 2018). In a similar way, we are now potentially at the beginning of an epoch in which humans will influence their bodies in just as fundamental a way as they are influencing the Earth system today (Coeckelbergh, 2013a; Braidotti, 2014, 2016).

Areas of application and ethical questions

Digitalization expands the horizon of possibilities for technically changing human characteristics and abilities. The areas of application range from implanted RFID chips as a kind of digital door key (Mair, 2015) to brain/computer interfaces (BCIs), e.g. by deep brain stimulation (Perlmutter and Mink, 2006; Schermer, 2011; Birbaumer, 2017; Rezeika et al., 2018), and the analysis of DNA using artificial intelligence (Domingos, 2015). For example, brain activity can be converted via BCIs into signals for technical systems, enabling people to give instructions to a computer without touching anything or speaking. In the opposite direction, brain activity can be influenced by small electrical currents to improve sleep quality or long-term memory (Birbaumer, 2017; Rezeika et al., 2018). In the literature, the military application possibilities of this technology are currently being prominently discussed; for example, brain implants could increase the vigilance of soldiers in stressful situations or if they lack sleep (Tracey and Flower, 2014; McCarty, 2014; Pugliese, 2015; Beard et al., 2016; Caron, 2018; Harrison Dinniss and Kleffner, 2018). But there are also numerous medical areas of application. Deep brain stimulation is used, for example, in the treatment of Parkinson's disease or in controlling prostheses (Perlmutter and Mink, 2006; Schermer, 2011; Birbaumer, 2017). However, when technology is used on humans, questions arise regarding ethical guidelines and possible red lines. Such debates can potentially be confronted by situations in which today's ethical discussion becomes too far removed from actual future technical and societal developments (Ferrari et al., 2012). Nevertheless, if we are a forward-thinking society, we must start asking the right questions today (Section 7.5).

In the medical field specifically, the focus must be on technologization's actual healing effect and patients' autonomy. If, for example, an obsessive-compulsive disorder is treated by deep brain stimulation, the question arises as to the extent to which the technically induced state of mind actually represents an improvement: "Making people feel good is not the same as enhancing their well-being" (Schermer, 2011). Furthermore, such treatments mean a sensitive intervention into the innermost part of the patient's being. By linking BCIs with AI evaluation, mind reading – i.e. technically identifying thought statements – also becomes possible, at least it will be at some time in the future, although such attempts have been rudimentary up to now (Mecacci and Haselager, 2017; Roelfsema et al., 2018). So far, there have been no legal limits or guidelines on appropriate safety measures to protect those affected, and many manufacturers and legislators lack the necessary sensitivity (Birbaumer, 2017). Should technical extension become the norm in non-medical areas, it also threatens to become a category for social status and could thus lead to social pressure for technical self-optimization (Fukuyama, 2002, 2004; Buchanan, 2009).

Fundamental questions about being human

Beyond concrete areas of application and their ethical implications, fundamental questions arise as to which understanding of being human the technologization of human beings is based on, and where the development is leading (Box 2.1.2-1). Transhumanist perspectives understand the technologization of human beings as overcoming their biological limitations. Human enhancement is intended to lift humans from *Homo sapiens* to *Homo digitalis,* i.e. onto a new evolutionary stage of development (Allhoff et al., 2010; Domingos, 2015; Kehl and Coenen, 2016). It is argued that the technologization of human beings is nothing fundamentally new and that humans have always striven to extend their qualities and abilities (Daniels, 2009; Coeckelbergh, 2013a). Some people go even further and consider any restriction of technologization as problematic, because it prevents humans from fully developing their own physical potential in the context of what is technically possible (Savulescu, 2009). Nevertheless, other authors point to an irrefutable core of what it means to be human. The fact that human beings might be relieved of their biological limitations by human enhancement would not make them less human. On the contrary, new vulnerabilities would take their place (e.g. susceptibility to problems with the technology); it is not biological characteristics, but precisely these vulnerabilities in relation to their environment that constitute being human (Coeckelbergh, 2011, 2013a). From this point of view, therefore, the decisive issue is not humans as supposedly unchangeable biological beings (human nature), but the essence of being human (human being). Critical posthumanist perspectives reject both transhumanism and a categorical understanding of the natural, biological human self; instead, they propagate an understanding of human intelligence that can also develop in interaction with machines (Hayles, 1999). The focus widens from the humanistic image of the human being as a rational being to detached, open-ended reflection on the essence of being human, which cannot be categorically defined by demarcation from animals or machines (Haraway, 1991; Braidotti, 2016). Being human cannot be understood separately from possible machine components; rather, there is an indissoluble relationship between body and technology (Box 2.1.2-1).

These different views show that the technologization of human beings touches on fundamental questions of being human. In view of the expansion of possibilities created by digitalization, it cannot be ruled out that hitherto hypothetical ethical and societal questions might become concrete in the future. This makes it all the more important to create a suitable societal framework. Although this is an issue for the future, it is imperative that changes in the relationship between humans and technology be responsibly anticipated. Just as planetary guard rails must be adhered to in the relationship between humans and the environment, guard rails for changes relating to the technologization of humans in the Digital Age must also be negotiated in a discourse and laid down with binding force. The need for this is illustrated by another analogy relating to climate change: geoengineering to mitigate or even reverse global warming through technical interventions has been discussed for some time (Marchetti, 1977), but increasingly so in recent years (Blackstock and Low, 2018), as a possible response to climate change. However, the risks of unleashing such an invasive, untested and costly influence on such a complex system as the Earth's climate are immense. As in the case of the technologization of human beings, it will therefore be crucial to agree on global guidelines and regulations before individual actors create facts with an irreversible societal impact.

The fact that general terms and conditions are frequently changed without necessarily informing the users contributes to the lack of transparency for users and ultimately to the loss of their informational self-determination (Rey, 2018: 14).

Overall, the 'arena' covered in this section illustrates that digital self-tracking potentially offers advantages and opportunities, but also involves disadvantages and risks with regard to a Transformation towards Sustainability. In a first step, it is necessary to conduct empirical research to deepen our knowledge of the effects of self-tracking, and to implement quality-assurance measures relating to the devices, applications, data quality and data protection.

5.3.8 International division of labour and digitalization: consequences for developing countries and emerging economies

In recent decades, there has been a global 'shift in wealth' from industrialized countries to emerging economies and developing countries, and a 'new global middle class' has formed as a result (Kharas, 2010; Milanovic, 2012, 2016). The increasing integration of these countries into the trading structures and global value chains that have been emerging since the 1980s has played a major role in this economic upswing. One widespread assessment is that digitalization will change these economic interdependencies and the international division of labour. On the one hand, there is very high technical potential for digitally enhanced labour substitution and automation in some developing countries and emerging economies; on the other, there are new opportunities for economic integration and inclusion through digital networking and digital work platforms. The following discussion focuses on the consequences of this for future development dynamics. However, a comprehensive, conclusive assessment is not yet possible on the basis of the current state of research (Lütkenhorst, 2018: 28f.; Schlogl and Sumner, 2018: 34; Rodrik, 2018).

5.3.8.1 Starting position: advances in development during the second wave of globalization

The development advances of the past decades are closely linked to the second wave of globalization that began in the 1980s ('second unbundling of globalization'; Baldwin, 2013; Baldwin and Evenett, 2015; World Bank, 2016: 60; Timmer et al., 2014), which was initiated by technological progress in information and communication technologies (ICTs). By making the logistics and coordination of business activities considerably easier, even over long distances, it became possible to split up production steps into outsourcing and offshoring processes and to distribute them internationally, exploiting local locational advantages. The result was a further deepening of international economic interdependencies. Even from the 19th century onwards, the use of fossil fuels had made it possible to reduce the costs and duration of goods transport, making it possible to geographically separate consumption and production and initiating the first wave of globalization ('first unbundling of globalization').

In the course of the second wave of globalization, new development models emerged for developing countries and emerging economies. Their locational and competitive advantages, especially in the form of low-cost labour and extensive natural resources, allowed them to integrate into production and value chains (Norton, 2017). Thus, especially in the 2000s, some of them achieved much more dynamic (economic) growth than industrialized or OECD countries and increased their share of global economic output (as a percentage of global GDP) and trade volume (OECD, 2016c: 54ff.). As a result, the number of absolute poor living on less than US$ 1.90 a day, as defined by the World Bank (World Bank, 2019a), fell from 1.8 billion (1990) to 770 million (2013). Their share of the world population was thus reduced from over 40% at the beginning of the 1980s to 10% by 2015 (World Bank, 2019b; status in January 2019). This was accompanied by further advances in development, such as a reduction in infant and maternal mortality, a decline in years lost to disease measured in Disability Adjusted Life Years (DALYs), and a global increase in life expectancy (Roser, 2019). There has also been a sharp decline in illiteracy (Roser and Ortiz-Ospina, 2019). However, the growth and development dynamics described were primarily driven by China, India and some other Asian countries (Rodrik, 2014; UN DSP, 2015; Milanovic, 2012; 2016). Around a quarter of the developing countries, especially in Africa, were only integrated into value chains and the international division of labour to a small extent (UNDP, 2010).

Technological progress, especially in ICT, has therefore already had a significant impact on trade patterns and patterns of international division of labour in the past. It is precisely the importance of ICT for the second wave of globalization that supports the expectation that the patterns of the international division of labour and current international economic interdependencies will continue to develop and change in the course of digitalization (OECD, 2016c: 63f.). It cannot be ruled out that the locational advantages of many developing countries and emerging economies, which have been decisive in the past, are becoming less important during this process, and this poses dangers for the development progress that has been achieved and the economic inclusion of these countries in global prosperity. In view of the foreseeable structural changes in labour markets (Section 5.3.9), this is – as further explained below – even probable, not least because the industrialization processes have not led to an extensive transfer of technologies and knowledge to all countries as a result of the international division of labour. Not all countries have therefore been able to develop from a mere 'workbench' into more independent technology locations with correspondingly highly qualified employees (Baldwin, 2013: 198), as this requires, in particular, economic inclusion in the potential of digitalization.

5.3.8.2
Changing value chains through digitalization

Future prospects for economic development based on the international division of labour in industrial production processes are regarded critically in the context of digitalization for two reasons in particular (UNCTAD, 2016; Stiglitz, 2017a: 630; McKinsey Global Institute, 2016).

On the one hand, digitalization is creating new production processes that can be expected to reorganize production structures. New additive manufacturing processes such as 3D printing (Section 3.2) allow a simpler and more cost-effective design of products and eliminate (labour-intensive) intermediate stages of production. They are thus leading towards more decentralized production structures and a shortening of global value chains (Gebler et al., 2014: 161; Rehnberg and Ponte, 2017; WEF, 2018b). Previous cost advantages of geographically concentrated, large-scale production structures are declining accordingly (UNCTAD, 2017b: 15).

On the other hand, the development of increasingly intelligent technical systems is increasing the possibilities of automation, and thus the substitution of human work in the production process. This development affects not only developing countries and emerging economies, but also industrialized countries (Section 5.3.9). Due to the higher proportion of routine work tasks, however, the number of jobs at risk in developing countries is estimated to be higher. Table 5.3.8-1, which summarizes recent estimates, illustrates this (World Bank, 2016: 122; Schlogl and Sumner, 2018; Section 5.3.9).

However, as discussed in Section 5.3.9, assessments of the technical potential of labour substitution as a result of automation should not be equated with forecasts of actual job losses. It is not yet clear, for example, whether automation really will result in cost savings, given the frequently very low labour costs in developing countries and emerging economies. However, other factors, such as the growing importance of transport costs or customer proximity, can more than compensate for labour-cost advantages and contribute to the relocation of production stages back to industrialized countries (or at least to countries geographically closer to home markets or relevant customer groups).

The growing demand for individualized products, which can be better met through more decentralized and customer-oriented production structures, is one of the central trends in the manufacturing industry (WEF, 2017b: 11, 2018). For the target countries, however, no major increases in employment are to be expected, since relocations and backshoring are associated with a switch to highly automated production processes.

There has been a lack of more systematic studies of the relevance for re-, back- or near-shoring processes up to now. In individual cases, however, such processes can already be observed today with a direct reference to digitalization (De Backer et al., 2016). The battery manufacturer Varta, for example, closed its production in Singapore at the end of the 1990s, relocated it back to Ellwangen (Germany), and cut the number of employees in Singapore from 500 to 100 (Rückverlagerung.de 2006). However, even during the partial relocation back from Singapore, labour-intensive production steps were still being outsourced to Indonesia and later also to Shanghai. Outsourcing and backshoring processes therefore took place in parallel here. In 2017 for the first time in years, Adidas opened a new factory in Germany, where sporting-goods manufacture is robot-controlled and uses 3D printing for some products (shoes). This was driven in particular by the desire to be able to respond as quickly as possible to dynamically changing, specialized customer requirements in certain product segments. With this highly automated method of production, it should be possible in future to relocate production to where the demand is, using the 'copy and paste' principle (Busse, 2017).

In the course of such restructuring, developing countries lose jobs and opportunities for economic inclusion in global profits on value-added. From a development-policy perspective, developing countries and emerging economies are threatened by early deindustrialization: their economies are developing into service economies after a much shorter period of industrialization and thus at a significantly lower level of income and productivity than was the case in many industrialized countries in the past (Rodrik, 2016; Lütkehorst, 2018: 60). There are already signs of a trend towards 'early deindustrialization', particularly in Latin American countries (Rodrik, 2016; Schlogl and Sumner, 2018: 1). It is precisely for these countries and African countries, which so far have hardly benefited

Table 5.3.8-1
Estimates of the employment effects of automation in developing countries and emerging economies.
Source: Examples taken from: Schlogl and Sumner, 2018: 20-21.

Author(s):	Country group/region	Estimate
Chandy, 2017	Developing countries	Automation is expected to replace jobs in developing countries even faster than in industrialized countries (p. 15).
Chang and Huynh, 2016	Southeast Asia	In ASEAN countries, 56% of workplaces are exposed to a high automation risk.
Frey et al., 2016	Developing countries	Developing countries are very vulnerable to a growing degree of automation (p. 18).
Frey and Rahbari, 2016	OECD plus Ethiopia, India and China	China will lose 77% of jobs as a result of automation, India 69%, Ethiopia 85%; in the OECD an average of 57% of jobs will be lost.
World Bank, 2016	Developing countries	Two thirds of all jobs are prone to automation (1.8 billion jobs).
Avent, 2017	Developing countries	New technologies seem to make life more difficult for upcoming countries in particular (p. 171).
WEF, 2017a	Africa	41% of all jobs in South Africa are prone to automation, 44% in Ethiopia, 46% in Nigeria and 52% in Kenya.

from the export-driven industrialization processes of globalization, that new growth and development models seem necessary (Norton 2017: 26; Rodrik, 2018; Stiglitz, 2018). The main challenge here is that a shift to service jobs seems unlikely to lead to a similar structural change promoting long-term employment and development potential as the migration of labour from the agricultural sector to the manufacturing industry. This assessment is based on the observation that at least many traditional service sectors generally have only a labour productivity comparable to that of the agricultural sector and only little potential to increase it, not least because, for example, they offer no opportunities for economic development via trade and exports (Rodrik, 2018). However, digital change in particular can alter this starting position and open up new development potential in the field of services. Thus, in the course of digitalization, new jobs for the highly qualified are created in the service sector which are not necessarily subject to these restrictions and which, for example, permit further integration into international value chains (Miroudot and Cadestin, 2017; WEF, 2018b). Examples are highly qualified activities in financial and business services or in IT, knowledge-intensive business services. However, in order for these specific services to become a new development model, substantial investment and reforms of the education systems are needed in developing countries and emerging economies (Stiglitz, 2018; World Bank, 2019c).

However, the lack of comprehensive educational and further-training systems and the corresponding lack of qualifications for handling new technologies will also mean that new technologies and production processes will not be deployed at all in developing countries and emerging economies in the field of industrial production. In addition to pure cost issues, this creates an additional obstacle to locating or maintaining manufacturing processes in the countries concerned (Rodrik, 2018). There are already signs of changing qualification requirements in developing countries: in these countries, too, the demand for labour has increasingly shifted towards non-routine activities, which are generally regarded as less easy to automate, but which require completely different skills from the routine activities typical of labour-intensive manufacturing processes (Reijnders and de Vries, 2018; Section 5.3.9).

The lack of technological expertise and qualifications can also prevent independent local businesses from using new digital technologies in production and marketing. Even when they do succeed, the necessary technologies often have to be imported (for example to automate production and maintain international competitiveness). In this case, there will be no direct, but an indirect, relocation of value creation back to the industrialized countries (UNCTAD, 2017a: 24). The shift towards service economies and the structural changes

Box 5.3.8-1

Digital labour platforms

In 'digital work' a distinction can be made between 'cloud work' and 'gig work'. A task that can be performed from anywhere over the internet is called 'cloud work'. 'Gig work', on the other hand, refers to location-based work facilitated by digital platforms (UNCTAD, 2017a: 46). Companies or individual clients post job offers on these digital labour platforms, for which contractors can then submit a bid. The further reduction of information and transaction costs on digital work platforms can also help ensure that production processes are no longer organized within a company. Instead, individual tasks can be distributed globally on a very small scale and completely outsourced from companies to quasi-independent contractors. These outsourcing processes with the help of agencies or the auctioning of work assignments on internet platforms, referred to as the new 'global gig economy' (Norton, 2017), can be interpreted as a digital continuation or transformation of the global analogue workbench to a digital workbench. As digitalization progresses, a global structural change is emerging in which developing countries and emerging economies are increasingly offering (high-quality) services on the global market. English-language global digital labour platforms (e.g. for translating, programming, marketing, accounting, office assistance) are currently growing by approximately 25% per year (Kässi and Lehdonvirta, 2018). In 2016/17, 46% of the companies offering jobs on digital labour platforms came from the USA, followed by Europe, India, Australia, the UK and Canada (Kässi and Lehdonvirta, 2018). Offers were also received from Brazil, South Africa and Egypt. When it comes to the origins of the contractors, however, developing countries are more strongly represented, above all India and the Philippines (UNCTAD, 2017a: 49).

Despite these impressive growth figures, the relevance of the gig economy is still limited today. Estimates available to date of the proportion of the working population who are employed full-time via job platforms vary, albeit at a very low level of less than 3% (OECD, 2019a). The World Bank estimates that less than 0.5% of the world's working population is currently employed in the gig economy, and less than 0.3% in developing countries (World Bank, 2019c).

on the labour markets – the increasing demand for (highly) skilled labour compared to the falling demand for less-skilled labour – generally harbour the risk of rising inequality and growing social tensions, and this also applies within developing countries and emerging economies (UNCTAD, 2016; Stiglitz, 2018). In developing countries and emerging economies, however, these developments become even more explosive as a result of greater political instability, the often weaker (state) institutions, and the frequently lacking or considerably weaker social-security mechanisms and systems (World Bank, 2019c; Section 5.3.9). Automation can also lead to lower demand for migrant workers in industrialized countries. The consequence would be a collapse in return remittances, which in many developing countries and emerging economies account for a significant proportion of GDP (Norton, 2017).

On the other hand, technological leapfrogging can offer positive development opportunities. In principle, this potential is also inherent in digitalization. Prominent examples are mobile communications and the mobile internet, which enable communication over long distances and internet access even in remote regions without the capital-intensive development of cable infrastructures, opening up access to banking and financial services, for example (World Bank, 2016). However, it should also be noted in this context too that sufficient education and qualification in handling new technologies and media are essential prerequisites for all development opportunities based on leapfrogging. Against this background, the possibilities for leapfrogging have so far been seen as being rather low (UNCTAD, 2017a; Niebel, 2018).

5.3.8.3
The changing international division of labour: from the analogue to the digital workbench?

By reducing the costs of communication, information and searching (Goldfarb et al., 2019), digitalization also opens up opportunities for developing countries to develop their economies independently. Companies and employees can also gain easier access to international markets when barriers to market entry are falling (World Bank, 2016: 59f.). For instance, digital technologies can reduce the amount of capital needed to participate in international (digital) markets. In principle for example, cloud computing also offers smaller companies in developing countries access to the latest technologies without their having to fully bear the high investment costs and risks of server infrastructures (World Bank, 2016: 69). At the same time, with the help of digitalization (service) activities can be outsourced and traded internationally. Digital work platforms represent a new, global labour market for such jobs, to which developing countries and emerging economies also have direct access. Digital work platforms (Box 5.3.8-1) can thus lead to a new quality in the international division of labour.

There are many examples of how such platforms can improve the income situation of people in developing countries and emerging economies and connect service providers in poor countries with the markets of wealthy countries (UNCTAD, 2017b: 47ff.). For example, a former university lecturer in Manila can earn much more doing programming work for a US company without having to undertake a time-consuming commute (for more examples, see: Graham et al., 2017b).

Box 5.3.8-2

Recommendations for action on the arena 'International division of labour'

Even in the Digital Age – and especially in view of the challenges associated with automation – traditional fields of action such as education, social security and institutional development are still important 'analogue' prerequisites for creating and using development potential (World Bank, 2016).

- *Establishment and promotion of education and training systems:* The spread of digital technologies involves specific challenges and new opportunities. In particular, investment in education is more necessary than ever, as education and training are becoming increasingly important as a basis for skilled work. In the Digital Age, education and training are key to the successful use of digital technologies in developing countries, especially in order to open up the possibilities of new development models based on 'high-quality' services. Questions such as what educational content should be taught and how abilities such as creativity, flexibility and general analytical and cognitive skills can be promoted in developing countries – also taking into account regional characteristics – cannot yet be answered conclusively; the same applies in industrialized countries. Particularly in the context of developing countries, questions arise as to what influence regional and cultural characteristics have on developing and redesigning suitable education systems. However, digital technologies can generally be used to make it easier to multiply educational opportunities and offer them universally. This is particularly true in the remote rural regions of developing countries, provided that the still-large digital divide between urban and rural regions can be quickly closed.
- *Promotion of infrastructure development:* The targeted promotion of inclusive infrastructure development adapted to local conditions, for example within the framework of development cooperation, is a key approach to reducing regional disparities and ensuring future economic inclusion. This expansion of infrastructures must be accompanied by technology transfer in order to build up IT industries in developing countries and thus reduce their dependence on imports. One important concrete approach here lies in new regulations in the field of the protection or transferability of intellectual property rights (Baker et al., 2017) or open-source solutions. Furthermore, there is a need to counteract the 'brain drain' from developing countries and emerging economies. There should be more incentives for highly skilled workers in the digitalization sector to return to their home countries from industrialized countries.
- *Establishment and expansion of social security systems:* There is still a great need for action to improve social security in developing countries and emerging economies. Along with improved access to financial and banking services, digital technologies should be used to register and document the population – also in rural areas. Development cooperation could also support the establishment of functioning social security systems. In order to effectively counter the high international competitive pressure and the bargaining power that individual contractors usually lack, there should also be efforts to pursue the agreement of minimum labour standards in digital work within the framework of international agreements (e.g. with the ILO). Digital technologies and international networking can also be valuable tools in verifying compliance with labour standards and thus monitoring the implementation of international agreements.
- *Development of guidelines for new challenges in occupational health and safety:* However, ICTs also make it increasingly possible to monitor employees – ethical guidelines already need to be drawn up at the development stage. Especially industrialized countries, where these technologies are largely developed, have a responsibility not to export technologies that might contravene labour law in their own country.

With sufficient training and continuously improving access to the internet, it can be assumed that millions of people in developing countries can potentially benefit from the opportunities of generating income on digital work platforms (Graham et al., 2017b; Norton, 2017). The fact that digital work platforms can reduce the number of informal jobs, which are prevalent in many of these countries, can also have a positive impact on the development of developing countries and emerging economies. This can contribute to the state's ability to act, for example by laying the foundations for functioning tax systems. However, a fall in informal employment also removes one of the key hurdles to improving people's situations by providing corresponding social-security systems (OECD, 2019a; World Bank, 2019c; Section 5.3.9).

Despite these advantages, however, the effects of the new opportunities for integration into newly emerging global labour markets and self-employment can be ambivalent, especially for developing countries and emerging economies (World Bank, 2019c). Although formal employment relationships are increasing, many developing countries and emerging economies lack adequate social security systems. Where such systems exist at all, they are generally geared to regular employment relationships. Yet the intensified international competitive pressure is currently leading to a growing fragmentation of contracts into sub-projects for the self-employed and thus to a decrease in regular, i.e. socially insured, (full-time) employment. As a rule, contractors lack the negotiating power to enforce social standards and labour rights (van Doorn, 2017b). The increasingly decentralized organization of work processes also plays a role here. This also makes it more difficult to monitor working conditions, although this is partly counteracted by increasing transparency in the course of global, digital networking.

Against this background, it is feared that this contin-

Box 5.3.8-3

Research recommendations on the arena 'International division of labour'

The existing considerable uncertainty about the impact of digitalization on work and employment also touches on the question of how digital change will alter the economic integration and inclusion of developing countries and emerging economies. At a very fundamental level, there is considerable scope for research to identify at an early stage the potential of digitalization for the further economic integration of developing countries, as well as the possible risks (Lütkenhorst, 2018: 28f.; Schlogl and Sumner, 2018: 34).

- *A more systematic understanding of the effects of digital progress:* Whereas in the past, industrialization processes generally increased labour productivity and created employment at the same time, this is no longer guaranteed in the course of digital change. The question of how automation and digitalization affect developing countries with their own specific production, employment and export structures has hardly been studied. More detailed research is also needed into the conditions under which productivity and income growth are likely to translate into employment growth in the future, and what relevance possible processes of re-, back- or near-shoring will have for the economy as a whole. Such a deeper and more systematic understanding of the consequences of digitalization on labour markets in developing countries and emerging economies would also be necessary to be able to assess at an earlier stage political risks from possible deindustrialization processes and job losses, as well as from rising social tensions caused by any unequal development of capital and labour income.
- *Identification of possible new development models* Globalization and the use of low-cost labour have allowed longer-term development progress in developing countries and emerging economies by triggering structural change from agricultural economies to increasingly industrialized economies. In the future, alternative development models will become necessary – models that open up new prospects for the young populations in developing countries, some of which are growing rapidly. How development can succeed under these conditions, however, is still largely an open question. In this context, the possibilities and prerequisites of technological leapfrogging should also be studied in greater depth.
- *International division of labour, new development models and environmental protection:* In the search for new development models, little attention is paid to the question of how the reorganization of the international division of labour and the possible shift from analogue to digital workbenches is related to environmental and climate protection: does digitalization help reconcile development models with environmental sustainability goals or not? Under the above conditions, there is an urgent need to develop alternative economic-policy strategies for developing countries in line with planetary guardrails. Here, the necessary knowledge for orientation and action is lacking, making it difficult to point to alternative, future-proof possibilities for development.
- *Changes in working conditions and quality:* Similarly, little research has been done into the question of how digital technologies are changing working conditions in developing countries and emerging economies, what opportunities digitalization offers for creating equal working conditions worldwide, and what is necessary for the implementation of equal working conditions. There is also a considerable need for research into the potential of sustainable work (UNDP, 2015), the influence of gainful employment on the socio-ecological shaping of lifestyles, and the question of what contribution digitalization can make by changing the division of labour. In addition, societal change will be needed in developing countries to establish the importance of lifelong learning more firmly in society. In order to address from the outset new forms of unsustainable working conditions caused by international competitive pressure and a lack of bargaining power, it would also be necessary to ask how industrialized countries can shape their national labour (market) policies and regulations to make a globally fair and sustainable international division of labour possible.

uation of the analogue workbench in the digital world – parallel to positive employment effects – may lead to the emergence of a new type of service precariat, especially in developing countries and emerging economies (UNCTAD, 2017b: 51): "Employment in much of the informal sector has always lacked security and protection of rights. The 'gig economy' is nothing new in developed or developing societies. But digital work platforms seem likely to spread these characteristics more widely, to increase both access and competition, and introduce these ways of working to new sectors – probably quite rapidly" (Norton, 2017: 9).

It must be critically questioned whether the hopes raised (for example by the World Bank and many governments) on the development potential of digital online platforms are not being thwarted by existing inequalities and power relations (Graham et al., 2017b). In particular, access to international product markets and to a newly emerging labour market on digital platforms is highly dependent on the skills of the workforce. There is thus a danger that only highly qualified people will benefit from the development potential, while the majority of the population will be affected by increasing competitive pressure, inadequate social security and growing vulnerability: "There is a risk that the present system will create good and well-paying jobs only for a few, while for the majority, there will be little security and persistent concerns over job quality and level of compensation" (UNCTAD, 2017a: 51).

5.3.8.4
Conclusions

The ongoing process of digital structural change in the international division of labour has the potential to re-order global economic relations on many levels. It has been evident for many years that there will be a readjustment of the role of developing countries and emerging economies in the international division of labour. The possibility of unequivocal conclusions on the impact of digitalization on the international organization of value chains is currently limited. This also applies to the question of whether the progress made during the second wave of globalization could be again jeopardized in many developing countries and emerging economies. However, several studies estimate the technical potential of job losses due to automation in developing countries and emerging economies to be very high (Table 5.3.8-1).

A change in the international division of labour is foreseeable. Robotics and 3D printing will reshape entire production processes and structures; digital work platforms will result in fewer analogue, but more digital 'extended workbenches'. Some people are already talking about a third wave of globalization (Baldwin, 2016), as individual tasks can be distributed and outsourced globally in ever smaller parts with the help of new, digitally enhanced manufacturing technologies, as well as digital networking and platforms. It is conceivable that this new form of the digital division of labour will have positive consequences for sustaining the natural life-support systems if the resource-intensive transport of goods and labour can be significantly reduced. New additive manufacturing processes can also contribute to this, enabling production to be closer to the customer, even if products are designed at remote locations. In view of the challenges described here for the future development models of developing countries and emerging economies, however, it also becomes clear that such positive sustainability implications of new production structures and technologies at the level of resource and environmental protection can generate tension with societal goals of sustainable development. This also applies in particular to the further potential for saving resources through more efficient, more automated production processes (Section 5.2.1), whereby automation reduces resource consumption, but is also associated with a (net) loss of employment in developing countries and emerging economies in view of a low level of education and the correspondingly weaker global economic integration of these countries. These possible sustainability implications, which go beyond economic inclusion, are currently hardly being considered in connection with the further development of the international division of labour. They should become the subject of intensive research, as should possible new development models and the further development of existing economic interdependencies, in order to provide a more secure basis for policy-making (Chapter 10).

5.3.9
Sustainable working environments of the future

Work, i.e. gainful employment, fulfils broad societal functions: it produces goods and services that are relevant to society, secures people's livelihoods, guarantees societal inclusion, and is a source of self-esteem and personal respect. Taxation of earned income is also an important basis for financing state budgets and, in particular, social security systems. Not least against this background, the successful integration of people into the labour market is a largely undisputed, sensible economic-policy objective that is also part of development and sustainability policy and reflected in the SDGs (SDGs 1, 8 and 10).

Labour markets and gainful employment in their current form are being profoundly transformed by digitalization and the Transformation towards Sustainability. The structural change needed for a sustainable economic system poses great challenges for people, regions and entire societies. To ensure the social compatibility of this change, future prospects must be developed for people who are currently employed in non-sustainable sectors, such as industries dependent on fossil fuels (WBGU, 2018b). At the same time, technical systems and machines are acquiring (cognitive) abilities through interconnectedness and a vast abundance of data with which they can compete with human work in an ever increasing number of areas. This development fuels fears of loss and uncertainty, as already illustrated by the discussion on technologically induced (mass) unemployment and distributional conflicts that has been ongoing since the beginning of industrialization (Mokyr et al., 2015; Allen, 2017). Fears of social relegation and loss of acceptance on the part of those affected can also play into the hands of populist movements.

Digitalization undoubtedly poses significant challenges to the societal functions of (paid) work today and the role of work and employment for sustainable development. However, the initiated transformation also offers opportunities for a new social contract and the development of new models for decent work with a new quality of work that strengthens inclusion, *Eigenart*, and more humane and sustainable working conditions.

5.3.9.1
Automation and employment

Tasks and jobs with clearly definable and repetitive processes are particularly suitable for automation. In contrast to these routine activities, non-routine activities require creativity, flexibility or adaptability, as well as analytical, cognitive or organizational skills, and social or communication skills (empathy; World Bank, 2019c). How non-routine activities can be successfully mastered can often only be imperfectly explained via standardized approaches or solutions, so that it is difficult to codify the necessary processes ('Polanyi's Paradox', Autor, 2015). Yet even some jobs with high qualification requirements, e.g. in banks or insurance companies, are categorized as routine activities; in some cases, they too have already been taken over by AI (Mayer-Schönberger and Ramge, 2017: 126ff.). Conversely, in addition to analytical or 'abstract' activities, some forms of manual work are also classified as non-routine activities, e.g. if they do not require high educational qualifications but high sensorimotor skills and a high degree of adaptability to individual tasks (Autor, 2015).

Quantitative estimates of the technical potential for automating today's occupations and jobs arrive at mixed results. If individual occupations are considered, almost half of the occupations present in developed economies today could be taken over by machines over the next 10–20 years (Frey and Osborne, 2013, 2017). However, the estimated automation potential is significantly reduced when the fact is taken into account that occupations generally involve different activities that cannot all be performed by machines in the same way. In the USA, for example, it is reduced from 38% to 9% of jobs (Arntz et al., 2017). Similar orders of magnitude are found in other industrialized countries such as Germany (Arnold et al., 2016; Dengler and Matthes, 2015). For developing countries, however, this potential is regularly estimated to be higher (Section 5.3.8). Whether existing substitution potential is actually exploited, however, depends ultimately on societal, legal and economic framework conditions (Frey and Osborne, 2017; Südekum, 2018) and can therefore in principle be shaped by society and politics. Technological progress can not only lead to job losses, it also induces counteracting effects: it can stimulate positive growth and can lead to the emergence of new occupations and jobs (Benzell et al., 2015; Mokyr et al., 2015; Autor, 2015; Acemoglu and Restrepo, 2018a). Up to now, it has been difficult to predict whether these effects will be as strong as in past technological revolutions (Autor, 2015; Mokyr et al., 2015; Allen, 2017). However, new areas of employment have already emerged today. Examples include programmers and entrepreneurs who develop concrete applications for digital technologies (Benzell et al., 2015; Bresnahan and Yin, 2017), or agencies that improve the search-engine friendliness of websites. Positive employment effects from digitalization may also arise from possible improvements in the functioning of (labour) markets, the reduction of search and information costs, and the reduction of labour-market friction (World Bank, 2016). In particular, digital labour platforms such as Uber, Amazon Mechanical Turk or Etsy allow the placement of work orders and the mediation of jobs in (at least ostensible) self-employment even for the smallest tasks (Goldfarb et al., 2019; Section 5.3.8). However, this does not always create additional employment; sometimes regular employment relationships are replaced (Eichhorst et al., 2016).

Negative effects of digitalization and automation on the amount of work available can also be mitigated by adjusting working hours. Keynes already speculated at the beginning of the 20th century about the working week being reduced to 15 hours in his grandchildren's generation (Keynes, 1930). Even if reality has lagged behind this forecast, working hours have fallen in the course of societal negotiation processes in many countries. As a result of rising labour productivity and increasing material prosperity, this has been possible without endangering employees' material livelihoods (Mokyr et al., 2015; Boppart and Krusell, 2016; Stevenson, 2018). At the same time, leisure activities have become more accessible for broad sections of the population (Mokyr, 2013; Irmen, 2018). Today, visions of future developments even include fully automated post-work societies (Aira, 2017) in which people receive an appropriate share of the economic wealth generated (Pfannebecker and Smith, 2013) and pursue activities no longer for gainful employment but primarily with the aim of self-realization. In a pessimistic vision, by contrast, society is split into a class of rulers and the 'useless,' who have no political or economic significance (Harari, 2017).

5.3.9.2
Distribution implications

Already today, the distribution of income and wealth is discussed as a central challenge for social cohesion and political stability (Dabla-Norris et al., 2015; OECD, 2015c; World Inequality Lab, 2017; Alvaredo et al., 2018; Guriev, 2018). Not least against this background, the distributional implications of digitalization and the Transformation towards Sustainability, as well as the structural changes on the labour markets described above, are currently increasingly coming into focus. Compared to the question of (absolute) employment development, it is relatively undisputed that these changes can pose major societal challenges and significantly exacerbate existing social tensions (Korinek and Stiglitz, 2017; Berg et al., 2018a; Südekum, 2018). Moreover, not only the actual measurable consequences are of societal and political relevance. Rather, the spread of a feeling of insecurity and growing fears of social relegation, which can arise from dynamic digital development, are also relevant (Bussolo et al., 2018). From a sustainability perspective, such developments threaten not only societal and economic inclusion, but also the necessary political support for, and the shaping of, sustainable development.

Implications for regional and spatial distribution

Since some industries particularly affected by digitalization and the Transformation towards Sustainability are concentrated in certain areas, induced distribution effects will vary from region to region. Similar to the current debate about job losses in the coal industry, regional economic and social upheavals can arise as a result of incipient structural change, which must be accompanied and cushioned in good time by appropriate measures (WBGU, 2018b). Regional economic shifts due to technological progress have also frequently been observed in the past and addressed in numerous studies (Arntz et al., 2016). However, there is still a considerable need for research in order to understand the concurrence and interaction of the effects on the labour market of digital change and the Transformation towards Sustainability. Spatial and regional differences do not completely lose their significance even with advancing interconnectedness and virtualization through digitalization. At the international level, factors such as proximity to customers and the declining significance of labour costs can lead to new patterns of trade relations and the division of labour with consequences for distribution and development policy (Section 5.3.8).

Distribution between jobs requiring different qualifications

There is a widening gap between existing and required skills and qualifications among people of working age as a result of structural change in the labour market ('mismatch of skills': Acemoglu and Restrepo, 2018a). This is exacerbated by highly dynamic digital technological progress, as expressed, for example, by the relatively large increase in the potential for labour substitution in Germany (Dengler and Matthes, 2018). In the course of digitalization, employment opportunities will be preserved or newly created, especially if they involve non-routine activities that are difficult to automate. As these activities include both highly paid, highly skilled 'abstract' jobs and low-paid 'manual' jobs, it is expected that employment will shift to both ends of the wage distribution, while routine middle-income jobs will disappear (Autor, 2015). This 'polarization of employment' to the opposite ends of wage distribution has been observed in many countries since the 1980s and is explained, inter alia, by technological progress in ICTs (Michaels et al., 2014; Bárány and Siegel, 2018).

In addition, income inequality can be exacerbated between non-routine activities requiring high and low qualifications (Eden and Gaggl, 2018). Due to the limited labour supply, disproportionately large wage increases can already be observed today among employees with special skills in handling digital technologies (Gallipoli and Makridis, 2018; Falck et al., 2016). On the other hand, wages for low-skilled, manual non-routine jobs are likely to come under increasing pressure if more and more workers move into these jobs from employment that is based on routine tasks and thus highly susceptible to automation because of lower skill requirements (Autor, 2015).

Development of growing inequality between capital income and earned income

Particularly in industrialized countries, earned income as a percentage of overall value added has fallen since the 1980s in favour of capital income and corporate profits, especially since the turn of the millennium (Piketty, 2014; Dao et al., 2017; OECD, 2017b). This development is attributed inter alia to automation and, more generally, to technological progress in ICT (Eden and Gaggl, 2018). The work-substituting effect of digital change plays an important role here; this ultimately reflects the classic distribution conflict between labour and the owners of capital and/or machines which has existed since industrialization. But the change of market structures into 'winner-takes-all' markets – which is seen to be induced by the parallel increase in the importance of immaterial (digital) assets – also plays a role: it promotes market concentration and thus rising profits on the corporate side (Autor et al., 2017a, b; Guellec and Paunov, 2017; Section 4.2.2). If these developments were to continue or were reinforced in the course of further digital change, (paid) work would contribute less and less to ensuring economic inclusion in society as a whole (DeCanio, 2016; Korinek and Stiglitz, 2017). The complete substitution of human labour by ever-more-intelligent AI systems would ultimately be only the most extreme form of this development.

Market-economy adjustment processes can limit losses in wages and thus also distributional implications in addition to reducing the number of jobs (Section 5.3.2.1). The emergence of new occupations again plays a key role here: new occupations counteract inequality developments if they evolve around activities which are not susceptible to automation or for which technical progress has an effect that is complementary to labour. In this respect, it should also be noted that the direction of technological development may change over time. For example, other challenges, such as sustaining the natural life-support systems, can become more 'pressing' problems and the use of labour can become more attractive compared to other production factors (Acemoglu and Restrepo, 2018b).

These possible adjustment processes only partially reduce the societal challenges and formative tasks that result from labour-substituting technological progress. They do not prevent phases of transition in which people are confronted by changes in occupational profiles and qualification requirements. The stabilization of employment and earned income can take long periods of time – as became clear in the course of the Industrial Revolution (Allen, 2009) – and raise intergenerational distribution questions accordingly. These are exacerbated by the fact that trade-offs can arise between income gains for future generations and a more even distribution of income in favour of earlier generations (Berg et al. 2018a).

5.3.9.3
Social security systems and income distribution mechanisms

In view of the foreseeable impact on income distribution and labour markets, it is important to develop approaches that cushion structural changes in labour markets and preserve economic and societal inclusion. People need financial and temporal flexibility and support so that the transition from old to new occupations can be managed successfully and those who struggle to cope with the speed of technological progress are not left behind. Functioning social security systems are therefore more necessary than ever. However, should (paid) work lose so much economic importance that it no longer guarantees broad economic inclusion and an adequate income distribution, further mechanisms of income (re)distribution will be needed to maintain social cohesion.

In addition to the growing need for social security, digital change endangers the functioning of social security systems in their current form. In many countries, benefits and individual entitlements are directly linked to the time people have spent in, and the amounts they have earned under, regular employment contracts. Additional, more unconditional benefits mainly target particularly needy population groups as part of basic security benefits, or people not yet of working age. Already today, however, the work biographies of young people in particular show ever shorter regular employment relationships, multiple job changes and non-regular jobs found, for example, via digital labour platforms (Section 5.3.8). Digital change is likely to reinforce this trend. However, digital work platforms also have ambiguous implications in this respect. Especially in developing countries, the coverage of social security systems is often limited today, due to the traditionally large number of informal employment relationships there. Digital labour platforms can help overcome institutional deficits in the registration of work and employment, and thereby promote formal employment in these countries (World Bank, 2019c).

An additional challenge arises from the impending erosion of the funding bases of social security systems (OECD, 2019a; World Bank, 2019c). On the one hand, the financing of these systems has so far been based primarily on income from regular employment, which is threatening to become less important. On the other hand, with digitalization it becomes less and less important where people work, which can lead to work being moved to countries with lower social security contributions for companies (Section 5.3.8) and simultaneously reduces the bargaining power of employees (OECD, 2018d). With earned income's share of overall value added declining, the financing of social systems also risks becoming based on an ever smaller share of national income. This opens up another dimension of inequality and is a possible source of social tension.

To prevent ever larger sections of the population losing access to social security, reform efforts are aimed at increasing the flexibility of social security systems with respect to frequent changes of occupation and employment, and at broadening their coverage of an increasing variety of employment forms, thus putting regular and non-regular employment on an equal footing (OECD, 2018d, 2019a). This approach would simultaneously broaden the funding base and help curb the sometimes abusive cutting of labour costs by transforming regular into non-regular employment and creating quasi-self-employed jobs. Extending the social security obligation to self-employment and non-regular employment is also being discussed. This would counter the risk that, with the emergence of occupations not subject to compulsory insurance, more and more people, trusting in social solidarity in emergencies, or in view of their own economic capacity, would opt out of social-security systems and thus undermine the systems' principles of solidarity and risk spreading (Eichhorst et al., 2016; OECD, 2019a).

Rising financing needs for social security and the distributional consequences of digital change make a further broadening of the funding bases appear sensible. Such an expansion could also relieve the burden on labour in relation to other production factors. This would dampen incentives for automation and thus also influence future technological development (Stiglitz, 2017a; Acemoglu and Restrepo, 2018a, b; World Bank, 2019c). Higher charges on capital income, wealth and corporate profits are under discussion in this context (Bussolo et al., 2018; Box 4.2.2-2). Proposals for the introduction of digital taxes or robot taxes also point in a similar direction (Guerreiro et al., 2017; Acemoglu and Restrepo, 2018a, b).

The more issues of a fundamental redistribution of income come to the fore and require social security systems to become more detached from concrete employment relationships and earned income, the more relevant additional funding bases become (Bussolo et al., 2018; World Bank, 2019c). At a very fundamental level, considering the longer term and possible developments of AI, it is necessary to think about how an appropriate distribution of value added and income can be ensured while preserving the other societal functions of gainful employment (Korinek and Stiglitz, 2017). There is much discussion on concepts of an unconditional basic income in this context (Hoynes and Rothstein, 2019; Banerjee et al., 2019). Whether, and in what form, a basic income can be a suitable response to future challenges of income distribution is controversial. A number of economic and societal questions arise with regard to fiscal effects, distributional implications and consequences affecting individual incentives for societal and economic inclusion (World Bank, 2019c). Alternative approaches to guaranteeing broad inclusion which are currently being discussed include concepts of broader holdings in companies, either directly in the form of a broader distribution of company shares (Eichhorst et al., 2016; Südekum, 2018) or indirectly via state-organized future funds (Corneo, 2015; WBGU, 2018b). Finally, addressing rising market concentration, and with it strongly rising corporate profits on digital markets, also helps to alleviate concerns about distributional implications and social tensions (Sections 4.2.2, 9.2.3.3; Autor et al., 2017a).

5.3.9.4
Guiding concepts for sustainable work in the future

Even if gainful employment remains a component of modern societies, forms and environments of work as well as the societal significance of some occupations and activities will change considerably. Changes in the societal status of work and in the societal concepts of 'decent' work or top-quality work are also possible, and these also influence the general perception of technical progress itself, as became clear in past epochs (Shiller, 2019).

In view of the change in the significance of currently established jobs and the advance of 'intelligent' machines, a change in societal values can be a prerequisite for people to continue to experience self-efficacy and a meaning in life. Up to now, however, there has been no public discussion about future concepts of work that might also be used as orientation for shaping digital change. The lack of orientation is currently increasing uncertainty and fuelling fears about the future. Dystopian and utopian scenarios of post-work societies (Chapter 6) can be helpful in initiating such discussions and developing ideas on how societal functions linked to gainful employment today might be fulfilled in the future. The further development of societal concepts of work should always take into account the goals and requirements of sustainable development. The following elements are essential for future models in an integrated view of digital change and the Transformation towards Sustainability:

1. *Gainful employment in a sustainable economic system:* The compatibility of newly emerging work and employment with environmental sustainability goals is key to successfully accomplishing the Transformation towards Sustainability. However, this aspect is largely neglected in the current debate on the employment effects of digital technological progress. Equally little attention is paid to the future viability of digitally enhanced business models against the background of the sustainable development goals. Accordingly, this question plays only a secondary role in the promotion of business start-ups (Trautwein et al., 2018). For example, structures and qualifications representing new obstacles to adaptation on the way to more sustainable societies are threatening to spread (Section 4.3). Instead of this, the jobs and business models created in the course of digital change should also follow the guiding principle that they support the creation of more sustainable economic systems ("There are no jobs on a dead planet": ILO, 2018). In terms of concrete implementation, this means that clear frameworks are needed that reconcile private-sector interests and drivers of digital change with sustainable development (Section 8.4.1). Here, more stringent taxation of environmental damage can also help to align environmental sustainability objectives with issues of the labour-market effects of digital change: it can create room to reduce (fiscal) burdens on labour relative to other factors of production and value creation and thus help curb strong automation trends (Korinek and Stiglitz, 2017; Acemoglu and Restrepo, 2018a).
2. *Decent and sustainable working environments:* Although some existing models of future working environments such as decent work, 'green jobs' (ILO,2018) or 'sustainable work' (UNDP, 2015) refer to environmental sustainability challenges,

Box 5.3.9-1

Recommendations for action on the arena 'Sustainable working environments of the future'

- *Reform of systems of taxes and levies:* A comprehensive reform of systems of taxes and levies is a core component of the task of sustainably designing the necessary double structural change – consisting of labour-substituting, digital progress and the Transformation towards Sustainability. The financial scope for action by the state and social systems must be maintained and possibly even expanded, so that structural change can be accompanied by socio-political measures and new tasks in public services can be fulfilled in the course of digitalization (Sections 5.3.5, 5.3.10). One aim of such a reform should also be to reduce the tax burden on earned income, thus reducing incentives for automation or labour substitution in view of labour's far-reaching societal functions. In addition to a reform of corporate taxation (Box 4.2.2-2), stringently and comprehensively using taxes and levies for the pricing of environmental damage creates financial leeway. It also helps integrate the protection of the natural life-support systems directly into private-sector decisions and research and development efforts.
- *Promote the societal establishment of an expanded understanding of work:* Financial incentives can provide stimuli for expanding the societally recognized understanding of work over time. The reform of systems of taxes and levies can include a stronger promotion of voluntary and social activities by taking them more into account when assessing taxes and levies. At least on a transitional basis, the state can also provide financial support for work that has hitherto been unpaid and thereby help ensure that areas of work that were previously unpaid, but important from a societal and sustainability point of view, are converted into paid employment. In addition to such financial stimuli, these activities can also promoted by lowering time constraints on people, for example by supporting a reduction in working hours and/or encouraging companies to give their employees time off. The creation of favourable framework conditions, for example for collaborative forms of economic activity, can also contribute to a change in the understanding of work (Section 5.2.2).
- *Secure and promote social standards in occupational health and safety:* The WBGU recommends an international initiative to develop and establish (minimum) standards of occupational health and safety and social security that are as global as possible. The initiative should follow on from the global dialogue process entitled 'The Future of Work We Want' of the International Labour Organization (ILO, 2017) and address new topics such as the possibilities of workplace surveillance, the safety and health of employees in times of the technologization of humans, and enhance an understanding of 'decent work' (ILO, 2018:9) in the Digital Age. National approaches and regulations that oblige companies to comply with national minimum standards when outsourcing or relocating work from employees to quasi-self-employed people should be strengthened. A stronger organization of employees engaged in such quasi-self-employed jobs, for example in the sense of a trade union representation that strengthens their bargaining power, could be specifically supported for this purpose.
- *Enable participation:* Structural changes through decarbonization and, where foreseeable, digitalization should be disclosed as early as possible. Such openness can help to reduce uncertainty and resulting fears about the future and creates the necessary conditions for involving those affected, both positively and negatively, in the development of new economic and societal prospects for the future. In this way, alternative, sustainable development models can be negotiated and new regional identities created, for example for regions particularly affected by decarbonization and digitalization (WBGU, 2018b).
- Education: Awakening a lifelong interest in and openness to new ideas and independent motivation is an important prerequisite for ensuring that people are not overtaxed by processes of societal and technical change, that they use their freedom to shape their lives in a more self-determined way, and that they can experience a meaning to life today even without similarly far-reaching and fixed structures of gainful employment and labour markets. New educational content and formats must be developed for this purpose (Section 5.3.4; Harari, 2017; Trajtenberg, soon to be published). The possibilities for continuing vocational training should also be expanded and institutionally embedded more strongly (ILO, 2019). This applies not only in the shorter term with a view to the generations active in the labour market today, but also in the longer term in view of the very-likely rising dynamics of technical progress and societal change (Section 3.4.5).

many have been developed without explicit reference to digitalization. New forms and conditions of work through digital technologies represent essential topic areas relating to the quality and definition of decent work. They offer considerable opportunities to shape more sustainable work, as illustrated, for example, by the question of time sovereignty as an important feature of work quality and a prerequisite for reducing gender disparities (ILO, 2019). New forms and possibilities for more independent or less location-based work through digitalization can undoubtedly strengthen these opportunities, but they must not be at the expense of social security, for example (Section 5.3.8; World Bank, 2016; Hodgson, 2016). However, digital technologies can also expand the possibilities for monitoring at the workplace. Some companies are already tracking computer work steps and implanting microchips into employees (Astor, 2017; Anthes, 2017). This raises new questions and challenges for the safety and health of employees in times of comprehensive monitoring possibilities and the possible 'technologization of human beings' (Topic box 5.3-2).

3. *Extended understandings of the meaning of work:* Experiencing self-efficacy and meaning in life via work and jobs usually also depends on whether and

Box 5.3.9-2

Recommendations for research on the arena 'Sustainable working environments of the future'

- *Jointly examine the impact of digital change and the Transformation towards Sustainability on the labour markets* Existing research projects on the Transformation towards Sustainability and related processes of structural change should add labour-substituting digital progress to their research agenda. Projects on the effects of digitalization on the labour market should also focus on the Transformation towards Sustainability and the associated processes of structural change. In addition, regional forecast maps could be produced in developed economies to assess the changes in employment relationships as a result of these transformation processes; this information could help develop (regional) structural programmes with a more precise 'fit'. In Germany, for example, the BMWi and BMAS could set up a corresponding project together with social- and labour-policy research institutes such as the Institute for Labour Market and Occupational Research of the Federal Employment Agency.
- *Develop and experimentally test new distribution mechanisms:* New concepts of redistribution and participation should be developed at an early stage and examined in feasibility studies. Initial insights on the societal consequences of forms of participation such as corporate holdings, an unconditional basic income, or payouts from future funds could be gained in experiments with a limited number of participants and time horizon. The following questions in particular should also be addressed: (1) whether, and under what conditions, different redistribution mechanisms allow people to experience self-esteem and a meaning in life, (2) whether, how and over what time periods a widely accepted societal change could be implemented, and (3) whether there are consequences for the stability and functioning of democratic societies (Cowen, 2019). Finally, in addition to experiments, systemic, comprehensive analyses of concepts for financing such distribution mechanisms are required which also take into account the need for a reform of tax systems as a whole and the consequences for the financing of the state and social security systems.
- *Develop new models for sustainable work in the future:* In the WBGU's view, different scientific disciplines should be involved in researching the guiding principles for societies that guarantee sustainable work in the future. The digitally enhanced transformation to a sustainable economic system is a key starting point for a corresponding guiding principle. Newly emerging jobs and activities, as well as new business models and corporate forms, should be compatible with environmental objectives so as not to create new adaptation barriers and path dependencies. Furthermore, existing models such as decent work, 'green jobs' or sustainable work should be further developed to meet new challenges arising from digital technologies, e.g. by increasing monitoring possibilities at the workplace and by safeguarding new forms of self-employment. A third key element in developing future concepts of sustainable working environments is the societal understanding of what work is. From today's point of view, an extension of the current understanding of work seems sensible and necessary. On the one hand, it can serve societal goals of sustainable development. On the other, however, it is also a prerequisite that special, essentially human activities and abilities that can scarcely be automated are given the societal recognition and status that is necessary for a feeling of self-efficacy. How such a societal (value) change can be initiated and actively promoted, however, still appears to be largely an open question, so that the need for research is correspondingly high.
- *Expand our understanding of the implications of digital technological progress for work and income distribution:* There is still a considerable need for both theoretical and empirical research in order to systemically and profoundly understand the effects of digital technological progress on work and income distribution. Especially in the long term, when thinking about the implications of AI, very far-reaching research questions arise: Which factors (e.g. land, energy, capital) are still economically relevant in extreme scenarios of highly automated production and highly developed AI? According to which rules should ownership of these factors be distributed? Is there rivalry and competition for the use of factors between humans and intelligent technical systems, and if so, how can human access be ensured and the (natural) life-support systems thus sustained?

how society recognizes and values the contributions that all individuals make within their work efforts. Especially with intelligent machines taking over more and more tasks and jobs in currently highly respected areas of human work, societal discussion about future concepts of work should also include the underlying understanding of the meaning of work. Taking into account the goals of sustainable development, the main issue here is recognizing and raising the status of work activities that contribute to sustaining natural life-support systems or to social cohesion by promoting *Eigenart* and societal inclusion. Today too, these activities include voluntary activities, political or social work, and generally activities that are often not organized via regular labour markets and are therefore often less visible in society. With creative thinking and empathic action, many of these activities are characterized by abilities that make them difficult to automate (Section 5.3.3.1). Financial support or more time sovereignty in gainful employment relationships can be first steps to raising the societal status of such activities. In the past, the understanding of the meaning of work has been successfully broadened by, for example, making the typical features of female life contexts visible, so that jobs traditionally carried out by women (e.g. housework, raising children, caring for those in need of help) were recognized and received a higher societal status than before.

5.3.9.5 Conclusions

Without doubt, labour markets are being profoundly transformed by digitalization and the Transformation towards Sustainability. The broad impact and speed of digital technological progress and the new quality of automation represent a special feature in any historical comparison. However, in the foreseeable future the WBGU does not expect digitalization to herald the end of work and employment, as some have imagined as either a utopia or a dystopia. People will continue to work in the future, but it remains to be seen how these work efforts can be embedded into society and organized in such a way that the functions of gainful employment as we know them today – securing a livelihood, societal inclusion, the basis of self-esteem – can be guaranteed in the future. To this end, structural change in labour markets should be accompanied by measures of social and educational policy. New distribution mechanisms that ensure adequate economic inclusion, preserve incentives for individual participation, and are accepted by society should be developed and experimentally tested. Digital change and the Transformation towards Sustainability offer opportunities to develop and establish new models for more sustainable working environments.

5.3.10 Digital commons

In the Digital Age, an enormous increase is taking place both in digitized data (Section 3.3.2) and in information and knowledge goods based on them. These can be used in whole or in part for the common good to strengthen social cohesion and boost societal and economic innovation. The WBGU describes such goods as digital commons. They can be produced or maintained either directly or as by-products (like the online encyclopaedia Wikipedia, Open Street Map, Open Sea Map or the data and applications related to WheelMap), but they can also come from other sources, such as the public sector. Clear concepts and fundamental organizational, regulatory and financial decisions must be taken for their realization and preservation – to ensure that these valuable goods are accessible for common-good-oriented uses and to protect them from misuse.

5.3.10.1 Digital commons as a key instrument for the digital common good

The traditional term 'commons' is not a technical term in the narrower sense of the word; it is more general and refers to a multitude of non-private goods that are used by a group (whose size can vary considerably from local to global) and are susceptible to different social dilemmas such as overuse, supply shortages, containment or exclusion. The term is often used and the subject of very lively discussion in academic, political and civil-society discourses, although in very different manifestations (Dorsch and Flachsland, 2019).

In the WBGU's understanding, unlike classic natural commons, digital commons share the characteristics of 'social commons' (Heller, 2012) such as knowledge, language or the internet, which in principle are non-rival, i.e. they are not reduced or consumed by use. However, social dilemmas frequently arise in everyday life, for example through exclusion, privatization or underuse. The WBGU therefore defines digital commons in a normative way as all digitized data, information and knowledge goods which are non-rival resources for the common good and should be made accessible to the public as widely as possible and be provided technically via public-sector ICT (Section 5.3.5). Examples of digital commons include free education in the sense of open education and Open Educational Resources (OERs; Section 5.3.10.2), freely accessible knowledge via open access (Section 5.3.10.3), freely accessible data and facts via open data (Section 5.3.10.4), and the digitized cultural and natural heritage (Section 5.3.10.5). Digital spaces open up new possibilities for these common goods in terms of broader, non-rival availability.

Each of these types of digital commons are digital instruments for understanding our natural life-support systems and societal conditions, and for an informed and mature society. They are sources of education, open discourse and participation and make an original contribution to strengthening participation and dignity as well as an implicit contribution to sustaining the natural life-support systems. Based on them, the digital divide can be reduced, diverse skills can be strengthened, and offers oriented towards specific needs can be created, e.g. for open innovation and civil science (Section 10.2.4.1) or for needy social groups. In this way, digital commons can strengthen *Eigenart*. Creative Commons licenses (CCDE, 2019) have for some time offered a broad and frequently used portfolio of options for the regulated provision of digital commons through a flexible licensing model for open and free offers. The Equitable Licensing Model (Box 5.3.10-1) is also widespread in the USA and the UK – describing a socially acceptable form of patent exploitation, which is used particularly in publicly funded medical research (Godt et al., 2019).

5.3.10.2
Open education

The aim of open education is to "make education and educational materials freely available. In the narrower sense it is often related to knowledge transfer via the internet, which is based on the one hand on free learning materials, and on the other hand on generally accessible learning platforms" ([do:index], undated).

Open materials for learning and education, also known as Open Educational Resources (OERs), have many definitions with different emphases regarding the breadth of the target group, the formats (digitized or other materials), and conditions of use with regard to the payment of usage costs (Dobusch et al., undated: 5f.). Following UNESCO's definition, the term OERs is used here to refer to educational materials that can be available in the form of different media (e.g. books, courses) and are made available in the public domain or under an open licence. This means that they are accessible and usable free of charge with no, or only minor, restrictions and can be modified and distributed by the users (Neumann and Muuss-Merholz, 2017: 11). OERs are not in competition with educational institutions, but should rather be seen as a supplement to conventional educational offers made by schools and other educational institutions (Section 5.3.4).

OERs are seen as having the potential to increase educational equity by improving knowledge sharing, capacity building and access to quality education (Neumann and Muuss-Merholz, 2017: 11). For example, the exchange of materials among teachers across institutional and national borders and the preparation of school lessons, seminars, etc. could be facilitated in this way (Arbeitsgruppe zu Open Educational Resources, 2015: 4). In addition, OERs offer the possibility of accessing teaching materials independent of time and place and hold potential for informal learning outside educational institutions such as schools and universities (Arbeitsgruppe zu Open Educational Resources, 2015: 4). Furthermore, OERs allow the promotion of individualized teaching and learning processes because teaching content can be more easily adapted to specific learning needs and contexts (Arbeitsgruppe zu Open Educational Resources, 2015: 2; Metze-Mangold, 2017: 9). They are also seen as having the potential to improve the cost efficiency and quality of teaching and learning outcomes (UNESCO, 2012b), because free teaching and learning materials could reduce costs for educational institutions, students and especially for disadvantaged groups (European Commission, 2014). Overall, therefore, free education can have a positive impact on achieving SDG 4, which aims to ensure inclusive, equitable and quality education by 2030 and to promote lifelong learning opportunities for all (Orr et al., 2018: 12).

On the other hand, there is the risk that the materials provided might be of poor quality (Falconer et al., 2013: 39), even though there is in principle a chance that these will be continuously further developed by users and their quality improved (Metze-Mangold, 2017: 9). Where the creation and further-processing processes are non-transparent, there is a risk that OERs may contain content errors or tendentious statements. It is therefore necessary to sensitize teachers and learners to a critical approach to these educational materials (Arbeitsgruppe zu Open Educational Resources, 2015: 4). In addition, implementation involves the risk of potential copyright infringements (Neumann and Muuss-Merholz, 2017: 17). Another problem is that OERs are unlikely to break the dominance of large publishers. With regard to Germany, it is assumed that the use of OERs at least in Germany will not contribute to reducing the costs of teaching and learning materials (Arbeitsgruppe zu Open Educational Resources, 2015). In Germany small and medium-sized enterprises (SMEs) or spin-offs would seem most likely to create and disseminate OERs, but large publishing companies could also take on this task (Arbeitsgruppe zu Open Educational Resources, 2015). New business models that are adapted by large companies as part of their strategy are problematic here – this has already happened, for example, in the context of open-source software and open access (Section 10.2.4.1). The same is also conceivable in the case of OERs with regard to quality generation and assurance by established publishers in the school and further-education sector (Arbeitsgruppe zu Open Educational Resources, 2015: 7). In implementation, it is important to ensure that OERs maintain or increase the diversity of teaching and counteract the dominance of individual actors and institutions. In order to be able to use the advantages of OERs, the users need media skills as well as skills of independent learning, which must be trained accordingly (Section 5.3.2).

5.3.10.3
Free knowledge

Although open access is already firmly embedded in scientific practice, both its definition and its concrete implementation remain the subject of intensive debates on the openness of science (Open Science; Section 10.3.1). In the first implementations, open access refers to scientific publications and generally remains distinct from open access to data in the general research context in the sense of open data (Sitek and Bertelmann, 2014). One exception is the still rarely used supplement Open

Box 5.3.10-1

Licensing models

The Creative Commons licence

Creative Commons (CC) is a non-profit organization founded in 2001 that has developed standards-based licence agreements enabling creators to make their works available for use by others to varying degrees. CC has developed a total of six standard licensing agreements that enable authors to determine what may or may not be done with their works (CCDE, 2019):

- Attribution 4.0 International,
- Attribution – ShareAlike 4.0 International (distribution on the same terms),
- Attribution – NoDerivs 4.0 International,
- Attribution – NonCommercial 4.0 International,
- Attribution – NonCommercial – Share Alike 4.0 International (distribution on the same terms),
- Attribution – NonCommercial – NoDerivs 4.0 International.

CC licences allow content to become "part of the growing and living commons" through the ability to share content (CCDE, 2019).

The model of equitable licences

Equitable licensing refers to a socially acceptable licensing model in which the results of publicly funded research are not patented, so that poorer countries in particular have easier access to research results (Ferretti et al., 2016). The model has its origins in the USA, where it was developed in 2001 in the course of the debate about access of poor sections of the population in Africa to medicines for treating HIV (Godt et al., 2019). In the meantime, there are various forms of these equitable licences, "which either impose direct supply obligations on the licensee or, by waiving patent enforcement in certain countries, indirectly make a domestic, inexpensive production of drugs possible" (Godt et al., 2019: 1). While the model is already increasingly being used in the Anglo-American region, it is not yet widely used in Germany (Ferretti et al., 2016). The Universities Allied for Essential Medicines network, founded in response to the debate on access to HIV drugs, advocates the use of this licensing model in publicly funded research worldwide. Equitable licensing makes the societal responsibility of publicly funded research clear (Ferretti et al., 2016) and is regarded as "a pragmatic example of the implementation of public demands on research as commons" (Godt et al., 2019: 3).

Access to Data (Klump, 2012) for the underlying research data. At the same time, however, there is also a broader understanding: while UNESCO (undated) emphasizes free access to scientific information and the unrestricted use of electronic data for all, knowledge is 'open' according to the the 'Open Definition 2.1' of the Open Knowledge Foundation (undated) when it is freely accessible, usable, modifiable and shareable. In this case, open access to knowledge explicitly aims at the possibility of downloading complete works free of charge, stating the necessary information about the licence and the author. Such a broad definition therefore includes not only research results, but also raw and metadata, other source materials and digital representations in the form of images, graphics or multimedia material, and thus potentially also affects other components of the discourse on open science, such as open methodology to ensure the traceability of data analyses carried out (Section 10.3.1).

The main potential lies in a greater visibility of research results, better knowledge transfer, increased research efficiency and promotion of good scientific practice, as well as potential opportunities for cooperation and new ways of working and financing; more efficiency, faster scientific progress, and a strengthening of citizen science are also frequently mentioned (Fecher and Friesike, 2014). In addition to better and faster dissemination of scientific information (Max Planck Society, 2003), open access also emerged against the background of rising costs in scientific publishing (Swissuniversities, undated) and the dominance of profit-oriented publishers. With the help of open access, the dissemination of knowledge should no longer be restricted by high costs or copyright. Whether this has been achieved or whether publishing monopolies have even been strengthened by open access (Hagner, 2018) is disputed, but the criticism is not directed at the concept as such, but at its implementation in the scientific field to date. In the WBGU's view, publicly financed research results should generally be understood (in the sense of open access) as commons that are accessible to all and usable without restriction. The extent to which the further implementation of open access will do justice to this ideal is currently still open and can therefore be shaped politically. Ultimately, even in a global context, what remains decisive at the end of the day is what knowledge is available to whom via what path. An example of a particularly successful international free knowledge infrastructure that has digitally democratized knowledge and made it available is the online encyclopaedia Wikipedia. This has also helped to overcome linguistic barriers, although there is still room for improvement in the multilingual aspect. Beyond questions of linguistic boundaries and opportunities, such as automated translation proposals via AI, challenges for free access to knowledge include both over- and under-use as well as the quality management of content in corresponding repositories.

5.3.10.4 Open data

Not only open science and its potential for interaction with society depend on open access to knowledge. Open data, a term that is similarly not clearly defined, at its core stands for freely accessible data via the

Box 5.3.10-2

The digitized cultural heritage Europeana

The Europeana Collections by its own account grants users access to more than 50 million objects (books, music, works of art, etc.) in digitized form (Europeana, 2019b). The aim is to make it easier for people to access European cultural assets for different purposes. Through its work, Europeana wants to contribute to an "open, informed and creative society" (Europeana, 2019b). The Europeana prototype was launched in 2008 (and has been in regular operation since 2010); it made 4.5 million digital objects accessible at that time. In addition to libraries, museums, archives and galleries are involved in Europeana and have created a common access point to European cultural heritage (Europeana, 2019a).

internet and their unrestricted use. Open data thus offer broad opportunities for specific applications in the sense of the common good. Examples include platforms providing open data – e.g. on the voting behaviour of politicians, statistics, transport, environmental and geodata, scientific publications or radio and television programmes. This not only makes better infrastructure management possible, but also facilitates exchange between citizens and authorities, as well as data deliveries within the framework of citizen science – up to jointly created, freely available digital cartography (Hagendorff, 2016b: 127ff.).

Knowledge that is particularly relevant for the general public, e.g. that is made available by public administration (e.g. open government data) or private companies, requires practicable solutions and incentive structures. As in science, open data without methodological documentation on collection, cleansing, maintenance and analysis cannot be used meaningfully. Therefore, the current state of research on reproducibility of results by open data and methodology (Hampson, 2017) should also be taken into account by repositories for open (government) data.

Also in the sense of inclusion, the efficient dissemination of knowledge and data in the exchange between society and science ultimately depends on the extent to which new collaborative approaches to open science are applied not only there, but also in society. From an economic perspective, the German Federal Network Agency (Bundesnetzagentur, 2018: 7) has pointed out not only the great importance of data as a competition and value-creation factor in network sectors and for the digital network economy, but also the multifacetedness and complexity of data-related issues. The main challenge for an appropriate balance of interests between different market players is the development of clear, innovation-friendly and data-protection-compliant regulations. With regard to conflicting objectives, e.g. between exploitation interests and consumer protection, according to the Federal Network Agency comprehensive, continuous and proactive market observation and also reporting obligations for companies are crucial for a well-founded situation assessment (Bundesnetzagentur, 2018: 7).

5.3.10.5
Digitized cultural and natural heritage

According to UNESCO, cultural heritage includes monuments, groups of buildings and sites of exceptional universal value (UNESCO, 1972). Digitized cultural heritage is created by the digitization of these physical cultural assets (artefacts, objects) and the information about them (e.g. data on cultural assets, digital texts, image sources or reconstructions of buildings and their history). A large part of the research carried out in the field of digital humanities is already contributing to digital heritage. Examples include digital editions of the writings of classical authors or 3D scans of ancient works of art (Kornwachs, 2016; Sahle, 2013).

According to UNESCO, natural heritage includes "natural features consisting of physical and biological formations or groups of such formations", geological and physiographic formations that are habitats for endangered plant and animal species, as well as natural sites (UNESCO, 1972: Art. 2). For aesthetic or scientific reasons, or for reasons of nature conservation, all are considered to have exceptional universal value (UNESCO, 1972). Digitized natural heritage is the digitally recorded physical natural heritage, e.g. data sets on plants, animals, minerals, nature reserves or fossil sites.

Since cultural and natural heritage belongs to the foundation of our lives and our quality of life, it is important to preserve it for future generations (DBU, undated). This is becoming increasingly important, for example, in the face of rising sea levels (e.g. the imminent demise of island states such as Kiribati, including its world cultural heritage), the progressive destruction of nature (e.g. logging in rainforests) or in the wake of armed conflicts and terrorism (e.g. cultural vandalism). The digitization of the cultural and natural heritage serves to secure and provide broad access to natural and cultural content for people across countries and generations over the long term (Section 5.2.11), but should not be a substitute for committed measures to protect the physical cultural and natural heritage. In this way, cultural and natural heritage, as well as previously protected knowledge (reserved for experts only) from galleries, libraries, archives and museums, can be

Box 5.3.10-3

Recommendations for action on the arena 'Digital commons'

A wide range of organizational, regulatory and financial decisions are necessary in order to further expand the valuable digital commons, make them accessible to all, and protect their availability:

- The importance of digital commons in a digitalized sustainability society and the need to provide and secure them should be placed on the political agenda both nationally and internationally. They must be secured both organizationally and legally.
- Inclusive and equitable access to digital common goods should be ensured. This includes making them available in open, accessible formats, and developing or improving tools and environments that help make digital commons easier to find and access, e.g. by adopting international metadata standards.
- Measures should be taken to ensure the quality of digital commons, e.g. the introduction of seals of quality and the systematic involvement of users ('collaborative processes') in further developing and maintaining digital commons, such as free educational resources (Arbeitsgruppe zu Open Educational Resources, 2015: 5; UNESCO, 2017a: 4, 8f.).
- It is also important to train and motivate interested people to participate in the production and dissemination of high-quality digital common goods, taking into account local needs and the diversity of potential addressees, for example with regard to knowledge and educational resources. Broad participation in the creation and development of digital commons should be encouraged. For example, the public sector could hold competitions or promote flagship projects.
- In addition, it is key to work towards improving legal certainty in licensing with regard to the creation, storage, distribution, duplication and alteration of digital commons. Furthermore, review procedures should be developed to ensure that availability and changes are allowed with respect to copyright and personality rights (Arbeitsgruppe zu Open Educational Resources, 2015: 6).
- In addition, politicians, society and computer scientists should be made aware of the 'transience' of knowledge and the digitized cultural and natural heritage in order to initiate measures to conserve it (Królikowski, 2014: 2).
- The development of digital infrastructures and public-sector ICTs (Section 5.3.5) should already be accompanied by efforts to promote digital commons and the technical possibilities for their use.

Box 5.3.10-4

Recommendations for research on the arena 'Digital commons'

On the one hand, research should focus on digital commons as an object of research to expand the methodological and technological foundation and, on the other hand, to examine the effects of digital commons on society, the economy and within the framework of the Great Transformation towards Sustainability in order to strengthen their positive impact:

- Digital commons should be taken into account in research on commons, especially with regard to the similarities to and differences from traditional commons and their implications.
- Existing standards for the publication of data and knowledge assets should be further developed with a view to the particularities of digital commons. In new, hitherto less digitized fields (e.g. areas of the natural and cultural heritage), it is also important to develop them and establish international standards in order to strengthen the interoperability of digital commons and their further use.
- In the UNESCO World Action Programme 'Education for Sustainable Development', digital commons should be increasingly integrated and new didactic formats researched.

made accessible to an almost unlimited number of interested people (Królikowski, 2014). Consequently, access to digitized cultural and natural heritage offers opportunities for the creation and exchange of knowledge worldwide (UNESCO, 2003). For example, the possibility of learning independently of place and time can improve the achievement of the UN's educational goals, e.g. using apps such as 'App – in the wild forest'. This app is a joint project of four German federal states, "a modern and effective medium in nature conservation communication intended to communicate the important topic of biological diversity in the natural old beech forests of Germany" (Kohlhammer, undated).

There is also the possibility of (remotely) exploring natural and cultural assets (Pieraccini et al., 2001: 64). For example, virtual walks can be taken through national parks, such as the Ordesa National Park in Spain (Aragón virtual, 2015); or historical sites can be experienced via virtual reality, e.g. using the KotinosVR application, which allows interested parties to discover the treasures of the Archaeological Museum of Ancient Olympia (Kotinos, 2016). Digitally experiencing the natural heritage can contribute to the creation or strengthening of a world environmental awareness (Section 5.3.1), which in turn could promote actions to preserve the Earth system and enable the development of a lifestyle based on solidarity (Section 5.3.1). Monitoring (Sections 3.3.5.1, 5.2.11) can also be used to record the condition of and changes in the natural and cultural heritage (e.g. monitoring cultural assets for damage due to atmospheric influences or cultural vandalism, or the digitalized monitoring of breeding birds). This data and information can be used to formulate strategies for protecting and conserving the cultural and natural heritage (Pieraccini et al., 2001: 64) or reconstruct the destroyed cultural heritage.

However, along with the many opportunities offered by a digitized natural and cultural heritage, there are also a number of challenges. First, experiencing physical artefacts is very different from seeing digital, virtually accessible artefacts, so it is important to ensure a combined offer of physical and digital libraries (Królikowski, 2014: 1f.). A core problem of purely digital cultural objects lies in their dependence on digital data carriers and formats and the resulting low levels of durability and accessibility (Królikowski, 2014: 1f.). Furthermore, the effort required for long-term archiving is considerable and this is associated with specific problems: from preservation, accessibility and minimizing information loss, to the modelling and standardization of software and archiving processes, to complex copyright issues (Królikowski, 2014: 3f.) or even a change in cultural heritage through content censorship. Another discussion involves the reliability of records and a lack of awareness of the importance of preserving and accessing digitized natural and cultural heritage. Digitized natural and cultural heritage can serve as an alternative to experiencing the physical natural and cultural heritage (Section 5.3.1). However, this does not mean that measures to protect and conserve the physical natural and cultural heritage to be preserved should be neglected.

5.4 Conclusions

All the 'arenas of digital change' were chosen because they have a direct reference to digitalization while at the same time being significant for the Great Transformation towards Sustainability. They provide a multifaceted impression of the way in which digitalization can be shaped in the service of the Transformation towards Sustainability. The analysis covers both central topics at the direct interface between digitalization and sustainability (e.g. monitoring of biological diversity, e-waste, circular economy) and areas in which simultaneous potential for digitalization and sustainability will become relevant in the near future (e.g. workplaces of the future, urban mobility). In addition, issues for the future are also presented which will only become relevant in the longer term, but will have repercussions for the environment and the Earth system, so that the societal discourse should begin now (e.g. technologization of human beings).

An important finding across several arenas is that the destruction of ecosystems and resource consumption as a result of growth and rebound effects have steadily increased (e.g. online commerce, e-waste), with digitalization appearing to be an accelerating and reinforcing factor. A trend reversal towards sustainability is urgently needed. For example, there is an acute need for action to move towards a digitally supported circular economy. The example of e-waste shows that not only the longevity and ease of repair of electrical appliances, but also problems in the extraction and use of raw materials, and the recycling and disposal of e-waste should be taken into account. Another example is precision agriculture, which offers opportunities for environment protection and sustainable land use, but has so far mainly benefited large-scale farming and monocultures.

Indeed, it often becomes clear that technological innovations do not generate sustainability 'by themselves', but that the positive potential of digitalization for the Transformation towards Sustainability can only be achieved in conjunction with institutional, normative and regulatory frameworks. For example, there are technological innovations in the health sector that are used for the benefit of humankind; on the other hand, developments have also become possible that can be used for human self-optimization with the help of technologies, making a normative and regulatory framework necessary. In online commerce, technological innovations have created many opportunities to increase efficiency, but a regulatory framework is needed to avoid negative social and environmental externalities or rebound effects. Scoring procedures are another example of how digital assistance can be used to provide incentives for more sustainable consumer behaviour; yet this can come at the expense of personal freedom and decision-making sovereignty. Alternatives to this are feedback systems, e.g. relating to one's own resource consumption by showing the ecological footprint. Here, too, it is clear that there is a growing need for research on societal norms and moral standards as well as normative frameworks.

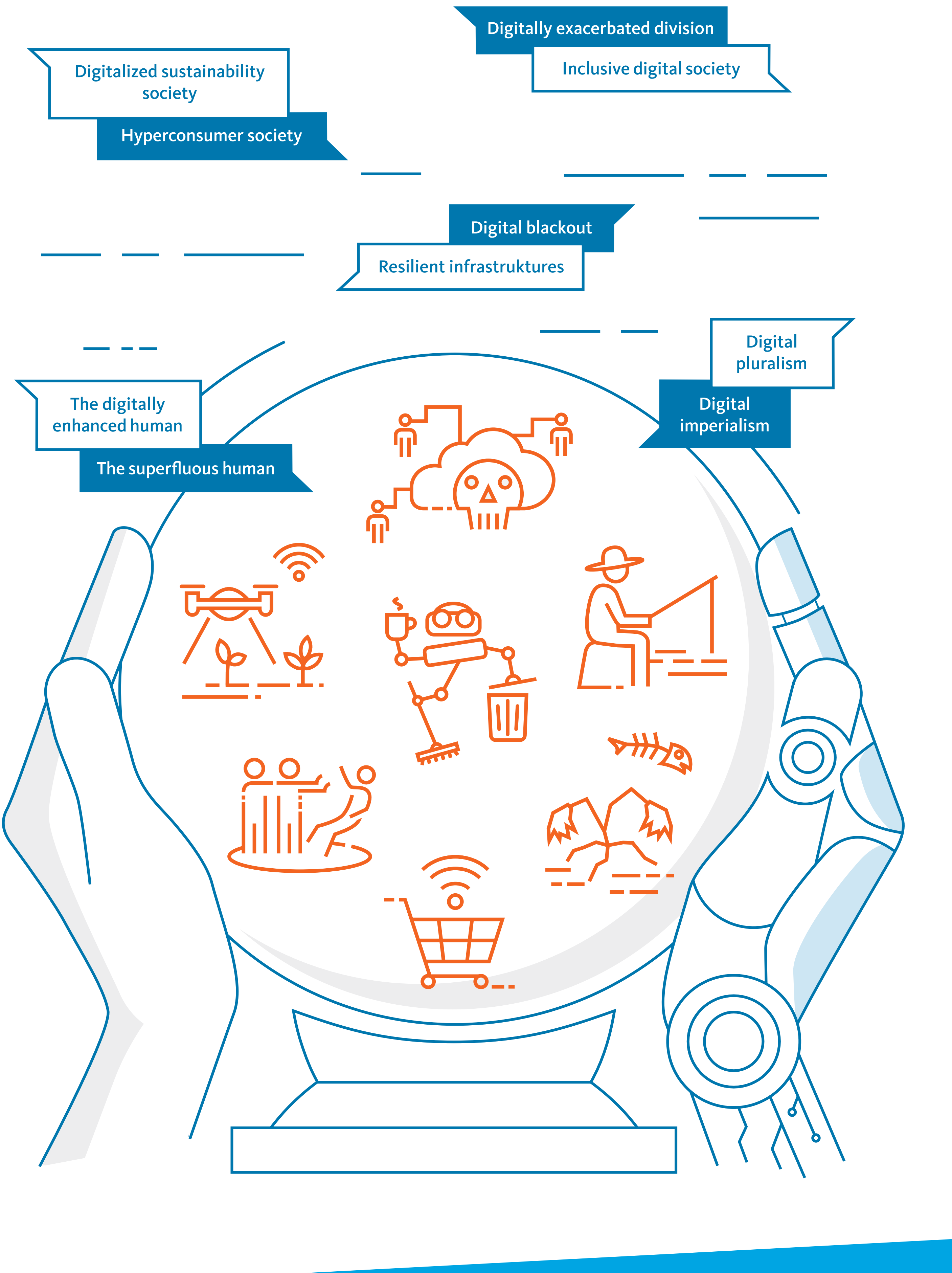
Structural shifts are to be expected on the international labour markets, and these can be accompanied by a reorganization of value chains, the relocation of production processes back to industrialized countries, and consequently to a shift in power between industrialized and developing countries. However, the flexibility of the labour markets is also being increased by online platforms and sharing economies – an aspect broached in the arenas on the new approaches to sustainable business and public discourse. Even with these new concepts and lifestyles, it remains to be seen how the implications for sustainability and the circular economy will be assessed. It is quite possible that we can currently only see the tip of the iceberg of a major process of change and structural shifts. Digitalization could even act as a catalyst for growth patterns that are already driving the overuse of natural resources and increasing social inequality in many countries, although the impact cannot yet be accurately assessed or grasped in its full dimensions (Second Dynamic; Section 7.3).

Data protection and data security are recurrent topics of key importance in the arenas. Significant deficiencies in this field have the potential to undermine fundamental and human rights. Protecting these rights is therefore one of the great cross-cutting challenges of the Digital Age. This aspect is of importance not only with regard to the digitalization of the healthcare system, which is the subject of the arena on the quantified self, but also, for example, in scoring or in precision agriculture. The privacy, personal freedom and self-determination of users can be either impaired by digitalization or strengthened, if regulated and normatively embedded in institutional frameworks. This is particularly evident in the context of the smart city, where many digital applications are concentrated and people find it difficult to escape digitalization, e.g. in the use of digitally assisted mobility.

There is also a need to consider a cross-section of issues that have received little attention up to now in the context of digitalization, such as education for sustainability, for which completely new funding opportunities are opening up in connection with digitalization, as well as the issues of gender and digital commons. All three topics are very closely linked to inequalities in access to digital services and to the future-proofing of a society. It becomes clear that existing gender inequalities are often manifested in technical systems, including the internet. In education, too, the promotion of digital and sustainability skills and the necessary infrastructures and services do not appear to be adequate. For example, the education sector also requires new initiatives in the conceptual combination of digitalization and sustainability. Furthermore, digital services must be developed that are oriented towards the common good and accessible to the general public.

On the one hand, the 'thematic deep drilling' of the arenas results in concrete material for the synthesis in Chapter 7, which represents the connection between digital change and the Transformation towards Sustainability in the form of three 'Dynamics of the Digital Age'. On the other hand, the arenas provide valuable material not only in terms of concrete recommendations for action and research, but also of overarching knowledge requirements and policy challenges, which are addressed in Chapters 9 and 10.

All in all, the arenas clearly show that the agendas of sustainability and digitalization, both in research and in politics, should be linked and further developed together. In this context, digitalization must be placed at the service of sustainability. This is the core message of the present report.


Digitally exacerbated division
Inclusive digital society
Digitalized sustainability society
Hyperconsumer society
Digital blackout
Resilient infrastruktures
Digital pluralism
Digital imperialism
The digitally enhanced human
The superfluous human

Blueprints of the Future and Visions on Digitalization and Sustainability 6

The future of society in the Digital Age has been predicted in many ways. The WBGU combines elements from scientific and popular-scientific sources with utopian and dystopian narratives that extrapolate and illustrate trends, thus making them tangible. Utopian and dystopian aspects are not always clear-cut, and their classification is subjective. However, the dystopian visions illustrate where there is a risk of certain borders being crossed; these should be contained at an early stage to avoid endangering sustainability goals.

When reflecting on future-proof forms of interaction between digitalization and sustainability, one should not overlook the visionary creativity with which technology forecasting, science vision and even science fiction have for years been attempting to anticipate the Digital Age. Taking the example of blurring borderlines between humans and machines, the Office for Technology Assessment at the German Bundestag, for instance, has found that the corresponding discourses can be very powerful and can shape real technology expectations (Kehl and Coenen, 2016). Such blueprints of the future take up diverse facets of digitalization and combine them with speculations that also relate to different areas of sustainability. Although the visionary sketches are often aimed at entertainment rather than the political shaping of a sustainable future, they also contain surprisingly ground-breaking messages. A study published by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) on whether, and in which areas, works of science fiction can guide action in real-life urban-development processes (BBSR, 2015) has shown that science-fiction literature can indeed come up with likely predictions for the future.

A systematic evaluation of science vision and forecasting literature cannot be carried out within the scope of this report. However, this chapter looks at some visionary, hypothetical and speculative drafts and assessments made by various scientists, journalists, entrepreneurs and people in public life on the societal effects of predicted technology development in the field of digitalization. The aim is to inspire and supplement thoughts on the best ways to shape a sustainable future.

Thus, this chapter does not outline the WBGU's own vision of the future, but brings together selected elements from different sources of science vision, (popular) scientific futurology and statements by individuals to form narratives that illustrate incipient, potentially medium- to longer-term change trends. Since these are not WBGU statements, they are presented in a different font. First, the WBGU presents a positively connotated narrative, i.e. utopian drafts on interaction between digitalization and sustainability (Section 6.1), then it looks at destructive and dystopian visions (Section 6.2). The quotations are interspersed as examples. It should be emphasized that the sources given do not always outline utopian or dystopian drafts of the future; some also take up current developments which either have dystopian potential or can be a source from which such potential can be derived. It should also be borne in mind that, when it comes to details, utopian and dystopian aspects are not always clearly distinguishable and classification is a matter of subjective assessment and cultural preferences.

Because of the disruptive, complex dynamics of digitalization, any consideration of its interaction with sustainability over several decades is dependent on such visionary drafts of the future. The WBGU uses them above all to flesh out the Second and Third

Dynamics of the Digital Age (Sections 7.3, 7.4). By contrast, the 'arenas' explored in detail in Chapter 5 on the basis of scientific studies and data primarily address the First and Second Dynamics (Sections 7.2, 7.3). Finally, after a tabular compilation of identifiable opportunities and risks (Section 6.3), conclusions are draw for the report's further line of argumentation and for the kind of formative action that needs to be taken (Section 6.4).

6.1 Utopian vision of a digitalized sustainability society

In this section, selected utopian ideas and aspects are presented and assembled into a multi-faceted picture of a fictitious future of the interaction between digitalization and sustainability. The interspersed quotations are examples of sources that mention the respective aspects, albeit possibly with differing assessments.

Digital utopia

In the digitalized sustainability society, sustaining the natural life-support systems is fully ensured and emissions of CO_2 and other greenhouse gases are reduced to the technically feasible minimum. 100% of energy is generated from renewable sources (Jacobson et al., 2017), smart grids and storage systems provide a reliable and affordable power supply for all. Motorized traffic and heating systems in buildings are electrified and emissions-free, the use of fossil fuels has been completely discontinued (Helm, 2017). In such a future, electricity could be 'too cheap to measure' once capacity is installed, and flat rates like those charged for the use of telephones or the internet could be made available.

“Almost all of these new electricity generation technologies do not have an energy cost once they are built and installed. The energy they generate is free. [...] A zero-carbon world is close to a ‘zero marginal cost electricity generation’ one.” (Helm, 2017:7)

Dieter Robin Helm is an economist at the University of Oxford and the author of ‘Burn Out: The Endgame for Fossil Fuels’.

The extensive use of precision-farming technologies – which use sensors, geographic information systems and robots to monitor and optimally tend plants and animals, utilize fertilizers and water precisely, and replace pesticides with automated mechanical processing – saves resources, protects the environment and cuts costs (Eberl, 2016).

“More and more robots will be working independently in the fields of the future – controlled by digital maps, satellites and weather forecasts, as well as by sensors with which they can detect weeds and measure temperature and humidity. They will fertilize the soil, sow seeds and apply pesticides precisely within a centimetre of where they are needed, and gather the harvest. Autonomous drones will then circle above them to check the condition of the fields, detect fungal infestation or damage caused by game, and prevent crop failures.” (Eberl, 2016:181).

Ulrich Eberl is a science and technology journalist and the author of ‘Smart Machines. How artificial intelligence is changing our lives’.

The digitally optimized combination of intelligent product design, reparability and automated deconstruction at the end of a product's life significantly reduces the demand for new raw materials. It allows a circular economy according to global standards and on a global scale (EMF, 2016). Distributed-ledger technologies (blockchain) provide proof of origin, improve product traceability and contribute to consumer confidence.

As people have become comprehensively interconnected via the internet and communication platforms – i.e. with unlimited possibilities for their communication and collective initiative and no restrictions of time and space – a global awareness of each person's responsibility for overarching sustainability issues has developed among the individuals of the digital society (e.g. an awareness of the effects of individual consumption on nature and the environment; Weng et al., 2018). Global commons, which are indispensable for sustaining the natural life-support systems and for the continued existence of humanity in peaceful coexistence, are placed under protection by united efforts.

"Soon all the people on our planet will be connected. If another five billion people populate the virtual world in the near future, in the physical world this boom will mean, among other things, increases in production, health, education, quality of life for everyone, from elite users to people at the bottom end of the economic scale." (Schmidt and Cohen, 2013:27)

Eric Schmidt is a technical consultant at Google. He was CEO of Google from 2001 to 2011 and CEO of Alphabet, Google's parent company, until 2018. Jared Cohen is founder and director of Jigsaw, a technology incubator at Alphabet.

The Internet of Things makes it possible to bring the marginal costs of production close to zero, creating a world of global commons in which people in open democratic societies work together voluntarily and not for profit (Rifkin, 2014). The digital society is inclusive across all social classes and living environments; everyone has access to essential goods, poverty has been largely overcome, and inclusive development has become a reality. Basic human needs are secured, the communitization of property and profits through digitalization enables a guaranteed minimum income ('social wage') for all people, as well as universal access to adequate housing, education and healthcare (Merchant, 2015). A general, reliable supply of high-quality and sustainably produced food has been achieved (Wahlen et al., 2012). Billions of people have access to individual healthcare based on the use of digital technologies ('eHealth', GeSi, 2016).

"I am also guardedly hopeful that a near zero marginal cost society can take the human race from an economy of scarcity to an economy of sustainable abundance over the course of the first half of the twenty-first century." (Rifkin, 2014:644)

Jeremy Rifkin is the author of 'The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism'

Work and income have become largely decoupled in the digitalized sustainability society. Robots and other intelligent machines perform much of the physically demanding, dangerous or boring work. The inclusion of everyone in global prosperity is made possible through communitization (Merchant, 2015); extreme inequalities can be reduced. In general, digitalization fundamentally changes many economic practices by making market-related information widely and equally accessible to all actors in the spirit of pluralization. Because the relationship between (paid) work and leisure time is changing, the development of a 'post-work' society creates much greater scope for individual self-realization and activities for the common good. Work forms and business models are also experiencing a form of pluralization, with commons-based peer production and platform cooperatives on a digital basis helping to meet sustainable and individualized needs independent of income.

"AI will also lower the cost of many goods and services, effectively making everyone better off. Longer term, AI may be thought of as a radically different mechanism for wealth creation in which everyone should be entitled to a portion of the world's AI-produced treasures." (Stone et al., 2016)

Initiated in 2014, the 'One Hundred Year Study on Artificial Intelligence' is a long-term study on the field of AI and its effects on humans, their communities and society. The first report quoted from here appeared in 2016.

New high-quality companies, professions and jobs are being created for the development, mediation and operation of digitalized infrastructures and terminal devices in the sustainable digital society. Skills requirements and skills offered in combination with the necessary training and education opportunities can be tracked and taken up digitally and thus coordinated in a timely manner. Cooperative teleworking in cyberspace becomes an essential part of work, so locational ties are no longer a selection criterion for choosing a job, which considerably reduces commuting and occupational traffic. A cooperative division of labour applies between humans and machines (or collaborative robots, so-called cobots), in which each person takes on the job they do best (Schmidt and Cohen, 2013). In a smart society, however, no one is forced to do paid work.

"People of the free internet, we now have the opportunity to create a world where we choose to work a 4 hour work week at our whim, collaborating globally with whom we like, freely choosing compensation in currency or equity, frolicking in our hyper-creative and artistic, fractally self-organized fluid work groups, protected from catastrophic risk by a basic income provided by our egalitarian peer to peer protocols. In this vision the tragedy of the commons is stamped out like polio by a collaborative network of trust and enforced by a consensus-based cryptographic protocol that ensures our aligned incentivization towards the expression of our personal and collective purposes." (Thorp, quoted from Swartz, 2017:88)

Noah Thorp is co-founder of the blockchain startup Citizen Code.

Knowledge and educational resources are commons and openly and freely (except for marginal costs) accessible to all in digital (and analogue) formats. Digital platforms, access points, services and applications provide suitable information for everyone, anywhere, at any time and according to any preference, both in private and professional environments.

"It is really possible with the technology of today, not tomorrow. We can provide all the works of humankind to all the people of the world. It will be an achievement remembered for all time, like putting a man on the moon." (Kahle, quoted from Kelly, 2016:97)

Brewster Kahle is a computer scientist, entrepreneur and activist.

In a universal digitalized library, every book in the world is available to every human being in every language (Kelly, 2016: 97). In a society that is both smart and media-literate, education is communicated digitally and can be made accessible in an individualized and tailor-made way for every person. AI revolutionizes research and leads to new scientific breakthroughs (Alkhateeb, 2017).

"If you can use AI to read 400,000 research papers automatically, organize the knowledge and then combine your intuition with machine learning, you can sharpen the research field – instead of fanning out for a solution, you fan in. This is what I believe is going to be really game changing for research in the future." (Bekas, undated)

Costas Bekas is a cognitive solutions research manager at IBM.

The relationship between data management and individual data protection is balanced, and digital self-determination is guaranteed. People keep control of the data they release for further processing, and 'digital oblivion' is possible. An international digital charter, drawn up in a participatory manner by the entire global community, regulates the principles governing the handling of personal data, their economic exploitation and individual personal rights, perhaps as a further development of the Charter of Fundamental Digital Rights of the EU that has been proposed by a group of citizens (Zeit-Stiftung, 2018).

The digitalized sustainability society has reliable and resilient infrastructures (Francis and Bekera, 2014).

All functional areas of society, such as administration, mobility, energy, food and water supply, urban and rural infrastructures, transport and production facilities, healthcare and education, are digitally networked, coordinated, quality-controlled and protected against failure and attack. This applies not only to the urban agglomerations developed as 'smart cities', but also to a considerable extent to optimally equipped rural areas, the smart countryside.

“As cars will become better drivers than people, city-dwellers will own fewer cars, live further from work, and spend time differently, leading to an entirely new urban organization.” (Stone et al., 2016)

See above: ‘One Hundred Year Study on Artificial Intelligence’.

All individual transport based on fossil fuels has been successfully eliminated without in any way restricting the right of all citizens to mobility (Nikitas et al., 2017). Mobility as a Service (MaaS), which can be optimally adapted to individual demand using digitalization, has contributed to this and ensured that the population of both urban and rural areas can access all important basic existential functions in good time.

“A near perfect version of transport futures, based on such an integrated approach, therefore would be revolved around shared used CAVs [Connected Autonomous Vehicles] fuelled by electricity, produced solely from renewable energy sources, that will operate under MaaS principles, meaning that they should be accessible only as part of packages primarily offering electrified public transport from initiatives like BRT [Bus Rapid Transit] and Hyperloop.” (Nikitas et al., 2017:17)

Alexandros Nikitas and his co-authors conduct research on the topic of mobility.

Any economic or political concentration of power through data monopolies is resolutely prevented (West, 2017). Rather, digital pluralism is emerging. The digital flexibilization of the use of goods that are in limited supply also strengthens common-use scenarios in the sense of a sharing economy (Hamari et al., 2016).

The digitalized sustainability society follows the principle of open government. Democratic participation is fully guaranteed; all social groups can participate equally in decisions affecting the common good (Macintosh, 2004). Access to information and the possibility of political participation are facilitated and made ubiquitously available through the use of modern ICT (Mossberger et al., 2007).

“If we want to renew democracy in the coming decades, we need a sense of indignation, a sense of the loss of what is being taken from us. […] What is at stake here is people's expectation to be masters of their own lives and originators of their own experience. What is at stake here is the inner experience from which we form the will to want, and the public spaces in which we can act on it. What is at stake is the ruling principle of social order in an information civilization and our right as individuals and societies to find answers to the old questions: Who knows? Who decides? Who decides who decides? […] The digital future cannot be stopped, but people and their humanity should come first.” (Zuboff, 2018: 595f.)

Shoshana Zuboff is an economist and author of ‘The Age of Surveillance Capitalism’.

In the digitalized sustainability society, people are digitally empowered. Digital technologies, especially applications of AI and machine learning combined with genetic testing, promise great advances in personalized diagnostics and therapy (Stone et al., 2016; Fierz, 2004).

"If machine learning can help reveal relationships between genes, diseases and treatment responses, it could revolutionize personalized medicine, make farm animals healthier and enable more resilient crops. Moreover, robots have the potential to become more accurate and reliable surgeons than humans, even without advanced AI." (Tegmark, 2017:101).

Max Tegmark is Professor of Physics at MIT and President of the Future of Life Institute.

The digitalized sustainability society is peaceful. In a world where broadly available knowledge is the central source of prosperity, wars disappear (Harari, 2015). A life free from physical and psychological suffering and the possibility of dignified ageing are achieved by replacing or optimizing bodily functions (cyborg; Kurzweil, 2005). Humankind reaches a completely new stage of evolution (Harari, 2015) – Humanity 2.0 comes into being. 'Natural' evolution will be replaced in the future by a technological further development of human beings. The gradual substitution of the human body by technical systems becomes possible (Kurzweil, 2005) – even the transfer of the human mind to technological systems in the sense of the emulation of the brain. Such an 'upload' can theoretically live indefinitely and would have almost unlimited access to all digitally available or stored cognitive resources (Moravec, 1988).

„Although these ideas may sound like science fiction, they certainly don't violate any known laws of physics, so the most interesting question is not whether they can happen, but whether they will happen, and, if so, when. [...] I think of an upload as the extreme end of the cyborg spectrum, where the only remaining part of the human is the software." (Tegmark, 2017:154)

6.2 Dystopian vision on the risks of digitalization for sustainability

The utopian vision of the future is now contrasted with a highly dystopian vision, characterized by misguided and negative developments, one that could emerge in the distant future. Again, we include selected statements and quotations from the public debate and sources of science vision in an overall narrative, which this time emphasizes many different risks.

Digital dystopia

Contrary to hopes, increasing digitalization has not led to the development of a sustainable society or to dematerialization, but to the emergence of a hyperconsumer society in which people uninhibitedly pursue their desires for consumption at the expense of the natural environment (Wahnbaeck and Rolof, 2017:3).

"Clearly, the ICT has a potential to decouple economic growth from environmental degradation. However, without considering potential rebound effects of increased ICT consumption, the environmental implications can quickly become detrimental. The environmental impacts of ICT largely depend on how the ICT applications perform when human behaviour becomes a very important factor. The society should not be too optimistic about the positive role of ICT in economy without accounting ICT's environmental impacts." (Plepys, 2002:521)

Andrius Plepys is a researcher at the International Institute for Industrial Environmental Economics (IIIEE) at Lund University in Sweden. His research addresses strategies for sustainable consumption and sustainable lifestyles.

Not only does the sale of digital devices rise sharply with significant negative effects in the area of resource exploitation; the wide range of options for targeting individual people with customized advertising in all areas of consumption resulting from big data also considerably accelerates growth in demand. The explosion in online commerce has led to a further increase in transport costs and traffic congestion. In addition to increasing the level of consumption, the construction and operation of virtual and physical infrastructures require massive inputs of raw materials and energy (Lange and Santarius, 2018: 48). Resource consumption is also increasing as a result of rebound effects, as the potential of new digital technologies to reduce resource use is outweighed by their increased use. The deliberate shortening of the service lives of digital devices and the acceleration of innovation and product life cycles also contribute to the destruction of the natural life-support systems (Santarius, 2017).

In the hyperconsumer society, people are entirely disinterested in the natural living environment and its ongoing destruction. By extensively using virtual spaces, they live in illusory worlds and mentally distance themselves from their natural environment. Thus the planetary guardrails are flouted, resulting in the destruction of the natural life-support systems. Because the 2°C guardrail aimed at limiting climate change is exceeded, and CO_2 emissions from fossil sources are further increased, the global surface temperature and the acidification of the oceans are increasing drastically, resulting in the loss of biodiversity and ecosystem services in the oceans and on land. In addition, digitally enhanced agriculture intensifies land and soil overuse and degradation as well as the loss of phosphorus, regardless of the disastrous effects on food security and biomass production. In addition to CO_2 emissions, there are also sharp increases in emissions of other long-lasting pollutants (e.g. mercury and persistent organic pollutants). This has catastrophic effects on the natural life-support systems and endangers the health of large sections of humanity (WBGU, 2014b: 21). The planet is getting out of equilibrium, and collapse is imminent (Diamond, 2005).

As the natural life-support systems are destroyed, the material division of society grows, further exacerbated by the digital divide. Signs of poverty spread and intensify worldwide. There are famines and increasing migration of people who have lost their homes as a result of climate change and the destruction of the natural environment.

“The economy is having to face ever-greater disruptions in the work force because of A.I. And in the long run, no element of the job market will be 100 percent safe from A.I. and automation. People will need to continually reinvent themselves. This may take 50 years, but ultimately nothing is safe.” (Harari, 2018, cited in Kaufmann, 2018)

Yuval Noah Harari is Professor of History at the Hebrew University of Jerusalem and author of the international bestsellers ‘Sapiens: A Brief History of Humankind’ and ‘Homo Deus: A Brief History of Tomorrow’.

The division in society is also deepened by the robotization of the labour market (Kling, 2017: 142). Progressive digitalization threatens to end gainful employment with no compensation for lost incomes. As a result of this digitally enhanced divide, almost every job is threatened by rationalization and automation via digital technologies, even in occupations requiring a high level of skills (Andersen and Zinner Henriksen, 2018).

„Low-wage jobs are especially at risk: in its 2016 report to the president, the U.S. Council of Economic Advisers estimated that 83 percent of jobs paying less than $20 per hour could be automated.“ (McAfee und Brynjolfsson, 2016: 140)

Andrew McAfee and Erik Brynjolfsson are senior scientists of the MIT Initiative on the Digital Economy and authors of the bestseller ‘The Second Machine Age’.

Mass unemployment and economic inequality are growing in both industrialized and developing countries and in emerging economies, as fewer and fewer people benefit from the wealth created by new technologies

(Collins, 2014: 51, quoted from Dörre, 2016: 4; Nourbakhsh, 2015: 27). There is a gap between a limited number of highly qualified people and the majority of the population, who, for example, carry out routine activities, but also between industrialized and developing countries and emerging economies (Brynjolfsson and McAfee, 2014). The super-rich on the one hand, and mass unemployment and misery on the other, create the potential for massive unrest, violence or revolution.

“The privileged, we’ll see time and again, are processed more by people, the masses by machines.” (O’Neil, 2017)

Cathy O’Neil is a mathematician and the author of ‘Weapons of Math Destruction’.

The developing countries lose their comparative advantage in the availability of cheap labour because products are now produced fully automatically by digitally controlled production lines, and production is being relocated back to industrialized countries (Al-Ani, 2017; Deutscher Bundestag, 2017a: 6f.). This is especially problematic for developing countries because they hardly have any social security systems; it is therefore unclear how social transfer payments could be structured and financed (Al-Ani, 2017).

In the industrialized countries, by contrast, social security systems threaten to collapse under the burden of the large numbers of unemployed. The now growing inequality far eclipses the previously known socio-economic disparities (Nourbakhsh, 2015: 27). The majority of people worldwide live at the subsistence level. Only a small elite – e.g. the owners and managers of leading technology companies – benefit from the effects of digitalization on the world of work (Barwise and Watkins, 2018: 44ff.; Hilbig, 2017). Monopolies or oligopolies are formed by a handful of globally active IT corporations or IT-based corporations, leading to a concentration of capital (Deutscher Bundestag, 2017a: 6f.; Barwise and Watkins, 2018). These powerful digital corporations abuse digital possibilities in their own destructive interests. A form of digital imperialism emerges. The deep social division of society leads to dramatic conflicts, as well as national and regional unrest, and destabilizes entire regions (Hilbig, 2017).

“[W]ork’s value both for individuals and for communities goes well beyond its financial role. As Voltaire put it, ‘Work saves us from three great evils: boredom, vice, and need. But isn’t work itself becoming passé, thanks to automation?’” (McAfee and Brynjolfsson, 2016: 145)

As a result of the lack of work for the majority of the population due to mass unemployment, an ignorant, self-focused and bored society emerges. However, digital technologies not only take away all people's work, they are also used for population monitoring on a massive scale. In this digitalized surveillance state, every individual is spied on using digital technologies by organizations of all kinds – from state intelligence agencies to global private companies (Wolf, 2012; Lyon, 2003). Established freedoms and rights, such as the right to informational self-determination or the right to privacy, are a thing of the past in this post-privacy age (Bauman et al., 2014; Lynch, 2015).

“A child born today will grow up with no conception of privacy at all. They’ll never know what it means to have a private moment to themselves, an unrecorded, unanalyzed thought. And that’s a problem because privacy matters, privacy is what allows us to determine who we are and who we want to be.” (Snowden, 2013)

Edward Snowden is a former CIA employee who became known in 2013 through his revelations about the practices of the US intelligence services.

"No, the ‚targets' here are me and you: everyone, all of the time. In the name of ‚national security', the capacity is being built to identify, track and document any citizen constantly and continuously." (Wolf, 2012)

Naomi Wolf ist Schriftstellerin und politische Aktivistin.

This is made possible by the advanced development and dissemination of digitally upgraded surveillance technology. The use of technologies (e.g. drones) to capture movement profiles, recognize faces or other features makes it possible to identify each individual person in a public space. The omnipresent surveillance takes place not only in public, but also in the supposedly private sphere: the recording and evaluation of people's online surfing behaviour allows conclusions to be drawn about the thoughts of every user of an IT device (Helbing, 2018).

They are continuously monitored via smartphones and voice assistants. Smart televisions and game consoles monitor leisure-time behaviour, and fitness and health-data trackers collect every individual's most sensitive health data (Helbing, 2018).

"George Orwell's dystopian novel '1984', written in 1948 [...] was intended as a warning. But apparently it was used as an instruction manual: Google knows what we think, Amazon's Kindle Reader what we read; YouTube and the game console know what we look at; Siri and Alexa listen to our conversations; Apple and IBM measure our health; [...] Apps, cookies and browser extensions evaluate our internet activities. And our car is a data leech." (Helbing, 2018).

Dirk Helbing is Professor of Computational Social Science at the Department of Humanities, Social and Political Sciences and a member of the Department of Computer Science at the ETH Zurich.

Digital surveillance technologies are also used at the workplace, for example for monitoring and predicting the behaviour of all employees (Solon, 2017a; Ball, 2010). Compared to earlier practices, surveillance by the state and companies now takes on a new dimension because it takes place everywhere, incessantly, permanently collecting, linking and evaluating all recordable patterns – be they movement data, data on behaviour or ways of thinking – in both public and private spaces.

"Democracy and the internet are less and less compatible. Content censorship and mass surveillance of users are spreading in both totalitarian and democratic states; disinformation and propaganda are increasingly becoming effective antidemocratic instruments." (Gaycken, 2016)

Sandro Gaycken is the founder and director of the Institute for Digital Society at the ESMT Berlin.

In this totalitarian state, the knowledge acquired by mass surveillance is deliberately used to monitor, control and oppress the population. With the help of a social credit system, a data-based credit-rating system based on the Chinese model, citizens are assessed on the basis of their behaviour (e.g. in a work context), religion, ethnicity, diseases, DNA or the products they buy (Lee, 2018). Monitoring and assessment target a wide variety of activities such as payment behaviour, criminal records, shopping habits, lifestyles, moral conduct, social behaviour and political convictions. Depending on the conformity of personal behaviour with the values of the ruling regime, individuals are rewarded – or punished for non-compliant behaviour – for example when looking for accommodation, enrolling in schools, applying for social services, in work promotions, when asking for loans, taking out insurance or seeking employment (Kühnreich, 2017, quoted from Gruber, 2017; Helbing et al., 2015; Kling, 2017: 38f.). The aim of the keeping records is (external) control of all individual behaviour.

"If you draw the timelines, realistically by 2050 we would expect to be able to download your mind into a machine [...]." (Pearson, 2005)

Ian Pearson is futurologist.

Based on extensive knowledge of every person's individual preferences and behaviour patterns, the state and the companies collecting the data predict people's behaviour and exert deliberate influence on them in order to bring about behavioural changes in their own interest. In the private sector, the focus is on influencing purchasing behaviour, but also increasingly on exercising control over the population in competition with the totalitarian state. As a result, social scoring leads to enormous pressure on citizens to conform – controversial opinions are no longer voiced and divergent behaviour is avoided (Christl, 2014: 72). Diversity and freedom are lost.

"[T]he net stores everything. Nothing is ever lost, no piece of information however tiny, no e-mail, no online photo however embarrassing, no Twitter or Facebook entry, no booking request with a travel agency. Digital memories have deprived society of its ability to forget and given it a comprehensive memory instead: a memory that takes away our freedom, because each of our steps, every recorded thought becomes controllable." (Polke-Majewski, 2011)

Karsten Polke-Majewski is a journalist at ZEIT Online and head of the Investigative/Data team.

All a person's activities, be they entries in the criminal record, tax returns or activities in social networks, are digitally recorded and stored even after their death. Thus, every activity can be tracked forever. Forgetting is impossible, because the recordings are also stored decentrally on any computer, but cannot be changed by the person concerned. As a result, humans become digitally immortal.

"Throughout the entire history of humankind, throughout the entire analogue age, remembering was the exception and forgetting the rule. So we remembered the important things and forgot almost everything else. Today, remembering, storing has become the rule, and forgetting, deleting, has become the exception." (Mayer-Schönberger, 2014: 2)

Viktor Mayer-Schönberger is Professor of Internet Governance and Regulation at the Oxford Internet Institute.

The all-encompassing use of digital technologies also increases the vulnerability of vital infrastructures, which are increasingly being targeted by hackers in the new age of cyber wars.

"As technology continues to reshape the world, it's clear that conflicts between nations are no longer confined to the land, sea and air. A cyber arms race is underway with nations developing and unleashing a new generation of weapons aimed at governments and civilians alike, putting at risk the critical data and digital-powered infrastructure that we all depend on for our daily lives. [...] If we do not do more to address the risk of nation-state cyberattacks, the world will become a more dangerous place." (Smith, 2017)

Brad Smith is President and Chief Legal Officer of Microsoft.

An arms race has long-since begun with governments, secret services and the military instructing hackers to carry out cyber-attacks (Reissmann, 2012). Now there are armed conflicts all over the world, a cyber world war breaks out using digital technologies to immediately interrupt or control enemy resources, especially critical infrastructures. In addition to serious attacks on infrastructures and terminal devices, there is also disinformation and election influence (Kurz and Rieger, 2018a: 8) and other destabilizing cyber-actions. The militant aggressions emanate from states that declare war on each other, but also from non-state forces; it is often no longer possible to say clearly who started the aggression (Baur-Ahrens, 2016: 262; Reissmann, 2012; Kurz and Rieger, 2018a: 7f.). The cyber-attacks take place in different ways using different levels of violence. Automated weapons such as drones are also used.

In addition to the use of malware for espionage, sabotage, crippling or destroying the critical infrastructures of the opposing forces, cyber-attacks are also carried out in the form of spreading false reports (fake news). Disinformation is disseminated in social media, and new conflicts are stirred up to destabilize political systems (Baron, 2017: 37).

"The new, highly granular, centralized possibilities of targeted and completely invisible, uncontrolled manipulation are [...] a diabolical contortion of democratic opinion-forming. Democracy and its institutions must fight it. [...] Otherwise we will lose core elements of democracy to the invisible evil of this machine." (Gaycken, 2016)

In large parts of the world, critical infrastructures, such as the financial system, energy and water supply or transport, fail temporarily or permanently, and the economy and public life collapse (Hutter, 2002: 37f.). Digital blackouts occur again and again, paralysing infrastructures and information systems on a large scale. The result is the loss of civilizational knowledge, which is now only available in digital form. In contrast to 'analogue' warfare, cyber war is also characterized by cyber espionage, disinformation campaigns and strategic activities to achieve advantageous positions (Kurz and Rieger, 2018a: 7).

The use of unconventional weapon systems is not necessary because the war is waged with everyday components like computers, and anyone with a minimum of IT skills can become an attacker (Baur-Ahrens, 2016: 263). Since every person potentially poses a danger, there is widespread mistrust in society. Once put into operation, the weapons used can neither be deactivated nor their effects or functions controlled. Not only the military, but also the civilian population become victims (Baur-Ahrens, 2016: 264). The cyber attacks, for example on nuclear facilities, are on such a scale that, in addition to objects, people are also injured or even killed (e.g. by exposure to radiation; Baur-Ahrens, 2016: 263f.).

The cyber world war immerses society in digital chaos, where it is controlled not for the common good, but to serve the egoistic interests of various actors. In particular, multinational digital corporations and powerful nation states try with all their might to advance their own interests. The former multilateralism practised in international institutions such as the EU and the UN comes to an abrupt end.

A transhuman era begins with ground-breaking technological developments. Digitally controlled human enhancement technologies allow socially privileged groups to optimize their bodily functions according to individual preferences or health needs (Miah, 2016; Nourbakhsh, 2015: 26). Only a limited number of people have the necessary financial resources and access to technologies to halt the ageing process, alleviate their physical ailments and enhance their mental and emotional capacities (Faber, 2012; Allhoff et al., 2010: 16ff.).

"The fundamental experience is that technical progress opens up possibilities for action which interfere with the natural life-support systems of our existence and sometimes entail the risk of attacking the essence of these very foundations, thus turning against the basis of technical progress itself." (Krieger, 2011)

Gerhard Krieger was Professor of Philosophy at the Faculty of Theology in Trier and president of the Medievalists' Society.

Human enhancement not only leads to a new dimension of inequality, but also entails fundamental risks to human existence.

"The concentration of power in the global pharmaceutical industry has already reached staggering proportions. The implications of a new market-driven eugenics are enormous and far reaching. Indeed, commercial eugenics could become the defining social dynamic of the new century." (Rifkin, 2005)

Jeremy Rifkin is an economic and social theorist, writer, speaker, political consultant and activist.

The self-optimization of humans continues to the extent that all bodily functions are replaced. Machines are created with abilities such as empathy, emotionality and the feeling of social connectedness, which were once purely human abilities. With the development of an AI with emotional awareness, the last 'competitive advantage' of the human being is lost.

"[I]t's my conclusion that it is possible to make a conscious computer with superhuman levels of intelligence before 2020 [...]. It would definitely have emotions – that's one of the primary reasons for doing it." (Pearson, 2005)

Technological advances, especially in the field of AI, gradually lead to the creation of a destructive robotic civilization and finally to the abolition of humans.

"I fear that AI may replace humans altogether [...]. If people design computer viruses, someone will design AI that improves and replicates itself. This will be a new form of life that outperforms humans. [...] A super intelligent AI will be extremely good at accomplishing its goals, and if those goals aren't aligned with ours, we're in trouble." (Hawking, 2017)

Stephen W. Hawking was a theoretical physicist and professor of mathematics at the University of Cambridge.

Social, highly intelligent machines are created that replicate themselves and constantly improve themselves until they are superior to humans in all areas and can no longer be controlled by them (Bostrom, 2014; Hawking, 2017; Nourbakhsh, 2015:27f.). Humans become the puppets of these autonomous, super-intelligent creatures, which develop their own urge to survive and ultimately threaten the existence of human life (Nourbakhsh, 2015:27f.; Barrat and Bostrom, 2014; Hawking, 2017). In their fight for survival, these almost almighty robots not only attack human targets, but also fight each other. The result is a war of the 'killer robots' in which the human species is finally exterminated (Schäfer, 2018).

"[T]he development of superintelligence will be associated with significant challenges, likely including novel security concerns, labor market dislocations, and inequality. It may even involve, in the form of accident or misuse, significant existential risk." (Bostrom et al., 2016:2)

Nick Bostrom is a philosopher at the University of Oxford and director of the Future of Humanity Institute.

6.3 Synopsis: Comparison of visionary future hopes and risks

The preceding sections have revealed selected utopian and dystopian developments of digital change from the perspective of sustainability. However, since there are in fact many more development options, the synoptic Table 6.3-1 gives a brief overview of utopian and dystopian development possibilities and relates them to the key issues for a digital, sustainable society that were published by the WBGU in 2018 (WBGU, 2018a).

6.4 Conclusions

What conclusions can be drawn from the above-outlined visions of the future that might boost present-day efforts to (a) support digitalization's constructive role in the global Transformation towards Sustainability that will take place in future decades, and (b) to avoid foreseeable undesirable developments? This section examines (1) the relationship between optimistic and pessimistic expectations, (2) essential fundamental driving forces behind the longer-term development dynamics of digital change, and (3) insights into indispensable requirements for shaping a sustainable society as the Digital Age advances. It reveals the need for long-term thinking and systemic foresight, a return to the basic consensus of human rights (with human dignity as its basis), and a general willingness to innovate and question technological developments.

Dystopian drafts of the future regarding the interplay of technical progress, natural life-support systems and socio-political developments are much more prominent than utopian visions. This is not surprising, since dystopian narratives, like negative scenarios in general, are easier to describe. As is generally the case for dystopian movies and novels, as well as the narratives of computer games, dystopian narratives are particularly successful and appealing when their main themes address people's 'primal or basic fears'. In psychology, fear is in principle considered to be an unpleasantly experienced inner state of terrible expectations that cannot be precisely predicted at the present time, i.e. are connected with the impression that future threats can be neither anticipated nor controlled (Butcher et al., 2009). Basic fears can be derived from basic needs, such as the motivation to socialize or the pursuit of recognition (e.g. Maslow, 1943; McClelland, 1991).

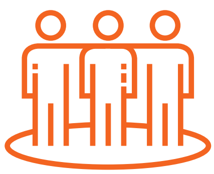
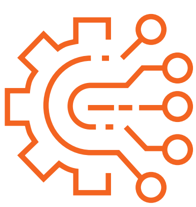
Dystopian narratives address such losses of control or identity, for instance relating to societies where individual control is no longer possible and unequal power relations undermine identities. Therefore, in discourses on possible dangers of digitalization, it should always be borne in mind that visions of the future are often determined more by culturally pre-formed basic dystopian themes than truly derived from the new technical possibilities (Kehl and Coenen, 2016). The WBGU, with its commitment to enlightenment and emancipation from immaturity, consciously adopts a distanced, critical attitude towards dystopian narratives and sees a need for research here, both in the sense of technically unemotional feasibility studies and impact assessment and with a view to addressing culturally heightened fears.

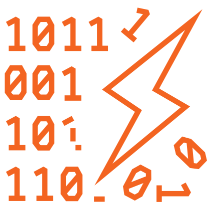
It is an open question whether the utopian or dystopian futures are more likely to manifest themselves. This is precisely where the political and societal mandate for proactive governance lies. When designing ecologically and societally sustainable pathways for technology development, it is important to keep an eye not only on potential but also on risks. This applies all the more since, already in the present, attention gaps, a failure to act, or a lack of foresight can set in motion later-irreversible, cumulatively intensifying processes involving destructive forces which no one will be able to stop in just a few decades time. On the other hand, the outlined utopian blueprints of the future show that particularly the task of shaping desirable positive interactions between digitalization and sustainability still requires a lot more incentives in order to promote the necessary inventiveness and creativity and to strengthen implementation options.

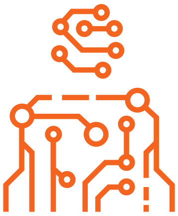
It is precisely the more extreme visions of the future that reveal the driving forces the underlie development dynamics in the technology field of digitalization and shape sustainability effects. There is a lot of evidence of highly self-serving actions by different actors who, when developing and using digitalization, are guided primarily by motives like convenience, consumer enthusiasm and the pleasures of life, economic competitive advantages and profit expectations, the exercise of power and the pursuit of control. There is little evidence of any motivation among actors from business, society or politics to explicitly pursue sustainability goals (such as the SDGs) and thus to prioritize gearing digitalization to serving these goals. This omission may lie, so to speak, in the 'weakness' of human nature, so that it seem advisable to focus primarily on incentives, controls and regulations benefiting sustainability goals keep a check on such weaknesses. Or else the actors are unaware of the harmful consequences of their actions and/or do not notice the opportunities offered. It is therefore important to vehemently propagate and promote on a broad front the great, as-yet-undeveloped potential offered by digitalization for the future safeguarding of natural life-support systems, societal inclusion and the preservation of *Eigenart*.

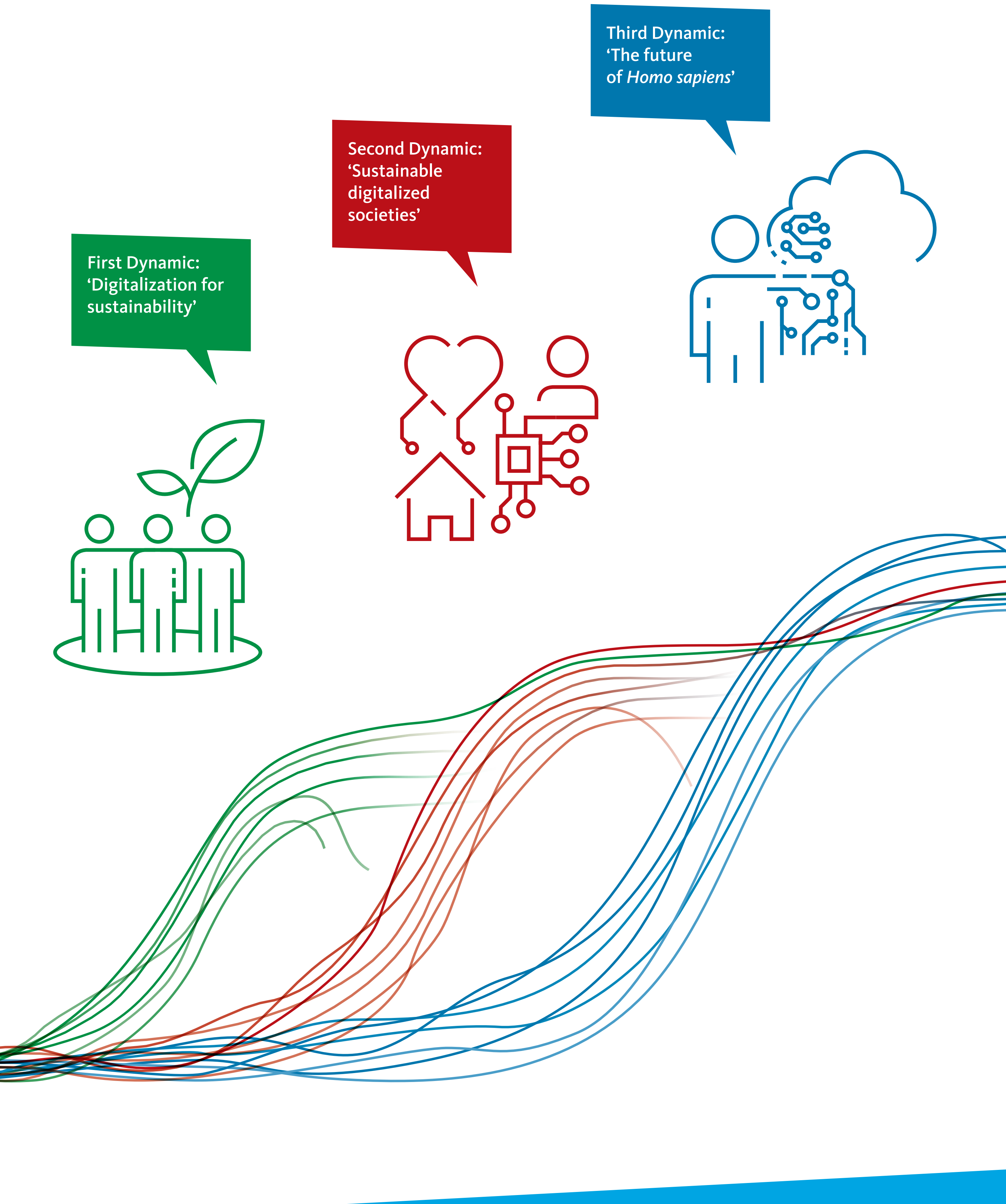
As far as findings on indispensable requirements for shaping a sustainable society and humankind in the Digital Age are concerned, the quoted visions clearly reveal certain 'guardrails' which the digital society must not breach under any circumstances. There are technological advances and lines of development that – against the background of the WBGU's understanding of sustainability – must not be tolerated and are to be avoided at all costs. This applies above all to the risks of the autocratic, kleptocratic total surveillance of all individuals by digitally upgraded state institutions (in the sense of 'Orwell 2084'), the complete assumption of power over consumer needs by a small number of corporations, and the replacement of human beings by digitally constructed and operating technical creatures. In many ways, it is to be hoped that the drafted dystopia will never become reality. Yet this is precisely why the dystopian narrative must be told now in order to prevent its realization in good time, and to make it possible to use digitalization constructively for a sustainable future.

Table 6.3-1
Synoptic comparison of utopian and dystopian visions of the future. The visions are assigned to key issues that were published by WBGU in its discussion paper (WBGU, 2018a). Source: WBGU

Key topic	Utopian vision of the future	Dystopian vision of the future
Sustaining the natural life-support systems 	**Digital sustainability society** › Comprehensive use of renewable energy › Use of digital technologies for monitoring sustainable land and ocean use and the sustainable use of all natural resources › Comprehensive conservation of biodiversity and ecosystems › As complete a circular economy as possible › Virtualized services replace analogue services › Dematerialization	**Hyperconsumption society Ecological division** › Disinterest in the natural living environment › Ecocide: progressive destruction (climate impacts, loss of biodiversity and ecosystem services, soil degradation)
Poverty reduction and inclusive development 	**Equal access for all people to all basic existential functions** › Personalized medicine › Worldwide access to education through digital and digitalized educational resources › Improved food supply through the use of digital precision-farming technologies › Dematerialization	**Material division, extreme widening of disparities** › Perpetuation of poverty with consequences such as (environmental) migration and hunger crises
Future of work and reduction of inequality 	**Inclusive digital society** › Self-determined work and social security for all › Robots and machines take over hard, dangerous and monotonous forms of work	**Digitally exacerbated division** › Increasing inequalities in the distribution of wealth and income › Wage slavery; environmentally hazardous and exploitative work concentrated in developing countrie
Knowledge, education and digital literacy 	**Open, free access to information in an open society** › Free access for all to digital commons › Development of creative potential by digital means (digital creatives)	**Dark age** › Organized stultification of the masses by outsourcing all forms of (thinking) work to machines › Absolute boredom

Key topic	Utopian vision of the future	Dystopian vision of the future
Big data and privacy 	**Self-determination** › Informed (personal) responsibility › Digital sovereignty and data sovereignty	**Post-privacy age** › The digitalized surveillance state ('Orwell 2084') › Everyone is digitally immortal: no digital oblivion › External control
Fragility and autonomy of technical systems 	**Resilient digital society** › Digital skills › Resilient infrastructures › Responsibility and liability in a networked society › Redundancies and quality levels according to security risks	**Digital blackout** › Inadequate cybersecurity › Keeping security gaps open
Economic and political power shifts 	**Digital pluralism** › Digital commons and public-service ICT › Sharing economy › Fair taxation of digitally generated profits	**Digital imperialism** › Winner takes all: monopolies instead of diversity resulting in a deepening of unequal distribution › Digitally enforced conformity › Misuse of digital possibilities to meet destructive vested interests
Acceleration and limits of governance 	**Global sustainability governance** › Digitally supported multilateralism › Creation of transparency relating to governmental and administrative action, strengthening of democratic participation and collaboration with government and administration through the use of digital technologies (in the sense of open government)	**Digitalized chaos** › Vested interests of digital multinational corporations or nation states leads to the end of multilateralism / the UN and the EU

Key topic	Utopian vision of the future	Dystopian vision of the future
Further development of humans 	**The digitally enhanced human being** › Individualized health; cures for physical and mental sufferin › Human beings enhanced by digitalization	**Human enhancement** › Digitally exacerbated division › Cyborg competition: enhancement of one's own body and mind only for privileged elites
Future of civilization 	**Humanity 2.0** › Peaceful world › A life free of physical and psychological suffering › Dignified old age › Optimum assistance through AI	**End of humankind / abolition of human beings** › War of (autonomous) weapon robots › Superintelligence / singularity › Destructive robot civilization


First Dynamic: 'Digitalization for sustainability'
Second Dynamic: 'Sustainable digitalized societies'
Third Dynamic: 'The future of *Homo sapiens*'

7 Digitalization and Sustainability – Synthesis

The WBGU presents three 'Dynamics of the Digital Age' to illustrate different areas where action is urgently needed. First, they concern the sustainability challenges that are already described in the 2030 Agenda. Second, they are about dealing with fundamental societal upheavals that go beyond these challenges and are triggered by digital change. Third, the future viability and identity of *Homo sapiens* itself is discussed.

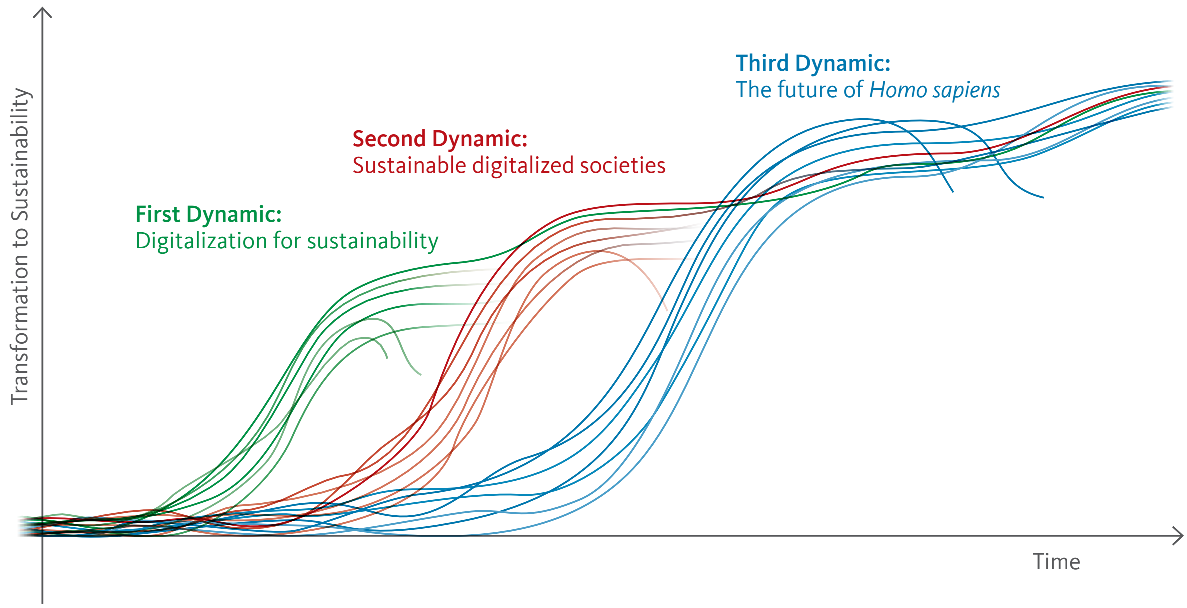
7.1 Three Dynamics of the Digital Age

In times when many societal structures and solutions are being questioned and look fragile, the likelihood of transformative or radical change increases. Such times are characterized by uncertainty, and questions about shaping the future come to the fore. Tipping points are reached when a return to previous development paths no longer seems possible. Societies will be in a state of radical openness to the future during the coming decades – at the latest after the simultaneous transformations caused by sustainability challenges and the wave of digitalization. Tipping points have been reached in both cases. In order to achieve the sustainability goals, a strategic transformation of deeply embedded path dependencies in economic and societal processes is necessary to comply with planetary guard rails. If this transformation fails, societies will be forced into upheaval by major changes in the natural life-support systems and available resources. The outcome of this upheaval, however, is even less predictable, but it is likely to drastically reduce many people's quality of life and welfare.

Similarly, it seems unlikely that the networking of processes and actors, or of the development and use of AI and virtual spaces, will be rolled back. In particular, the transfer of human decisions to technical systems is currently being promoted, turning these systems into new 'actors' with formative power and displacing typical human qualities from decision-making processes. In business, this has already been taking place for some time in the form of algorithmically controlled, high-frequency trading in the financial sector; state social institutions in several countries use algorithms to allocate their funds; and doctors and lawyers also use AI for diagnoses and judgements. This gives rise to new normative questions which our societies must face up to.

This chapter aims to develop the relation between digitalization and sustainability, with its fundamental questions and long-term dynamics. Three 'Dynamics of the Digital Age' are presented, which are intended as heuristics to illustrate three different, but acute needs for action. They should not be understood as a strict chronological sequence; the developments of all Three Dynamics are already taking place in parallel today. The Dynamics differ in their thematic focus, as well as in their time-staggered impact and societal discourse intensity (Figure 7.1-1). The Three Dynamics are interwoven and interdependent, so that clear-cut distinctions are not possible. Instead, the WBGU's purpose here is to bundle together relevant issues at the interface between digitalization and sustainability in this century in order to identify action-relevant perspectives on key challenges and areas of potential.

At this point, we would like to recall the WBGU's central guide: the normative compass (Chapter 2). Sustaining the natural life-support systems, the comprehensive facilitation of inclusion, and the promotion of *Eigenart* remain guiding principles in the age of digitalization. For the special tasks facing humankind in the



↑ Digitally support sustainability

- Comply with planetary guard rails (climate, nature, soils, oceans)
- Secure social cohesion (against hunger, poverty, inequality; for access to water, health, education, energy)

↓ Ecological and societal disruption

- More emissions and resource use
- More inequality
- Greater concentration of power
- Erosion of civil rights and privacy
- Erosion of the state's governance

↑ New humanism

- Networked world society as a further advancement of Enlightenment and humanism
- Development of global (environmental) awareness
- Culture of cooperation, empathy, global solidarity

↓ Digitally empowered totalitarianism

- Hollowed-out democracies and digitally empowered autocracies
- Massive inequality, domination by elites, total surveillance and loss of freedom
- Environmental destruction and loss of social cohesion

↑ Strengthen *Homo sapiens*' self-confidence

- Preservation of the biological human in its natural environment
- Ethically reflected advancement of humanity
- Design human-machine collaboration

↓ Blurring of borderlines between humans and machines

- Abuse of human-machine relationship
- Superintelligence
- Artificial human evolution

Figure 7.1-1a
Three Dynamics of the Digital Age.
The chart shows the positive case of the Dynamics being successfully contained by setting goals and through governance. All three Dynamics are already emerging in parallel today, albeit at different levels of intensity, so there is no strict chronological sequence involved. Each Dynamic consists of different subpaths pointing in different directions. The name given to each Dynamic reflects the priorities for action required in each case. The texts below the illustration give keywords to the *potential outcomes* (↑: upper row) and the *risks* (↓: lower row) of the three Dynamics.
Source: WBGU; diagram: Wernerwerke, Berlin

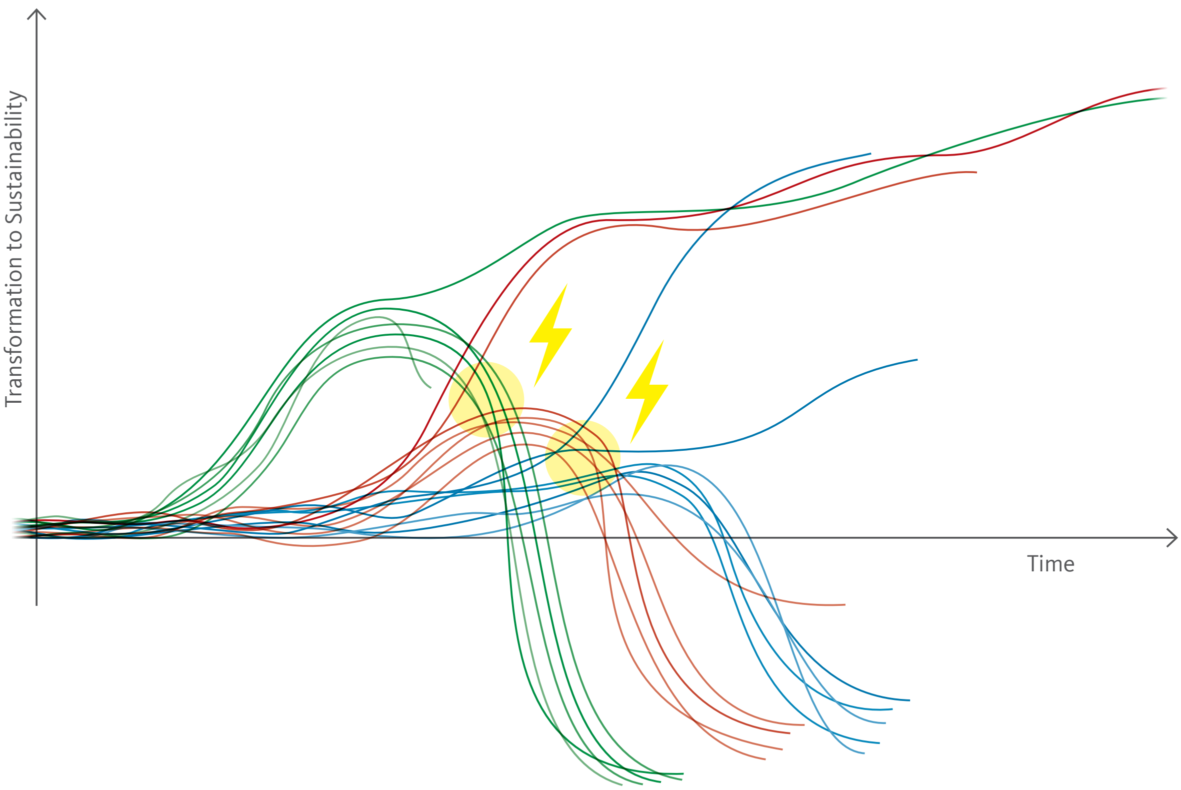


Figure 7.1-1b
Three Dynamics of the Digital Age.
The chart shows the negative case of unsuccessful attempts to deal with the challenges. The failure of the First Dynamic has a negative overall effect on the Second Dynamic's prospects of success; a failed Second Dynamic has a corresponding negative effect on the Third Dynamic (yellow flashes).
Source: WBGU. Diagram: Wernerwerke, Berlin

short, medium and long term as a result of digitalization, it is also important for the WBGU to draw attention to the fundamental category of *human dignity* as a normative guiding principle (Section 2.3). Since simply being human could itself be challenged by digitalization in such different and radical ways, this perspective is relevant for all subsequent dynamics.

The WBGU recommends conducting the urgently needed discourse on digitalization and sustainability along the following three central Dynamics of the Digital Age (Figure 7.1-1):

- *First Dynamic: 'Digitalization for sustainability' – use digitalization to protect the Earth system and ensure social cohesion:* The First Dynamic focuses on the 2030 Agenda with the SDGs (Section 7.2). The questions are: How can digitalization be used both to protect the Earth system and to achieve social cohesion – e.g. to mitigate climate change, biodiversity loss and soil degradation, and to eliminate hunger, poverty, extreme inequality and exclusion? How can digitalization help to effectively implement the ambitious programme for complying with planetary guard rails, protecting the environment and expanding inclusive development, which has been successively developed over decades? But there is also the other side: digitalization can accelerate environmentally harmful developments (e.g. the use of fossil fuels or valuable mineral resources) and thus aggravate the risk of breaching the planetary guard rails. It also has the potential to weaken the social cohesion of societies. Digitalization will be judged according to whether it can reinforce the trend towards ecological and societal sustainability. In other words, we are at a crossroads. An internationally agreed target system for sustainability already exists with the 2030 Agenda, the Paris Agreement and other multilateral treaties in the field of the environment and development. Despite these international agreements, significant contrary trends can be observed (Section 7.2). With regard to the ecological situation, there is a risk of breaching planetary guard rails and degrading local ecosystems. With regard to social cohesion, the following trends can be observed in many countries: (1) rising inequality, (2) an increasing concentration of political and economic power, (3) a rising threat to civil rights and privacy, (4) an erosion of governance capacity among states. An uncontrolled form of digitalization that is not geared towards sustainability could reinforce or even multiply these negative ecological and societal trends and lead to severe societal distortions. If efforts to contain these risks fail, this will reduce the chances of using digitalization in the Second Dynamic to realize a positive vision of the future in national societies and throughout the world.

- *Second Dynamic: 'Sustainable Digital Societies' – realize a new humanism and prevent digital totalitarianism:* Parallel to this, the processes of the Second Dynamic are already underway. They are concerned with how to deal with the fundamental societal reconfigurations made necessary by digitalization, i.e. ultimately with reshaping the world in the Digital Age (Section 7.3). The digital societies of the Second (and Third) Dynamic will be as fundamentally different from today's societies as industrialized societies were from agricultural societies. In this context, the Second Dynamic seems to be like a Janus head with positive and negative potential, each involving corresponding challenges for shaping society. In the positive case, this offers hope that digitalization will open up new perspectives for development in order to develop and advance a humanist vision for a connected global society of the Digital Age that reflexively ties in with the legacy of the Enlightenment ('New Humanism', Box 7.3-2). But digitalization also involves the risk that undermined democracies and digitally empowered autocracies might destroy previous achievements in sustainability, and that societies will increasingly exhibit massive inequalities, power monopolies and elite rule, total surveillance, a loss of freedom and environmental destruction. Such developments are already visible today and are beginning to have an impact; active work can and must therefore begin now on the various fundamental choices.
- *Third Dynamic: 'The future of Homo sapiens' – discourses:* The Third Dynamic is also already beginning to take shape today. It deals with the most fundamental of all sustainability issues: the future viability and identity of humans themselves, embedded both in society and in the environment transformed by it (Section 7.4). Seemingly futuristic but already highly relevant core questions are being asked: What relationship will future humankind develop with an environment that has been fundamentally transformed in the Anthropocene *(Natura futuris)*? How will humans in the Digital Age change through interaction with AI or the fusion of the physical and the virtual world? What will a *Homo digitalis* look like and how will he develop? What will a new humanism mean for *Homo digitalis*? How will it be possible to distinguish artificially intelligent, cognitively powerful machines *(Machina sapiens)* from humans? What characteristics and decision-making powers do we want to assign to a *Machina sapiens*? How can people, organizations, societies, international organizations and networks prepare to keep these fundamental changes in the history of *Homo sapiens* under control?

Moving from the First to the Third Dynamic, there is increasing uncertainty and insecurity, less sharpness of detail, fewer reliable research findings, and ever fewer concrete recommendations. Instead, there are more fundamental questions which our societies should tackle in order to develop a sense of direction and the ability to shape and plan. With the debates on sustainability, the environment, development and the 2030 Agenda in the First Dynamic, the WBGU is still within its area of 'core competence'. The issue is how the potential of digitalization for sustainability can be mobilized to limit the risks of drastic global environmental changes and threats to the social cohesion and stability of many societies, and to reopen positive options for shaping and planning them. Beyond this short-term perspective, however, digitalization is changing societal realities so comprehensively (e.g. through AI and machine learning) that concepts of sustainability must be further developed and ideas formulated on the future of the human species. A new paradigm of sustainability for 'environment' and 'human beings' (or 'human societies') must be developed in the Digital Age, not least so that the future human environment does not degenerate into a virtual illusion. In this context, the WBGU would like to make contributions to formulating a paradigm on sustainability and human development and a new humanism in the Digital Age.

To this end, it is first of all necessary to stimulate or intensify a public discourse focusing on the impact of the potentially fundamental effects of digitalization. In addition, the relevant trends that are emerging should be shaped by society in good time. In view of digitalization's potential, steps should be taken towards a jointly developed positive vision, and a way should be devised to ensure forecasting of possible future systemic risks. In addition to the WBGU's repeated calls for compliance with planetary guard rails (e.g. WBGU, 2014b), the First Dynamic (Section 7.2) explains current risks of societal development already mentioned above that might gain momentum with digitalization: an increase in *inequality, problematic concentrations of power*, the loss of *civil rights and privacy*, and the failure of *governance*. If no action is taken to counteract the developments that are already visible, there is a risk of aggravating societal systemic risks. Some of these risks relate more to relatively slow erosion processes. However, other systemic risks could lead to tipping points being exceeded beyond which radical systemic changes must be feared. Finally, there are risks associated with major uncertainties for which there is little forecasting capacity ('black doors').

In the following three Sections 7.2, 7.3 and 7.4, the Three Dynamics are described in more detail and guiding principles for action added.

7.2 First Dynamic: use digitalization for sustainability

In the First Dynamic, the aim is to relate digitalization directly to the Transformation towards Sustainability, which the WBGU has described in its flagship report 'World in Transition – A Social Contract for Sustainability' and other publications (WBGU, 2011, 2014a, b). The planetary guard rails must be complied with, the corresponding tipping points of the Earth system must not be exceeded (WBGU, 2014b; Lenton et al., 2008), and social cohesion must be ensured by combating poverty, among other things.

In recent decades, the two megatrends 'sustainability' and 'digitalization' have developed in parallel and largely independently of each other; there has been little systematic coordination between them. This is illustrated for example by the fact that digitalization is not mentioned as an essential factor in the 2030 Agenda and the SDGs (Chapter 8). Conversely, digitalization strategies seldom have a sustainability dimension, regardless of whether they are the strategies of large digital corporations, governments, NGOs or academia (Section 4.2, Chapter 8). Digital technologies are used in all sectors to improve effectiveness and efficiency; for example, renewable energy systems have long-since been unthinkable without digitalization (Section 5.2.6). However, at best there are only initial signs of digitalization being geared towards and targeting the Transformation towards Sustainability (Section 8.2).

An evaluation of ten examples of reports by international organizations on the topic of digitalization and sustainability shows that the issue of digitalization has arrived in the strategy departments of international organizations (Section 3.6), although the way this topic is dealt with can often still be described as a search process.

The arenas of digital change that are studied (see Chapter 5) illustrate the fact that linking digitalization and sustainability can open up considerable opportunities. Digitalization and sustainability must be systematically considered together, and digitalization must be actively shaped and systematically used for the Transformation towards Sustainability.

With reference to sustainability, preliminary ideas relating to this First Dynamic have already been developed in recent decades. The relevant scientific evidence is already available in many areas of the sustainability agenda, and there is a worldwide political consensus for the global sustainability agenda with its approach of preserving the environment, complying with the planetary guard rails, combating poverty worldwide, and enabling development for the 'bottom billion' (Collier, 2017). The multilateral target system for the Transformation towards Sustainability exists in the form of the 2030 Agenda and its SDGs, the Paris Agreement and other multilateral treaties (Chapter 8). They clearly outline in principle which routes along this path need to be followed and which must be avoided. These goals still neglect the full breadth and consequences of digitalization; their relevance to digitalization is therefore yet to be determined. But the first step has to be their implementation, and digitalization can play a decisive role here.

Digitalization as a way of enabling sustainability

As in many areas of society, digitalization also makes valuable and in some cases indispensable contributions in the field of sustainability to finding better and faster solutions to global environmental and development problems. The arenas of digital change in Chapter 5 show that there is potential in many fields relevant to sustainability. Some of these can accelerate incremental developments, while others can trigger disruptive changes.

However, this technological potential for solving sustainability problems is not 'automatically' used. It is therefore a matter of active policy: the societal objectives must be operationalized in such a way that digitalization does not reinforce trends towards existing negative developments, but can have a positive, transformative effect for a sustainable society.

Digitalization is a prerequisite for the decarbonization of the electricity sector, for example (Section 5.2.6). In particular, it facilitates the integration of fluctuating and decentralized renewable-energy sources into the electricity grids, and plays an important role in the electrification of other sectors (e.g. transport, heating and refrigeration).

Digitalization's potential for dematerialization, resource conservation and the circular economy is as yet far from exhausted (Sections 5.2.1, 5.2.5). New regulatory approaches, business models, monitoring options, services and cultural practices are necessary, especially in the field of electronic waste (Section 5.2.5). Yet this must not only be about improved recycling. Setting the course for a circular economy that is as complete as possible includes a prudent digitalization offensive to leverage the positive potential of digitalization along the entire life-cycle of products, as well as the creation of suitable economic and regulatory framework conditions that make the corresponding technologies and business models competitive.

Digitalization also fosters the diffusion of sustainable consumption patterns by means of a greater diversity of information and offers, and via new services, such as a resource-saving sharing economy based on smartphone technology (Sections 5.2.2, 5.2.3).

Sustainable land use is indispensable in order to supply humankind with agricultural and forestry products, and to preserve ecosystems, their biological diversity and ecosystem services in the long term. Even though many approaches to solving this problem lie outside the realm of digitalization and mechanization (e.g. plant breeding, soil restoration, climate adaptation), and in some cases even outside the realm of agriculture itself (e.g. food loss after harvesting, nutrition styles), precision agriculture is an interesting instrument for globally sustainable land use, and its potential should be exploited (Section 5.2.9). In developing countries, digital access to agricultural information and advice is an important starting point (Section 5.2.10).

Digitalization also offers valuable new opportunities for monitoring ecosystems and biological diversity to improve knowledge and, for example, to counter overuse or illegal activities (Section 5.2.11).

Digital technologies could enable a new quality of monitoring and revolutionize our understanding of the interdependent social, ecological, economic and technological dynamics of the Anthropocene (Sections 3.3.5.1, 5.2.11). They could fill the gaps between observation, experimentation, modelling and theory formation and open up a route to a collective global awareness for sustainable development (Section 5.3.1). However, they also open up valuable opportunities for promoting social cohesion, e.g. by facilitating access to education (Section 5.3.4) and digital commons (Section 5.3.10) or by improving public discourse (Section 5.3.2).

Digitalization as a risk to sustainability

However, digitalization can also massively exacerbate existing sustainability problems. Without suitable framework conditions there is a risk of societies even drifting faster towards the planetary guard rails and moving ever further away from the goal of sustainable development. Digitalization currently acts as an amplifier and accelerator of economic processes that are still predominantly based on fossil fuels and resource extraction. Take the production and operation of electronic devices which are replaced in a rapid cycle; this in itself is a major driver of energy and resource use. Without a change of course in the direction of sustainability, unbridled digitalization could jeopardize the success of the sustainability transformation.

In concrete terms, digitalization threatens to increase resource consumption (e.g. strategic metals, rare earths), because more and more digital devices with brief lifespans keep coming onto the market (Köhler et al., 2018). Digitalization accelerates the linear economy (Section 5.2.5). Furthermore, if billions of new devices are networked over the coming years, the demand for energy from data centres and network services will also increase. This could be limited by increasing energy efficiency (IEA, 2017a). However, despite high efficiency gains, there are currently no signs of a trend reversal in the ICT sector; direct demand for energy continues to rise rapidly (Köhler et al., 2018). A continuation of these two trends increases ecological risks and the threat of breaching planetary guard rails. As a result, the challenges for an energy transformation (decarbonization) and a resource transformation (circular economy) are increasing considerably. An example of the indirect effects of digitalization on consumption is the resulting increase in energy and resource consumption and the negative social and societal consequences of online commerce (Section 5.2.4).

Even using the positive potential of digitalization for the Transformation towards Sustainability involves further societal dangers; this is because it means collecting and handling (in some cases large) amounts of data, which are processed by software and converted into concrete actions by partially or fully automated decisions or via actuators. Leveraging sustainability potential is therefore inherently linked to questions: Who can use these data and how? Who designs, manufactures, operates and controls the algorithms for evaluation? Which data are regarded as personal? Who benefits from the new, associated business models? Who becomes dependent? How fragile are the new technical infrastructures? Which decisions are still made by human beings? What should the interplay of human intelligence and AI look like in order to strengthen people and societies instead of weakening them (Rosol et al., 2018)? For these reasons alone, questions concerning data handling, privacy, rights of use, decision-making power and monopolization are already relevant in the First Dynamic and should be addressed in order to contain the risks involved. The arenas of agriculture, the circular economy, decarbonized energy systems, and smart cities provide clear examples of this connection (Section 5.2).

Furthermore, it must be feared that inclusion in the digitalized society is more difficult for poverty groups and minorities, and that they face an increased threat of discrimination, e.g. for lack of access to ICT or as a result of inadequate education (Sections 2.1.2, 5.3.5, 5.3.4).

In addition to the urgency of complying with planetary guard rails, the WBGU also believes that the following four trends are a challenge for our societies. Their effects could be mitigated by the targeted use of digital solutions, but if they are not properly shaped, there is a great danger that they may become more severe. Ultimately, all these risks of societal development also threaten human dignity (Section 2.3).

The first risk arises from the increase in *inequality* within societies and, despite some partial successes, also between societies. Today, inequality is already a worldwide threat to social cohesion. Although the effects of digitalization could counteract this, they could also increase inequality and thus, in extreme cases, become a global multiplier of inequality. Preventing this effect through formative action is an urgent project of any form of digitalization geared towards sustainability.

The second risk is the growing trend towards new, potentially problematic *concentrations of power* at many levels. The five most valuable companies today are already digital corporations. The economic market power they have as a result is not necessarily a problem in itself, albeit only unless it is augmented by poorly regulated, powerful access to the data of billions of users. Politically, the figure of the 'strong autocrat' is once again in the ascendancy. Even within the European Union and in the USA the hitherto clear commitment to the separation of powers and the rule of law has been shaken. Even if digitalization effects are not the unequivocal cause of this, the risk of the misuse of digital technologies is evident.

Thirdly, the increasing erosion of *civil rights and privacy* can already be seen today. Driven by economic or state interests and made possible by technical infrastructure and lax handling of data by individuals, we are experiencing an unprecedented relativization of privacy and a growing threat to civil rights. In view of the above-outlined possibilities of a technological development towards societal totalization and individual transparency, measures must be taken to prevent a post-privacy society.

Fourthly and finally, the rapid pace of developments threatens to overtax the ability of governments and the multilateral system. The risk of an *erosion of the state's* ability to govern is increasing – recognizable as a loss of the conventional ability to act, shape and plan. Even now, governments are completely unprepared for the formative challenges of digital upheavals. There is a lack of knowledge and experts in the governments, administrations and networks to exploit the potential of digital change and prevent the gradual creation of a self-learning technosphere that might slip out of human control, manipulate human behaviour, and be misused by powerful actors. If the sustainability transformation is already dependent on multifaceted cooperation and a wisely designed polycentric architecture of responsibility, this requirement is reinforced by the consequences of digitalization (Section 4.1). The digitalization-driven acceleration of economic and socio-political developments must not lead to a further loss of political, national or multilateral ability to govern. However, democracies in particular can potentially deal well with complexity and diversity – if they are prepared to do so on a institutional and discursive level. As in the area of climate change, individual and national contributions to the governance of digitalization must be globally embedded and coordinated.

The societal challenge will be to contain these four risks of societal development. Implementing the 2030 Agenda and achieving the SDGs are important prerequisites for this. If time is wasted and the sustainability goals are not achieved, there is a threat of intolerable effects on the Earth system (breaching of planetary guard rails) and severe societal upheavals in global society (loss of social cohesion, e.g. due to poverty, hunger, failed states). The four risks are already having an effect in the First Dynamic. If they cannot be contained, their impact will be maximized in the Second Dynamic, where a fundamental restructuring of social systems is about to begin. This would in turn significantly reduce the chances of using digitalization to make real progress towards realizing a 'new humanism' (Box 7.3-2).

Guiding principles for action

Figure 7.2-1 illustrates the challenge in a simple way. If the two central axes of sustainability (environment and Earth system; development and social cohesion) are plotted against each other, and both a positive and a negative area are assumed for each axis, then the challenge in the case of the First Dynamic is to set the right levers in motion so that global society can find its way into the double-positive 'green' quadrant. The other quadrants or scenarios, and particularly the dark red area, represent failure to contain the risks of societal development and thus also the failure of the hope in the Second Dynamic of being able to achieve a 'new humanism' with the help of digitalization.

In order to reach the 'green quadrant' of a digitalized sustainability society, the WBGU expressly recommends that *digitalization be put at the service of global*

Figure 7.2-1
Compliance with planetary guard rails and securing social cohesion; both must be achieved. The core question of the First Dynamic is which digitalization strategies are suitable for moving societies in the direction of a digitalized sustainability society (green quadrant, top right). Only if this is achieved is there a good chance of avoiding systemic risks in the Second Dynamic and approaching a 'new humanism'.
Source: WBGU

sustainability WBGU, 2018a; Chapter 9). The motto of this First Dynamic should be: society must act now to achieve the transformation to a digitalized sustainability society! Digitalization provides powerful tools which are already in wide use in society, but need to be deployed more intensively to implement the 2030 Agenda. In order to exploit the new possibilities of digitalization for the Transformation towards Sustainability and to avoid the risks, actors at all levels, from local to intergovernmental, must be addressed (Chapter 4).

However, by no means all sustainability problems can be solved with digitalization. In the WBGU's opinion, it is primarily a question of society's willingness to make a decision in favour of the Transformation towards Sustainability and to commit itself to this goal (Chapter 9). In Germany, for example, the obstacles to phasing out coal are not rooted in the insufficient application of digitalization.

Several urgent guiding principles for action in the First Dynamic emerge from the WBGU's analysis.

- *Understand digitalization and sustainability:* The information and knowledge base about the ecological effects of digitalization is insufficient. The gaps in knowledge that have been identified should be closed through targeted research (e.g. energy and resource requirements, Section 10.3.1).
- *Integrate engagement with digitalization and sustainability:* Digitalization and sustainability are not sectors that can be treated separately. They are cross-cutting issues that need to be included ubiquitously in analyses. In this context, sustainability is above all a system of objectives; digitalization is above all a means to this end involving many positive and negative side effects. The 2030 Agenda should therefore be examined to determine its links to digitalization; corresponding potential should be leveraged (Sections 8.2.1, 10.3).
- *Shape digitalization* for *sustainability:* The current pace of technological development will not be redirected towards sustainability of its own accord. For example, urgent action must be taken to counteract the threat of a multiplication of the demand for energy and resources caused by the increasing number of digital devices and applications and rapidly growing infrastructures. Efforts should be made nationally and multilaterally to reduce the digital divide and make digital services accessible to all. Digitalization needs to be shaped for sustainability by society so that digitalization can have a productive impact on the Transformation towards Sustainability. To this end, policy-makers should consistently further develop or create the legal framework for sustainability policy. The foundations should be laid early on for the advancement of the 2030 Agenda in a way that includes the megatrend of digitalization (Section 9.3).

- *Engage responsibly with data:* In order to leverage the positive potential of sustainability, it is essential to clarify *beforehand* the way in which the data, algorithms and knowledge from digitalization applications are handled and used. This involves both guaranteeing privacy, self-determination, data protection and data security, and the resilience, robustness and fault tolerance of the emerging systems (Section 9.2). The designers and operators of digital solutions should be enabled through education and further training to understand and implement these characteristics together with sustainability aspects.
- *Move towards resource-conserving consumption:* Some of the societal challenges outlined above cannot be met without changes in behaviour. Regulation (e.g. pricing) of negative environmental impacts can make an essential contribution to steering consumption towards resource conservation. Education for sustainable development (Section 9.1.4) should also raise awareness of the need for a critical attitude towards consumption (Section 5.2.3). Education in line with the normative compass (Chapter 2) can help promote values related to the well-being of people and the environment. A corresponding long-term strategy for future-proof education is a prerequisite for shaping digitalization in the sense of the Great Transformation towards Sustainability (Section 5.3.4; Box 7.5-1).

7.3 Second Dynamic: Sustainable digitalized societies – anticipate and shape fundamental changes

While the First Dynamic is primarily concerned with using digitalization as a means of solving existing sustainability problems and of maximizing its benefits for the 2030 Agenda canon of objectives, the Second Dynamic points to more fundamental changes. Digitalization can be a radical and potentially system-changing driver of societal change. Our relationship with the environment and the Earth system, our ways of doing business, our societal practices and political institutions, the use of technologies – even on and in people – all this will change fundamentally. 'Digitalization' should neither be mystified nor glorified in this context. Yet, just as in the early days of the Industrial Revolution it was impossible to foresee what enormous influence mechanization and the use of steam engines, coal and iron would have, it is not clear today what consequences digitalization will have for our present societies, or what will be the effects of the increasing *networking*, the *cognitive* abilities and *autonomy* of technical systems, or *virtuality* and the *knowledge explosion* (core characteristics of the Digital Age: Section 3.4).

The transformative power of the Industrial Revolution made great prosperity and progress possible, but it also produced or enabled environmental degradation, climate change and enormous social upheaval, impoverishment and exploitation. In many societies, it was only after long social struggles that the most blatant social consequences were later contained with completely new forms of social and economic policy. Even today the social question is not adequately addressed in many countries, not to mention the key unresolved issues of worldwide decarbonization, effective climate policy, and decoupling wealth creation from the consumption of natural resources. This 'retarding moment' in the history of innovation should be pre-empted in the case of the digital revolution, precisely because its penetration, range and speed are likely to eclipse previous phases of technological progress. In view of the core characteristics of the Digital Age (Section 3.4), the course should already be set today, proactively, in all key spheres of life (Section 3.5). These characteristics and their current impact must be understood, critically and anticipatively thought through, and shaped to sound out their future realms of possibility.

The fundamental openness of the future is both an incentive and a mandate to exert a influence to shape changes. Societies can already prepare themselves today for this important and challenging task. The democratic nation-state has many possibilities for technical and institutional further development, and also for promoting awareness and competence among other societal actors. Scientific advice for policy-makers, technology-impact assessment, and strategic early detection ('horizon scanning' and 'visioning') – as well as the broad-based integration of expertise on digitalization and its societal consequences in the executive and legislative core areas of government – are important options for maintaining a future-sensitive ability to shape and plan. Today, tomorrow and in the future, parliaments and governments should develop the necessary expertise to make the diverse effects of digitalization transparent and tangible; and society as a whole should publicly discuss them and critically reflect on them. On this basis, far-reaching societal changes for the sake of sustainability can also be mastered.

A canon of objectives for a sustainable digitalized global society is still lacking at the global level. The Agenda 2030 does not provide this: first, it only marginally addresses the effects of digitalization; second, its impact extends far beyond the 2030 Agenda (Section 8.3). Here, too, in the WBGU's view, the normative model and guideline for such a canon of objectives should be its compass dimensions – *sustaining the* *natural life-support systems*, *inclusion* and *Eigenart* – as well as the *protection of dignity* (Chapter 2). If it is possible to make use of digitalization for sustainability in a timely manner (First Dynamic), then it may be possible to sustainably shape the more extensive digitalization effects of the Second Dynamic. This begins with a critical (self-)reflection of the current situation, because our world is already profoundly influenced by the rationality and incentive structures of digitalized business models. Where do our societies stand today, and what fundamental steps must now be taken to make positive use of digitalization for digitalized sustainable societies? The manifold, concrete decisions facing humankind can lead us into radically different worlds (Section 7.5). An overarching key question of this Dynamic should therefore be: will global society succeed in realizing the old dream of humanism in a new and global way in the Digital Age (Box 7.3-2)? Or will it slip into digitally empowered totalitarianism with radically intensified power asymmetries, environmental destruction, massive threats to democracy and societal deliberation, the loss of social cohesion, and multiple global inequality dynamics – for instance between a small elite and those who are left behind?

Understand digitalization and shape it proactively in all key spheres of life today

In order to achieve a Great Transformation towards Sustainability (WBGU, 2011), many old paths and established patterns must be abandoned and new roads adopted. If properly shaped, digitalization, with its disruptive potential, can open up many of these new avenues and make them viable (Section 7.2). However, another important finding of this report is that both the many small innovations and the potentially far-reaching system changes are already being actively driven by certain actors and individual interests today (Chapter 4) – and that this by no means automatically leads to more sustainability. In many areas – employment and agriculture, mobility and urban development, democracy and inequality – it is not yet certain which direction developments will take in the medium and long term (Chapter 5). In these arenas it has become clear that although the respective systemic framework conditions often have a greater effect than individual technological innovations, these technological innovations can nevertheless have a system-changing impact.

To master this task of shaping an entire society, it is necessary for society as a whole to be vigilant in order, first, to anticipate systemic risks and, second, to identify paths towards the realization of a 'new humanism' in the Digital Age and in many cases to actively follow those paths in the spirit of a 'polycentric responsibility architecture' (Chapter 4). Such at-times radical openness to the future should not lead to impotence or speechlessness, for transformative change can also be shaped by anticipatory governance (Section 4.1). The normative compass can help provide orientation as to which directions should be taken, which paths will lead us astray, and which landmarks should be followed and fundamental decisions taken to initiate timely participatory societal discourses and research. The analysis of changes in key areas of life in the Digital Age (Section 3.5) provides numerous pointers for these creative and formative tasks.

This means that standards and rules should also apply to the global, increasingly digitalized *economy*. Risks such as an accelerated opening of the gap between rich and poor within and between societies, or too one-sided value creation by a few global corporations must be prevented. To this end, the 'digital' potential of both new and old economic forms for sustainable production and consumption should be promoted, and ways of steering the economy (such as competition control) newly or further developed. Concrete innovation projects, such as the creation of public-service infrastructures or the expansion of effective data protection as a locational advantage for the EU, could bring about relevant changes and support long-term cornerstone choices (Sections 5.3.5, 5.3.10). Societal debates and scientific research on the form and function of work, working hours, employment and inclusion in the Digital Age (Section 5.2.9) should be initiated and carried out as promptly as those on a collaborative economy, the challenges and opportunities of platform and circular economies, and the importance of secure data use (Sections 5.2.1, 5.2.2, 5.2.5).

The conscious and rights-based handling of data is also one of the core issues in defending the principles of liberal and social *democracy*. Adhering to individual privacy protection and joint arenas of public exchange is an important prerequisite for a functioning democratic public sphere (Section 5.3.2). It is not easy to contain the currently growing tendency to digitally 'publish' privacy, while arenas of the digital public sphere are simultaneously being privatized and parcelled out on manipulation-prone platforms. However, effective data-protection laws, well thought-out media policies, and educational initiatives promoting digital literacy are three relevant building blocks in this direction. The state as a whole should play a structuring and, where appropriate, orchestrating role in concert with the many other relevant actors in proactively shaping digitalization for sustainability. The WBGU recommends a 'polycentric responsibility architecture' as a guiding principle (Chapter 4). The diversity of policy levels and actor profiles to be included can be recognized from this perspective, making a concrete allocation of responsibility possible.

Box 7.3-1

Avoiding systemic risks in the Digital Age

In order to be able to exploit the potential of digitalization, we must be aware of the possible systemic risks in the Digital Age. Digital systemic risks include conceivable, large-scale changes in our societies, each of which could in itself trigger destabilization in those societies. Knock-on and cumulative amplifying effects would multiply accordingly and have a broad-based impact.

While some of these threats are undisputed (e.g. labour-market disruptions), the magnitude of the changes is uncertain. The probability of other systemic risks occurring is significant (e.g. breaching planetary guard rails, digital authoritarianism, further power gains by major digital corporations), while the likelihood of other risks occurring is relatively low from today's perspective (e.g. acceptance of human enhancement to create an optimized *Homo sapiens*). However, even the latter systemic risks must not be neglected because, in a worst-case scenario, they would have a major impact on the future of civilization. The WBGU identifies the following systemic risks in the Digital Age:

- the breaching of planetary guard rails as a result of digitally driven, resource- and emissions-intensive growth patterns,
- the disempowerment of the individual, threats to privacy and an undermining of the digitalized public sphere through digitally empowered authoritarianism and totalitarianism,
- an undermining of democracy and deliberation by normatively and institutionally non-embedded, automated decision-making or decision-making support,
- dominance by companies that can elude government control, driven by further data-based power concentration,
- disruption of labour markets by the comprehensive automation of data-driven activities and the danger that human labour will become increasingly irrelevant to the economy,
- a deeper division of global society as a result of limited access to, and use of, digital potential, mainly by wealthy minorities in the global society,
- abuse of the mechanization of humanity on the basis of human-enhancement philosophies and methods.

It is also important to bear in mind that the digital upheavals are being experienced by societies that are already unsettled by globalization, the rise of new powers, refugee flows and forms of authoritarian populism. The bow-waves of digitalization are colliding with the current crisis in Europe and the West, as well as with frontal attacks on a multilateral world order based on cooperation and rules. The systemic risks of the Digital Age could overlap with and reinforce the centrifugal forces that already exist in many societies.

For individual *people*, individual autonomy and self-determination become the focus of attention. In view of the self-tracking and external scoring in the growing data economy – including the beginnings of dystopian standardization and control by state actors – it is difficult, if not impossible, for people not to interact with the digital or digitally recorded environment (Sections 5.3.3, 5.3.7). This makes it all the more important to promote individual maturity and education and to create structural conditions that contain encroachment by technical systems and activate the potential for expanding human empathy and developing global mutual perception (Sections 5.3.1, 5.3.4; Box 7.5-1).

Actively maintain foresight and the ability to act: develop positive guiding principles and avoid systemic crises

A critical and reflective perception of the already existing imperatives of increasingly digitalized societies and economies is therefore important in order to set the course today for a sustainable global society in the Digital Age. In view of the potentially disruptive power of digital innovation, it is all the more important to reflect in good time on the long-term visions and prospective goals. Disruptions are useful when they help to breach path dependencies of unsustainable development, be it in the transition to renewable energy systems and new sustainable mobility or in overcoming scarcity in key areas of our economic system. However, disruption triggered by digitalization can also lead to systemic crises in all spheres of life. The WBGU believes it is important to discuss and illustrate both perspectives in society to enable people to gain a better understanding of the possibility of radically different futures. To achieve this, societies need both long-term visions for realizing key potential benefits of digitalization, and an informed ability to anticipate dystopias in order to contain system risks (Box 7.3-1).

The WBGU proposes a global and digitally enabled 'new humanism' for a possible positive development perspective that helps to overcome the prevailing 'dictatorship of the present' (Figure 7.1-1a; Box 7.3-2). In this way, digitalization offers hope for a new phase in which human curiosity, diversity and physicality can be liberated from material restrictions and structural constraints, and conditions can be created for all people to largely overcome deprivation and conflict. The WBGU's vision here is that of human beings *becoming more profoundly human* with the help of technical systems. This humanistic vision is not just a vague utopia: digital technologies are already making transnational communication, networking and the growth of information and knowledge possible in unprecedented ways. Looking ahead to the future, this can encourage the human capacity for a more profound culture of cooperation, mutual empathy and global solidarity.

For the WBGU, the dystopian antithesis to this is digitally reinforced authoritarianism or even 'digitally

Box 7.3-2

Strengthen humaneness as a humanistic digital project

Many seemingly self-evident tenets are re-scrutinized at times of societal upheaval. Historically, this has always related to humans' role on Earth and the prevailing human self-image. After Classical Antiquity, the Renaissance and the Enlightenment, the transition to the Digital Age has given rise for the fourth time to the humanist hope that new technological and societal breakthroughs could serve the full unfolding of civilizational and human potential. Improving the preconditions of human life, human self-determination and human dignity are important building blocks of humanist schools of thought (Wolf, 2007).

Discussions about digital change are often conducted from a highly technical and economic point of view and are similar to the strands of the sustainability debate, which focus primarily on resource efficiency potential and technological solutions to sustainability challenges. The sustainability of societies depends not only on efficiently designed technologies and institutions, but above all on the goals, motivations and justifications with which people create and use these technologies and institutions. Specifically at times when hitherto self-evident tenets and certainties are being challenged, these goals, motivations and justifications are also questioned and renegotiated. For example, people also changed their 'intellectual map of the world' (Goldin and Kutarna, 2016) in previous major innovation surges such as the Renaissance by adapting to new knowledge, new technical possibilities and new societal challenges. Conversely, the objectives, motivations and justifications that prevail have a strong impact on which new technical possibilities, societal institutions, certainties and self-evident tenets will prevail.

New humanism in the 21st century

In the Digital Age, for the first time in history, technical progress opens up an area of possibility for a potentially fundamental change in the human condition. Particularly in connection with AI – in the sense of the rule-guided machine-generated evaluation of large data sets and its possible applications (Section 3.3.3) – four central questions of a humanist project are therefore discussed (Floridi et al., 2018): (1) Who or what can we become (autonomous self-realization)? (2) What can we do (human activity)? (3) What can we achieve (individual and social skills)? (4) How can we interact with each other and with the world/environment (social coherence and people as part of the natural environment)? In all these points, digital technologies can be used in such a way that they strengthen, underuse or limit potential by being overused or misused, thus leading to considerable risks (Floridi et al., 2018).

In the WBGU's view, interaction between people and technologies should always be considered in the context of the natural life-support systems and whether they can be sustained. This applies particularly if this new humanist project is to encompass humanity as a whole and not be limited to the maximum possible technological support of privileged persons (Harari, 2018).

Furthermore, a humanist reading of digital change requires that current societal discourses be turned upside down. Up to now, discourses on digital change, with their structural determinism, have resembled the economic narrative of the 20th century, according to which people have to toughen and improve themselves for a changed environment and society. A humanist vision, by contrast, looks for ways in which people can once again increasingly become actors and subjects in shaping their technologically supported societies and developments. This appeal to creative power is thus a central component of an expanded sustainability paradigm and the basis for leveraging humanistic potential in the 21st century. Such a vision thus offers an alternative narrative to technological fantasies that declare that the *Eigenart* (i.e. individuality, uniqueness; Section 2.2.4) of human existence in particular will soon be a thing of the past. These technological fantasies appear in variations of the following two directions:

- 'The technologization of the human being', a fundamental extension of human beings (human enhancement) through digital technologies with the aim of overcoming their biological limitations (Topic box 5.3-2),
- 'The humanization of the machine', the creation of a human-like, sentient and independent artificial species (Section 7.4).

Navigating between these two extremes through and beyond the 2030 Agenda, a broad space opens up for the development of human *Eigenart*. Describing and defining future development paths – and also the human self-image – is therefore an integral part of many ethical discussions. These decisions cannot be made by political, scientific or financially strong elites. The emancipatory hope of a 'new humanism' can only be legitimized and realized as a broad-based societal process of searching and shaping.

The role of a new Enlightenment in the 21st century

The connection between humanism as a societal vision and the historical-philosophical project of the Enlightenment in the 17th and 18th centuries is well summarized in Immanuel Kant's 'emergence of man from his self-imposed immaturity' (1784). The search for new intellectual maps begun in the Renaissance manifested itself in this epoch. Absolutism, God's grace, the system of the 'estates of the realm', and the dominance of the Catholic Church were replaced by human reason as the universal, progressive authority for judgement. The Enlightenment included currents of rationalism (Descartes), empiricism (Hume, Locke), encyclopaedism (Diderot, d'Alembert), and universalism (Kant), and created important foundations for general human rights, evidence-based sciences, and the principles of popular sovereignty and the rule of law. Four main characteristics of the human self-image often referred to (or disqualified) as Western can be traced back to the Enlightenment. Humans are understood to be (1) capable of rationality (Kant), (2) communicative (Habermas) and (3) autonomous (Descartes, Locke) subjects with (4) natural rights (Kant, Rousseau).

These key achievements must be defended in view of the rapid changes brought about by digitalization, because societies are sustainable precisely if they maintain the principles of the ability to discuss, act, innovate and shape (Section 7.5), even in the face of greatly changed framework conditions. To defend the central elements of the Enlightenment, the following questions should be put to society:

1. How can human maturity and democratic voting processes be preserved in the context of increasingly automated decision-making?
2. How can deliberative processes be protected and orientation secured in view of the massive increase in knowledge and opinions?
3. How can key rights such as freedom, equality, privacy and property be protected for all people in the digital space?

4. How can the sovereignty of the people and the rule of law – as opposed to arbitrariness (Locke) and divine grace (Rousseau) – be defended against digital surveillance?

An anticipatory and extended humanism for the 21st century will also further develop the (universalistic) image of humankind, since it is sharply criticized not only in intercultural dialogue and in the reappraisal of colonialism, but also by 21st century science. The basic features of a further development of the central ideas and scientific findings of the 17th and 18th centuries can be summarized in four points (Braidotti, 2014; Whatmore, 2002; Hayles, 1999; Haraway, 1991; Bennett, 2010; Box 2.1.2-1):

1. Reducing people to their thinking neglects the importance of physicality and emotions.
2. Individualism as a culture and scientific methodology neglects the importance of society and social networking for human development.
3. Looking at human life decoupled from nature neglects systemic interconnections of the biosphere, to which humans also belong and on whose dynamics human existence depends.
4. Universalism that ignores differences when describing people and societies neglects the role of culture, institutions, and even technologies in the shaping of individuals.

So historically we are again in a phase in which not only the societal narratives and structures are being challenged in terms of their effect on human freedom and potential development – as the sustainability agenda has done since the publication of the Brundtland Report (WCED, 1987). The onset of both the Anthropocene and the Digital Age is so comprehensive in character that, as in previous great transformations, they affect societal relations as a whole. Enlightenment in the 21st century therefore again encompasses the human self-image itself, as formulated at the very beginning of the Brundtland Report: "In the middle of the 20th century, we saw our planet from space for the first time. Historians may eventually find that this vision *had a greater impact on thought* than did the Copernican revolution of the 16th century, which *upset the human self-image* by revealing that the Earth is not the centre of the universe. From space, we see a small and fragile ball dominated not by human activity and edifice but by a pattern of clouds, oceans, greenery, and soils. Humanity's inability to fit its activities into that pattern is changing planetary systems, fundamentally. Many such changes are accompanied by life-threatening hazards. *This new reality,* from which there is no escape, must be recognized – and managed" (WCED, 1987; no italics in the original).

In view of the comprehensive penetration of societies by new technologies, this enlightenment project should also include technology-impact assessment in particular. Visions, narratives, scenarios and simulations are integrated there as "content in the form of ideas about future developments," but are based "exclusively on current 'input data' such as knowledge, interests, assumptions and values" (Grunwald, 2012: 26). Without this emancipatory scrutiny, new technologies are conceived and used with precisely the human self-image and world view on which many of the sustainability problems are already based. This would be more likely to lead an acceleration than to a correction of these negative trends. The practice of questioning the assumptions, knowledge, interests and values of current input data forms the basis of reflexive science, in which terms like 'futures literacy' and 'anticipation' are established as new fields of research and practice (Chapter 2). The emergence of socio-technical systems of machine intelligence and decision-making, as well as technical possibilities for manipulating human beings, raise questions relating to human life and dignity, as well as to self-determination and the foundations of life.

Use digitalization as potential for humanity

An approach in the spirit of the Enlightenment is a prerequisite for new technological possibilities to help advance the vision of a 'new humanism' and the development of human potential:

1. Can human abilities such as empathy, personality development, physical sensitivity and self-regulation be strengthened by digitally transmitted data, information or educational games? Or, on the contrary, are restrictions in the use of digitally mediated experiences required?
2. Can new forms of communication, interaction or infrastructure make it easier to experience systemic connections and social feedback loops in societies and thus also to embed individual actions within them? Or is digitally mediated communication weaker here than analogue communication?
3. Does digitalization enable us to overcome the lack of mediation and speechlessness between local communities and global ecosystems? How could augmented reality, simulations, gaming or even citizen science help here? What role does directly experiencing nature play?
4. Which cultural influences and digitally mediated practices find an echo and are disseminated in an increasingly global space of discourse and interaction? Which ideas of human self-determination and solidarity, dignity and way of life are dominant; which are hardly represented? What effect does this have on the human self-image in the 21st century?

Research, science and education often have a constitutive effect, especially in times of profound upheaval, which they should courageously and responsibly accept. People can become co-creative and successful actors in shaping the future if they are enabled to meet the current challenges: observation, reflection, imagination and creativity drive alternatives, experiments and innovations. In times of crisis they are important components of resilience (UNESCO, 2012a: 15).

empowered totalitarianism'. In view of the challenges that already exist today because of extensive data collection and economic incentive structures in liberal democracies, and scoring approaches in authoritarian systems such as China, the danger of total individual and collective surveillance and the end of genuine privacy is by no means distant doom-mongering. Here looms the danger of an insidious destruction of the model of the free individual as a person with dignity and rights. The ongoing shifting of decisions to digital systems, if it goes beyond meaningful automation (e.g. security-relevant backup functions, more effective process control), will also be crossing a threshold if it threatens to erode democracy and public deliberation as the central mechanisms of societal decision-making. The economic system could develop further by means of monopolization tendencies in the direction of increasing concentrations of power and consumption of natural resources that would further underpin the above-mentioned totalization dystopia. Disruptions of the work-oriented society could cause the global collapse of forms of work and participation that are established today. The consequence of these and other potential systemic risks would be increasing inequality and exclusion (Box 7.3-1). Small digital elites, equipped with considerable economic and political power, would have exclusive access to human enhancement, global databases and the vestiges of intact nature; everyone else would increasingly be left behind and form a global precariat without dignity or purpose, sedated by multimedia and frozen in the apparent imperfection of their biological existence.

Under no circumstances should these systemic risks, which describe negative extremes of possible futures, obscure our view of the challenges and shortcomings of the present. The joint development of positive guiding concepts is just as necessary for actively shaping digitalization and sustainability as clear and early analyses of the future dangers and risks of digitally empowered totalitarianism.

Guiding principles for action

It is thus evident that the disruptive force of possible developments makes 'profound' digital change a key sustainability issue. Like recognizing and overcoming path dependencies, projections in the face of great uncertainty are a known problem in sustainability science and policy. In environmental policy, there are established and proven principles (precautionary principle, cooperation principle, polluter-pays principle and integration principle) that can be used for shaping digitalization (Section 8.4.2). In the context of this experience, further guiding principles for this Second Dynamic therefore include the systematic strengthening of societal far-sightedness and constant reflexivity, the ability to act, and long-term resilience.

In order to set the course for sustainability *today*, societies should hold discussions *today*, strengthen their creative power and develop long-term visions. Scientific advice for policy-makers, methods for strategic foresight, technology-impact assessment, research and education initiatives, as well as societal and transnational discourses with all stakeholders are ways to fight together anticipatively to realize a 'new humanism' (Box 7.3-2) – and at the same time prevent a gradual collapse into a convenient 'more-of-the-same' attitude, or even 'digitally empowered totalitarianism'. This requires multilateral cooperation and a global framework (Chapter 8). Technologies and increasing innovation and knowledge often know no national borders, whether positive or negative. The EU in particular has a responsibility to develop its own citizen-oriented, constitutional and democratic model for the digital 21st century (Section 8.5). The development of strong guiding principles that go beyond the 2030 Agenda can form the starting point for this.

- *Societal 'update' for broad and institutional digitalization competence:* Sustainably shaping digital (global) societies requires a systematic strengthening of societal reflexivity and the ability to act. This competence-building process, which must be embedded technically and institutionally, should encompass the political and institutional core areas, i.e. the government, ministries, authorities and parliaments. In addition, business, civil society, the education system and academia, too, require self-reflection, technical expertise and, perhaps, embedding in institutions to enable them to anticipate and influence digitalization effects in their respective spheres of life and fields of activity. New and old forms of scientific advice to decision-makers in politics and society, technology-impact assessment, methods of strategic foresight, and diverse societal arenas for discourse (e.g. stakeholder formats, science, the media, but also art and cultural institutions) remain key in this context.
- *Develop visions and shape pathways proactively:* A critical and reflexive debate about visions and models for society as a whole is important to be able to use creative power proactively. The dominant, economic- and technology-policy-oriented discourse on 'innovation leadership', on 'being driven' and 'not being left behind' does not lead to a meaningful model for a digital, sustainable society. This narrative constricts arguments and fuels fears. With its outline of a 'new humanism' (Box 7.3-2), the WBGU offers a possible positive vision of how digitalization could sustainably enrich our world society. Such a target perspective can also be a guiding factor for institutional processing, for example by ministries and authorities, e.g. to answer the key question of 'Why digitalization?' The EU as a pioneer of a dignity- and rights-based, sustainable digitalization strategy is a similarly powerful vision – particularly as a global alternative to the liberalistic paths of Silicon Valley and Chinese state authoritarianism.
- *Clearly identify and avoid dystopic systemic risks in the present and the future:* Both as a precaution and to structure digitalization in the best possible way, it is important to anticipate possible dangers and traps. With a tentative list of 'systemic risks' (Box 7.3-1), the WBGU suggests conducting the discourse on

negative consequences throughout society, paying attention to the varying character of such systemic risks in order to promote resilience in societies. Some of these systemic risks relate to gradual processes, others to abrupt turnarounds. Still others are today hardly tangible and will need further research and precautionary action ('black doors').

7.4 Third Dynamic: The future of *Homo sapiens* – discourses

Digitalization opens up completely new realms of possibility for the future of *Homo sapiens* that go beyond biological and cultural evolution. This future has long been part of societal discourse, not least in science fiction, which explores utopian and dystopian possibilities (Chapter 6). Digitalization can furthermore have fundamental effects on the relationship between human beings and the environment. For example, virtual components might increasingly be added to the future human environment. Completely new questions are arising: Could there be a *Natura futuris* that from today's point of view is impoverished, but in which a future, adapted human being can still live? Should digitalization focus primarily on improving the world/environment or human beings? In the end, can a technological, posthumanist human being, freed of everything biological, manage completely without nature or the planet (Box 2.1.2-1)? The preservation of humankind on this planet can be seen as the 'ultimate sustainability problem': The question is about the future viability and identity of humankind itself and human societies as such.

In the WBGU's view, this should not be a matter of redefining human health or environmental health by enabling people to live by means of digitalization in an otherwise ruined environment. Rather, the WBGU recommends the aim of preserving biological human beings and their societies embedded in their natural environment (Section 2.2).

Human beings in the Digital Age, referred to by the WBGU here as *Homo digitalis*, to use a term coined by Capurro (2017), are not only in constant interaction and closely interwoven with digital tools and media; they are already increasingly in the process of repairing, changing or even improving their bodies using digital methods (Box 2.1.2-1; Section 5.3.7). The technologization of human beings has already begun and is progressing turbulently (Topic box 5.3-2; Kehl and Coenen, 2016; Birbaumer, 2017). As the WBGU (2018a) writes, "assistance systems, implants, sensors and other forms of interaction between people and technical systems can compensate for physical limitations (e.g. with prostheses), or even shift the parameters of human capabilities, e.g. improve our cognitive potential." This development is very much driven by technological and economic interests and science; the focus often is on individual benefit (e.g. in the form of scientific findings, commercial usability or individual quality of life), while the societal or ethical consequences of the potential benefits or risks often receive too little attention.

There is already an urgent need today to examine the framework conditions of these technologies (Kehl and Coenen, 2016: 150) and a need for regulation to limit and monitor some of the already visible negative consequences (Yuste and Goering, 2017; Birbaumer, 2017; Section 9.4). Even if the term *Homo digitalis* does not mean a new species in the transhumanist sense (Box 2.1.2-1), this Third Dynamic is about the incipient, gradual transformation towards, in the future, increasingly digitalized people within digitalized societies. In the digital Anthropocene, therefore, the future of what it means to be human is itself becoming a topic of sustainable development

Furthermore, there is an intensive and controversial discourse on *Machina sapiens*, i.e. on cognitively powerful machines (Section 3.3.3). Are we threatened by a humanization of machines (Box 7.3-2; Section 10.3.3.1)? To what extent can and should machines be human-like at all? Technical systems can already imitate intelligence and make autonomous decisions today – albeit hitherto only to a limited extent. In public discourse, however, they are often even humanized, i.e. they are attributed genuinely human qualities or behaviours (Rehak, 2016). The problem here is "not so much that technology is increasingly approaching or visually resembling human beings – rather, it is a matter of the subtle blurring of the fundamental characteristics that make up a person or a machine" (Kehl and Coenen, 2016: 147). In any case, AI and automated decision-making systems will fundamentally change and challenge people and our societies, confront them with previously unknown problems while at the same time opening up new options for action: "Machines are now good or excellent at arithmetic, chess, proving mathematical theorems, stock picking, image captioning, driving, arcade game playing, Go, speech synthesis, speech transcription, translation and cancer diagnosis" (Tegmark, 2017: 80). AI is already superior to human analytical capabilities in an increasing number of sub-areas, while human intelligence is (still) unique in its ability to assess multiple contexts. It is uncertain when or whether technical systems will ever be generally equal or superior to human cognition. However, long before such a point might be reached, the connections between technical systems and human beings, people's self-image and our world views will change fundamentally in more and more areas of business, society, politics and science.

At the same time, there are distinguishing features that not only make people unique in relation to machines, but also emphasize this uniqueness. The human ability for empathy, emotionality and social community distinguishes us fundamentally from machines. Only humans have their own reasons for their actions – motives, feelings, moral sensitivity. The mutual recognition of these motives – and thus recognition as human actors – can only be the basis of interaction between humans, because machines do not have intrinsic reasons for their actions (Nida-Rümelin and Weidenfeld, 2018).

A key unique feature of human intelligence in relation to machines is thus based on the emotional and social components of human action. Although machines in their interaction with humans can increasingly interpret human emotions and also depict emotions themselves (Yonck, 2017), it is never anything more than a simulation of feelings (Nida-Rümelin and Weidenfeld, 2018). As the director of MIT Media Lab, Joichi Ito, noted in this context: "More computation does not makes us more 'intelligent', only more computationally powerful" (Ito, 2018). The computing power of machines, which may appear superior to ours, therefore does not *per se* eclipse human intelligence (Sections 3.2; 3.3.3). Rather, the inability of machines to generate their own genuine emotion can help people to better recognize and strengthen the unique features of their thinking; after all, these characteristics are indispensable for human coexistence. "We trust other people not because they are incredibly smart – like AI – but because they have emotional connections, specifically with us" (Gray, 2017: 21). The unique characteristics of human intelligence cannot on principle be ascribed to any machine, no matter how advanced it may be.

However, as already mentioned, there is speculation that autonomous and intelligent machines – beyond the present-day achievements of AI, which are already impressive in some areas, e.g. pattern recognition – could in the future significantly surpass humans in terms of cognitive performance ('singularity'; Vinge, 1993; Kurzweil, 2005; Bostrom, 2014). Under more advanced technological conditions than today's, it is even speculated that powerful AI could one day achieve some kind of 'superintelligence', with the associated risk that machines could gain power over humans (Bostrom, 2014). In extreme cases, transhumanists and technological posthumanists even speak of overcoming the shortcomings of the biological body, particularly death, by 'uploading' human identity into a digital machine (Box 2.1.2-1; Kurzweil, 2005; mind uploading: Loh, 2018: 80ff., 122ff.). Under these extreme scenarios, even human beings' natural environment could become superfluous if they were to digitally distance themselves so far from their biological origins that their relationship to the Earth system became obsolete (Tegmark, 2017).

In view of these visions, the borderline between humans and machines, and thus between humans and the environment, threatens to become increasingly blurred (Kurzweil, 1999; Kehl and Coenen, 2016). At present, these discourses appear speculative, but they are already powerful in culture (science fiction), society and science and are associated with both hopes and fears (Chapter 6).

Other authors are sceptical about these speculations and see no dangers from superintelligent machines (Floridi, 2014: 129ff.; Domingos, 2015: 283f.; Kehl and Coenen, 2016: 16f.; Misselhorn, 2018: 205ff.), or deny that software-based systems of any kind, including AI systems, can have any kind of mental characteristics such as perceptions, emotions or decision-making abilities; they merely see a "more or less successful simulation of cognitive and emotive processes" (Nida-Rümelin and Weidenfeld, 2018: 205). Irrespective of where one might like to draw the line between humans and machines, society faces the challenge of understanding and negotiating the further dissolution of borderlines between humans and machines to the benefit of humankind, or of designing the interaction between humans and machines in a positive way. In the course of technical progress and in the context of societal challenges, the relationship between human beings and technology will have to be constantly redefined (Kehl and Coenen, 2016).

Further fundamental questions arise in view of a potential 'artificial evolution of humankind'. It is already possible today to select in-vitro fertilized eggs according to desired criteria before they are implanted into the uterus. Even more profound would be the application of new methods of genetic engineering (e.g. CRISPR/Cas9; Jinek et al., 2012); modern digital technology is indispensable for the development and use of these methods. An artificial modification of the human genome in the germ line could be used to cure hereditary diseases resulting from genetic defects (Nuffield Council on Bioethics, 2018). Corresponding research has been carried out on human embryos for several years now (e.g. Liang et al., 2015; Kang et al., 2016). The alleged editing of the genome of twins by the Chinese scientist He Jiankui using CRSIPR/Cas9 in November 2018 has encountered massive criticism worldwide (Cyranoski and Ledford, 2018) and led to an ongoing societal discourse on responsible human germline editing (Deutscher Ethikrat, 2019).

But the new genetic engineering methods also open up the transhumanist-eugenic prospect that *Homo sapiens* 'takes evolution into his own hands' and purposefully steers it towards a new 'posthuman species' (Annas et al., 2002; Fukuyama, 2002). In this way, human adaptations and traits could be cultivated, such as tolerance to adverse environmental conditions caused by global environmental changes, or extremely enhanced sensory abilities (Nuffield Council on Bioethics, 2018: 47). These approaches thus have the potential to fundamentally change the biological constitution of the future *Homo sapiens*. Because of the ethical problems associated with this, researchers warn against genetic manipulation of the human germ line (Lanphier et al., 2015; Baltimore et al., 2015); it is banned in many countries.

With regard to the above-mentioned necessary discourses, and to the potentially far-reaching effects on societies and the environment, fundamental questions on ethics and human dignity arise – some of which are quite speculative. Therefore, the WBGU's Third Dynamic cannot only be about concrete recommendations for action or research in the sense of classic advice for policy-makers. Rather, it is above all a matter of looking at these issues and problems early enough and drawing societal attention to them, because the changes outlined will fundamentally challenge and change existing concepts of 'human development' and 'sustainability'. The WBGU's main aim here is to ask the right questions and not to present ready-made answers. In a second step, ways and methods should then be found for societies and cultures to prepare for the possible paths of society in relation to *Natura futuris*, *Homo digitalis* and *Machina sapiens,* and how they can democratically and transparently shape the discourse on criteria, rules and demarcations.

In order to stimulate this discourse on the future range of possibilities, the WBGU briefly presents here three speculative, optimistic mind games. The WBGU recommends using John Rawls's method to reflect on possible futures. In his Theory of Justice (Rawls, 1972), Rawls advised his readers, citizens and decision-makers to think about 'fair conditions' from a position in which the thinkers do not know what status they themselves have in the imagined society. This 'veil of ignorance' allows ideas and principles to be generated of justice that are not shaped by the immediate self-interests of the thinkers, but geared towards imagining a fair society that does justice to 'every man and woman'. Such a 'veil of ignorance' could also be helpful when thinking about future human images in the Digital Age against the background of the WBGU's three mind games:

1. *Humankind finds itself:* AI already surpasses human cognitive performance in some areas today (Section 3.3.3). All the more reason for us to focus our attention and appreciation on the unique features of humankind described above, which specifically do not directly relate to cognitive capacities: emotional and social abilities. AI could take on more tasks in measurement, calculation and documentation, and in this way enable us to turn our attention more to such capabilities as empathy, care and solidarity. In contrast to the 'hard' clichés of the superhuman with a computer brain, or omniscient computer systems with increasingly human characteristics, this would outline a 'soft' vision of societal progress.
2. *Humans create companions:* The further the advances that AI makes in ever more application areas, the more diverse and intimate can the points of contact and interfaces become between technology and people. This can even lead to symbiotic connections, which, however, are likely to turn out differently than imagined in the popular 'cyborg' dreams. It is also possible that AI-enabled entities will emerge that will become well-integrated, loyal companions of humans in societies that are more liveable than those of today. For example, digital assistants could increasingly take over our monotonous activities (e.g. logistical tasks), support us in learning and understanding (e.g. by synthesizing and interpreting overwhelming amounts of information), and, not least, help us to value ourselves and our environment more highly (e.g. through diagnostics and mirroring). If people themselves had control over all the data they generate, they could be empowered to understand and develop themselves and their behaviour better. Such a prospect encounters less scepticism in the East Asian cultural sphere than in Western societies, for example, and promotes a world view that does not categorically isolate humans from nature and technology.
3. *Humans invent their masters:* As described earlier in this chapter, speculation about the future progress of AI – and thus ultimately also about the future of *Homo sapiens* – diverge widely (Section 3.3.3; Box 2.1.2-1). Nevertheless, against the background of the already impressive cognitive achievements of AI today, it is both disturbing and highly controversial to ask whether not only conscious but also animate artificial entities with independent decision-making and reproductive capabilities might be formed in a later phase of the digital revolution. In this context, protecting human dignity would remain a quintessential challenge. Nevertheless, the following question could be posed in the discourse: could the combination of humankind's social and emotional

intelligence with the superior cognitive abilities of machines make a form of co-evolution possible, whose creatures possess even more humanity than we ourselves do?

The WBGU has discussed these thought experiments and recommends that our societies should proactively and rapidly concern themselves in the Digital Age with the future of human development, understanding human dignity and concepts of sustainable development, i.e. the interaction between societies and the Earth system. This is the only way to develop the ability to shape and plan. The intuitively 'reasonable' option would be a general moratorium that would fundamentally prohibit R&D efforts to create conscious and therefore sentient systems. But is such a complete and, above all, global moratorium even feasible? And if the development of civilization since the Neolithic Age has evidently been self-organized and directed towards substituting and transcending human (physiological, manual, cognitive) capabilities, can the creation of a new being by humans be excluded *per se*? Against this background, WBGU has resolved to recommend discourses on desirable futures.

Guiding principles for action

These three thought experiments might seem extremely speculative. Nevertheless, the Third Dynamic has already begun. The WBGU therefore recommends anticipating the future of humanity in the Digital Age now in a way that is democratic and oriented towards the common good, and using regulatory means to contain the current challenges of digitalization. "It is still largely an open question how 'anticipatory governance', which should involve not only science and technology but also politics, business and potential users, might be organized" (Kehl and Coenen, 2016: 17). The new challenges, e.g. with regard to individual autonomy, self-determination and sovereignty over personal data, are already pressing, but they could be considerably intensified by the future digital possibilities.

In view of such momentous questions, a broad and transparent societal discourse and state policy on framework conditions should take priority over simply leaving things to the momentum of commercial interests. The necessary societal decisions must be made in a democratic process. In order to prepare these formative tasks at an early stage, we need a worldwide, differentiated, joint and dynamic debate on values and standards. Fundamental philosophical and ethical questions must be discussed in a societal discourse; the normative dimension gains decisive importance. Here, too, the WBGU would like to place the concept of dignity at the centre of the deliberations (Section 2.3). Discourses on the following action-guiding points are particularly important:

- *Discourse I: Homo digitalis:* Beyond the welcome compensation of physical limitations, e.g. with mechanical or sensory prostheses, the rapidly growing technical possibilities pose the following questions: How can the identity of humans or what it means to be human be preserved in view of the 'technologization of human beings' (Topic box 5.3-2)? Where should boundaries be drawn to limit the technologization of human beings? Which "genuine characteristic of human beings and their culture" do we want to preserve and protect from interference or mechanical replacement (Kehl and Coenen, 2016: 18)? To what extent do we want to control the future evolution of the *Homo sapiens* species itself? What does a new humanism mean for *Homo digitalis* (Box 7.3-2)?
- *Discourse II: Machina sapiens:* Humans will always have the responsibility for machines, data, algorithms and software. To this extent, the WBGU urges the positive approach of seeking self-assurance of which characteristics and what kind of well-being the natural *Homo sapiens* should strive for in their relationship with machines and automatisms. The aim should be to strengthen humanity's self-confidence and to actively shape human/machine collaboration in accordance with human responsibility. In view of questions such as whether and where people need to be protected from machines, and whether and where human well-being can be endangered by machines, the WBGU also advocates a moratorium on the development and application of fully automated autonomous weapon systems, as can be found in the draft of the 'Charter for a Sustainable Digital Age' (Section 8.6). There are a number of other relevant questions that the WBGU would like to raise in the discourse: Should there be a limit on the ability of machines to feel empathy, or on the humanization of machines? Or would this even have advantages if it were carried out with the necessary 'containment measures'? Is the 'superintelligence' of machines nothing more than a dystopian science fiction vision, or is it a scenario or risk that needs to be discussed? At some time in the future, will we perhaps even face the challenge of drawing a borderline beyond which even the dignity of artificially intelligent machines would have to be discussed? Or should this be excluded from the outset by fundamentally outlawing and excluding research on machine consciousness for ethical reasons (Metzinger, 2001)?
- *Discourse III: Natura futuris*: In the age of the digital Anthropocene, the question arises as to where to draw the borderlines of human intervention in nature and the environment. Are the existing political objectives enough? How is the relationship

between humans, nature and technology changing in the Digital Age? If biological humans are to be preserved in their natural environment, what prerequisites are needed for nature and the Earth system? Should further objectives that go beyond this be pursued?

The overall question arises as to how can we shape a positive co-evolution between human civilization, the technosphere and the environment? The WBGU sees these guiding principles here:

- *Create discourse arenas and engage in a societal discourse:* In view of these possible and, in some cases, necessary issues, an important task that already exists today is to organize an ongoing societal discourse with broad participation and to create suitable arenas for discourse (Section 9.4.4). At the heart of these discourses lies the question of how – on the basis of common values and norms, perhaps based on the normative compass – the interaction and co-evolution of human civilization and intelligent technical systems could be shaped in such a way that human well-being takes centre stage (Chapter 2). These discourses should therefore discuss not only the current state of affairs, but also different positions, conflicts of interest and power constellations. Not least, they should examine whether the existing institutional regimes need to be adapted.
- *Think ahead about the new digital society:* Digital technologies make completely new ways of shaping the future possible. The fundamental strategic decisions and cultural upheavals of the Digital Age should already be thought through today. The above-mentioned profound philosophical questions must be asked and discussed now in new discourse spaces yet to be created (Section 9.4.3). Philosophy should therefore become one of the leading sciences of the Third Dynamic. Research and education must create a foundation for future decisions (Section 10.3.3). In this context, technology-impact assessments of possible future scenarios and applied ethics offer constructive approaches for developing early-warning functions and proactively shaping technological change (Section 10.3.3.3).

7.5 Conclusions: Place digitalization at the service of global sustainability

The WBGU's overarching message is that digitalization should be put at the service of global sustainability. Digitalization is not a 'force of nature', but a people-driven development which, given its potential and risks, must be shaped for sustainability. The decisive starting points for the Transformation towards Sustainability (depending on the dynamics and problems) lie in the political framework (politics, law), the societal practices (business, consumers), and in the further development of sustainability models and ideas of 'human development' that do justice to the dynamics of the Digital Age. In this context, digitalization is both a subject of observation and a possible instrument of specific solution strategies.

Current developments clearly do not yet point in this direction. The possibilities of the Digital Age are currently not being sufficiently placed at the service of global sustainability. Current framework conditions and societal realities mean that the digital revolution is reinforcing and accelerating existing unsustainable trends rather than helping to overcome unsustainable path dependencies. The many concrete changes described and analysed in this report do indeed hold great potential. However, they will not *per se* lead to a trend reversal. From a transformational perspective, this can be termed 'incremental radicalism': the sum of a multitude of concrete practices reproduces and accelerates sustainability crises without these negative consequences being intended or completely foreseeable in individual cases.

By comparison, the putative utopias of those who deliberately want to use the means of the digital revolution in a disruptive way are relatively clear. Here, a society that takes surveillance to extremes and where personal data becomes an important raw material meets with the totalitarian control-state that tries to prevent any deviation using digital means. From a transformational perspective, a kind of 'radical radicalism' emerges. On the one hand, digital strategies radically geared towards resource efficiency, climate-change mitigation and Earth-system protection would be conceivable that use the technical possibilities of monitoring production and consumption for ecological progress. On the other hand, systemic disruptions are then fuelled as an end in themselves, without paying attention to important system functions that are absolutely worth preserving – such as the preservation of freedom and human dignity.

Putting digitalization at the service of sustainability therefore means using the many concrete possibilities of digital applications systematically in such a way that successive, unsustainable path dependencies can be overcome. The Transformation towards Sustainability is a comprehensive project of society made of many ingredients that significantly changes the shape and driving forces of our economy and coexistence. In such a fundamental sense, the intention of this transformation is a kind of 'radical incrementalism': many important changes are made step by step in a reflexive and anticipatory way, so that the essential core functions,

Box 7.5-1

Education for future-proof societies

How people perceive and understand reality affects how they experience and evaluate it – and thus also which ideas and entrepreneurial or political measures they regard as meaningful, feasible and legitimate. The way in which people feel empowered to advocate these measures that they feel to be meaningful, feasible and legitimate, and to pursue them in cooperation with others, determines a society's ability to innovate, discuss, shape and act. A sustainable society in the sense of a new humanism (Box 7.3-2) systematically promotes its decision-makers' – i.e. also its voting citizens' – capacity for reflection and self-efficacy.

Future-proofing is thus the result of what the WBGU (2011:352ff.) has described as 'transformative education' and is being developed under the concept of transformative learning in educational theory: an understanding of options for action and approaches to solutions as well as one's own efficacy in shaping future developments. This understanding includes a critical-constructive questioning of basic scientific assumptions and cultural patterns that have guided and legitimized the previous shaping of society with its conventions, roles and institutions. The World Social Science Report 2013 (ISSC and UNESCO, 2013) described this reflexive capacity as 'futures literacy' and as being central to transformative processes in the sense of social learning (Section 2.1.2). Educating for the societal challenges of the coming decades should rediscover its humanist roots and help citizens to see themselves as designers of the future in their diverse societal roles (Section 5.3.4). Digitally simplified participation in the generation and dissemination of knowledge for the orientation and legitimization of transformation processes (Section 5.3.1.1) supports this capability. Corresponding media and technology literacy and resilience transcends the currently often instrumentally defined digital literacy, which is limited to successfully operating technical devices (European Commission, 2019a). Technologies are integral elements of social and institutional systems as regards their invention and dissemination, and this, too, should be integrated into the new understanding of education. In sustainable societies, ethics, the ability to reflect, personality development and cooperative skills also belong to the educational canon. This can enable people to participate actively and anticipatively in shaping and transforming social structures such as decarbonization or digitalization.

The central role of values, attitudes, self-control and personality development in dealing with the rapidly increasing complexity and speed of societal developments due to digitalization and networking processes is also being discussed in the companies. The same applies to risk and resilience research, which focuses on dealing with ignorance and nonlinearity in these systems. In times of great uncertainty and rapid and profound changes in societies, increased abilities of empathy, cooperation and self-regulation offer good prerequisites for the preservation of cooperative and common-good-oriented values and democratic abilities. Furthermore, the selection and quality of reliable information and knowledge is of particular importance when it is a matter in legitimizing decisions or anticipating possible consequences. Broad access to data and public authorities with high quality-assurance standards are key to a societal understanding of plausible, possible and desirable futures and their entrepreneurial and political design (Section 5.3.2).

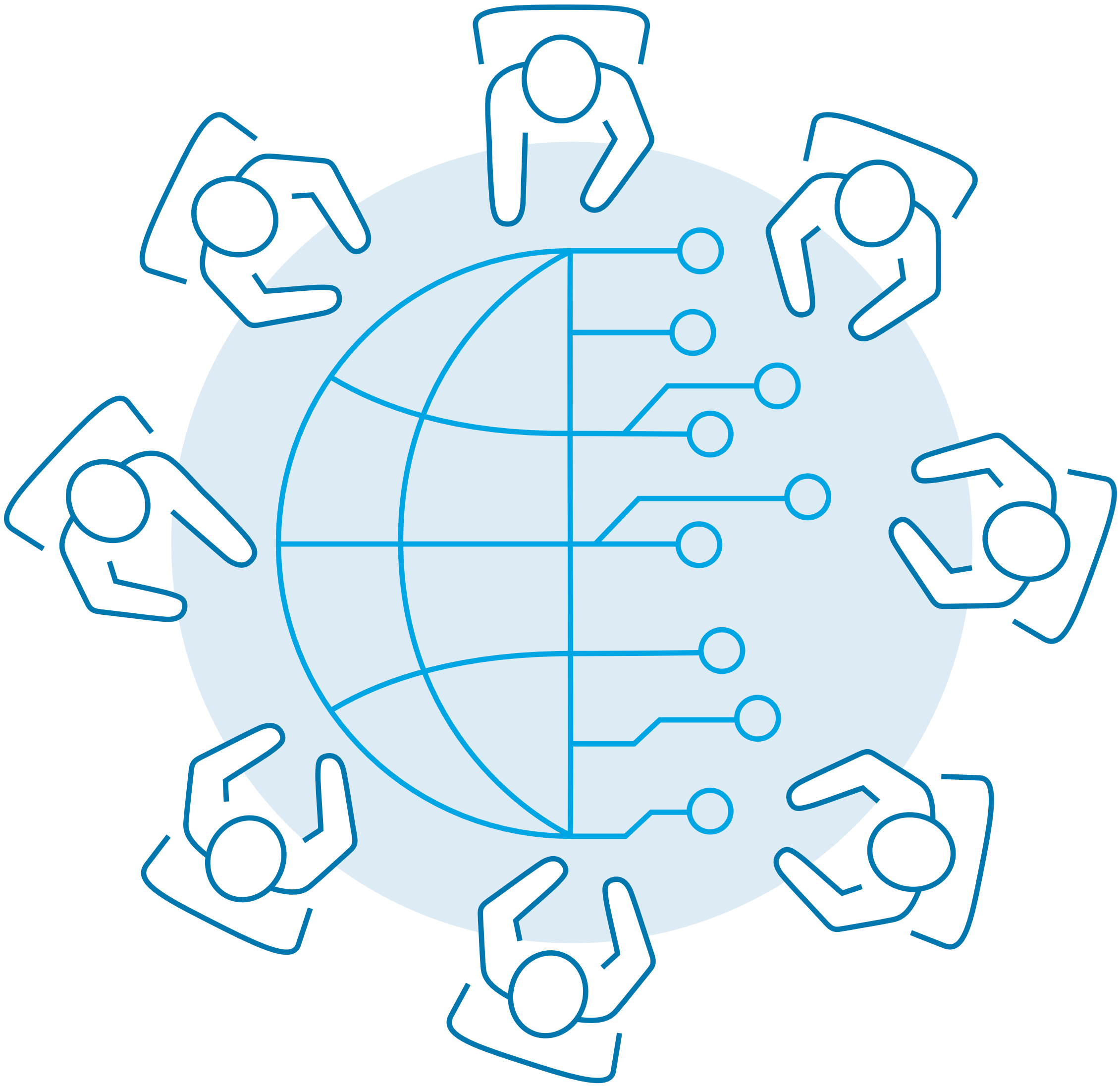
i.e. our ecological, social and species-specific life-support systems, are sustained in the long term.

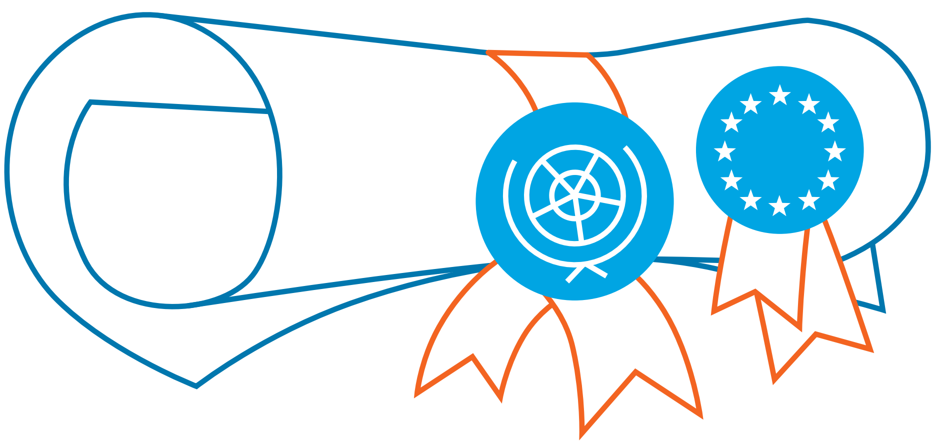
The following elements for this comprehensive, formative task emerge from all the dynamics analysed. Societies must be able to quickly and effectively tackle the urgent problems for sustainability with the help of digitalization *(acting societies)*. This applies with particular urgency to sustaining the natural life-support systems (Section 9.1.1) and to securing social cohesion (Section 9.1.3). This concrete need for action must be taken seriously and addressed by means of active governance by a 'proactive state' (WBGU, 2011:203ff.; Section 4.1), by companies and civil society, and not least by educational actors (Box 7.5-1; Section 5.3.4). At the same time, there should be a focus on ensuring the future ability to act *(societies capable of action)*. Strategies need to be developed in good time to deal with the profound changes in societies brought about by digitalization and its impact on sustainability. People must be empowered through education to understand the upheavals outlined in order to learn to shape them (Box 7.5-1). Finally, discourses should already be made possible today in which the fundamental questions of the digital future are reflected on and negotiated *(forward-thinking society)*. A responsible society with the ability to act can develop in the interaction of these elements.

Against this background, the WBGU sees the EU as an economic and values community, as an important actor in progressing towards the integration of sustainability and digitalization. This opens up the possibility for the EU to realize a sustainable, free and equal civil society through digitalization, especially in contrast to the American laissez-faire attitude towards digital companies and the Chinese model of exploiting digitalization for the exercise of state power. Europe should therefore develop its own powerful vision of the use and regulation of digitalization for sustainability and the protection of human and fundamental rights. Up to now, the decisive drivers of digitalization have been the potential for economic profit and government surveillance. Instead, efforts should focus on strengthening and promoting the sustainability of natural life-support systems, inclusion, *Eigenart* and human dignity (Chapter 2) through digitalization, and on responsibly containing risks. The outline of the core elements of a 'new humanism' suggests the possible direction of such a development (Box 7.3-2). In such a process, Europe is not separating itself from the world community, but making the most of opportunities to give new momentum to global digital development.

Four overarching, action-guiding principles are presented in the following that can be applied to all three Dynamics.

- *Promote global society's ability to shape and plan:* Many different dimensions of a reduced ability to shape and intervene can be identified in the field of digitalization and sustainability; here are some examples: (1) it is very difficult for political actors to muster the creative power to prevent the planetary guard rails from being breached; (2) states are at risk of losing the sovereignty to actively shape the behaviour of multinational digital corporations; (3) people are losing their formative sovereignty over the way their personal data is used by companies or states and the way in which decisions are influenced by this. Because of their commercial interests, private actors develop many different options and products that can have both positive and negative effects from a normative point of view. Containing these effects for the common good is an important formative task. States and, not least, global governance also have an especially important role to play in view of the global reach of digitalization and the global impact of a failure to shape sustainability. Guiding concepts should be developed and goals defined at multilateral level for a sustainability policy that takes into account the potential and risks of digitalization (Chapter 9). On this basis, the state should be able to lay down in a democratic process the framework conditions for private actors and companies in such a way that development does justice to the interests of society.
- *Promote global society's innovative capacity:* The potential of digitalization should be used for sustainability and human well-being. It is therefore a matter of 'responsible innovation', in which both goals and possible risks to sustainability are taken into account from the outset. The recommendations of this principle are primarily directed towards academia and education, but also towards technology-impact assessment and technological change (Section 10.1).
- *Promote global society's ability to understand:* For societies to remain able to shape their future, the processes and effects of the digital revolution must be understood by societal actors, and there should be transparency about who or what causes and drives them. This applies, for example, if the systemic risks of the Digital Age (Box 7.3-1) identified by WBGU are to be avoided. This is about education and the communication of science, thus ultimately also about digital literacy (Section 9.1.4). The recommendations of this principle are primarily related to education and discourse, and not least at scientific advice for policy-makers.
- *Promote global society's ability to engage in discourse:* We already need arenas in which to discuss, for example, how an exemplary 'new humanism' (Box 7.3-2) can be developed in the 21st century. How can digitalization be linked to societal goals, and what roles should public and private, local and global actors play? The recommendations of this principle are primarily aimed at education and the democratic public sphere (dialogue, media, open society).





Global Governance for the Transformation towards Sustainability in the Digital Age

8

The WBGU makes initial proposals on how the international community might agree on common guiding concepts, principles, regulatory and institutional frameworks, and ethically-based borderlines. The EU should develop its own model of a sustainable, digitally enhanced future and work towards a shared understanding at the international level in a multilateral network. To provide impetus for global processes, the WBGU presents a draft charter for 'Our Common Digital Future'.

Shaping the Digital Age with the aim of sustainability is a global task that requires a framework of principles, rules, laws and institutions: global governance is therefore a decisive lever for the Transformation towards Sustainability in the Digital Age. Digitalization is both an object and an instrument of global sustainability policy. In the course of digital change, some path dependencies of unsustainable developments are breaking open, creating windows and spaces of opportunity for new actor constellations that can be mobilized for a Transformation towards Sustainability in the sense of the 2030 Agenda. At the same time, however, significant new actors of the Digital Age, such as developers, tech communities and digital corporations, can continue and intensify old, unsustainable development patterns and themselves create completely new sustainability challenges and unsustainable path dependencies (Chapter 4). Some digital corporations are amassing ever more market power and already providing societally relevant services and technologies today without any assurance or even indications that ecological or other societal goals of sustainable development are being taken into account. States are taking little responsibility for the development of digital and digitalized infrastructures and technologies; decisions are made by cross-border alliances dominated by the private sector; the rights of individuals can be eroded in the Digital Age (Section 4.2). So how is the global understanding of sustainability changing, and how can it be linked to digitalization?

Over the last five decades, international sustainability goals have developed as a vision of global, long-term well-being, reflected in particular by the 2030 Agenda with the SDGs, the Paris Climate Agreement and the Aichi biodiversity goals. By comparison, efforts to reach international agreement on a regulatory framework and cooperation in the field of digitalization, e.g. on societally controversial uses of digital solutions, are still in their infancy, and the need for regulation is increasingly becoming the focus of public attention (Section 8.1). There is a particular need for international cooperation and regulation gearing digital change towards achieving the SDGs. The WBGU shows how digital change currently can and does affect the chances of achieving global sustainability goals (Sections 3.6, 8.2). Just as the Brundtland report on 'Our Common Future' (WCED, 1987) launched a global understanding of sustainable development by integrating environmental and development issues, a similar new stimulus is needed today for a global understanding of 'Our Common Digital Future'. The existing sustainability goals and their underlying understanding of sustainability largely ignore key challenges posed by the use of digital technologies in core societal areas. In the WBGU's view, sustainable development in the Digital Age requires not only ecologically oriented digitalization, but also a common understanding of the problem of how to handle privacy and, closely linked to this, maintaining human decision-making sovereignty, guaranteeing digital inclusion, and shaping the relationship between people and machines (Section 8.3). Based on analyses and assessments of existing international governance and the identification of new needs for action and cooperation (Sections 8.1, 8.3), Section 8.4 extrapolates the first overarching approaches and governance instruments for integrating sustainability and digitalization at the global level. As a potential pioneer, the EU can play a prominent role in the global development of digitalized sustainability societies. This requires a sustainability-oriented digital policy and a sustainability policy that places digitalization at the service of sustainability (Sections 8.1.6, 8.5). With its draft charter for 'Our Common Digital Future' (Section 8.5), the WBGU presents for discussion an integrated understanding of digitalization and sustainability which aims to provide orientation for shaping the Digital Age in the spirit of sustainability.

8.1 Approaches to the governance of digitalization at the global level

In recent years, numerous reports at the global level have addressed the influence of the Digital Age on the economy, societal development and achieving global development goals (Section 3.6). At the same time, examples like the convening of the World Summit of the Information Society (2003 and 2005) and its follow-up processes, the report of the High-level Panel on Digital Cooperation to the UN Secretary-General entitled 'The Age of Digital Interdependence' (UN High-Level Panel on Digital Cooperation, 2019), and the appointment of the Special Rapporteur on the right to privacy (2015) show that the issue of digitalization is increasingly receiving international attention. The UN General Assembly's resolution 'The Impact of Rapid Technological Change on the Achievement of the Sustainable Development Goals and Targets' (UNGA, 2018a) contains particularly clear references to sustainability issues. This increasing importance of digitalization and its consequences for fundamental and human rights at the international level is also reflected in initial governance approaches and institutional responses at the global level (Sections 8.1.1 to 8.1.3).

In contrast to discourses in the 1990s, when state action was still seen as an encroachment on the freedom of the internet, the call for more global cooperation and greater responsibility on the part of the international community is also growing louder in the tech communities (Section 4.2.4). For example, in 2018, a large number of tech actors addressed an open letter to the governments of the G20 states calling on them to work together on key digital fields of action at the global level (Joint Call to G20 Leaders, 2019).

8.1.1 Private-sector development as a starting point for global digital policy

Today, the development of digital technologies, the expansion of digital and digitalized infrastructures and the dissemination of digital applications and services are essentially driven, financed and shaped by globally active companies and private organizations. The basic functionality of the internet is guaranteed, for example, by ICANN, a private (non-profit) organization (Box 4.2.7-1), and the necessary standardization processes for digital goods are often informal and unregulated (Hofmann, 2017). In many countries, digital services such as search engines, map services or social networks have become a basic component of everyday private and business life. Measured in terms of their societal significance and function, some of them already bear the hallmarks of goods that meet basic human needs; at the same time, however, a large proportion of them are provided purely privately. Not least because of the effects of networking and economies of scale, the multinational digital corporations Google/Alphabet, Apple, Facebook, Amazon and Microsoft, now known as the 'Big Five', are playing a particularly prominent role in shaping the future (Chapter 4).

On the one hand, this global, proactive role of digital companies and private organizations in the digital sector has sparked a high level of dynamics technical development and dissemination of digital applications. On the other hand, the societal challenges of this hitherto mainly one-sided private influence on digitalization are also becoming increasingly clear; they are also reflected, for example, in the systemic risks identified by the WBGU (Section 7). The lack of influence in the administration and organization of basic infrastructures and services exerted by states or the international community leads to problems in the enforcement of standards (Hofmann, 2017).

With search engines, digital communication services and social networks, private companies have also created new sources of information and spaces for the exchange of information and interaction, and their use is having increasing societal and political implications (Section 5.3.2). In contrast to traditional media such as radio and television, however, this scope has hitherto not been adequately reflected in corresponding regulations and rules, for example to exclude the misuse of these services and platforms or to sufficiently guarantee the transparency of information flows such as election advertising. A higher level of protection for personal data is now enshrined in the GDPR, which applies in the EU (Box 4.2.6-1). Furthermore, states occasionally enact laws to combat the manipulation of online communication and hate content on the internet (Box 4.2.6-2). However, there are still flaws in the design and, particularly, in the enforcement of this legislation (Boxes 4.2.6-1, 4.2.6-2). Another factor in these challenges is the fact that digital networking and internationalization, which has been significantly driven by companies and private organizations, has created structures and reached dimensions that often severely restrict the intervention options of individual states, which are frequently overburdened in their attempts to represent societal interests (Section 4.2.6).

The topic of sustainable development has so far been hardly embedded at all in tech communities that make decisions about the development of technologies and standards for devices and system solutions (Section 4.2.4). Only a few topics are being addressed: in the meantime the tech communities are increasingly discussing privacy issues (Hofmann, 2017), and companies are becoming involved in network expansion in developing countries and the provision of internet connections. With the Free Basics programme, part of its internet.org project, Facebook, for example, gives people in developing countries free, restricted access to selected internet services. However, this provision of access also raises new questions about the power of major corporations in the provision of infrastructure and related problems such as safeguarding the privacy of users or net neutrality (Solon, 2017b).

8.1.2
UN conferences and processes

The first major international conference on digitalization was the World Summit on the Information Society (WSIS) hosted by the International Telecommunication Union (ITU, a UN special organization) in 2003 and 2005, which prominently addressed the Digital Age as an international policy issue. The WSIS conferences passed the 'Geneva Declaration of Principles' entitled 'Building the information society: a global challenge in the new millennium'), the 'Geneva Plan of Action' (WSIS, 2003a, 2003b), the final declarations 'Tunis Commitment' and the 'Tunis Agenda for the Information Society' (which called, inter alia, for the establishment of the 'Internet Governance Forum': WSIS, 2005a, b). ICTs are enshrined as instruments for environmental and resource protection in the WSIS Forum's 'Geneva Plan of Action'. One of the most controversial issues at the WSIS was the question of who would organize the internet in the future. One unsuccessful proposal was for the administration of domain names and IP addresses to be organized by the private ICANN under the aegis of the ITU, which, as a UN organization, is under the control of the international community (Kleinwächter, 2005; Box 4.2.7-1). Instead, the conference decided to set up the UN's Internet Governance Forum (IGF). The IGF has met every year since 2006 and offers stakeholders from all countries an opportunity to participate in the debate on internet governance. The IGF is not intended to replace or supervise existing forums or organizations, but to provide an additional transparent, multilateral exchange platform between all stakeholders (private, state and civil society). Among other issues, the IGF 2018 focused on the future of work, the internet, the SDGs, internet access in public spaces and its funding, and multi-stakeholder participation to develop global transnational governance (IGF, 2018a). Topics of ecological sustainability, particularly Green IT, were underrepresented here.

In addition to the IGF, the annual WSIS Forum was set up as a continuous follow-up process to the WSIS. The Forum is jointly organized by the ITU, UNESCO, UNDP and UNCTAD in cooperation with other UN organizations. The WSIS Forum, which can draw on the budget and the well-established secretariat of the ITU, is a strong competitor of the IGF (Kleinwächter, 2016). The WSIS Forum is the world's largest meeting of UN institutions on the theme of 'ICT for development'. The Forum's task is to coordinate the implementation of the measures agreed at the WSIS (UNGA, 2016a) with the implementation of the 2030 Agenda. It provides an opportunity to exchange information and create knowledge, while identifying new trends and promoting partnerships, taking into account the developing information and knowledge societies (WSIS Forum, 2018).

The UN General Assembly evaluated the implementation of the WSIS's decisions in 2015 (UNGA, 2016a). The resolution adopted at that time included a commitment by the states to harness the potential of ICT for the 2030 Agenda. It states: "[We] call for close alignment between the World Summit on the Information Society process and the 2030 Agenda for Sustainable Development, highlighting the crosscutting contribution of information and communications technology to the Sustainable Development Goals and poverty eradication" (UNGA, 2016a). No concrete measures were agreed. Up to now, the international community has hardly been a relevant actor in the further development of ICT or in setting standards. It has recently begun taking global sustainability goals into account, but has not identified any concrete issues or areas of application.

8.1.3
UN agencies, UN programmes, UN special rapporteurs and high-level advisory groups

More and more organizations and subunits in the United Nations system are dealing with digital change. This is demonstrated, for example, by the increasing number of reports from UN organizations (Section 3.6). Recent annual reports – such as UNCTAD's World Investment Report 2017 entitled 'Investment and the Digital Economy' or the World Bank's World Development Report 2016 on 'Digital Dividends' – illustrate this trend. Furthermore, publication series have also emerged, such as the UN's E-Government Survey, which has been published regularly since 2001, UNCTAD's Information Economy Report since 2005, the UNESCO Series on Internet Freedom since 2009, and the ITU's 'Measuring the Information Society Report'.

Particularly important for the Digital Age is the work of the ITU, which deals with the technical aspects of global telecommunications. In addition to the ITU, UNCTAD is represented in the UN system with numerous publications on ICT topics such as the digital economy, e-commerce and the information economy. As a body of the UN General Assembly, UNCTAD has the task of promoting trade between countries at different levels of development and offers advice to developing countries on their own ICT strategies.

Issues of privacy, the ethical dimension of digitalization, access to knowledge and education via the internet, and freedom of the media are addressed by UNESCO, also a UN specialized agency. It has published reports on digital literacy, digital citizenship and digital inclusion, for example.

Only a few references to digitalization can be found to date in the UN Environment and UNDP programmes, whose subject matter is particularly close to global sustainability policy. The UN Habitat programme addresses the issue of smart cities. However, digitalization has hardly been mentioned in the New Urban Agenda or in the 2030 Agenda up to now.

The appointment of UN Special Rapporteurs is another element that can be used to address pressing issues or new problems in the UN system. The UN Special Rapporteur on the right to privacy, who is attached to the UN Human Rights Council and was first appointed in 2015, has a tenure of three years (Section 8.3.1) and has the task of reporting annually to the UN General Assembly and the Human Rights Council (HRC, 2018). The UN Special Rapporteur on the promotion and protection of the right to freedom of opinion and expression, first appointed in 1993, pointed out in his current report to the UN General Assembly (2018) that algorithmic decision-making systems can violate human rights (UN, 2018a).

Since 2006, the United Nations Group on the Information Society (UNGIS), which was set up by the Chief Executive Board for Coordination chaired by the UN Secretary-General as a new cross-organizational mechanism, has been responsible for intensifying the integration of digitalization into the UN system. The aim of UNGIS is to generally raise the profile of ICT-related issues in the UN, embed them in all relevant UN institutions, and thus contribute to achieving the WSIS goals set out in the four outcome documents (Section 8.1.2).

The appointment of the High-level Panel on Digital Cooperation by UN Secretary-General Guterres in 2018 was a reaction to the realization that current international cooperation is not an adequate response to the reach and speed of digitalization, especially if it is to be used to implement the SDGs. The advisory group's task was to draw up proposals for improving international cooperation between, among others, the private sector, civil society, international organizations, academia and technology developers. The advisory group also aimed to raise public awareness of the extent and challenges of digital change and its impact on the economy and society. A report entitled The Age of Digital Interdependence was published in 2019 (UN High-Level Panel on Digital Cooperation, 2019). It makes recommendations on building an inclusive digital economy and society, developing human and institutional skills, protecting human rights and human actions, promoting trust, security and stability in the digital world, and promoting global digital cooperation. However, it hardly mentions the conservation of natural resources or issues of global sustainability.

8.1.4
Initiatives in the World Bank, G20, WTO and OECD

Digitalization is a clearly visible and well integrated topic at the World Bank. 'Digital Development' is a separate thematic block in its own right among a total of 30 topics covering digital infrastructure, digital financial services and digital identity cards (e-identity), digital innovation and entrepreneurship, digital platforms (e.g. e-commerce) and digital skills (e-literacy). In the World Development Report 2016, the World Bank also addressed governance challenges, including the need to strengthen global internet governance (World Bank, 2016:303). References to ecological sustainability are only weakly represented, as can be seen from the focus of the blogs and reports on digitalization.

The topic of digitalization has also arrived at the

G20, although it has only been dealt with marginally so far. In 2017, the ministers responsible for digitalization in the respective governments adopted a Roadmap for Digitalization, in which digitalization was mentioned for the first time as an instrument for sustainability (Federal Ministry for Economic Affairs and Energy, 2017). The G20's objectives include securing worldwide access to ICT, building up infrastructures for this purpose, developing a common digitalization policy and standards, and using digital technologies to implement the 2030 Agenda.

Under the auspices of the World Trade Organization (WTO), which regulates economic cooperation among its 164 member states and the mediation of disputes between them, the Information Technology Agreement (ITA) was concluded back in 1996. It came into force in 1997 and has been signed by more than 82 states (WTO, 2019). The WTO is characterized by an effective dispute-mediation mechanism and the ability to impose trade sanctions in the event of any breach of the agreement. The ITA's jurisdiction was extended to more than 200 additional products in 2015. The aim of the agreement is to reduce all taxes and duties on the IT products listed in the agreement to zero. The WTO has also been running a work programme on e-commerce since 1998. These issues are also discussed in the Council for Trade in Goods, the Council for Trade in Services, the Council for Trade-Related Aspects of Intellectual Property Rights, and the Committee on Trade and Development. The WTO bodies have been mandated to examine the connections between existing WTO agreements and electronic commerce. Since then, a moratorium on levying customs duties on electronic communications ('e-commerce moratorium') has been agreed and extended at each subsequent WTO Ministerial Conference to date (WTO, 2018). In 2019, plurilateral negotiations are to begin under the auspices of the WTO in a WTO sub-group on electronic commerce, in which only some of the WTO members negotiate. Plurilateral agreements allow negotiations between an interested group, so that non-interested countries cannot block decisions. In 2015, such a plurilateral set of rules was already concluded with the ITA. Currently, the negotiating group on electronic commerce, which was agreed at the 2017 WTO meeting in Buenos Aires, comprises 76 states (including the EU, Japan, the US and China). The objectives of the negotiations include unhindered data exchange and cybersecurity. Data protection and the protection of privacy are major contentious issues, as individual countries have very different regulations on these or none at all (Section 8.3.3). However, it is not yet clear what the rules for unhindered data exchange might look like. It is also unclear what consequences this would have for developing countries; for example, there is a danger that such a plurilateral agreement might further deepen the digital divide. Recently, there have been discussions on the extent to which the different data policies of the EU, the USA and China might make cross-border data-traffic regulation more difficult and create "another digital divide" (Aaronson and Leblond, 2018). Overall, it has not been possible since 2001 to conclude the WTO round of negotiations ('Doha Round') or to include current issues (Schmieg, 2019). Many regional or bilateral trade agreements have therefore been concluded since then. Also in view of the currently growing protectionism and populism, as well as China's role in world trade, which has changed considerably over the last two decades, the G20 formulated the need for a reform of the international trading system in 2018. The range of problems has grown considerably since the Doha Round. In addition to unresolved issues such as rules for agricultural and fisheries subsidies, new topics have arisen, such as electronic commerce, the link between trade and climate protection, and the integration of the SDGs (including human-rights issues such as labour standards) in trade agreements (Schmieg, 2019).

Digitalization is also a prominent issue in the Organization for Economic Cooperation and Development (OECD), an association of 34 countries with high per-capita incomes. For example, the OECD's Going Digital project aims to achieve stronger and more inclusive growth through the 'digital revolution'. The OECD Ministerial Declaration on the Digital Economy, adopted in 2016, formulates the goal of maintaining an open internet, closing the digital divide, promoting digital skills, and generally doing more to exploit the potential of the digital economy (OECD, 2016a). Sustainability and the 2030 Agenda are only mentioned in the preamble of this declaration. At the OECD level, the BEPS (Base Erosion and Profit Shifting) project will also address the challenges to taxing digital companies and other internationally active companies – challenges resulting from the intensification of the problems of international tax competition in the course of digitalization. However, no agreement on concrete solutions has yet been reached (Box 4.2.2-2).

8.1.5 Initiatives in public-private partnership

One component of the fragmented discourse and decision-making spaces both at the UN and in the private sector consists of numerous initiatives, often promoted in public-private partnerships (PPPs), dealing with the digital future or specific technology-based developments such as the internet. Examples range from conferences (e.g. NETmundial, but also the IGF described above) to efforts to reach global agreements (e.g. Contract for the Web, Webfoundation.org, 2019) and forming commissions to develop scientifically based recommendations on the regulation of digitalization (e.g. Global Commission on the Stability of Cyberspace), or to promote the use of data for sustainable development (e.g. discoverdatascience.com).

- At the NETmundial event in 2014, Brazil, along with partners including representatives of governments, academia and research, civil society, the United Nations and the private sector, brought together some 1,500 people to jointly adopt principles on the use and development of the internet. The initiative was discontinued after important stakeholders such as ICANN (Box 4.2.7-1) withdrew. The principles put forward by NETmundial in a consensus-based multi-stakeholder process have found wide recognition. They are not binding, but have acquired a certain importance because of the broad participation. They state that all users should have the rights of freedom of opinion and association, privacy, accessibility, freedom of information and freedom of access to information and development – also on the internet. Intermediaries such as platform operators should be protected and cultural and linguistic diversity promoted, the security, stability and resilience of the internet and an open and distributed architecture should be maintained to create an environment for sustainable innovation and creativity (NetMundial, 2014).
- The contract negotiations for a transnational 'Contract for the Web' were launched under the leadership of Germany's Federal Government, the French government, the civil-society organizations CIPESA, Web Foundation, The NewNow and change.org, and the companies AnchorFree and Google (Webfoundation.org, 2019). The current negotiations are based on a number of principles designed to protect the 'open web as a public good and a fundamental right for everyone'. Governments commit to enabling people to connect to the internet, keeping the entire internet available at all times, and respecting people's fundamental right to privacy; businesses commit to making the internet affordable and accessible, respecting consumers' privacy and personal data, and developing technologies for the common good. Citizens should be creators and form a strong community that promotes public discourse and is committed to human dignity on the internet (Webfoundation.org, 2019).
- The Global Commission on the Stability of Cyberspace was founded on the initiative of two independent think tanks. It has identified functions of the internet worth protecting for the digital public sphere (such as the public core of the internet) and developed proposals for standards to ensure the internet's stability (GCSC, 2017, 2018a, b, c). These are intended to support the establishment of a legal framework for the internet. The Commission is funded by the governments or foreign ministries of the Netherlands, Singapore, France, Estonia, as well as the companies Microsoft, the Internet Society, Afilias and GLOBSEC.
- A number of international initiatives on the use of data for sustainable development have emerged in recent years. UN Global Pulse is committed to the safe and responsible use of big data and its classification as a public good (UN Global Pulse, 2019b). The Data-Pop Alliance ("for a people-centred 4th industrial revolution") is a global coalition on big data and development to promote a people-centred big-data revolution through joint research, capacity building and societal engagement (Data-Pop Alliance, 2019). The Global Partnership for Sustainable Development Data is an international initiative dedicated to building data services to meet SDG commitments (Global Partnership for Sustainable Development Data, 2016). The focus is on improving data collection, data quality, access to data and data use. The Principles for Digital Development – developed by ICT experts together with practitioners of development cooperation (DC) and humanitarian aid – also provide guidelines for DC projects (Principles for Digital Development, 2019).
- Data availability, data security and privacy in international cooperation are addressed by the Responsible Data Forum (UN Global Pulse, 2019c), the International Data Responsibility Group (data-responsibility.org) and the Data Privacy Advisory Group (UN Global Pulse, 2019a), among others. The Open Data Charter targets transparency through open data and the right of access to data (opendatacharter.net). Civil-society research and development institutes also document trends in the practical implementation of digital development cooperation, e.g. the Betterplace Lab with the trendradar_2030 (Betterplace Lab, 2017).

8.1.6
EU's strategies for sustainability and digitalization

The EU has become a global symbol of peace and international understanding, a distinction that was underlined by the award of the 2012 Nobel Peace Prize. The EU is also of global importance because of its economic strength. European integration is an example of a transformation process driven not only by economic interests, such as the establishment of a common internal market, but also by a common vision of a peaceful and politically stable Europe (WBGU, 2011: 104f.). Beyond its importance as a community of law for the member states, the EU is a key partner in international processes and agreements.

In its strategy for the period 2010 to 2020, entitled 'Europe 2020 – A strategy for smart, sustainable and inclusive growth', the European Commission mentions digital ('smart') and sustainable growth in the same sentence. Sustainability focuses here on resource efficiency, 'green growth' and economic competitiveness; European Commission, 2010b). However, the two topics are not systematically linked. The EU has had a 'Digital Agenda' since 2010 (European Commission, 2010a). Its action areas include the digital internal market, interoperability and standards, trust and security, fast and ultra-fast internet access, research and innovation, improving digital literacy, skills and integration, and exploiting ICT-based benefits for EU society. As early as 2010, the EU recognized the value of digitalization for achieving overall societal goals such as combating climate change and ageing with dignity. However, only one of 13 concrete indicators relating to the Digital Agenda goals is an environmental goal. The digital single market is of particular importance in the European Commission's work. At the heart of EU digital policy is the 'Strategy for a Digital Single Market for Europe' (European Commission, 2015b). The strategy is based on three pillars: (1) improving online access to goods and services across Europe for consumers and companies, (2) setting the right conditions for thriving digital networks and services, and (3) maximizing the growth potential of the European digital economy. The digital single market is also one of the ten Commission priorities for the 2014–2019 legislative period. Sustainability is to be embedded in the framework of the digital single market (RNE, 2018).

The European Commission's strategic vision on AI (JRC, 2018) shows a similar focus. It is primarily geared to international competitive strength. Sustainability, by contrast, is addressed both with regard to the SDGs and on the basis of concrete topic areas such as energy consumption. However, an overarching framework is lacking, as are guidelines and principles. Different features are emphasized, for example, by the French AI strategy (Villani, 2018), which explicitly takes a European perspective and was developed as a parliamentary 'mission' of the Prime Minister from September 2017 to March 2018. A separate chapter is devoted to the use of AI for ecological purposes and embedded in a broad economic paradigm shift towards sustainability.

However, it is an open question whether value-based AI development will or can be consistently implemented within the EU. The consistently ethical use of AI – actually intended to distinguish it from the way it is handled in the USA and China – is criticized by some politicians and businesspeople as a possible constraint on international competitiveness. Here, the EU is not yet pursuing a stringent path between the international race following the standards of US or Chinese digitalization models and a model of its own. A consistent, value-based approach to AI based on ethical principles and human rights could be crucial for the responsible and technology-open development of AI (Dignum, 2019). Approaches to ethical AI development, for example under the title 'AI4People' (Floridi et al., 2018), as well as ethical guidelines, are already being developed and discussed (Box 3.2.5-1).

The EU's sustainability policy is currently also in motion. The implementation strategy for the 2030 Agenda and a new environmental action programme is to be presented in 2019, and in 2020 the EU will submit a long-term strategy for its contribution to climate change under the Paris Agreement to the UN Climate Secretariat. Following the publication of a long-term vision for the decarbonization of the European economy (in preparation for the European contribution to the Paris Agreement) entitled 'A clean planet for all' (European Commission, 2018c), in January 2019 the Commission published a reflection paper called 'Towards a sustainable Europe by 2030' (European Commission, 2019f) in preparation for the implementation strategy of the 2030 Agenda. The documents also point out that digitalization is a trend that is changing lifestyles (e.g. less business travel as a result of video telephony) and provides new tools. Further automation and intelligent control are seen as ways of improving competitiveness through efficiency gains, while at the same time reducing greenhouse-gas emissions in industry (European Commission, 2018c: 15). In its reflection paper, the European Commission recognizes digitalization as a horizontal factor of sustainability change alongside education, science, technology, research and innovation (European Commission, 2019f.). This paper already states that the EU should take on a global leadership role in formulating the new ethical principles for AI and use the benefits of digital change to achieve the SDGs. Its focus is to be placed on sustainable, innovative agriculture and food systems, clean technology, human and animal health, ecosystem services, resource-efficient products and production methods. The forthcoming and pending adoption of an EU sustainability strategy implementing the 2030 Agenda will require strong links with and integration of digitalization in the sense that digitalization should be put at the service of sustainability. Furthermore, the Digital Agenda 2010 should be dovetailed by a newly developed EU Digital Agenda that integrates sustainability and makes it one of the goals of a digital agenda.

8.1.7 Conclusions

Digital change and its implications for sustainable development is a topic that is commanding an increasing amount of attention in international cooperation. This is demonstrated by the numerous digitalization initiatives and processes that have emerged in recent years, particularly at the ITU, UNCTAD, World Bank, WTO, OECD and even in its early stages at the G20. Digitalization is predominantly classified as an economic-policy issue that promises economic growth. This approach can also be observed in the EU's digital policy. UNESCO, on the other hand, is particularly committed to knowledge and education through the internet and freedom of the media. With topics such as digital literacy, digital citizenship or digital inclusion, it covers important areas of sustainable development. So far, there has been a lack of overarching concepts, guiding concepts and concrete principles and initiatives for linking digitalization and sustainability. It makes sense for the SDGs to be taken up by the UN institutions already dealing with digitalization (WSIS Forum, ITU, IGF). Environmental issues addressed by SDGs 13, 14 and 15, for example, are not yet having an impact. Conversely, the UN Environment and UNDP programmes, which are particularly responsible for sustainability issues, have so far only addressed the issue of digitalization to a limited extent. However, a number of initiatives on data and sustainable development, data security and privacy in international cooperation have emerged in recent years.

Although there are efforts to focus more on the dual topic of digitalization and sustainability in the UN system and to embed it coherently throughout the system, there is no robust and clearly visible placement, for example within the framework of a mechanism for digitalization and sustainability. There is also no systematic processing in the UN system of the state of scientific knowledge on this topic, which involves many uncertainties. Finally, there is a lack of an overarching orientation or action framework for sustainable digitalization in the form of a joint declaration by the international community, an agenda or a common codex. The direct and effective embedding of the goals and guard rails of sustainable development in the societal and political framework conditions of economic activity was and is therefore a fundamental field of global governance for the sustainable shaping of the Digital Age.

On the other hand, there is an increasing number of global companies that are decisively driving and shaping digital development and concrete applications of digital technologies in society and business. These actors wield global influence and usually pay only marginal attention to the goals of sustainable development. In particular, there is currently a certain disproportion between the influence of companies and the possibilities and structures available to regulate them. The EU has tentatively begun to link digitalization and sustainability through various policy processes and strategies. The extent to which these declarations of intent will be reflected in programmes and strategies (environmental action programme, sustainability strategy) and concrete implementation measures in individual policy areas (e.g. mobility) remains to be seen.

8.2 Potential benefits and risks of digitalization for global sustainability goals

Digital solutions can play an important role in achieving globally agreed sustainability goals, but they offer both new opportunities and new risks. The SDGs agreed in 2015 (Box 2.1-1) and the objectives of the Paris Agreement on Climate Change and the Convention on Biological Diversity are considered below as examples.

8.2.1 Digitalization and the Sustainable Development Goals

In 2015, the SDGs replaced the Millennium Development Goals as a global target system. They provide a universal framework and orientation for international and national policies over the next decade (UNGA, 2015; Box 2.1-1). The target year for achieving the SDGs is 2030. Many SDGs aim to provide access to basic services and supplies for all people worldwide, e.g. 'No poverty' (SDG 1), 'Zero hunger' (SDG 2), 'Good health and well-being' (SDG 3), 'Quality education' (SDG 4), 'Clean water and sanitation' (SDG 6) or 'Affordable and clean energy' (SDG 7). Other SDGs relate to the conservation of natural resources, such as 'Climate action' (SDG 13) and the protection and sustainable use of 'Life below water' (SDG 14) and 'Life on land' (SDG 15).

While progress has been made in recent decades through development cooperation and national development policies, existing positive development trends need to be accelerated and scaled up to make basic services available to all by 2030 (UN, 2018b). In addition, little progress has been made on environmental SDGs, which has repercussions on the development progress that has been made. For example, after many years of improvement, the number of malnourished people rose from 777 million in 2015 to 815 million in 2016; among other things, conflicts, droughts and climate-change-related disasters are seen as causes of this trend reversal (UN, 2018b).

There is currently no comprehensive and reliable analysis of the extent to which digitalization can contribute to the timely achievement of the SDGs. The Global e-Sustainability Initiative (GeSI), representing ICT-related companies and organizations, has presented an initial study linking access to ICT with progress towards SDG achievement across countries, based on observed correlations (GeSi, 2018). This study found a positive correlation for 11 of the 17 SDGs. No correlation was found for environment-related SDGs 13, 14 and 15, or for SDGs 10 ('Reduced inequalities') and 17 ('Partnerships for the goals'); SDG 12 ('Responsible consumption and production') correlates negatively with access to ICT. To what extent the respective (positive and negative) correlations are also associated with causal relationships, or whether other important external variables (e.g. GDP, quality of governance) are responsible for the correlations found remains open in this analysis.

A further analysis has been carried out under the auspices of the WSIS Forum and looks at the question of how the WSIS's objectives ('action lines') can be used to promote the achievement of the SDGs (WSIS, 2015). The study lists numerous starting points, projects and success stories illustrating the positive potential of ICT for achieving individual SDGs. However, in view of the global differences in development, it also points out that giving all people and countries the opportunity to benefit from the potential of ICT is a major challenge.

A meta-study has shown that there are numerous individual studies on the connection between ICT and SDGs, but that they focus predominantly on technical aspects and do not have a holistic view of overall societal contexts and the common good (Wu et al., 2018).

In the WBGU's view, it is necessary to adopt such a holistic view: connecting the use of digital technologies with SDGs must not be limited to technological potential, but must also address overarching potential benefits and risks (Section 9.1). This requires an inter- and transdisciplinary analysis, which should be supported by appropriate research programmes (Chapter 10). Against the background of its analyses, particularly of the arenas (Chapter 5) and literature analyses, in Table 8.2.1-1 the WBGU gives a tentative assessment of selected potential benefits and risks of digitalization for achieving the SDGs, as well as a qualitative assessment of the current status: are digital solutions being used more in the spirit of sustainability, or does the trend seem to be towards unsustainable development? The compilation is designed as a preliminary assessment and intended to provide an overview by way of examples. In this respect, it makes no claim to completeness and does not go into detail. However, it clearly illustrates both the opportunities and the ambivalence of the influence of digital change on SDGs and thus reveals the great need to actively shape digital change. It also makes it clear that, although digital technologies offer direct potential for individual goals, the main levers for achieving these goals lie in the institutional framework for systemic concepts and in creating incentives. This often requires structural changes. In addition, digital change gives reason to expect fundamental societal restructuring in the medium term (Chapter 7); however, it is unclear which of these changes will have a major impact in the course of the SDG period. For the period after 2030, the question remains whether and how the SDGs, if they are to be continued, should be meaningfully extended to take new developments into account (Section 9.3.1.1; Table 8.2.1-1).

8.2.2
Climate policy in the Digital Age

The Paris Agreement adopted in 2015 was celebrated as a milestone in climate policy. It pursues three binding objectives. First, it is about climate-change mitigation: climate-change mitigation aims to keep anthropogenic warming well below a 2°C increase compared to pre-industrial levels, and efforts are to be made to limit it to 1.5°C. Second, it is about adaptation: steps are to be taken to improve the ability to adapt to the harmful effects of climate change, to boost resilience and climate-friendly development, and to prevent any threat to food production. Third, the financial flows are to be brought into line with the objectives of climate-change mitigation and adaptation. The time horizon of the Paris Agreement goes far beyond that of the 2030 Agenda. For example, it was explicitly agreed that a balance must be achieved between greenhouse-gas sources and sinks by the second half of this century (UNFCCC, 2015).

It is currently an open question what contribution digitalization will make to climate-change mitigation, or whether it will undermine it. Digital technologies can be used either to technically implement the global transformation of energy systems towards sustainability (IEA, 2017a) – or to advance the exploration of fossil fuels (Mittal et al., 2017). They can enable efficient

Table 8.2.1-1
The WBGU's assessment of selected potential benefits and risks of digitalization in achieving the UN's sustainable development goals (SDGs), as well as a qualitative assessment of the current status: are digital solutions being used more in the spirit of sustainability, or does the trend seem to be moving towards unsustainable development? The table is designed as an initial expert assessment and, using examples, aims to provide an overview of starting points. It already clearly illustrates the ambivalence of digital change's influence on the sustainability goals, and thus demonstrates the great need for formative action. The figures in brackets refer to the sub-targets of the SDGs as set out in the 2030 Agenda (UNGA, 2015).
Source: WBGU

Selected potential benefits	Selected risks	Qualitative assessment
SDG 1 No poverty		
› Integration of the poorest into the world economy (globally, regardless of location, via the internet if access is available). › Creation of institutional framework conditions (microfinance services; identity verification via blockchain; spare parts by 3D printing). › Monitoring, data evaluation and access to information (in agriculture, medical care, humanitarian aid, etc.) make new forms of planning and coordination possible. › Virtual realities visualize areas of crisis and poverty and thus increase the willingness of the global community to donate and to act.	› Lack of access to infrastructure and institutions (internet, electricity, education) worsens the digital divide between and within societies, further marginalizing certain groups (e.g. the poor; 1.1, 1.2). › Provision of this access could create problematic infrastructural dependencies, especially if it is provided for purely profit-driven motives by private companies (1.4). › The substitution of work by automation and the backsourcing of companies limits employment opportunities and thus the potential for poverty reduction (1.1, 1.2).	› Digital technologies are increasingly attracting attention in poverty reduction and development cooperation. › The focus is currently still on pilot projects. Mainstreaming digital technology in poverty reduction and development cooperation is still in its infancy. › The extent to which the potential for poverty reduction will be exploited is as yet unclear.
SDG 2 Zero hunger		
› Precision agriculture can increase the quantity and quality of the products (2.1, 2.3, 2.4). › Sharing services via smartphone apps (e.g. AgriShare) enables smallholders to also use machines and services (2.3). › Drones for monitoring the soil, fertilizer use and plant protection, also for use in plant protection (2.4). › Children's height and weight can be monitored by 3D scanning to detect malnutrition (e.g. Child Growth Monitor 2.2 app). › The use of smartphones opens up new marketing and income-generating opportunities for women (2.3).	› Potential benefits can only be realized where there is access to infrastructure and institutions. › Smallholders, especially in developing countries, could be marginalized. › New dependencies on the multinational companies that provide digital technologies or improved input.	› The fight against hunger and for food security can be promoted by means of sustainable agriculture. › Precision agriculture is more likely to be implemented by large-scale agriculture, not by smallholders. › Application prototypes (e.g. Child Growth Monitor app and AgriShare app) are in the pilot phase. › Open-source solutions are occasionally made available. › Further concentrations of power by agricultural corporations endanger farmers' control over agricultural data.
SDG 3 Good health and well-being		
› eHealth (including mobile health, telemedicine, health information systems) enables or facilitates diagnosis, therapy, the exchange of experience, staff training, illness reporting, cost savings for transport and health facilities, as well as supplementary, decentralized advisory services (3.8). › Big data analyses, e.g. on medical contexts, global disease trends, prediction of epidemics (3.3). › Blockchain technologies for drug traceability and prevention of drug counterfeiting (3.8). › Protection against pollutants (3.9), e.g. with digital air or water sensors (3.3). › New possibilities through medical 3D printing (prostheses, orthoses, organs), also in developing countries. › Prevention (e.g. HIV education via the internet and apps).	› Costs for ICT, training and advisory services, as well as the necessary electricity supply can be problematic in developing countries. › Implementation of blockchain technology is difficult due to inadequate infrastructure, high complexity, high energy requirements and a lack of 'infostructure' (= roles, guidelines and procedures for information transfer). › Risk of loss of data control, data misuse and hacker attacks. › Internet and computer games can lead to 'gaming disorder', a disease recognized by the WHO (3.5). › According to the WHO, accident risk is three- to four-times higher if mobile phones are used (even hands-free) while driving (3.6). › Radiation-related health consequences of long-term (>15 years) mobile-phone use have not yet been clarified, according to the WHO. › Problematic emotional and social consequences possible because of lack of opportunities to controll digital technology.	› Demand for telemedicine has tended to remain constant; it has increased little. › First eHealth pilot projects launched, but no widespread application yet. › Trend towards self-tracking shows people's interest in their own health, but potential for addiction is suspected. › The internet is the main source of information on health, but there is a lack of control over the quality of information. › Access to telemedicine creates job opportunities for women doctors (e.g. the digital platform DoctHERs in Pakistan connects qualified women doctors with patients who cannot afford access to the health sector; changemakers.com).

Selected potential benefits	Selected risks	Qualitative assessment
SDG 4 **Quality education**		
› Participation in education through financial and spatial independence of use, e.g. continuing digital education and training for teachers and learners (4.1, 4.2, 4.3, 4.4, 4.6). › Active inclusion in and co-determination of education and participation. Inclusive development of new technology and creation of effective, safe, gender-sensitive, non-violent (digital) learning environments, especially for disadvantaged groups (e.g. refugees or migrant women; 4.5, 4.6, 4.A). › Future-proof education, future literacy: interlinkage of transformation education or ESD with education for digitalization (4.7). (Focus on cooperation, innovation and creativity, identity, cultural diversity, peace).	Education must offset risks to inclusion and *Eigenart* such as: › Intensification of existing inequalities (digital divide) and discrimination caused by the digitalization of educational opportunities (4.5, 4.6, 4.A, also 4.1, 4.2, 4.3, 4.4, 4.6; 5). › Dealing with uncertainties (individual and civil-societal), such as the truth content of digital information or technological developments and their future impact (e.g. on the world of work, 4.7). › New demands on the legal protection of privacy (against ok privacy violation), users' lack of competence when handling digital technology.	› Many actors support the goal of enabling better inclusion in education through digital technology and (further) developing educational opportunities (4.1, 4.2, 4.4, 4.6). › Major inequalities exist up to now; e.g. most adults in emerging economies and developing countries lack basic digital literacy; major gender inequalities have been identified in developed countries. › The potential of interlinking education for digitalization with education for sustainability – e.g. for future viability or cooperation – has not been exploited to date (4.7).
SDG 5 **Gender equality**		
› Emancipatory potential of digital technologies, e.g. via better access to information and education, as well as networking opportunities (5.B, C). › Improved measurability and visibility of gender inequalities and discrimination (e.g. in collective, digitally supported decision-making processes; 5.1). › Raising awareness of equality and gender diversity via digital experimentation spaces and flexible and diverse digital identities (10.2). › The use of smartphones opens up new marketing and income-generating opportunities for women.	› Discrimination against women and gender minorities because of ongoing gender-specific barriers preventing access to digital solutions, especially in developing countries. › Reproduction of existing gender inequalities and gender stereotypes in the development and use of digital solutions (5.1). › Limited participation of women and gender minorities in creative and decision-making processes within the tech sector (5.5). › New forms of gender-specific discrimination and violence, such as digital violence, which are not recognized or acknowledged as such (5.2).	› Despite growing political attention, gender equality has not been achieved in any country of the world. Technological solutions can do little to solve this fundamentally structural problem. › Existing gender inequalities and stereotypes are reproduced in socio-technical systems such as the internet, and this can lead to new discrimination. › The potential for using digital technology in the interests of equality is currently insufficiently exploited, particularly with regard to improved analytical options, the emancipatory use of digital solutions, and awareness-raising in digital experimentation spaces.
SDG 6 **Clean water and sanitation**		
› Improved and, where appropriate, more cost-effective and efficient management of water-supply and disposal systems. › Improved customer service and thus easier access to water-supply and disposal services for all population groups. › Improved irrigation systems. › Better seasonal water management through early detection of droughts or the risk of torrential rain. › Improved rainwater harvesting. › Better quality management of drinking water.	› Digitalization cannot have an effect without good analogue and common-good-oriented management. › Fragility and maintenance deficits of pipeline systems. › Vulnerability to cyber attacks of digitally controlled water systems. › Concentrating the use of digital water-supply and disposal technologies on privileged urban dwellers, neglecting informal urban neighbourhoods.	› The water sector is a key funding area of development cooperation. › Digital technologies increase the efficiency and effectiveness of projects in the water sector (e.g. monitoring and management systems; reduction of water loss).
SDG 7 **Affordable and clean energy**		
› Digital technologies can be used to enable access to stable electricity in off-grid regions (e.g. with mini grids based on renewable energies; 7.1). › They allow a high proportion of fluctuating renewable energies in the power grid. In addition, digital technology can be used to electrify other sectors and thus also to switch to renewables (7.2). › Efficiency potential can be tapped by monitoring, optimization and control (7.3). › Digitalization can contribute to breakthroughs in key technologies such as battery storage, e.g. using materials research or battery management.	› Ubiquitous digital applications could potentially lead to an increase in energy demand in all sectors, which would also overcompensate for possible efficiency gains ('rebound'). › Digital infrastructures themselves lead to an increase in the direct demand for energy. › The digital networking of energy systems and other sectors leads to an increased risk of attacks on critical energy infrastructures and of user data being misused. › New geopolitical dependencies on regions with critical resources for the development and maintenance of digital infrastructures may emerge.	› Digital technologies have long been used in the energy sector and facilitate the use of renewable energies, yet their share of the global energy system is increasing only very moderately. › New business models give poverty groups access to electricity in developing countries, e.g. the use of mobile payment systems for solar, off-grid electricity systems. › Up to now, digitalization has not yet been able to make a difference for the almost 1 billion people who do not yet have access to electricity. › The demand for energy in the ICT sector continues to grow.

Selected potential benefits	Selected risks	Qualitative assessment
SDG 8 **Decent work and economic growth**		
› New manufacturing technologies, virtualization, monitoring and the provision of information open up potential for improved efficiency in using natural resources; they thus contribute towards decoupling resource consumption on the one hand from production and consumption on the other. › Digital technologies can trigger further (productivity) growth (8.1, 8.2). Higher productivity and automation can help disseminate decent work environments and create space for new models of sustainable work (8.1, 8.2, 8.3, 8.5, 8.7). › New forms of access to (labour) markets and to goods and services (banking, education) can develop. For example, opportunities for economic inclusion expand, especially in developing countries and emerging economies (8.1, 8.3, 8.6, 8.10). › More precise monitoring of labour markets and, in particular, compliance with minimum social standards becomes possible (8.8).	› Rapid labour-substituting technical progress threatens to decouple economic growth from employment growth, thus jeopardizing social cohesion and political stability (8.3, 8.5, 8.6). › In addition to job losses, there is a particular threat of rising inequality and/or a widening digital divide (1) between developing countries and emerging economies on the one hand and industrialized countries on the other, (2) between regions, (3) between people with different qualifications, and (4) between earned income and other forms of income (8.5). › Work platforms and new (quasi-self-employed) forms of work can circumvent occupational safety standards and create new risks of exploitation and monitoring of workers. › The resource requirements of digital technologies and rebound effects threaten to increase resource consumption and to lead to only a relative decoupling of growth and resource consumption (8.4).	› The newly emerging forms of access and employment possibilities, especially in developing countries and emerging economies, today often still lag behind the societal challenges posed by automation and new forms of work. › There is a lack of consistent societal objectives and guiding principles for the possible future world of work and a sustainable economy, as well as of strategies for shaping societal change in a socially acceptable way. › An absolute decoupling of growth and resource consumption is not to be expected under the current (political) framework conditions.
SDG 9 **Industry, innovation and infrastructure**		
Industry › Creation of new jobs, including new fields of activity (9.2). › Increased economic inclusion for individuals – through improved access to financial services – and for developing countries as a whole through better market access (9.3). › Dematerialization and resource efficiency by means of Industry 4.0 (9.4). Innovation › Digital innovation for societal and ecological challenges (9.5). › Rising employment figures in the ICT-related R&D field (9.5). Infrastructure › Improved resilience to climate change through wider access to information via ICT (9.1). › Resource-conserving IT infrastructures (Green IT; 9.4). › Intelligent digital technologies (e.g. IoT) as drivers of sustainable smart cities (9.4).	Industry › Loss of employment and purchasing power due to automation (9.2). › Backshoring of industrial production to industrialized countries with negative economic effects for developing countries (9.2, 9.3). › Rebound effects resulting from efficiency improvements by industry 4.0 (9.2). Innovation › Lack of broadband and information services jeopardizes growth and innovation (9.C). Infrastructure › Privatization of infrastructures against the interests of users (9.1). › Increased consumption of resources and electricity by digital technologies (9.4).	Industry › Great potential for increasing the productivity of developing countries, although this has not yet evolved due to other development policy problems. Innovation › Digitalization promotes the emergence of innovations that are increasingly digitally based. ICTs contribute to the dismantling of innovation barriers, facilitate the emergence of new business models, and make the rapid transfer of technology and ideas possible. › However, technology-based leapfrogging in developing countries has so far been hampered by existing development policy problems (e.g. political instability, lack of infrastructure, lack of education). › Positive picture with regard to R&D in terms of increasing R&D expenditure and employment figures in the ICT sector. Infrastructure › Great potential for the establishment of sustainable infrastructures through smart cities. However, the development of smart cities is still in its infancy. Furthermore, smart-city concepts in developing countries and emerging economies are today in some cases at odds with the goals of sustainable development.
SDG 10 **Reducing inequalities**		
› Leapfrogging: catching up on development backlogs by making technological leaps (10.1). › New forms of employment (e.g. via platforms) and increasing spatial and temporal flexibility through mobile internet and mobile end devices (10.2). › Facilitating access to information on employment with new websites and a faster exchange of information (10.2). › Access for all to digital infrastructure strengthens education and health (10.3). › Revealing existing inequalities by means of increased transparency (10.3).	› Widened digital divide. › Existing gender inequality is intensifying and hampering development. › Automation endangers jobs requiring a low to medium level of qualification. › Backshoring: shifting employment from developing countries back to industrialized countries exacerbates inequality in developing countries. › The pressure to perform and meet deadlines intensifies in a digitalized working environment.	› Open-access data are increasingly being offered, especially for small or marginalized groups and groups with special needs. › Actors within value chains make informed decisions.

Selected potential benefits	Selected risks	Qualitative assessment
SDG 11 **Sustainable cities and communities**		
› Saving energy and resources, reducing greenhouse-gas emissions and air pollution (11.6). › More efficient energy generation and supply of electricity and drinking water. › Easier access to basic services for informal settlements and poor urban neighbourhoods, e.g. mobility as a service (11.2). › Improved municipal administration, including participatory urban planning and management (11.3). › Easier self-organization of city dwellers via municipal platforms and means of communication (11.3).	› The use of technology ignores the needs of large sections of the population. › The possibility of inclusion and use is often limited to the urban digital elite. › Dependence of municipalities on proprietary software or individual technology providers. › Total surveillance and loss of privacy versus security in public spaces (11.7). › Vulnerability of urban infrastructures (e.g. waterworks, electricity supply) to cyber attacks. › Online shopping creates challenges for the redesign of city centres. › Net impact on housing costs is unclear (11.1).	› There is criticism of smart city implementation, especially insufficient inclusion and common-good orientation, particularly in developing countries and emerging economies. › Hardly any holistic smart city approaches, mostly (isolated) pilot projects in individual fields of action (e.g. energy, mobility, waste management, e-government). › Masterplanned smart cities can be sustainable if inclusion, resource protection and *Eigenart* are the foundation of their design.
SDG 12 **Sustainable consumption and production**		
› Increased global environmental awareness through more information about the sustainability of products, as well as production and consumption methods (12.8, 12.A). › Comprehensive monitoring of environmental impacts using 'intelligent' products, sensors and big data, implementation in economic incentives for sustainable corporate action and competitive advantages (12.6 and 12.7). › More efficient use of resources via more complete information systems, platform-based business models and (virtual) corporate networks; dematerialization via virtualization or the addition of services to production (servitization), e.g. sharing (12.2, 12.6). › Improved production and supply-chain management reduces e.g. food losses (12.3). › Closing cycles by means of a digitally supported circular economy – not only in waste management (12.5). › Potential of 3D printing for producing spare parts. › Public procurement as a pioneer in the field of green IT (12.7).	› Increased demand for critical raw materials (12.4), electricity and natural resources (12.2). › Increase in the amount of electronic waste and related pollution (12.4). › Fewer possibilities of 'eco-sufficient' behaviour because of greater technical dependency and shorter product life cycles of technical devices, displacement of low-tech solutions (12.5). › Increasing complexity of products reduces reparability (12.5). › Short-lived software and increasing computing capacities increase product obsolescence (12.5). › Possible increase in consumption as a result of more comprehensive marketing and greater availability of goods, e.g. through online shopping (12). › 'Smart' labelling that equates digital products with sustainable products dilutes target orientation (greenwashing).	› A digitally supported change towards 'using instead of owning' is not yet sufficiently backed up by measures to limit rebound effects (e.g. intensification of use). › The digitalization of many product groups leads to a higher demand for resources and energy. › Additional ICT functions are currently not being developed or reviewed with the aim of resource and energy reduction. › The lack of orientation of digitalization initiatives (e.g. Industry 4.0) towards net resource and energy savings means that the potential for sustainability is not being fully exploited.
SDG 13 **Climate action**		
› Digital applications have the potential to contribute to emission reductions in many sectors (e.g. energy, agriculture, industry, buildings, transport), but also have the potential to increase emissions. › Networked early-warning systems can increase resilience to natural disasters and improve climate-risk management and weather forecasting (13.1). › Digital applications play a key role in deriving and providing information on future climate changes and their impacts as a basis for decisions on climate-change mitigation and adaptation (climate services; 13.3).	› Digital technologies can make it easier to extract and use fossil fuels. › New general-purpose technologies can lead to an increase in economic activity, which has a negative impact on emissions and climate-change mitigation. › The increasing dependence on ICT can reduce the resilience of infrastructures to climate-related disasters and extreme events (13.1).	› Digital solutions cannot make up for a lack of political ambition, a lack of regulation and a lack of institutions. In order to achieve SDG13, it is therefore essential to close these gaps, so that digitalization can make a positive contribution to climate-change mitigation and adaptation (13.2). › ICT is currently a driver of energy-related CO_2 emissions. › Earth observation and modelling already provide valuable information for adaptation, early-warning systems and disaster preparedness and form the basis of our detailed understanding of the climate system.

Selected potential benefits	Selected risks	Qualitative assessment
SDG 14 Life below water		
› Digital technologies offer long-term prospects for the circular economy and for combating marine garbage (14.1). › Digital technologies can help to improve the monitoring, surveillance and enforcement of ecosystem protection and to combat overfishing, as well as illegal and destructive fishing (14.2, 14.4). › Science, research and technological development, as well as the dissemination of their results, benefit from digital opportunities and networking (14.A). › Improved access to digital information systems could help improve market access for small-scale fisheries (14.B).	› The use of digitally supported technology means that very few shoals of fish now escape detection (14.4). › Digitalization is currently accelerating economic processes based on fossil energy (including off-shore oil and gas production) and resource extraction. This drives marine pollution (e.g. plastics) and acidification (14.1, 14.3). › Digital technology increases the demand for rare metals and with it incentives for deep-sea mining.	› The risks of economic development driven by digitalization and the resulting overburdened production and sink functions of the oceans currently outweigh their positive potential.
SDG 15 Life on land		
› Precision agriculture (apps, sensors, etc.) can improve environmental protection, resource efficiency and productivity (15.1). › Digitally enhanced monitoring of ecosystems and soil conditions (including forests and wildlife) strengthen the protection of terrestrial ecosystems and biodiversity (15.1, 15.2). › By using mobile phones, smallholders can benefit from advice on improvements in production planning and the management of weather-related risks. Other agricultural risks, e.g. pests, plant diseases or soil erosion, can also be identified using mobile phones and digital photographs; advice can be provided and risks thus mitigated or prevented (15.4). › Securing the land rights of smallholders, e.g. via blockchain technologies as a way of preventing large-scale land grabbing.	› Limited access to digital technologies and information in developing countries. › New dependencies on the multinational companies that provide digital technologies or improved input. › Marginalization of poor smallholders by 'land grabbing', among other things.	› Mobile-phone advisory services on new agricultural practices and better management. › Environmental protection, resource efficiency and productivity are increased in industrialized countries through precision farming; in developing countries, only individual elements (e.g. apps, SMS) are used. › Precision farming is not yet available to smallholders. › Drones and satellites are already being used to monitor forest areas and ecosystems (to prevent deforestation, biodiversity loss and poaching). › The development and diffusion of blockchain technologies is still in its infancy.
SDG 16 Peace, justice and strong institutions		
Peace › Better monitoring and data analysis improve the detection of illicit financial flows and illicit arms trafficking (16.4, 16.5). › Global networking and possibly virtual reality provide opportunities for more empathy worldwide (16.1). **Fight against crime/Justice** › Crimes can be detected by monitoring or tracking (16.4). **Strong institutions (16.5, 16.6, 16.7, 16.10)** › Open-government data can promote the transparency and verifiability of official decisions for citizens and civil society. › Digital data collection and processing can contribute to greater policy coherence and good governance. › Digital monitoring of target achievement can lead to increased accountability on the part of institutions. › Digital technology also creates new options for citizen participation and civil-society control. › Increases in efficiency lead to cost reductions for public services.	**Peace** › Robotics and AI are deployed in the development of autonomous weapon systems. › Cyber attacks (sabotage or espionage by attacking important digital systems) could be used militarily (cyber war) – particularly problematic with regard to critical infrastructures (see below). **Fight against crime/Justice** › Surveillance state based on monitoring or tracking (16.4). **Strong institutions (16.5, 16.6, 16.7, 16.10)** › States use digital technology specifically for the total surveillance of private and public institutions (infringement of human rights, independence of state institutions) and for the state and private control of behaviour by private and public institutions (e.g. social credit scores in China). › The authorities are threatened by the dependence of public institutions on digital tools and infrastructures, thus increasing their susceptibility to crises (especially cybersecurity). › Possibilities for manipulating or influencing democratic legitimation procedures (e.g. elections) are increasing. This could result in a crisis of confidence among citizens in state institutions, even in countries whose institutions are now considered stable.	**Peace** › Armed, remote-controlled military robots (drones) are already in use, automated to varying degrees. › Cyber warfare in the narrower sense of the hostile use of ICT has not yet been observed as the aspect of direct violence is lacking (16.1). **Fight against crime/Justice** › The fight against crime is moving in both positive and negative directions. **Strong institutions** › States use e-government both for better governance and for comprehensive government surveillance and control. › Lack of access to ICT hampers the potential for civic participation and citizens' services. › Information and communication alone do not bring about change as long as power asymmetries persist. › The complexity of providing reliable, secure, inclusive and transparent public services is increasing.

Selected potential benefits	Selected risks	Qualitative assessment
SDG 17 **Partnerships for the goals**		
› Transfer of knowledge and technology supporting the implementation of the SDGs (17.6–8, 17.16), e.g. broadband and information access, global exchange and access with minimal marginal costs through ICT and digitized manuscripts; in this context, technology transfer increasingly includes software, the transfer of which is subject to hardly any physical restrictions. › Capacity building for data evaluation and monitoring (17.16, 17.18-19) and for the concrete preparation of national implementation plans (17.9). › Use of digital solutions for development finance (17.1-3), debt reduction (17.4) and open, rules-based world trade (17.10-12).	› Possible disruptive impact of individual or cumulative digitalization consequences on world trade (17.10-12), macroeconomic stability (17.13) and – deduced from this – systemic issues in general (17.13-19). › Cooperation on technology transfer, the collection of data sets and statistics, or the dissemination of ICT use can lead to (new) dependencies and privacy conflicts. Nor is it a matter of purely 'technological fixes'; e.g. technology transfer is dependent on coherent framework conditions and the development of know-how on the meaningful use of technologies.	The political will to cooperate, the provision of financial resources and the establishment of institutional framework conditions for the implementation of the SDGs is essentially a task with no direct connection to digitalization. Currently, positive trends in the use of digitalization for SDG 17 are visible in some areas, but overall they are marginal. Although the use of ICT, data evaluation and monitoring is increasing in general – as in many areas of life – in detail the UN progress reports (2018) show a sober picture in detail, e.g.: › In 2016, only 6% had fixed broadband access in DCs, compared to 24% in ICs. › Moreover, in 2015 only 0.3% of all ODA was devoted to building statistical capacity to implement and monitor development agendas. › In 2017, 102 countries implemented national statistical plans, with 31 sub-Saharan countries forming the largest group. In addition, the risks described are still being insufficiently anticipated, both nationally and globally.

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climate-change mitigation through smart applications in buildings and industry, transport and agriculture, but they can equally cause further increases in emissions by boosting economic activity (de Coninck et al., 2018: 369). While, in the Paris Agreement, the international community agreed objectives that could prevent the most serious effects of climate change (IPCC, 2018), this commitment has not yet been followed up by adequate pledges on climate change by states (UNEP, 2018). Moreover, many G20 states have not yet introduced the policies that would enable them to achieve their – already weak – goals signalled for 2030 (UNEP, 2018).

The great potential of the new digital technologies is thus confronted by a political, regulatory and institutional environment that to date has been unable to direct their use productively and purposefully. It is therefore of the utmost urgency to create the appropriate framework conditions worldwide in order to put digitalization at the service of climate-change mitigation. The question also arises of how a global innovation policy should be designed to accelerate the development and introduction of technological solutions to the hitherto unsolved challenges of decarbonization. This applies, for example, to aviation, (long-distance) transport and shipping (Davis et al., 2018).

Digitalization opens up new possibilities for adapting to climate change and dealing with losses and damage. In the same way that human-induced changes and destruction can be better documented and understood through monitoring and modelling, the ability to make predictions about the precise effects also increases to the same extent. This improves the possibilities to take adjustment measures, reduce climate risks and record damage caused by disasters more quickly (de Coninck et al., 2018). The international community worldwide plays an important role in the use and provision of this information and growth in knowledge, also within the framework of bodies established – or yet to be established – by the UN.

A wide range of digital support options are conceivable with regard to the directions of financial flows. As with the other issues, however, it will depend on how much control and transparency the states allow.

The implementation rules for the Paris Agreement agreed in Katowice in 2018 relate, among other things, to the transparency of the states' measures on climate-change mitigation and to uniform reporting obligations. Digital technologies and solutions will often be a prerequisite for meeting the numerous complex government reporting and transparency requirements. They can also facilitate civil-society efforts to increase transparency. However, it is also to be expected that a number of states will not show any interest in too much transparency about their own actions and will take a sceptical to negative position on any compulsory use of new possibilities via big data, AI or the IoT. There are better chances for the cross-cutting use of digital solutions to create more transparency in areas where governments or other actors expect financial support for their measures, e.g. in the context of the international 'market mechanisms' yet to be negotiated.

Here, numerous actors are already in the starting blocks, emphasizing, for example, the potential of smart contracts for transactions and accounting systems. One example would be the financing of climate-change mitigation projects with automated compliance supervision using monitoring systems (CLI, 2018). Here too, however, the effectiveness of such systems depends to a large extent on what framework conditions are agreed. In the past (e.g. in the Kyoto Protocol), the accounting modalities and market mechanisms agreed at the international level were often designed in such a way that they could conceal the lack of ambition on the part of individual states (WBGU, 2009a: 18). If this continues to be the case, a digitalized implementation can only make the situation more visible and possibly thus give some impetus for change. Lack of political will cannot be substituted by technologies.

8.2.3 Global biodiversity policy in the Digital Age

The world community is currently experiencing a global biodiversity crisis (IPBES, 2019). Natural habitats and ecosystems are being destroyed and spatially fragmented. There is extensive overexploitation of biological resources by, for example, agriculture, fishing or poaching. Climate change, ocean acidification and pollution of the environment are further drivers of biodiversity loss (IPBES, 2019; WBGU, 2014b). World trade is contributing to the spread of invasive species (Bacon et al., 2012). These trends are leading to a dramatic and accelerating decline in biological diversity (Section 5.2.11.1). The consequences for human societies are increasingly being felt and could take on considerable proportions; they are described in global overview studies (IPBES, 2019; UN Environment, 2019; CBD, 2014). The biodiversity crisis is thus also an essential part of the sustainability crisis.

The 1992 Convention on Biological Diversity (CBD UN, 1992) aims, among other things, at the conservation and sustainable use of biodiversity. There is a broad political consensus in international biodiversity policy that the human-induced loss of biological diversity must be slowed down as soon as possible and ultimately stopped. The CBD's current strategic plan reinforces this vision (CBD, 2010) and has set clear and quantified political 'Aichi biodiversity goals'. The 2030 Agenda also takes up these goals in SDGs 14 and 15 (UNGA, 2015; Box 2.1-1; Table 8.2.1-1), even though these targets are currently hardly being met. The targets of the CBD's first strategic plan (CBD, 2002) have not been achieved either, and the interim assessment of the Aichi objectives shows that progress will, in most cases, not be sufficient to achieve them (CBD, 2014). The main problem here is that the above-mentioned drivers of biodiversity loss continue to have an impact (IPBES, 2019).

Digitalization is indirectly linked to these drivers. A crucial background factor is the significant increase in demand for biological resources, which is related not only to population growth but also to the significant growth of economic development and consumption observed since about the middle of the last century (IPBES, 2019). Insofar as digitalization further accelerates resource- and energy-intensive economic activities, and the demand for ICT-based services continues to rise, it can indirectly fuel demand for fossil, mineral and biological resources until the energy turnaround and a circular economy have been achieved. Increased resource extraction goes hand in hand with increased environmental damage (UN Environment, 2019).

Furthermore, there is a danger that rising global living standards, combined with the technical possibilities of digitalization, will lead to a further intensification of agriculture including the large-scale use of agrochemicals and a corresponding decline in insect and bird populations (Section 5.2.9.3). Agriculture is held responsible for 70% of the expected loss of biodiversity on land (CBD, 2014: 10). Increased extraction of fossil resources not only leaves an ecological footprint as a result of more oil- and gas-drilling rigs and coal mines, but also through accelerated climate change and ocean acidification. The extraction of mineral resources manifests itself in more mines, opencast mines and, in the future, deep-sea mining, with corresponding losses of biological diversity. In its entirety and simultaneity, digitalization can thus act indirectly as an accelerator of the biodiversity crisis.

On the other hand, there is hope that digitalization can also promote the decoupling of wealth development from ecosystem degradation. New digital solutions can also contribute to the conservation and sustainable use of biological diversity (Section 5.2.11). In particular, monitoring can make valuable contributions to supplying improved knowledge. This includes ecological knowledge about the interactions between species and environmental factors (Pereira et al., 2013), knowledge about the effects of the biodiversity crisis on ecosystem services and human welfare (Dirzo et al., 2014), and knowledge about the limits of the sustainable use of biological resources. Furthermore, there is new potential for the enforcement and monitoring of management rules and bans designed to prevent overexploitation. Finally, comprehensive knowledge about nature motivates many people and creates an incentive for political engagement or participation in citizen-science projects (Section 5.3.1.1). This may increase the pressure on policy makers to put the biodiversity crisis higher up on the political agenda. Box 8.2.3-1 deals with another current challenge of digitalization for international biodiversity policy, the handling of digital sequence information.

Ultimately, new technologies alone cannot save either threatened species or ecosystems (Pimm et al., 2015). The political will to combat the drivers of biodiversity loss and to implement the agreed objectives remains a prerequisite for the success of the CBD and the 2030 Agenda.

8.3 New global areas for cooperation beyond the 2030 Agenda

The agreement on the 2030 Agenda as a common target system for sustainable development was adopted largely without considering digital change and its Earth-systemic, individual, economic, societal and socio-technical implications. The need to critically anticipate digital change – and its broad impact on all areas of sustainable development and on all SDGs – in order to contain the dangers and realize its multiple potential benefits has become clear in many sections in this report. Consistent 'digital updating' of existing sustainability policy and sustainability research is a necessary prerequisite for developing common objectives for

Box 8.2.3-1

Current challenge of biodiversity policy: digital sequence information

The discussion on digital sequence information (DSI) can be referred to as a current example of the complex relationships between biodiversity policy and digitalization. In addition to the conservation and sustainable use of biological diversity, the third objective of the CBD is the fair and equitable sharing of the benefits arising from the use of genetic resources (Article 1 of the CBD). Article 15 of the CBD gives states sovereign rights over their natural resources and the power to determine who has access to genetic resources. The legally binding Nagoya Protocol to the CBD, agreed in 2010, clarified these provisions and laid down the rules on cross-border access to genetic resources and on equitable access and benefit sharing (ABS; SCBD, 2011). If, for example, a product (e.g. a drug) results from the use of a genetic resource in a developing country, the country of origin of the resource must have given its prior consent and must share in the benefits arising from its use. When the Nagoya Protocol was adopted, it was assumed that genetic resources were contained in biological material (e.g. plant components, seeds) that had to be physically exported across borders from their countries of origin in order for the genetic resources contained therein to be used.

In the meantime, however, genetic resources can also be available in digital form and transferred across national borders. DSI consists of digital images of genetic resources (DNA) that can be stored in databases, sent and thus exported. They can be transformed back into the original physical DNA in laboratories outside the borders of the country of origin. There is now controversy over whether DSI or only physical genetic material should fall under the Nagoya Protocol. Industrialized countries (and their business actors) are opposed to this and wish to maintain open access to genetic information. There are also significant concerns from the scientific community about the inclusion of DSI in the Nagoya Protocol (e.g. Prathapan et al., 2018; dos S Ribeiro et al., 2018). Developing countries see DSI as a loophole depriving them of rights and financial resources.

Three years ago, the discussion on DSI was still a debate for a few specialists, but today it is one of the most important unresolved and contentious issues in the CBD's political discourse; it should be clarified at future conferences of the signatory states to avoid legal uncertainty and a resulting lack of acceptance of the CBD and the Nagoya Protocol.

a common digital future in an informed manner through global cooperation.

In order to further develop the existing 2030 Sustainability Agenda, it is also important to identify new urgent global fields of action and cooperation resulting from the dynamics of digitalization. The existing 2030 Agenda is itself a further development of the Millennium Development Goals, which were primarily aimed at poverty reduction. Integrating development goals with environmental goals was a consistent further development of the international target system. The WBGU is convinced that digitalization requires a further development of the sustainability goals of the 2030 Agenda in at least four concrete thematic areas. These four areas are already of global importance today, but have not, or have hardly, been addressed up to now by the UN or state alliances. The new areas requiring global action and cooperation relate in particular to the need to:

- protect of the *privacy* of each individual,
- preserve and expand *inclusion* for all people in the Digital Age,
- ensure human *decision-making sovereignty*, and
- create a *human-machine relationship* based on human abilities and needs.

The respective state of discussion and understanding of the problem is different in each of these four fields of action and cooperation – as is the nature and scope of the existing governance architectures. The four fields are all of key importance for future ideas of 'people-centred development' and require action to shape the interplay between societal and technical systems.

8.3.1 Protection of individual privacy

In the Digital Age, ensuring privacy by protecting people's private spheres is becoming a turning point for coexistence in societies – both in terms of individual freedom and self-determination, and in terms of equality and political participation. Regular scandals over massive data abuse by corporations (e.g. Facebook and Cambridge Analytica) or government surveillance (e.g. Edward Snowden's revelations: Lucas, 2014; Lyon, 2014) are only the visible tip of the iceberg in the constant struggle for guaranteed privacy and its important function for the individual, society and politics.

The WBGU stresses that, from a normative perspective (Chapter 2), it is necessary to define and shape privacy as a sustainability issue (Section 9.2.1). In order to realize their *Eigenart*, people need the free space made possible by privacy, a space in which their own preferences and creativity can be tested so that variety develops in which people and groups of people can develop in a self-determined way. Privacy also protects us against unequal treatment and manipulation (Nationale Akademie der Wissenschaften Leopoldina, 2018) because it 'pulls a veil over societal inequalities' (Baumann, 2015).

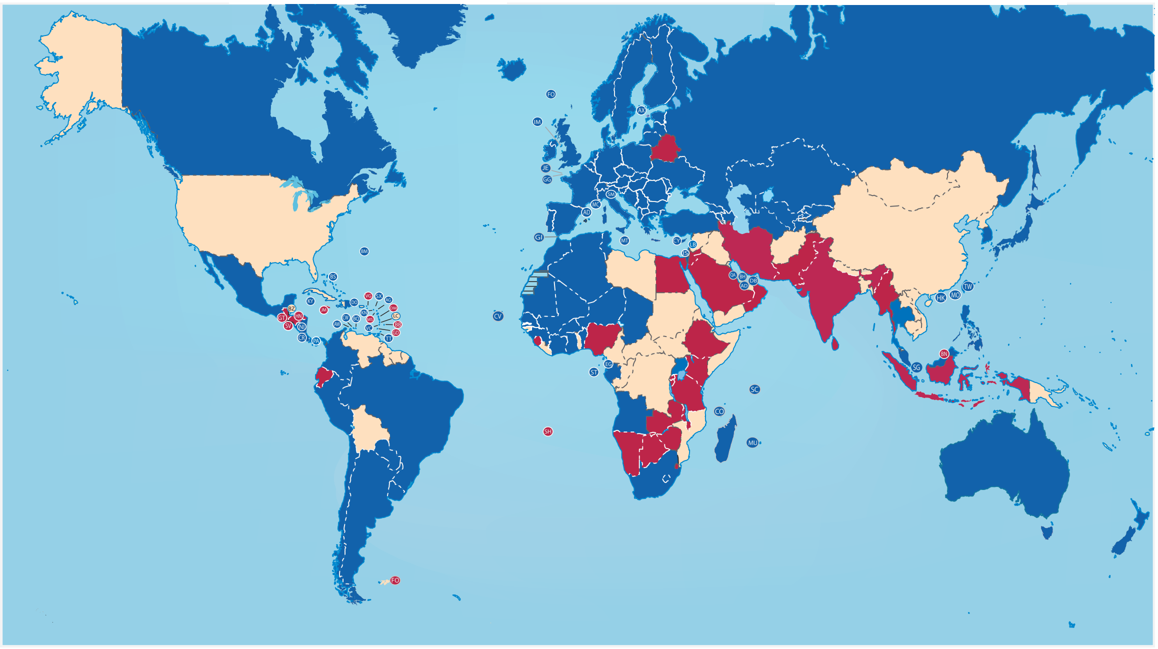


Figure 8.3.1-1
Overview of data-protection laws worldwide. Blue: comprehensive data protection law enacted. Red: pending bill of initiative to enact law. Beige: no initiatives or no information.
Source: Banisar, 2018

8.3.1.1
Status quo of the global protection of individual privacy

Numerous states or communities of states, such as the EU, have enacted data-protection laws. In autumn 2018, almost 120 data-protection laws or laws on privacy existed worldwide. Similar laws are currently being developed or discussed in almost 40 other countries (Banisar, 2018; Figure 8.3.1-1).

A special position is taken by the European General Data Protection Regulation (EU GDPR), which is a reference point for international data-protection laws and is having a considerable impact (Box 4.2.6-1). The German National Academy of Sciences Leopoldina (2018: 54) recently pointed out the need for regulation of big data and privacy: "Use of these possibilities is a challenge that can also – but not only – be met nationally or in the EU, but preferably worldwide; it requires trans- and international cooperation".

Human rights relating to the protection of privacy provide a normative starting point for a worldwide dialogue on the protection of privacy. The relevant provisions of international law (Article 12 of the Universal Declaration of Human Rights, Article 17 of the IPbpR, Article 8 of the ECHR) target the protection of privacy in the classic sense of the 'analogue world', i.e. the protection of private life, family, home and correspondence. The right to data protection is not explicitly standardized under international law, but is regarded as a specific part of the right to privacy (Kettemann, 2015: 33). As a first step, Germany's former Federal Commissioner for Data Protection, Peter Schaar, has proposed adding an additional protocol to Article 17 of the International Covenant on Civil and Political Rights, which covers protection against arbitrary or unlawful interference with a person's privacy (Leinen und Bummel, 2018: 221ff.). As early as 2009, 58 non-governmental organizations signed a declaration calling for an international agreement on the protection of privacy and informational self-determination of citizens (The Madrid Privacy Declaration: The Public Voice, 2009). In 2013, following Edward Snowden's revelations and the subsequent NSA scandal, Germany and Brazil initiated a working process within the United Nations on the 'Right to Privacy in the Digital Age'. Since 2013, the UN General Assembly has repeatedly confirmed that the rights to which people are entitled in the analogue world must also be guaranteed online, that states must safeguard these rights and urge companies and other private actors to comply with them (UNGA, 2013, 2014, 2016b, 2018b). Currently, the resolutions are not aiming at a formal agreement, but appeal to both states and private-sector actors to secure and strengthen data and privacy protection. The human right to privacy is in permanent conflict with the national governments' fight against crime and terrorism, i.e. with the internal security of states and the desire to use data comprehensively for societal and private purposes (Section 8.3.3).

From a global perspective, in addition to the creation of convincing data-protection laws in countries where there are currently none, the following urgent challenges for the protection of privacy in the Digital Age exist (Sections 4.2.1, 3.1.1):

1. an international agreement on common standards for the protection of privacy (Section 8.3.1.1),
2. the enforcement of privacy protection in countries that already have existing data-protection laws (Section 8.3.1.2).

8.3.1.2
Ensuring the enforcement of privacy protection

Currently, what is primarily lacking globally is not a basis in human rights, but the concrete implementation and enforcement of privacy protection in the digital domain (Section 9.2.1). While data are transmitted and processed across borders (Box 5.3.3-2), national and regional laws relate to specific territories. Binding, international minimum standards of privacy protection are therefore required: individuals leave digital traces on the internet, which can be accessed from anywhere in the world if there is no data security or data protection. Furthermore, the release of private information about individuals also has an indirect effect on the regulation of the privacy of other individuals from a similar environment or from comparable groups – also in other countries (spill-over effect; Fairfield und Engel, 2015).

The EU is responding to this challenge by introducing the principle according to which the user's place of residence is decisive, not the company's registered office, thus defining the legal framework for all data processing on people living in the EU (Box 4.2.6-1). This is also having a strong impact outside the EU (Kuner et al., 2017). However, this alone does not guarantee that the same standard will be enforced vis-à-vis companies that are based in other countries. Assuming that several states follow this example, a complicated web of data-protection laws will emerge. Under certain circumstances, this can result in trade and communication barriers. Intergovernmental cooperation is furthermore necessary to counter the market dominance of large digital companies. Through their extensive use of data, some corporations have built up a position of economic power against which individual states are virtually powerless. The current instrument for the enforcement of privacy protection at the global level is the Special Rapporteur on the right to privacy, a position that was established in 2015 by the United Nations Human Rights Council (HRC, 2015). As an ombudsperson, s/he pools information, monitors and evaluates developments and raises a voice for the right to privacy in the Digital Age. The Special Rapporteur contributes to improving transparency and raising awareness of privacy violations by taking a position on data-protection laws worldwide and can address criticism and suggestions for improvement to the relevant countries. S/he cannot, however, achieve binding enforcement against companies or states.

The protection of privacy can only be comprehensively guaranteed globally and particularly in the interplay of national and international policies. Increased regional and national levels of protection provide important initial stimuli in this regard and thus contribute to improving the global level of protection. These must be further developed and, in particular, decisively enforced (Section 9.2.1.2).

8.3.1.3
Cooperation to ensure privacy: a United Nations Privacy Convention

At the global level, the WBGU sees the need for the enactment of binding international law in the form of a 'United Nations Privacy Convention'. This would define a common global understanding of privacy protection, as well as common minimum standards and procedural rules for the enforcement of data protection and data security to protect privacy in the digital space (Section 9.2.1.2). Such an agreement should address the legal design and enforcement of privacy protection in the signatory states and transnationally. The integration principle (Section 8.4.2.4) can serve as a guiding principle: privacy protection is a cross-cutting issue that must be taken into account in all areas, especially in digitalized ones. Data protection and data security should therefore be integrated into all technical and organizational processes and into various policy areas. In addition to highly promising instruments such as data-protection officers as ombudspersons, there should be agreements on data protection by design and by default and on data-protection impact assessments, technology and experience transfer. Probably the most important point is cooperation in the cross-border enforcement of the protection of personal data. Civil society's involvement as a guardian of individual privacy is recommended and can be enshrined in the Convention, for example through complaint and action mechanisms for NGOs committed to data and privacy protection.

8.3.2
Preserving and extending inclusion in the Digital Age

Key issues of sustainable development in the Digital Age are decided via access to and possible uses of data and other intangible, digital and digitalized goods and services. On the one hand, there are risks such as growing inequality, a widening digital divide and an intensifying concentration of power (e.g. of the digital economy; Chapter 4); on the other, there is potential for strengthening societal and economic inclusion in the sense of sustainable development. Examples include an easier (including international) exchange or transfer of information and knowledge and easier access to markets.

The particular consequences, but also the particular challenges involved in shaping opportunities for access and use are essentially a result of the basic characteristics of data and digital goods and services. Digital goods and data are non-rival resources in consumption. They can be simultaneously and multiply used and reproduced, (largely) without this restricting their usefulness for other users. Against this background, it is in the interests of society and the economy as a whole to use digital goods, or at least make them available, as widely as possible once they have been created. From the point of view of sustainable development, non-rivalry in consumption combined with the ongoing digitalization of society and the overall economy offers new opportunities to expand the inclusion of people who have hitherto been denied access to education, information and culture. Non-rivalry distinguishes digital goods substantively from many physical goods and factors, as well as from private goods in general. As with the latter, and unlike public goods, digital goods also allow the exclusion of third parties from access and use.

Harmonizing opportunities for access and use in the digital domain as broadly as possible with the goals of sustainable development is therefore a key field of governance in the Digital Age. Opportunities for access and use should ultimately be effectively organized primarily by means of international agreement. Digital spaces and services are often cross-border by nature, and national borders do not usually play a role in data flows either. This inherently affects international policy fields, as well as trade policy in particular (OECD, 2018g). Against this background, individual states – with the possible exception of the USA and China – do not usually carry enough weight to be able to decisively shape digital inclusion for the purpose of global development. Obliging nation states to provide more open access to data that are key to future innovations and competitive advantages (Section 4.2.2), for example, would do little to change the dominant position of global internet groups.

Questions relating to opportunities to access and use digital and digitalized goods and services also concern (international) patent rights, copyrights or licences – and thus international agreements to protect intellectual or intangible property. However, the existing regulations seem to be becoming increasingly out of touch with the increasing (economic and societal) importance of intangible, digital and digitalized goods, ever stronger digital networking, and the development potential associated with these developments. Known problems of today's regimes for protecting intangible assets such as intellectual property are threatening to intensify and thus generate digital inequalities (digital divides), especially in view of the opportunities for the societal and economic inclusion of developing countries in the course of digitalization and the shift in importance towards digital goods and spaces (Baker et al., 2017). This can also be illustrated by the example of digital sequence information based on genetic resources (Box 8.2.3-1). Alternative forms of patents, licences and copyrights – such as equitable licensing (Section 5.3.10) and the applicability of environmental agreements to new kinds of digital goods – should therefore be further discussed and pursued. In view of increasing global networking, there is also a need for greater international harmonization and coordination of patent protection and copyright, which would also allow smaller companies, especially from developing countries, to operate in foreign markets at lower cost. The same applies to rules and standards for data exchange and protection (World Bank, 2016: 301ff.).

Many issues of data access and use are still largely unregulated, even though, for example, there are basic OECD guidelines for dealing with cross-border data flows (OECD, 2018g). The GDPR on the handling of personal data represents an important step towards closing these gaps, at least in Europe (Box 4.2.6-3). The handling of, and access to, non-personal data in Europe, on the other hand, has hitherto been de facto controlled by those who collect the data, and they can exclude third parties from using it, for example by means of encryption or local storage. From a legal point of view, no full ownership or intellectual property rights exist for data in European jurisdictions (Schweitzer and Peitz, 2017: 61). Data trading and data exchange – and thus data access in the field of private data that cannot be related to individuals – are essentially based on bilateral agreements negotiated by the private sector. At least for public-sector data, the 'PSI Directive' on the re-use of public-sector information already regulates access for the general public, and this access is to be made even more comprehensive in the future (European Parliament, 2019).

Shaping opportunities for accessing and using intangible, digital and digitalized goods, as well as the deliberate breaking up of hitherto de facto control possibilities almost inevitably generate tension between economic, societal and individual reasons in favour of and against openness: on the one hand there are the societal advantages of the broad use of non-rival goods, on the other the risk that increasing openness might lead to the loss of economic incentives to provide these goods. There is a risk of societal supply shortages. In addition to these well-known economic and societal ambivalences, in the digital space, there is often the additional need to consider the protection of privacy – and the potential for conflict here (Section 8.3.1).

It will not be possible to completely resolve this tension. Nor does it seem possible or sensible to have an across-the-board regulation that applies across different areas of life and the economy: too diverse are the many areas of life and the economy in which questions of access to and the use of data and digital and digitalized goods are relevant (Drexl, 2017). Differentiating opportunities for access and use must also be generally distinguished from the definition and enforcement of complete ownership rights to digital and digitalized goods and in particular to (non-personal) data. The latter rights are under discussion, but hardly do justice to the special role of data in the economy and society or to the real challenges involved in shaping how data should be handled (Varian, 2018): apart from issues of implementation (the appropriate allocation of property rights is often unclear, particularly in the case of non-personal data: Drexl, 2017), the definition of property rights would primarily address the fact that third parties can already be excluded from the use of data, as well as possible economic incentive problems with regard to investment in data collection, which are generally regarded as quite small (Duch-Brown et al., 2017). In this respect, ownership rights to data would not help to ease (Schweitzer and Peitz, 2017; Jones and Tonetti, 2018) excessive restrictions on access to (non-personal) data from a societal or macroeconomic point of view.

In the case of data, the added value of broad usage possibilities lies, for example, in the synergy effects of combining data ('economies of scope'; Duch-Brown et al., 2017; Dewenter and Lüth, 2018) or in the value that access to data sets has for the further innovation process. This is illustrated, for example, by the development of systems for autonomous driving, in which the combination of the 'training data' of various manufacturers and developers would basically be more promising than individual developers creating corresponding data sets separately (Varian, 2018; Jones and Tonetti, 2018). Nevertheless, the de facto scope for restricting data access is frequently used today to defend or even expand once gained competitive advantages for as long as possible, in view of the importance of data for new (data-driven) business models and innovations. More open, regulated access to data, especially data that are collected cost-effectively as the by-product of a service, can accordingly serve to break up structural drivers of increasing market concentration, thus creating space to develop competing offers and fair competition, and ultimately strengthening *Eigenart* and inclusion (Section 4.2.2).

Networking, collaborative cooperation and non-rivalry in consumption in the digital space also offer considerable potential for significantly improving inclusion in essential goods. Goods such as education, knowledge and culture in their digitalized form can be defined as new (global) commons, and their provision can be organized and supported accordingly (Section 5.3.10). In the development-policy context in particular, this may include, for example, the more targeted and timely structuring of development cooperation or the establishment of early-warning systems for environmental disasters or outbreaks of diseases (World Bank, 2016). In particular, information from monitoring the environment and ecosystems can be made publicly available as a global (public) digital common good in order to increase environmental awareness.

In principle, the question of access to and use of digital or digitalized goods also relates to the ecological dimension of sustainability via the associated consumption of energy and resources. These environmental impacts should, however, be addressed more generally and thus independently of the issue of access to specific data and digital and digitalized content. Otherwise, there is a danger that, for example, environmental regulation will distinguish between 'good' and 'bad' data and thus violate the principles of net neutrality on the internet.

8.3.3 Preserving human decision-making sovereignty

Algorithmic decision support and decision making is also increasingly spreading in core areas of society such as the judiciary, police work and social systems (Sections 5.3.3 and 3.2.3) due to advances in data processing and evaluation methods and the growing availability of large amounts of data (big data; Section 3.3.2). This development can have potentially far-reaching implications for decision-making sovereignty at both the individual and societal level, especially if such technologies are used without reflection and in a non-transparent way. This makes questions of the application and appropriate regulation of these technologies an important field of cooperation for sustainable digitalization governance (Box 4.3-2; Section 5.3.3). However, the creation of political and legal framework conditions that take into account the societal implications of algorithmic decision-making is still in its infancy. It is true that strategies for dealing with AI have now been adopted at a national level in several countries. However, there is no common international understanding or awareness of the problems involved.

In the WBGU's view, guaranteeing and protecting human decision-making sovereignty should be recognized as a general principle of societal and political decision-making at the global level (Section 9.4). Such a principle would be indispensable for respecting the demarcation between technical automation and societal discussion of political, social and legal issues (Box 4.3-2). The WBGU thus regards safeguarding human decision-making sovereignty as the overriding goal for maintaining societies' ability to take action in the long term (Chapter 7) and thus as part of the global sustainability agenda.

Moreover, algorithmic decision-making becomes a global area of cooperation in that it is applied to policy fields that by their very nature are already embedded at the intergovernmental and global levels. For example, the use of algorithmic decision-making systems is already significantly reshaping the rules of some global policy areas, such as cybersecurity (encryption technologies, etc.) or the financial sector (automated trading; Contratto, 2014). At the international level, therefore, agreement is needed on how to develop appropriate sets of rules to ensure the stability of the relevant international systems using algorithmic decision-making. The specifics of the societal sector in which machine-supported decision-making is applied are decisive in this context, i.e. separate agreements on how to deal with the new procedures will probably have to be reached in each global policy field. Armed, remote-controlled military robots (mostly drones, Box 3.3.5-2), for example, are already being deployed today and have varying degrees of decision-making autonomy (Asaro, 2012; Krishnan, 2016). At the economic level, questions of possible concentration processes on individual companies, and with them on individual decision-making systems, are also relevant (Section 4.2.2). In this context, there is a threat not only of potentially far-reaching influences on individual, societal and political decisions, e.g. by influencing and monitoring information flows, but also of the instability of entire markets, e.g. in the financial system (Contratto, 2014). There is a risk of over-dependence on individual decision-making systems in the absence of competing, independent assessments of the data.

A global agreement on possible exclusion from certain areas of application is also necessary. Particularly when automated decisions are routinely made in institutions in core areas of society, there is a danger that societal debates on mediation between different interests and values, which ultimately underlie such decisions, will no longer take place to the necessary extent. "[I]t is critical to ensure that in key areas where automation is not appropriate from a human rights perspective, it does not take place" (Council of Europe, 2018: 44). Where the use of systems involves high risks to human sovereignty over the design of social systems, then moratoria or other instruments that exclude use should be established at the international level.

Ensuring human decision-making sovereignty requires both normative guidelines and a concrete institutional framework in which these guidelines are manifested. In addition to the general principles of good practice in the use of AI and algorithmic decision-making (Box 4.3–2), guidelines are needed in societally relevant areas to preserve human decision-making sovereignty, which can, for example, be embedded in a Charter for a Sustainable Digital Age (Section 8.6, Box 9.4-1) or the UN Declaration on Human Rights. Institutionally, these guidelines could then be translated into concrete regulations at the EU level (Section 8.5). Depending on the area, it can also make sense to expand existing dialogue forums, agreements and organizations in order to embed decision-making sovereignty, e.g. the Geneva Conventions on autonomous weapons.

8.3.4 Protection of unique human characteristics in the human-machine relationship

Similarly to the way humans are having a formative influence on the Earth system in the Anthropocene (Crutzen and Stoermer, 2000; Crutzen, 2002; Rosol et al., 2018), at present humanity is potentially on the threshold of an age in which humans can technically change their own bodies in an equally fundamental and formative way (Section 7.4). This long-term prospect makes the human-machine relationship a global sustainability issue. In view of the new possibilities offered by technical medical interventions – implants, augmentation of (sensory) organs, brain-computer interfaces (Topic box 5.3-2) – and increasing human interaction with AI, fundamental questions are arising about the relationship between humans and machines. The human capacity for empathy, emotionality and social association are characteristics that clearly distinguish humans from machines (Section 7.4). Only humans have their own reasons for their actions – motives, feelings, moral sensitivity (Nida-Rümelin and Weidenfeld, 2018). Mutual recognition of these motives – and thus recognition as human actors – can only be the basis of interaction between human beings, because machines do not have intrinsic reasons for their actions

(Nida-Rümelin and Weidenfeld, 2018). The mere simulation of these characteristics by AI would also only be just that, a simulation, and therefore not the same as possessing these characteristics (Nida-Rümelin and Weidenfeld, 2018).

Although a future issue, the responsible anticipation of changes in the human-machine relationship is a decisive field for global cooperation in the Digital Age (Section 9.4). Just as planetary guard rails must be adhered to with regard to the relationship between humans and the environment, guard rails for the shifts in the relationship between humans and machines in the Digital Age must also be negotiated in a discourse and agreed upon as mandatory – both with regard to the mechanization of humans and to the humanization of machines (Topic box 5.3-2; Section 7.4). Here, too, an analogy to climate change is appropriate: the mitigation or even reversal of global warming through geoengineering has been discussed for a long time (Marchetti, 1977), and the discussion has been markedly stepped up in recent years (Blackstock and Low, 2018) as a possible response to climate change. However, the risks of unleashing such an invasive, large-scale, untested and costly influence on such a complex system as the Earth's climate could be immense. It will therefore be crucial to agree on global guidelines and regulations and, where appropriate, bans by multilateral agreements before individual actors create facts that may be irreversible. The same applies to the relationship between humans and machines. This requires a global normative framework, such as a charter (Box 9.4-1). In view of the global, polycentric actor structure (Chapter 4), the creation of a common normative framework can only succeed effectively if this process of anticipatory governance is initiated at the global, multilateral level. Human influence on the Earth's climate – i.e. an effect of the interaction between technology and the Earth system – has already established itself as a subject of international politics in the global governance system (Hamilton, 2017). Interaction between technology and humans is not yet embedded at this level. The observations in this report have shown, however, that the human-machine relationship, as a future topic, already requires forward planning and shaping today. In a similar way to climate science (at the IPCC), internationally networked research is crucial. On the one hand, this research must take technical developments and their implications into account, but on the other hand it must also establish an understanding of technology and the future in the scientific community with the necessary breadth and depth required by a holistic understanding of digitalization.

8.4 Elements for the sustainable shaping of the Digital Age at the global level

The 1987 Brundtland Report entitled 'Our Common Future', in which the basic understanding of sustainable development still valid today was formulated, is regarded as a milestone and impetus in the worldwide discourse on sustainable development: "Sustainable development is development that satisfies the needs of the present without compromising future generations' ability to meet their own needs" (WCED, 1987, para. 49). The Brundtland report became an important precursor of the Earth Summit in Rio de Janeiro. The 1992 UN Conference on Environment and Development (UNCED, also called the Rio Conference) is still an important reference point for international environmental and development policy. With the Rio Declaration (including the then innovative principle of common but differentiated responsibility), the Agenda 21, and the agreement of binding international treaties on climate, biodiversity and desertification (the Rio Conventions UNFCCC, CBD, UNCCD), the international community recognized for the first time the urgency of joint action to protect humankind's natural life-support systems.

Urgent action is still needed to achieve the objectives of these agreements. While digital technologies offer new potential in this context, they can at the same time jeopardize the achievement of objectives. To date there are very few assessments of whether the potential of digital technologies will be used for sustainable development or whether they are more likely to strengthen unsustainable developments (Section 8.2). On the basis of the analyses in Sections 8.1 to 8.3, there is also a concrete need for a reinterpretation of sustainability and the further development of global governance architectures. The following sections identify elements of a normative, organizational and institutional framework for global sustainability policy under the conditions of digital change. At the same time, these elements indicate a way of addressing the challenges relating to international digital companies with great market power (Section 4.2.2, Box 8.4-1). Shaping a concrete regulatory framework for the international digital economy requires further, scientifically based debates, proposals and an examination of suitable approaches for regulation and control.

Box 8.4-1

The digital economy as a subject of global governance

Powerful companies in the digital economy are already active and are shaping digital technologies and their applications at a global level. These companies are thus themselves part of the governance structures that exist today in the field of digitalization (Section 8.1). However, their global scope of action and the now prominent societal significance of their products and services necessarily make these companies themselves the subject of global governance for a sustainable shaping of digitalization. Global governance faces the following challenges, which are discussed at various points in the report:

- As a result of economies of scale and network effects, companies in the digital economy, especially the Big Five, have today achieved very powerful international market positions and considerable financial strength. This position allows them to collect unprecedented amounts of data and information from both private and public areas. Their largely exclusive access to this data not only gives companies competitive advantages at present, it can also prevent the development of competitive, alternative offers in the longer term (Sections 4.2.2, 8.3.2). Up to now, competition-law procedures have often been ineffective in dealing with these concentration tendencies. There is already intense discussion on further developing these procedures in order to better do justice to data-driven business models (services in exchange for data), the often unclear definition of market segments, possible substitution relationships, and the impact of network effects in the future. In view of the importance of data for business models and innovations, however, individual procedures under competition law may fall short even with greater international harmonization. The development of obligations requiring greater interoperability and more open, regulated data access should therefore be further examined and pursued (Section 9.2.3). The great development-policy potential that lies in shaping new regimes for access to and use of digital and digitalized goods/services and data must also be taken into account (Section 8.3.2).
- The powerful market position of companies also poses a challenge with regard to the protection of privacy and the decision-making sovereignty of individuals and groups. By combining data and information from different areas of an individual's life, very extensive profiles can be created which can be used for personalized advertising, the calculation of individualized prices (price differentiation) or the personalized design of decision-supporting systems (Sections 4.2.2, 8.3.1). The processes of linking and using data are generally non-transparent, so that the criteria and values on which the details of a digital service are based are hardly comprehensible to the individual (Section 3.2.5). Moreover, by linking data with big data and machine learning, conclusions can be drawn on what are actually protected areas of privacy; yet these are not covered by current data-protection provisions such as the GDPR (Section 5.3.3).
- Digitalization entails considerable challenges in the taxation of corporate profits, which also, but not only, affect companies in the digital economy. The digitally supported internationalization and virtualization of entrepreneurial activities raise questions of geographical allocation and evaluation. At the same time, opportunities for tax avoidance in international tax competition are growing. Box 4.2.2-2 discusses these challenges and possible reform approaches for company taxation in detail. International cooperation is key in this context. However, the already ongoing international negotiation processes have not yet led to an agreement on concrete steps for reform (Section 8.1.3).
- The special, prominent role of companies like Google/Alphabet, Facebook or Amazon is also reflected in the fact that these companies' products and services have become an integral part of everyday life in many countries, both in the private and in the public and economic spheres (Section 8.1.1). This enables companies to collect very large amounts of data with the consequences and challenges discussed earlier. It should also be noted, however, that companies use search engines or social networks to offer services and virtual spaces that have, in the meantime, become societally relevant, e.g. as key sources of information or forums for societal (political) decision-making. As initially purely private-sector services, the services and their use by third parties are not usually subject to regulation and supervision by socially/democratically legitimized authorities, or if they are, this control is inadequate in view of their significance. Thus, the extent to which societal values, such as freedom from discrimination, are taken into account when developing these products and services remains largely non-transparent. The same applies to the use of the newly created, digital and thus inherently international spaces by third parties, e.g. for political purposes in election campaigns (Sections 5.3.2, 5.3.5).

8.4.1
Economic paradigm as a strong lever

Since the dynamics of digitalization are largely shaped by business actors, an adaptation of the economic paradigm to the challenges associated with digitalization is a fundamental prerequisite for the transition to a sustainable Digital Age and the development of appropriate governance structures (Section 9.2.3). Disruptive technological developments, combined with an exponential increase in the world population, have already led to challenges for society and the economic system in the past, making demands on and changes to the economic paradigm that prevailed at the respective time. The development of the social market economy as a model for European economies can be seen not least as a long-term consequence of the Industrial Revolution, a growing population and the consequences of two devastating world wars. The development of socialist economic systems in the last century was also a result of the economic and societal challenges of an increasingly mechanized world. The spread of digital technolo-

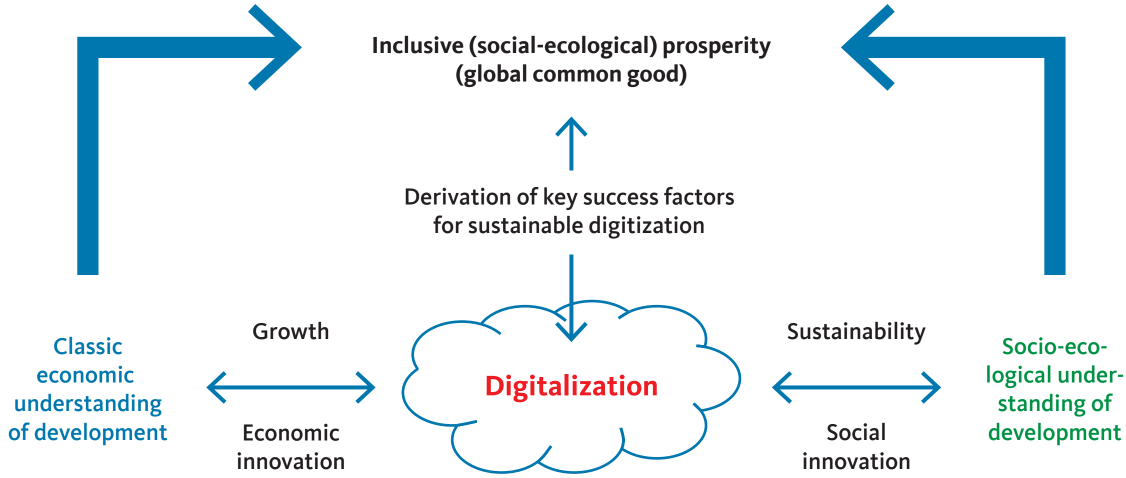


Figure 8.4.1-1
Extended guiding principles for digitalization that is geared towards the global common good.
Source: WBGU

gies and the business models based on them are also currently breaking up economic structures and path dependencies. Incumbent companies and markets are being challenged and are facing strong, sometimes far-reaching change dynamics (Chapter 4). Spaces for a change in the economic paradigm that developed in the course of industrialization in western market economies are once again emerging. Which direction this dynamic of transformation will take in concrete terms is currently not foreseeable. However, it is clearer than ever that, without an appropriate framework, purely private-sector dynamics are unlikely to fully meet the goals of sustainable development and the transformation processes required to implement them.

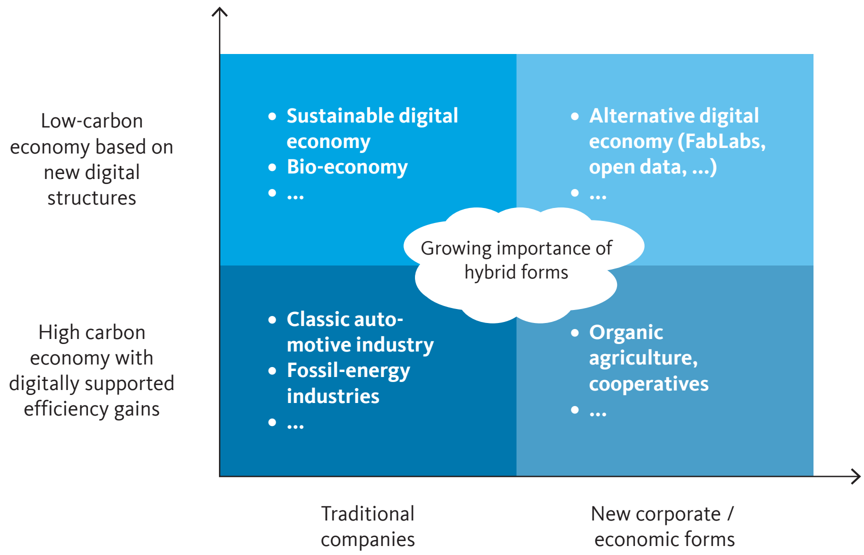
In the past, neither decentralized nor centrally controlled economic systems have succeeded in adequately addressing the overuse of natural resources and the threat of planetary guard rails being breached. Despite – or perhaps precisely because of – advancing economic globalization, the necessary long-term perspective and global approaches are still insufficiently integrated into political processes. This is also reflected in the traditional performance indicators of societal and economic systems. Indicators such as gross national product and economic growth date back to a time when rising material prosperity was often equated with rising welfare. Threats to the common good due to the overexploitation of natural resources, conflicts over distribution and other environmental or social externalities of private-enterprise activities do not play a role in these performance indicators.

8.4.1.1
Guiding principles and performance indicators of an 'empty' and a 'full' world

Historically, the performance indicators currently used stem from an 'empty world' (von Weizsäcker and Wijkman, 2018) with far fewer people and seemingly abundant resources. In this world, progress has basically been measured in monetary terms by a better supply of goods (rising incomes) or a more 'productive' use of factors (such as labour). For example, the productivity of the use of labour and land relates to the value created per hour worked or per hectare of land. Since for a long time the natural life-support systems were not perceived as systemically scarce, traditional performance indicators either do not cover the repercussions of economic activities on ecosystems and the environment at all, or, if so, only inadequately.

However, the situation in the 21st century has fundamentally changed compared to this starting position: today, humankind lives in a comparatively 'full world' with over 7 billion people and an average gross national product of approx. US$10,000 per capita (World Bank, 2019c). In the past, rising prosperity was possible without decoupling resource and environmental consumption; today, this development is reaching the limits of natural resources and ecosystems – or has already been exceeding them for decades. Rising material prosperity, as measured by traditional performance indicators, no longer reflects rising welfare to the same extent. In order to adequately map the challenges of a 'full world', new, or at least enhanced, performance indicators are needed that combine the classic understanding of development with a socio-ecological one.

Figure 8.4.1-2
Moving towards hybrid forms of a sustainable digital economy.
Source: WBGU



8.4.1.2
Towards a new (economic) guiding principle of digitalization

Digitalization offers great potential for overcoming the challenges of a 'full world' (Section 8.4.1.1), but often lacks appropriate incentives to use this potential. This lack of incentives reflects not least the orientation of the economy according to traditional guiding principles. Alternative guiding principles of (digital) progress that are more oriented to societal welfare must be developed and implemented for a future-oriented form of digitalization. Inclusive performance indicators can provide important support for this and for assessing development potential.

While the classic economic understanding of development assesses the opportunities of new technologies primarily by their contribution to developing material prosperity, the socio-ecological understanding of development assesses the ecological and social potential of innovations. In order to leverage the potential of digitalization in both dimensions, it is necessary to develop orientations that are based on an inclusive understanding of development which combines both perspectives and also adequately takes the benefits and costs of digitalization into account (Figure 8.4.1-1). An increasing demand for such integrative development concepts and models can already be seen today among many actors in society, politics and business.

Up to now, alternatives to conventional indicators have emerged in particular from the endeavour to reflect ecological and social development aspects more adequately. Examples range from the concept of "genuine savings" (Hamilton, 2000), the ecological footprint (Wackernagel and Rees, 1996), to the human development index (UNDP, 2019) and the index for ecological sustainability (Esty et al., 2005). However, the challenge remains to give these indicators the necessary weight and to pay more attention to them in policy processes. Initial approaches to using suitable indicators to measure the macroeconomic effects of digitalization are also emerging (Brynjolfsson et al., 2019a, b). However, so far no metric has been developed that comprehensively takes economic development, sustainability and digitalization into account.

8.4.1.3
New hybrid forms of economic activity

Simply developing new, extended indicators to measure economic and societal progress does not, however, meet the challenges of a 'full world' (Section 8.4.1.1). These indicators must ultimately be brought to the attention of the private-sector actors by creating a concrete framework. Regulatory measures, e.g. environmental and resource policy, can achieve a stronger welfare orientation of traditional prosperity indicators, but they do not make comprehensive, alternative measures of welfare superfluous. It is clear that an increasing departure from the laissez-faire principles of an 'empty world' is inevitable.

Private-sector actors have considerable potential to promote sustainable development within the framework of digitalization, for example through more resource-efficient production processes, monitoring and closing material cycles (circular economy), the dematerialization of consumption, or through business models based on the shared use of economic goods. However, this potential is generally only exploited if there is a corresponding return on investment (Section 4.2.2). Setting regulatory frameworks plays a decisive role in determining which technologies are associated with these expected returns. A synchronization of private-sector interests and an orientation towards the common good seems at least partially possible.

In this context, it is also important to determine the potential of alternative forms of private enterprise that are not primarily profit-oriented (e.g. cooperative approaches). However, this, too, presupposes creating uniform conditions for economic activity which take due account of the positive and negative societal consequences of economic activity. Suitable financing instruments must also be created for the provision of goods and services for which there is no market potential even under these conditions, despite their societal desirability (Section 5.2.2). Already today, there is a continuously rising interest in alternative forms of economic activity, such as platform cooperatives and citizen-supported sharing services, which would encourage a common-good-oriented form of digitalization (Section 5.2.2).

The extent to which it should at least partially be the state's responsibility to realize the potential of digitalization must be examined, particularly in the context of digital public goods and public-service ICT (Sections 5.3.5, 5.3.10). In the case of autonomous mobility systems, sharing services, the provision of digital educational resources – to name just a few examples – the state's role in relation to private-sector provision (whether for profit or common-good-oriented) needs to be discussed. Hybrid forms of economic activity (Figure 8.4.1-2) which combine the advantages of different ownership structures and understandings of development can offer considerable opportunities for leveraging inclusive development potential (not only, but also in the context of digitalization).

8.4.2 Principles and instruments of environmental law in the context of digitalization

The containment of negative impacts of digitalization on sustainability objectives requires a clear allocation and assumption of responsibility by state, economic and societal forces, as has already been largely devised in the environmental field. Shared guiding and lead principles are helpful for success in achieving the sustainability goals in a polycentric actor structure. Over the last 30 years, principles such as the precautionary principle, the polluter pays principle, the cooperation principle and the integration principle have been developed and applied in international environmental law as the basis for agreements, institutions, procedures and instruments to protect the environment. In the context of the challenges of digitalization already outlined, these experiences may provide some valuable guidance (Section 9.3.2.1).

8.4.2.1 The precautionary principle

The *precautionary principle* was developed for cases where there is scientific uncertainty in the development and application of (international) environmental law (Sands et al., 2018: 230). It has been included in several soft and hard law agreements, such as Article 15 of the 1992 Rio Declaration and Article 3 (3) of the UNFCCC. According to this principle, "where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNCED, 1992). The precautionary approach is contained in German law, e.g. Article 20a of the Basic Law (GG) and section 5 (1) no. 2 of the Federal Immission Control Act (BImSchG), and in European law in Article 191 (2) sentence 2 of the Treaty on the Functioning of the European Union (TFEU; Calliess, 2013). The precautionary principle is not yet recognized as universally applicable customary international law because of its slightly ambiguous content (SRU, 2011; Sands et al., 2018: 234). The precautionary principle may include risk- and resource-related precautions (Messerschmidt, 2011: 286): a risk-related precaution is the management of risk situations defined by uncertainty and insecurity; a resource-related precaution means preserving the present resources with a view to the needs of future generations (Calliess, 2013). The precautionary principle obliges the states to exercise preventive and planned governance (Kloepfer, 2016), use all accessible sources of knowledge, conduct a risk comparison and justify risk decisions (Schlacke, 2019). Precaution can also lead to procedural safeguards, such as participation rights for societal groups and the transparency of official decisions, or making it possible to trace the potential cause of danger in order to prepare for subsequent state action (Calliess, 2013).

A central element of risk precaution is the scientific determination of risk (Calliess, 2013). Social-science-oriented risk assessment is of particular relevance in the digitalization context, since not only physical and technical risks, but also societal coexistence in particular, are changing as a result of digital change. In a world with plural risks, impact assessments are also playing an increasingly key role, whether with a view to data protection, environmental impacts or other risks. Institutions that contribute to scientific risk identification and assessment at the global level include intergovernmental institutions, such as the Intergovernmental

Panel on Climate Change (IPCC) or the World Biodiversity Council (IPBES), which compile overviews of scientific research for political decision-makers.

8.4.2.2
The polluter pays principle

According to the *polluter pays principle*, the party that causes a negative environmental impact is to be made responsible for the prevention, elimination, mitigation of, or compensation for any environmental damage (Sands et al., 2018: 240). The polluter pays principle does not apply between states; rather, it is a guideline for the domestic level (Sands et al., 2018: 241). Between states, customary international law does not apply the polluter pays principle but prohibits any intentional or negligent cross-border environmental damage (USA vs. Canada, 1941).

The polluter pays principle is laid down, inter alia, in Principle 16 of the Rio Declaration (UNCED, 1992). This idea includes private responsibility for the primary obligation to avoid adverse effects (e.g. product responsibility of manufacturers), but also for the costs and compensation payments for losses, i.e. liability for environmental damage (Schlacke, 2019). This is based on the assumption that polluters can combat damage and losses most effectively and least expensively themselves (Kloepfer, 2016). Moreover, the environment as a freely available good should not be damaged without sanctions being imposed (Schlacke, 2019). Furthermore, applying the polluter pays principle aims to contribute to burden sharing and to distributive justice (Kloepfer, 2016). In addition to cost-reimbursement obligations and the internalization of external costs, measures and instruments that implement the polluter pays principle include bans and restrictions, as well as civil-law injunctions and product and procedural standards (Kloepfer, 2016: 193), such as regulations on product responsibility.

A clear allocation of responsibility is necessary in the context of digitalization, for example in the provision of critical infrastructures and in the context of automated decision making. Societal value decisions (e.g. privacy by design) must already be implemented during the development of technology.

8.4.2.3
The cooperation principle

The *cooperation principle* states that environmental protection is a common task of all societal forces, not just a purely state task. Principle 5 of the Rio Declaration also lays down a global principle of cooperation to combat poverty and inequality (UNCED, 1992). The state has a leading function here, since it is bound to the common good and charged with its realization. Cooperation serves on the one hand to integrate expertise for public concerns, and on the other to promote information and acceptance by involving the people affected and relieving the burden on the state (Schlacke, 2019). However, orientation towards the cooperation principle should not disregard the fact that it may be necessary in cooperation situations to reach a compromise on the object of cooperation (e.g. the environment). This can result in costs for the general public. Cooperation can also be used by negotiating partners for economic reasons to prevent enforcement (Schlacke, 2019).

In the Digital Age, cooperation between the different societal forces is of particular importance, as formative and market power is increasingly shifting to private companies. Public-private cooperation is needed to contain this power. The form of this public-private cooperation, which sees the shaping of the Digital Age as a public task, is becoming increasingly important. What is crucial is that the state not only retains the ability to play a leading role in shaping public-private cooperation, but also accepts and performs this function as a key task of the state. In addition, all relevant actors should be enabled to cooperate. Furthermore, the state should monitor and check whether certain forces are losing their ability to cooperate and whether they need to be strengthened.

Concrete instruments that can be derived from the cooperation principle and further developed in the digital context include, for example, the involvement of private individuals in legislation and enforcement, and the involvement of civil society in decision-making processes and their mobilization for law enforcement.

8.4.2.4
The integration principle

There are goals, such as environmental protection and climate-change mitigation, which cannot be achieved sector-by-sector but must be promoted as cross-cutting issues in all areas. The *integration principle* under environmental law aims precisely at that and states that environmental concerns must be integrated into all areas of society, particularly into economic development, and taken into account in all formative action by the state. In international environmental law it is understood as a component of the sustainability principle (Sands et al., 2018: 227) and is embedded at a high level in EU law with the cross-sectional clause in Article 11 of the TFEU. It means that environmental protection must be taken into account when implementing all aspects of political and societal action (including economic and development policy) and that the protection of the environment must be taken into account within the individual sectors (Kloepfer, 2016: 205). At the international level, it is laid down in Principle 3 of the Rio Declaration (UNCED, 1992). Instruments for implementing the integration principle include, for example, collecting and disseminating environmental information, carrying out environmental impact assessments (Sands et al., 2018), and appointing ombudspersons to advocate the principle. In the Digital Age, the integration principle must be applied in particular to topics such as privacy protection (including data protection and data security) and cybersecurity. At the same time, environmental protection needs to be integrated into the negotiation areas on digitalization.

8.4.3 Readjustment of sustainability governance 30 years after the Earth Summit of Rio de Janeiro

The rapid global spread of digital technologies requires urgent adjustments to global sustainability policy in order to set the course in good time for a digitalized sustainability society. Today, 30 years after the Earth Summit in Rio de Janeiro in 1992 (UNCED), a readjustment of global sustainability governance is needed (Section 9.3.1). The summit's achievements, e.g. the establishment of the three Rio Conventions UNFCCC, CBD and UNCCD, were marked by the political optimism following the end of the Cold War and a forward-looking response to growing challenges – such as sustaining the natural life-support systems and overcoming key development problems such as poverty and malnutrition. But the conditions for a new start are much more difficult than in 1992 in view of the currently growing obstacles to multilateral cooperation. However, the crisis of multilateralism that has only emerged in recent years could be overcome again in a few years' time. Chancellor Angela Merkel also emphasized this in her speech at the 2019 Munich Security Conference (Merkel, 2019), which attracted a lot of international attention. In order to set the right course, the WBGU proposes that Germany and the EU should advocate a UN summit on the topic of digitalization and sustainability (UN Conference for a Sustainable Digital Age; Section 9.3.1.1) in 2022 – 30 years after UNCED. The central theme of the conference with a global perspective should be to agree on the big strategic decisions that need to be taken to achieve sustainable development and avoid unsustainable consequences of digital change. Suitable thematic priorities include using digital technologies to support the implementation of the SDGs and new challenges to global sustainability policy after 2030. The global summit should take into account the recommendations of the UN High-level Panel on Digital Cooperation and the results of the world summits on sustainable development held since 1992 (UNCED, 1992; Millennium Summit, 2000; WSSD, 2002; UN Conference on Sustainable Development, 2012, and the world summits on the information society in 2003 and 2005). A key outcome of the UN summit could be a charter of the international community on 'Our Common Digital Future'. The WBGU has submitted a draft for such a charter (Section 8.6; Box 9.4-1). Such a declaration should list the fundamental issues for sustainably shaping the Digital Age, identify key political starting points, stipulate key levers, and present flagship initiatives for policy-making.

To prepare for the proposed UN Summit, the WBGU recommends immediately setting up a 'World Commission for Sustainability in the Digital Age' modelled on the 'Brundtland Commission' (Section 9.3.1.1). At the time, the latter aimed to develop long-term strategies, point out possibilities for improving international cooperation, propose effective measures and procedures, and provide ambitious common goals for the world community (UNGA, 1983). The new World Commission's task should be to develop the goals, long-term strategies, and a vision for a *common digital future*. In particular, it should identify the risks posed by digital technologies for the Transformation towards Sustainability and describe ways of containing them. At the same time, the World Commission should stipulate the conditions that will enable the potential of digital technologies for sustainable development to unfold. The results should in any case be incorporated into the further development of the SDG agenda after 2030.

8.4.4 Governance gap: adequate institutional capacities for new challenges

New global challenges not only make it necessary to strengthen civil society and local capabilities (Sections 4.2, 9.3.3), they also require changes in global governance. A sustainable digital policy requires people championing sustainability in all private, intergovernmental and transnational forums and organizational units. In the WBGU's view, however, firmly embedding the topic of digitalization in the institutions of the UN system is key. The WBGU sees various opportunities for achieving this. First, all UN institutions working on development issues (e.g. UN Environment, UNDP, UN-Habitat, IOM, as well as the World Bank and regional development banks) should systematically incorporate the issue of the digital transformation into their work and strategy-building processes. In addition, 'digitalization' should be embedded more firmly as a cross-cutting issue and in the interaction between UN organizations. The topic of digitalization therefore needs to be more firmly embedded in the institutions of the UN system beyond the existing United Nations Group on the Information Society (UNGIS; Section 8.1.3). To this end, a mechanism should be set up to ensure cooperation between agencies and system-wide coordination ('UN Digitalization' analogous to the existing UN Energy; Section 9.3.1.2). In particular, however, as representatives of their citizens and of general welfare in accordance with the understanding of the 'proactive state' with increased opportunities for participation (WBGU, 2011), states too should champion the interests of the common good, in particular environmental and privacy protection, digital inclusion and human decision-making sovereignty. This corresponds to their obligation to protect and take precautions against any dangers to society, individual citizens and the environment that are associated with digitalization. By virtue of their constitutions, states in this sense have the task and the duty to influence international processes (Hoffmann-Riem, 2016). This means that environmental protection and other aspects of sustainability, such as privacy protection, should be embedded as a cross-sectional task in all digital development agendas and practices. The Global Commission on the Stability of Cyberspace should also deal with material and energy consumption by cyberspace – and participating states should work towards this aim. Institutions that can demand and exercise societal control over states and companies include, for example, ombudspersons who promote under-represented topics such as environmental and climate protection in tech organizations and companies and put them on the agenda. Equally important are opportunities enabling civil society to participate. To this end, conducive framework conditions should be created and resources made available.

8.4.5 A binding framework under international law: the optimum solution

Important international agreements such as the CBD, UNFCCC and UNCCD have been among the driving forces behind the further development of international environmental law and global sustainability governance. Such framework conventions offer states an opportunity to stay engaged with issues on an ongoing basis, create further institutional capacity and take action. These conventions are arguably the most visible examples of an institutional embedding of global governance; however, they also involve the longest and most complicated negotiation processes and are politically the most difficult to achieve, given the current international situation. In the WBGU's view, the negotiation of a 'UN Framework Convention on Digital Sustainability and Sustainable Digitalization' would be necessary in order to integrate sustainability goals and digitalization (Section 9.3.1.3). This is the only way to create the necessary new negotiating spaces under international law for a form of digitalization that is oriented towards global sustainability. In particular, the following new topics should be placed on the international community's agenda: global cooperation for the preservation and expansion of inclusion in the Digital Age; human decision-making sovereignty in the deployment of algorithm-based decision making; AI and automation; and discourses on changes in the human-machine relationship. In any case, the enforcement of digital privacy protection should be the subject of a binding agreement under international law, either as a protocol to a framework convention on digital sustainability and sustainable digitalization or as a separate agreement (Section 8.3.1.3).

8.4.6 Role of science

Although future developments cannot be predicted, scientific expertise can help decision-makers to prepare better for possible futures, especially if disruptive developments seem possible. Science and research can also contribute significantly to raising awareness of the key challenges of digital change and thus promote societal acceptance. The example of the IPCC has shown that pooling scientific expertise is an important prerequisite for fact-based policy-making for political decision-makers. It would therefore be a good idea to set up an intergovernmental or international scientific body that would prepare regular progress reports on the state of scientific knowledge on all socio-technical and ecological aspects of the digital transformation that are relevant to sustainability (Section 9.3.1.4). Building on the experience gained to date, such a body could be structured in a similar way to the IPCC or IPBES.

8.5 The EU as a pioneer in the integration of sustainability and digitalization

In order for a global integration of digital change and sustainability transformation to succeed, states and alliances are needed that pursue this goal ambitiously and integrate it into global processes. As an economic region and an area of shared values and norms, the EU should, in the interest of its citizens and global sustainability, offer an alternative to strategies for regulating digitalization that are inadequate from a European perspective: e.g. strategies based on a laissez-faire mentality (like in the USA) or on the use of digital instruments to exercise authoritarian state power (like in China; Section 7.3). A visionary attitude on the part of the EU that consistently sets itself apart from these strategies (Sections 7.3, 9.3.2) can have a global impact, despite challenges to political implementation. The aim is not "to win a race" but "to ensure the well-being of humankind and the environment" (Dignum, 2019).

8.5.1 Appeal and political feasibility of a European model

The proposal of a European model for sustainability and digitalization (Section 9.3.2.1) faces the challenge of having to make a global impact and be politically enforceable, particularly in view of the current world political situation and intra-European problems. The EU's economic weight and soft power (Nye, 2004) play a role in the question of the global appeal and political feasibility of a European model for sustainability and digitalization.

The EU can bring its economic weight to bear in this way. Legal regulation in large economies can have a positive spill-over effect if companies adhere globally to the standards applicable there (Section 4.2.6). In the past, there has indeed been a Brussels effect in which legal regulation in the EU has de facto been adopted outside the single market (Bradford, 2012). In order to use and strengthen this effect in the sense of sustainable digitalization, and to thus codify the legal framework for sustainable digitalization more strongly, it would be conceivable to incorporate corresponding regulations into the EU's trade agreements, thus forming a coalition for common high standards. In the past, the EU has already used trade contract negotiations with partner countries to embed basic labour rights or economic development strategies (Meunier and Nicolaïdis, 2006). In the dispute over the trade in meat from hormone-treated cattle, for example, the EU has not shied away from a dispute with the USA in the World Trade Organization, although the protection of European farmers might have played a role (Josling and Roberts, 2001; Kerr and Hobbs, 2002). With the REACH chemicals regulation, it has also set standards across European borders and thus directly influenced international trade (Motaal, 2009). The EU has been a pioneer in climate protection, although it has lost this aspiration to some extent in the meantime (Fischer und Geden, 2015).

International reactions to the GDPR show that internal EU regulation on digital issues is also noted at the global level and that it carries weight (Box 4.2.6-1). The EU's pioneering role could spread to other countries and regions in this way. A European model for sustainability and digitalization could help establish the link between the two aspects in international politics and thus, in the medium and long term, initiate dialogues at the global level that ultimately lead to appropriate legal and institutional frameworks beyond the EU.

A European model for sustainability and digitalization is currently facing serious problems relating to the internal cohesion of the Member States, the rule of law in individual Member States, and the common understanding of fundamental freedoms. These existing problems complicate the political implementation of an ambitious integration of digitalization and sustainability as called for in this chapter. This is not only a European problem. Counter-movements against the liberal world order and its institutions are forming in the entire western world, including the USA (Hale and Held, 2017; Ikenberry, 2018).

In order to politically implement a European model for sustainability and digitalization, the social concerns of all affected population groups must be taken into account. A common vision of a sustainable digital future that places people at the centre of attention could be a new common project for Member States on the one hand, and actively address concrete fears of individual population groups on the other. This makes it possible to monitor the socio-economic structural change brought about by both the transformation to sustainability and digitalization. As with climate change (WBGU, 2018; Feist and Messner, 2019), ensuring social cohesion is essential for both normative and strategic reasons: on the one hand, for example, those affected by the upheavals in the working world as a result of digitalization (Section 5.3.9) need support; on the other hand, the successful setting of the framework conditions for sustainable digitalization is linked to broad public acceptance. To ensure an inclusive process, the EU should not act alone. Instead, it should join forces with the governments of the Member States and non-state actors who also have an interest in an active, sustainability-oriented shaping of digitalization, and develop deliberatively ambitious solutions that offer alternatives to the existing models. Such a stakeholder-oriented approach would contribute to the policy feasibility of a European model for sustainability and digitalization.

8.5.2 Setting the course for EU's political priorities, strategies and programmes

A new legislative period for the EU began in 2019 with the election of a new European Parliament and appointment of a new European Commission. As existing overarching EU strategies expire in 2020, there is currently a window of opportunity for the integration of sustainability and digitalization agendas and policies. Given their importance, both issues should be visible in the EU's overarching strategies and priorities, integrated into them on a permanent basis, and their interactions taken into account (Section 9.3.2.1). In the case of environmental protection, integration has already been achieved with the cross-sectional clause of Article 11 of the TFEU: environmental concerns must be "integrated into the definition and implementation of Union policies and activities, in particular with a view to promoting sustainable development." The same applies to other economic and social sustainability issues, such as protection against discrimination (Article 10 of the TFEU), consumer protection (Article 12 of the TFEU), and the protection of personal data of individuals (Article 16 (1) of the TFEU). Accordingly, there is already an obligation to ensure that EU digital policy is sustainable. However, also the use of digital technologies as instruments and tools for digitalizing other policy areas always needs to be aligned with the fundamental values and environmental and sustainability principles of the Union enshrined in the Charter of Fundamental Rights of the European Union, especially when it comes to adopting legislative acts, setting up institutions and establishing procedures.

In the future, the overall, overarching EU strategy and priorities should be explicitly aligned with the 2030 Agenda. In this way, the EU can send a signal to the world that strengthens the sustainability goals as a political guiding principle. With regard to ecological issues, high political priority should be given in particular to a digitalized energy and climate-protection union and to the application of digital technologies to a circular economy. It would also be possible to place the integration of digitalization and sustainability policy onto the political agenda as a general priority.

In order to leverage the potential of digitalization for overall societal goals alongside economic targets, greater weight must be given to sustainability goals in EU digitalization policy. The 2030 Agenda has differentiated the goals. The EU Digital Agenda should be revised and merged with the sustainability objectives in order to align Europe's digital innovation capacity with the target system. The principles of environmental law (Section 8.4.2), which already apply in EU environmental law, can be used to benefit the shaping of digitalization. In line with the precautionary principle relating to resources (Article 191 (1) of the TFEU; Section 8.4.2.1), the increasing demand for resources for digital products and infrastructures must be met by rapid progress in the switch to renewable energies and the establishment of a far-reaching circular economy. The precautionary principle relating to risk (Article 191 (2) of the TFEU; 8.4.2.1) requires that both the societal consequences of sustainability transformation and the societal effects of digitalization be taken into account. It also requires that the ability of society as a whole to cope with structural change and to build resilience should be promoted. In order not to lose the broad support of society, people must be informed about both sustainable development and digital competence via future-proof education. In addition, it is important to make use of the dynamics and broad impact that can result from the involvement of private-sector actors. What is needed, however, is a binding framework for meeting sustainability targets and correspondingly enhanced economic performance indicators in the EU in order to reconcile private and societal interests. Digital tools should be used to achieve overall societal objectives such as climate and environmental protection, climate adaptation, and for monitoring the way in which the goals are pursued and whether this is successful. This should be given greater priority in policy strategies, also in order to identify and promote possible technological game changers.

New, globally relevant areas of cooperation – such as the protection of privacy, inclusion in digital and digitalized goods, guaranteeing human decision-making sovereignty, and human-machine relationships that are in line with human needs – should also be the subject of a new EU Digital Agenda (Section 8.3). As a general rule, ethics, privacy, IT security, sustainability and fair production conditions in technology design, implementation and operation (ethics by, in and for design, privacy by design, security by design, sustainability and fairness by design) should be central principles guiding future European digitalization models (Section 9.3.2). Key projects for implementation can be the development of sustainable, public-service European ICT infrastructures (Section 5.3.5) and participation in digital commons (Section 5.3.10).

The EU has an opportunity to define ambitious steps and concrete measures to implement and enforce the goals for sustainable development in the field of sustainability and environmental policy in the ongoing process of relaunching an EU sustainability strategy as the 'Implementation Strategy for the 2030 Agenda', the new 'Environmental Action Programme' and the 'Decarbonization Strategy as a Contribution to the Paris

Convention'. The EU should now resolutely enshrine the existing approaches (Section 8.1.6) in the strategies and programmes to be formulated and in particular define and pursue ambitious steps and concrete measures for the implementation of the SDGs. In particular, the potential of monitoring in implementation should be exploited to the full. With an 'EU Strategy for Sustainability in the Digital Age', the EU could furthermore play a pioneering role in reinforcing and further developing the worldwide sustainability agenda after 2030. The strategy should jointly address existing sustainability goals and new cooperation requirements (Section 8.3), and thus look beyond 2030.

It is important not to lose sight of the fact that digital technologies cannot replace political will in order to solve urgent sustainability problems. Guiding principles and performance indicators for measuring economic success which reflect the resilience and sustainability of the economy can encourage companies to rethink in the direction of sustainability (Section 8.4.1).

8.6 On the need for a charter for a sustainable Digital Age

Global governance for the Transformation towards Sustainability in the Digital Age needs a fixed normative reference point. On the basis of the analyses in this report, the WBGU has therefore developed a draft Charter for a Sustainable Digital Age (Box 9.4-1). The Charter is intended as a system of principles, objectives and standards for the international community – complementary to the 2030 Agenda and beyond, and with a specific global sustainability perspective (Section 3.6.3). It contains condensed guiding principles for sustainable action in the Digital Age, covers the challenges of the three dynamics of digitalization, and is institutionally geared to the multilateral level in order to be able to offer a target system with the necessary global perspective complementary to the 2030 Agenda.

Based on the normative compass developed by the WBGU (Section 2), the draft first formulates objectives and principles for the protection of human dignity, the natural life-support systems, inclusion in and access to digitalized infrastructure and the underlying technologies, as well as individual and collective freedom of development in the Digital Age. On this basis, the Charter sets out concrete guidelines for action on how the global community should position itself to meet the challenges of the Digital Age. For this purpose, the Charter contains three core elements. First, digitalization should be designed in line with the 2030 Agenda, and digital technology should be used to achieve the SDGs. Second, beyond the 2030 Agenda, systemic risks (Chapter 7) should be avoided, e.g. by protecting rights, promoting the common good, and guaranteeing decision-making sovereignty. Third, societies must prepare themselves procedurally for future challenges by agreeing on ethical guidelines and ensuring future-oriented research and education.

Germany and the EU should work towards initiating a process at the global level to establish such a Charter for a Sustainable Digital Age and, as pioneers themselves, should shape policy in line with the stated principles. The WBGU's proposal (Box 9.4-1) should be understood in this context as a stimulus for a broad societal debate in the course of which the Charter should continue to take shape (wbgu.de/charter). The draft Charter is to be further developed in the course of a public consultation process.


Sustaining the natural life-support systems
Poverty reduction and inclusive development
Work in the future and reduction of inequality
Future-proof education
Big data and privacy
1011
001
10
110
Fragility and autonomy of technical systems
Economic and political power shifts
Global governanc
sustainable shaping of the
Digital Age

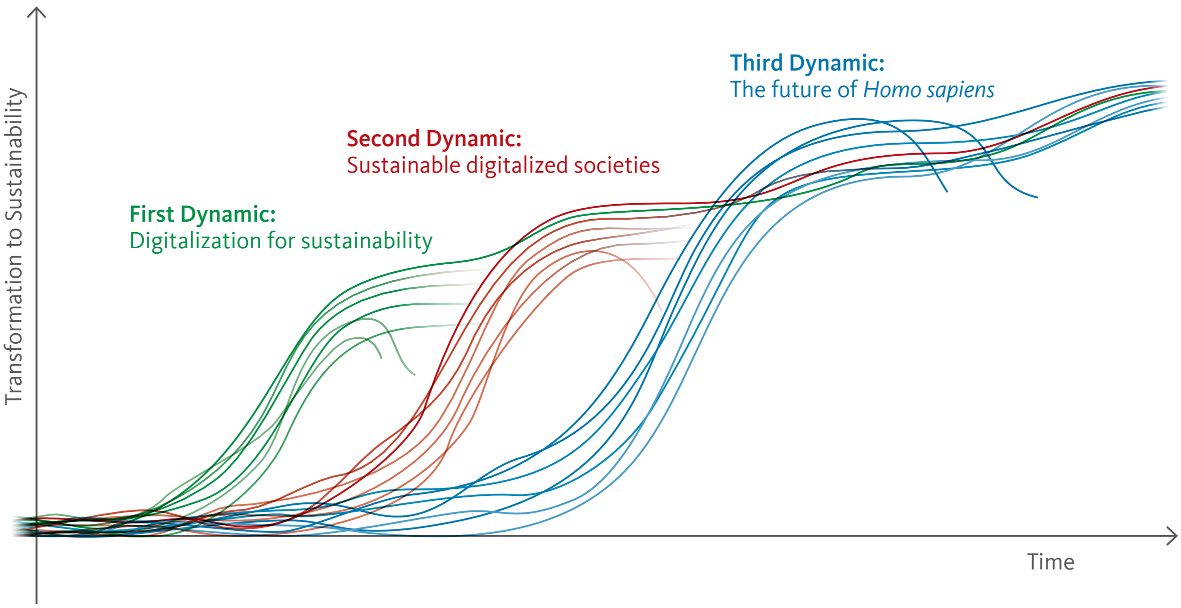
Recommendations for Action 9

The urgent challenge for politics and society is to steer digital change towards sustainability. In this regard, the WBGU makes a number of recommendations for action, which are primarily addressed to the German Federal Government, but also offer starting points for other actors. All states, organizations, businesses and individuals are called upon not only to participate in the discussions about our common digital future, but also to play an active role in shaping it.

The WBGU recommends that digitalization should be explicitly placed at the service of sustainability. Unless it is actively shaped, global digital change involves the risk of further accelerating the threat to humankind's natural life-support systems. Without regulation and democratic control, it can also endanger cohesion in our societies, violate fundamental and human rights, and weaken our democracies. The use of digital technologies needs to be embedded in a sustainable development strategy for it to make a positive contribution to *our common digital future*. This requires looking beyond 2030, the target year of the UN Sustainable Development Goals (SDGs). Unlike most of the studies on this subject conducted by international organizations, the WBGU therefore takes a longer-term perspective. From this perspective, adaptive policy-making and a culture of future-oriented thinking based on systemic long-term analyses and scenarios are required.

Digital change is happening at a time when decisions on the strategic course of action need to be taken and undesirable path dependencies overcome in order for the Transformation towards Sustainability to succeed. Experience shows that the probability of fundamental changes (system changes) increases during such phases. The challenge for policy-makers and societies lies in ensuring that digital change can be steered towards sustainability.

In order to grasp the opportunities for change that lie ahead, the WBGU distinguishes between three 'Dynamics of the Digital Age' and analyses their interactions together with sustainable development (Figure 9-1; Chapter 7). These Dynamics involve very different challenges at different times, but all require immediate action. The *First Dynamic* focuses on the implementation of the 2030 Agenda and the question of which course to set in order to harness digitalization for achieving the SDGs. The focus here is on concrete, political implementation measures, for which the WBGU offers a package of recommendations, e.g. on urban and rural development (Section 9.1). The *Second Dynamic* concerns the profound structural changes to society, the economy and the individual brought about by digitalization, such as new challenges in handling privacy and extensive changes in market dynamics. Digitalization opens up new opportunities, but it can also generate enormous risks: digital change is currently moving in a non-sustainable direction. This dynamic is therefore about preventive policy-making and ensuring that societies prepare themselves better for profound, in some cases disruptive changes. Key elements here are technology-impact assessment, risk analysis, the interlinking of digitalization and sustainability research and their integration into politics (Section 9.2). In the *Third Dynamic*, questions are raised about the future viability and identity of human beings and human societies in relation to the developing natural and technical environment. This raises new normative questions concerning the relationship between human beings and machines. In order to meet these challenges, societal dialogue processes are central to staking out desirable futures. To this end, the WBGU recommends, among other things, establishing discourse arenas on fundamental issues of what it means to be human in the Digital Age (Section 9.4).



↑ Digitally support sustainability

- Comply with planetary guard rails (climate, nature, soils, oceans)
- Secure social cohesion (against hunger, poverty, inequality; for access to water, health, education, energy)

↑ New humanism

- Networked world society as a further advancement of Enlightenment and humanism
- Development of global (environmental) awareness
- Culture of cooperation, empathy, global solidarity

↑ Strengthen *Homo sapiens*' self-confidence

- Preservation of the biological human in its natural environment
- Ethically reflected advancement of humanity
- Design human-machine collaboration

↓ Ecological and societal disruption

- More emissions and resource use
- More inequality
- Greater concentration of power
- Erosion of civil rights and privacy
- Erosion of the state's governance

↓ Digitally empowered totalitarianism

- Hollowed-out democracies and digitally empowered autocracies
- Massive inequality, domination by elites, total surveillance and loss of freedom
- Environmental destruction and loss of social cohesion

↓ Blurring of borderlines between humans and machines

- Abuse of human-machine relationship
- Superintelligence
- Artificial human evolution

Figure 9-1
Three Dynamics of the Digital Age.
The chart shows the positive case of the Dynamics being successfully contained through goals and governance. All three Dynamics are already emerging in parallel today, albeit with different levels of intensity, so there is no strict chronological sequence involved. Each Dynamic consists of different subpaths following different trajectories. The name given to each Dynamic reflects the priorities for action required in each case.
The texts beneath the figure give keywords on the potential (↑: upper row) and risks (↓: lower row) of the three Dynamics.
Source: WBGU; diagram: Wernerwerke, Berlin

For all the Dynamics, the challenge is to reconcile the impact of digitalization with the objectives of sustainable development. In view of the rapidly changing framework conditions, however, a common understanding of global sustainability also needs to be further developed. The overall discussion therefore covers proposals for a global governance architecture and a possible role for the European Union (EU) that can do justice to all three Dynamics. It becomes clear that policy-making must change its mode from a strong orientation towards the present – critics would call it 'managing the status quo' – to a greater emphasis on shaping the future, which can only succeed if policy-makers, society and business work together.

In its thematic analyses of the link between digitalization and sustainability, the WBGU looks at certain examples which are reflected in 'arenas of digital change' (Box 9-1). These provide a multifaceted impression of how digitalization can be shaped to serve the Great Transformation towards Sustainability. A detailed description of the arenas, including specific recommendations for action and research, can be found in Chapter 5.

In its 2018 discussion paper 'Digitalization: what we need to talk about', the WBGU formulated key questions on ten topic areas (WBGU, 2018a). The structure of the recommendations for action is essentially based on these sets of questions, without claiming to provide answers to all the questions asked in the paper. In many cases, concrete proposals on shaping digital change can already be made today. In other cases, in view of existing uncertainties, the first step is to create spaces for societal discourse in order to improve our understanding of the scale of the possible changes, and to develop normative principles for the design task that results from these changes. After all, digitalization is not a force of nature; rather, the road to *our common digital future* is a process that must be actively shaped.

Setting the course for a European road to a digitalized sustainability society

The EU should play a pioneering role in integrating sustainability and digitalization. By strengthening technological innovations and systematically linking them to sustainability-oriented social, cultural and institutional innovations, the EU could add something special to the global technology race and be a pioneer in the search for pathways to the digitalized sustainability society. In some areas of digitalization, the EU is already playing a pioneering role by setting legal frameworks. The EU Basic Data Protection Regulation (EU, 2016) is unique in the world when it comes to data protection and privacy. It gives concrete form to fundamental rights by protecting individuals from the unauthorized use of personal data by commercial or government entities. Furthermore, the EU is working on a European data space aimed at providing citizens and businesses with a highly developed, well-functioning, transparent system of public data, information, services and standards. This system would also help combine competitiveness with data protection in order, in the best-case scenario, to create competitive advantages for EU companies, e.g. in competition with China and the USA.

The EU is also at the forefront of sustainability policy: for example, environmental protection is enshrined as an EU goal in the Charter of Fundamental Rights and the EU Treaty. Furthermore, the EU is currently working on a new Environmental Action Programme and a decarbonization strategy as a contribution to the Paris Agreement. However, the EU is not (yet) a pioneer when it comes to the urgently needed, implementation-oriented dovetailing of sustainability and digitalization. Thoughts on how digital change can be used to implement SDGs, or which ethical principles should be developed to govern the use of artificial intelligence (AI, Section 3.3.3), are still in their early stages.

The WBGU proposes fundamental decisions to be taken on five different stages *for a European road to digitalized sustainability societies*, in order to master the profound and radical changes towards sustainability in the Digital Age. Taking this road can only succeed if the fundamental decisions made on the five stages are intermeshed.

1. *New humanism for the Digital Age – renew the normative foundations of our societies:* The WBGU develops essential features of a new humanism for the Digital Age with the aim of defending the fundamental, albeit endangered achievements of humanism and enlightenment over the past two centuries and, at the same time, creating attractive future prospects for a digitalized sustainability society. Our hope is that Europe will be in a position to make such a concerted civilizational effort
2. *Charter for the transition to a digitalized sustainability society:* Societal discourses for a new humanism need a starting point. On the basis of its analyses and discussions, the WBGU has condensed some key principles and guidelines for the digitalized sustainability society into a Charter, which the EU could embrace as its own. These guiding principles include the protection of the planet and the preservation of human integrity, above all by protecting human dignity. This Charter also encompasses support for local and global fairness, justice and solidarity under the conditions of a digital revolution. Finally, it involves strengthening global (environmental) awareness and the cultures and systems of global cooperation by making use of digital opportunities, and by also developing a form of AI that furthers human development possibilities, society's ability to learn and social cohesion. The Charter can become a starting point for the renewal of sustainability paradigms and place *our common digital future* at the centre of efforts at the national, European and global level. The Charter builds on the Agenda 2030 and, at the same time, goes beyond it to highlight the normative foundations of our societies in the Digital Age.
3. *Building blocks of a responsible society capable of taking action:* Science and education are fundamental for freedom, inclusion and the *Eigenart* of the individual in the sense of future-oriented and creative, inclusive societies. The demands placed on our societies cannot be 'solved' solely by individual instruments (such as a CO_2 tax, resource pricing or reforms of the existing global competi-

Box 9-1

Arenas of digital change

The 'arenas of digital change' are intended as examples to give a multifaceted impression of how digitalization can be placed at the service of the Transformation towards Sustainability. The report briefly presents and analyses concrete topics and extrapolates recommendations for action and research.

Industrial metabolism

Digitalization changes the energy- and material-exchange relationships (metabolism) within companies and value chains. In the case of digital devices, the main issue is currently environmental risks (e.g. electronic waste). In production, digitalized manufacturing processes that are coordinated in the sense of Industry 4.0 offer potential for higher resource efficiency. Digital platforms could enable a close linkage of material flows between companies. The global sustainability implications and the contribution to the circular economy are ambivalent and require in-depth analyses (Section 5.2.1).

New forms of digital economy

Digital technologies enable new, collectively organized economic systems that are oriented towards the common good. These include new business models (sustainable digital entrepreneurship, green digital start-ups) and corporate forms (platform cooperatives), alternative forms of production (prosumer, commons-based peer production), and participatory value creation (sharing economy). Unlocking the related potential requires a suitable legal framework, a corresponding promotion of economic development, and the development of infrastructure (Section 5.2.2).

Sustainable consumer behaviour

Digital technologies can be used to help people to consume in a sustainable manner (e.g. by buying only what they need, and through resource-sparing use, reuse, repairing and sharing). The focus is on consumer decisions about the type, quantity and use of products. It presents sustainability-relevant forms of 'digitalized consumption' and identifies the challenges and potential of digitalized consumption for sustaining natural life-support systems (Section 5.2.3).

Online commerce

Online commerce is growing rapidly. This involves both negative environmental effects – from delivery services, packaging waste and returned goods – and positive effects from fewer private journeys and optimized logistics. Most of the turnover in online commerce is currently concentrated on a small number of companies that are displacing bricks-and-mortar retailing outlets. Opportunities for monitoring compliance with environmental and social standards at the place of origin are diminishing. Municipalities and cities should develop strategies to react to the displacement of the local retail trade (Section 5.2.4).

Electronic waste and the circular economy

Digitalization is a driver of resource extraction and rapidly growing amounts of electronic and toxic waste. In order to reverse this trend, aims of the circular economy – e.g. resource conservation, durability, ease of repair, recycling – must already be integrated into business models and product designs. Clear regulations and incentives, societal embedding and a research offensive are levers for unlocking the potential of digital technology along the entire product life cycle (Section 5.2.5).

Digitalization for climate-change mitigation and the energy transformation

Digital solutions support the integration of fluctuating renewable energies into energy systems and can promote access to modern energy in off-grid regions. Increases in energy demand triggered directly and indirectly by digitalization can be problematic. Long-term targets must be clear and reliable to ensure that investment and innovation are used for climate-change mitigation. The reliability and security of the increasingly complex energy systems and data protection should be taken into account from the outset (Section 5.2.6).

'Smart City' and sustainable urban development

Sustainable urban development using digital technologies presupposes that municipalities and urban societies retain their governance sovereignty vis-à-vis the digital economy and develop their own technological sovereignty. A growing number of cities are actively investing in decentralized digital urban platforms, open architecture and an orientation towards the common good. If this trend prevails, there is justified hope that the digital transformation can be used for inclusive, sustainable urban development (Section 5.2.7).

Sustainable urban mobility

Digitally supported innovations in the transport sector are currently being tested in many cities and give us an idea of future disruptive changes. In many cases, it is not clear how data and liability issues will be handled. However, solutions to key problems of urban transport systems (e.g. high CO_2 and air-pollutant emissions, land consumption, noise pollution, increasing travel and transport times and accident risks) are not a purely technological matter; rather, they will be decided by how digital solutions are embedded into comprehensive concepts of sustainable urban mobility (Section 5.2.8).

Precision farming

Land use is a key sustainability issue for food security and nature conservation. Digitalization must not reinforce the trends towards industrial agriculture. It should be used to reduce environmental damage caused by the use of fertilizers and pesticides and to promote the diversity of cultivation methods and landscapes. Trustworthy data systems, a focus on data sovereignty, Open Data and Open Source can all help prevent farmers from increasingly losing control and becoming dependent on agricultural corporations (Section 5.2.9).

Agriculture in developing countries

Most of the world's agricultural land is farmed by smallholders. Precision agriculture is highly capital-intensive and therefore less suitable for smallholder agriculture in developing countries. Even so, digitalization can increase the efficiency, productivity and sustainability of small farms by improving access to information, advice and education. Mobile connectivity and organizing small farms in cooperatives play a key role here (Section 5.2.10).

Monitoring ecosystems and biodiversity

Digitalization is changing nature conservation in fundamental and transformative ways. Digitally enhanced ecosystem monitoring cannot directly influence the drivers of the biodiversity crisis, but it is a source of valuable knowledge and opens up new opportunities for monitoring compliance with management rules and bans that are aimed at preventing the overexploitation of biological resources. The vision of a global system for monitoring biodiversity with semi-automated inventories of species and ecosystem services is becoming more realistic (Section 5.2.11).

Collective global awareness

Individuals can be motivated to act in a way that preserves the Earth system by creating a corresponding awareness of the problem and specific knowledge of how best to act. New digital possibilities, such as interactivity, gaming, virtual experiences of nature and citizen-science projects offer new opportunities for promoting environmental awareness. In the longer term, this will lead to a new willingness for global cooperation and a strong sense of global citizenship (Section 5.3.1).

Public discourse

Digital technologies are changing how we communicate, how we perceive societal debates, and how we can take part in them. New forms of participation, algorithmic pre-structuring of media content, the use of social media, and new forms of content editing are restructuring public discourse. New skills and suitable legal and institutional framework conditions are required to ensure that the foundations of democratic opinion-forming and journalistic quality are preserved in the long term (Section 5.3.2).

Scoring society

Scoring procedures map human behaviour using numbers. They are being used in more and more core areas of society (e.g. health care, law enforcement) as a basis for decision-making, often without the knowledge of those affected. The potential for more objective decision-making is being undermined by a lack of transparency concerning areas of application, methods and data, as well as a lack of supervision. Individuals should be given a right to have decisions justified by rational reasons. The way in which scoring influences societal norms and moral standards should be a central research topic (Section 5.3.3).

Future-proof education

Up to now, digitalization has not been systematically incorporated into educational programmes. The planned promotion of digital skills and infrastructure (e.g. in the German 'Digital-Pact for Schools') seems necessary, but it is not enough. The conceptual combination of digitalization and sustainability requires a variety of initiatives in the education context. The WBGU shows how education could be 'future-proofed', which risks (e.g. 'fake news') should be countered, and where there is potential for more solidarity-based quality of life (Section 5.3.4).

Public-service ICT

Information and communication technologies (ICT) have become a lot more important in society and are increasingly influencing citizens' lives. The public sector has a responsibility for the operation and content of public-service ICT. This is an important prerequisite for equal inclusion in societal life, for the provision of, and access to, digital commons, and as a locational factor for innovation, competition, employment and sustainable economic growth (Section 5.3.5).

Digital technology as a gender bender?

Despite growing political attention, gender equality has not been achieved in any country in the world. Existing gender inequalities and stereotypes are reproduced in socio-technical systems such as the internet, and this can lead to new discrimination. Equal-opportunity measures are still necessary, and not only in the context of a two-gender understanding of the issue. Digital technology offers emancipatory potential by providing access to information and networking, exposing discrimination, and raising awareness in digital arenas for experimentation (Section 5.3.6).

Digital self-tracking

Digital self-tracking apps supply people with information about their own bodies and offer comparisons with others. The WBGU uses this example to reveal the implications of healthcare-system digitalization and universal data collection and availability. The potentially better information base for users is partly offset by major quality deficits in data protection, data quality, collection and processing. In addition, users' privacy, personal freedom and self-determination could be restricted (Section 5.3.7).

International division of labour

The ongoing digital structural transformation in the international division of labour will lead to a readjustment of the role of developing countries and emerging economies. Unequivocal conclusions on the impact of digitalization on the international organization of value chains are currently limited. On the one hand, there are large potential job losses due to digitally supported automation and production relocation processes; on the other, new markets are accessible, primarily via digital platforms (Section 5.3.8).

Working environments of the future

Digitalization and sustainability transformation are radically transforming labour markets. People will continue to work in the future, but it remains to be seen how this can be embedded into society and organized in such a way that the functions of gainful employment as we know them today – securing livelihoods, social participation, the basis of self-esteem – can be guaranteed in the future. However, digital change and sustainability transformation offer opportunities to develop and establish new models for more sustainable working environments (Section 5.3.9).

Digital commons

Based on common goods in general, digital commons are data, pieces of information, educational and knowledge artefacts in the public interest that are available to the public barrier-free. They must be protected from exclusionary use for profit maximization and from abuse. To this purpose, fundamental organizational, regulatory and financial decisions, e.g. obligations to provide information, are necessary to develop a public-welfare orientation using digital common goods (Section 5.3.10).

tion order). Rather, responsible societies capable of taking action must be developed and strengthened, so that the upheavals outlined can be mastered and managed. The WBGU proposes the following building blocks of a responsible society capable of taking action, which – in their entirety and if they are cleverly combined – will result in the architecture of these societies and should be promoted by the EU:

- People must be enabled to understand and participate in shaping the coming upheavals. Comprehensive education for sustainable development in the Digital Age is the key to this.
- Science should generate knowledge about the future in order to shape digitalized sustainability and sustainable digitalization. Four decades ago, the Herculean task was accomplished of bringing together climate and Earth-system research with social science and economic disciplines to form the sustainability sciences that are established today. Similarly, it is now necessary to quickly and closely interlink them with digitalization research.
- States must be able to assume a formative role themselves: states and public institutions should invest in their own capabilities in order to establish and consolidate digital skills for the transition to a sustainable society.
- The creation of arenas for experimentation and discourse in Germany and Europe would make it possible to prepare and accelerate innovations, to think ahead and to develop examples for shaping the future.
- The new power constellations must be contained in order to secure democratic inclusion. Important examples in view of high global mobility in the digital economy are an international harmonization of competition law and corporate taxation, as well as non-discriminatory, clearly regulated cross-border exchange processes in virtual spaces that are standardized to ensure interoperability.
- The digital changes have a fundamentally worldwide effect, so that global, rule- and fairness-based regulatory models are needed that make it possible to combine digital change with the Transformation towards Sustainability as proposed in the WBGU Charter. Only if the EU develops a common policy in this direction will European societies be able to influence the global restructuring of the future.
- Digitalization will fundamentally change the development opportunities available to societies in developing countries and emerging economies – for better and for worse. International cooperation for sustainable development, and Germany's and the EU's collaborations with the United Nations and other multilateral actors, should therefore be urgently expanded in this direction.

4. *Technological game changers can accelerate sustainability transformations:* Digitalization offers an enormous toolbox of instruments and methods that must be used effectively and efficiently to achieve the sustainability goals. Here are some examples of technological game-changers that the EU should rapidly promote in order to trigger change processes in European societies and in the world economy, in cooperation and competition with other states and the United Nations:
   - The extended possibilities of digitalized remote- and near-Earth observation, and the sensors, equipment and infrastructure required for this purpose, should be developed worldwide and upgraded for the comprehensive and real-time monitoring of the natural Earth systems, their condition and development. The resulting international digital commons (Section 5.3.10) should be used as a starting point for the establishment and realization of services and applications for global (environmental) awareness (Section 5.3.1).
   - Building on this, the nation states should, in the context of the UN, establish a globally coordinated and interoperable system of digital SDG indicators to improve the topicality, transparency, comparability and verifiability of digitalized national and international SDG reports.
   - In parallel, the sustainability and environmental data collected for SDG indicators and Earth observation should be made available as digital commons.
   - ICT infrastructures should not least be made available on a non-discriminatory basis as part of basic public services (Section 5.3.5), thus fostering inclusion and the emergence of 'quality media' also in the digital sphere.
   - Digital technologies should be used to establish global processes and infrastructures that make it possible to map the emission and resource footprints of both traditional industries and the digital economy across the entire value chain.
   - The multifaceted potential of AI should be harnessed for sustainability issues, for example to improve our understanding of material cycles, production processes, supply chains, usage contexts and consumption patterns, to determine key triggers and patterns, and to identify and implement optimization potential.
   - Using digitalization to determine ecological

parameters and correlations (e.g. achieving SDGs, footprints, material cycles) creates the information base needed for an efficient regulation of environmental resource consumption. Especially for the central goal of decarbonization, digitalization can make the difference, as it not only plays a key role in the realization of renewable energy supplies, but also makes specific production- and consumption-oriented regulation possible. In combination with economic policies for decarbonization, these can have a real impact.
- However, none of these digitalization-related levers will become effective unless there are comprehensive safeguards protecting not only the resilience, cyber-security and trustworthiness of digitalized infrastructures, their longevity and robustness, but also human decision-making sovereignty in the case of societally relevant automatic systems involving AI.

5. *Strengthen the sustainability and resilience of the economy:* Digitalization processes open up opportunities not only to advance a green economy, but also to strengthen the diversity and resilience of economic structures by adding new business models to the private sector. Digitalization is also used by cooperative, public and common-good-oriented enterprises to create new business models. This emerging diversity again ties in with the old strengths of post-war European economies: a strong private sector, a diversity of enterprise types, and markets embedded in institutions and normative systems. In order to exploit the potential of digitalization, it is important to find a new balance between entrepreneurial competition, regulatory and legal frameworks, societal responsibility and an orientation towards the common good. The guard rails and values set out by the Paris Agreement on Climate Change, the 2030 Agenda and the WBGU's Charter for a Digitalized Sustainability Society could thus become guidelines for the renewal of Europe.

Immanuel Kant analysed the essence of the Enlightenment as a 'change in the way people think'. Having arrived at a new level of civilization in the Digital Age, we face a similar challenge in the struggle for sustainable, globally and virtually networked digitalized societies and in the search for a new humanism: *the further development of our civilization on a finite planet in the digital Anthropocene*.

9.1 Use digitalization for the 2030 Agenda and the Transformation towards Sustainability

In many cases, using digital solutions can help achieve the goals of the 2030 Agenda. However, it is also necessary to contain risks to achieving the SDGs that are caused by digitalization. The WBGU's analysis makes it clear that there are no simple technological solutions for achieving the SDGs – they must always be embedded into society as a whole (Section 8.2.1). Digital solutions are no substitute for a lack of political ambition, a lack of regulation, a lack of institutions or a lack of control instruments. The focus should be on creating the appropriate framework conditions to steer the momentum of digitalization in the right direction. In addition, the WBGU believes that the urgency of the 2030 Agenda will increase as a result of digital change, since achieving the goals can often also be seen as a prerequisite for making societies fit for the extensive upheavals that digitalization will bring. Initial approaches to making digitalization sustainable already exist in specialist literature and recent reports (Box 9.1-1).

The WBGU takes a profound, holistic look at various areas of the existing sustainability agenda with in-depth examples, and makes selected recommendations. This reveals the close connection between the SDGs (Section 8.2). Since many of the issues involved will still be topical after 2030, some of the recommendations go beyond this date and refer to the Transformation towards Sustainability in general.

9.1.1 Digitalization and sustaining the natural life-support systems

Sustaining the natural life-support systems is one of the three dimensions of the normative compass developed by the WBGU (Section 2.2.1). It involves, on the one hand, respecting planetary guard rails (e.g. on climate protection and the preservation of biodiversity) and, on the other, avoiding local environmental problems. These topics are addressed in several SDGs. At present, many trends are moving in the direction of an increasing risk of breaching guard rails, rising emissions and a growing use of resources. Digitalization can contribute to reinforcing these trends. This makes it all the more important

Box 9.1-1

Recommendations on digitalization and sustainability in specialist literature

Preparations for writing this report's two chapters of recommendations included reviewing already existing recommendations for action; corresponding text passages from 90 source documents that implicitly or explicitly position digitalization in the context of sustainability were condensed into compact statements in a qualitative-interpretive discourse analysis. The entire analysis, covering recommendations both for action and for research, is available as a separate PDF document for download at www.wbgu.de. Some of these recommendations are repeated by different sources. This analysis reveals that, both internationally and nationally, there is currently a strong emphasis on recommendations formulated from a perspective that is oriented more towards technical solutions. A broader perception of digitalization as a socio-technical system is comparatively rare. The topics were structured in line with the categories used in the discussion paper on Digitalization and Sustainability that preceded this report (WBGU, 2018a).

With regard to *sustaining the natural life-support systems* (Section 9.1.1), several texts propose solving global environmental problems with the help of artificial intelligence (AI), reducing the ecological footprint of ICT during life cycles, implementing energy labels at the national to global level, and using technology that is as energy-efficient as possible in public institutions in order to lead by example. Furthermore, the spectrum of topics ranges from technological optimization (e.g. indicators, evaluation) and concrete regulatory options such as standards to a fundamental transformation of the economic system (e.g. the sharing economy).

Also in the context of *poverty reduction and inclusive development* (Section 9.1.2), one of the two most frequent proposals aims to solve problems by means of AI. However, several texts call for disadvantaged groups (e.g. children) to be protected from the negative impacts of digitalization and for it to be used instead to promote their inclusion. The wider spectrum includes both general and topic-focused anti-discrimination proposals, technical solutions relating to SDGs and general problems of global and local social inequality (e.g. raw materials, digital inclusion), as well as recommendations for action that are specifically designed to solve concrete problems.

In the area of *work in the future and reducing inequality* (Section 9.1.3), the most common proposal is to use the return on investment in automation to deal with its consequences, for example to finance an unconditional basic income. Closely related are more specific proposals for a socially equitable distribution of the productivity gains achieved through AI or for a tax on data. However, it is also stressed that work will continue to be an important basis for people's livelihoods and for self-determination in the future. The remaining proposals cover topics ranging from education and training to a digital revolution in the financial system.

AI is also the most frequently discussed topic in the area of *knowledge, education and digital literacy* (Section 9.1.4), albeit with regard to the discourse on this topic, which should be promoted in a dialogue with and in society. Another subject addressed is 'digital enlightenment' in the sense of promoting individual and, ultimately, collective literacy. In this context, recommendations include an informed public debate on digitalization, a right to education for a self-determined digital life, and a right to free digital expression without censorship. Along with other references to digital literacy, the remaining proposals are more specific (e.g. consumer-centred data portals, training a new generation of applied AI ethicists).

By far the biggest share of recommendations in the texts analysed relates to *big data and privacy* (Section 9.2.1). The most common demand relates to data protection and calls for the principles of privacy by design and by default to be enforced. Other sources address the right to data protection and privacy, the right to self-determination regarding personal data, and the principle of data economy; they oppose data retention and the idea that informed consent can be given via general terms and conditions. On the technical side, there is a call for anonymization and transparency in big data processing, and for data portability and data exchange to be ensured and promoted. With regard to algorithmic decision-making (ADM; Section 9.2.2), demands include transparent and traceable processes, as well as independent human supervisory bodies, especially with regard to bias. Some sources argue in favour of subjecting algorithms to regular testing (similar to roadworthiness tests for vehicles); others support stricter statutory regulation in general, human monitoring (especially of objectives), or want the creators of ADM processes to be unequivocally responsible for the latter's results. The remaining recommendations address other aspects, suchas giving more power to data protection officers, strengthening corporate data governance or preserving personal data sovereignty.

Alongside more general recommendations, when it comes to the *fragility and autonomy of technical systems (*Section 9.2.2) some studies specifically address IT/data security, while others focus on how to ensure that machine learning complies with human rights. The responsibility of (legal) persons for AI actions is most frequently emphasized. Recommendations in the field of IT/data security include promoting open standards, maximizing data security, and ensuring the intactness, confidentiality and integrity of ICT. They frequently concentrate on preserving human autonomy and control over technology, demanding, for example, that there be no 'black-box' use of AI in core areas of society. Further recommendations address in particular the development of a European and global AI charter (Metzinger, 2018; Section 3.6.3), as well as further ethical elements (e.g. gradual technology-based ethics in robotics, ethical and legal standards for autonomous driving).

The most frequent demands on the topic of *economic and political power shifts* (Section 9.2.3) relate to ensuring net neutrality and a greater decentralization of platforms. The remaining recommendations cover a wide range of aspects, from empowering citizens to take part in legal processes, to a right to non-digital voting, making ICT companies transparent for the public, the promotion of societal and economic diversity, and data as a democratically regulated common good. Further recommendations address various issues ranging from the digital public sphere to software development in line with public interest, and effective corporate liability. Beyond this, suggestions include modernizing international contracts on data security and embedding a collaborative AI ecosystem into the corporate strategies of original equipment manufacturers.

As regards *global governance for the sustainable shaping of the Digital Age*, which was already touched upon at the end of the previous Section (Section 9.3.1), the focus is on the further development of international legal frameworks, on safeguarding principles of stakeholder diversity by region, language, gender and interests, enabling stakeholders to participate and interact on an equal footing, as well as on procedural aspects and, above all, internet governance. Other aspects range from a data-driven EU economic policy to the responsibility of the private sector and the demand that it respects human rights.

New normative questions about the future of Homo sapiens (Section 9.4) are brought up comparatively rarely, although they address heterogeneous issues that differ in terms of topicality and scientific basis. Based on the inviolability of human dignity – also in the Digital Age – discussions cover an international convention on 'neurorights', the privacy of neural data and strict regulation of their (re-)sale, physical integrity, and preventing machine decisions on matters of life and death. In this context, there are also calls to halt research on autonomous weapon systems, not to deploy fully automated weapon systems, and for international condemnation of drone-based killing. Others also say that the military AI arms race should be prevented, as should the creation of a post-biotic consciousness or an artificial subject – or corresponding research. However, another source argues that super-intelligence should only be developed in an ethically planned and controlled manner.

The list shows that some approaches to shaping sustainable digitalization are already being addressed in the specialist literature. In this chapter, the WBGU takes up these ideas in a way that is thematically broader and more concrete as regards content. It should be noted, however, that the previously analysed material is selective and cannot be representative, since further publications are appearing all the time.

to create the political, economic and regulatory framework to reverse these trends and use the potential of digitalization to preserve the natural life-support systems in the long term. Examples of recommendations for selected topics are given in the following.

9.1.1.1 Promote decarbonization and climate protection in the energy sector, avoid rebound effects

For a successful implementation of the Paris Agreement, global energy systems must be largely decarbonized by the middle of the century. Depending on how quickly greenhouse-gas emissions decrease, it will be necessary in addition to remove CO_2 from the atmosphere in the medium term to achieve the Agreement's objectives. Another aim is to ensure access to sustainable and modern energy for all by 2030 (SDG 7).

The WBGU recommends working towards an accelerated expansion of renewable energies worldwide (WBGU, 2016b). In this field, digital technologies are increasingly assuming important system-integration functions and can make it possible for off-grid regions to access electricity. Furthermore, they allow the electrification of sectors that have so far been characterized by the use of fossil fuels. However, if the Transformation towards Sustainability is to succeed, global demand for energy must not rise too sharply (WBGU, 2011). In order to systematically quantify the potential benefits and risks of digital change for the mitigation of climate change and to derive starting points for political action, the WBGU recommends considering the establishment of a Digitalization Commission for Decarbonization.

Without clear framework conditions, digitalization can act as a fire accelerant, driving increasing demand for energy and resources as well as greenhouse-gas emissions (Section 8.2.2). If billions of new devices are integrated in networks over the coming years, the demand for energy from data centres and network services will increase. The basic prerequisite for exploiting the potential of digitalization for energy-system transformation and climate-change mitigation is therefore an effective framework of climate and energy policies, as already outlined by the WBGU in previous reports (WBGU, 2011, 2016b). This involves well-known (but insufficiently used) climate-policy instruments such as CO_2 pricing (Section 9.2.3.2) and the abolition of subsidies for fossil fuels, but also suitable technology promotion. Long-term targets must be set clearly and reliably in order to steer investment in the right direction. Timely infrastructure investments are also necessary to make smart grids for renewable energies a reality on a large scale.

The WBGU also recommends establishing efficiency standards for digital solutions and digitalized infrastructures, as well as, for example, certifying efficient data centres in order to counteract rising energy consumption. Energy and resource efficiency should be set as dedicated innovation targets for digital technologies and applications. In order to give all people access to modern energy services in off-grid regions, the WBGU also recommends exploiting the potential of 'virtual power plants' and mini-grids based on renewable energies. Digital applications can eliminate the need for the diesel generators currently still frequently integrated into such systems. Mini-grids reach far higher service levels than solar home systems, for example, and can thus also make productive energy use possible in off-grid regions. Specific recommendations on the decarbonization of energy systems are also to be found in Section 5.2.1.

9.1.1.2
Use the circular economy to improve resource efficiency and avoid electronic waste

A key component of the Transformation towards Sustainability is converting an economy that is now predominantly geared towards linear value chains into a circular economy oriented towards the principles of sustainable resource use and based on largely closed material cycles (Section 5.2.5). The orientation towards the 3Rs ('reduce, reuse, recycle') strategy involves a system of priorities in which waste avoidance (e.g. through eco-design, sufficiency, sharing) takes precedence over reuse (e.g. treatment, repair, re-manufacturing) and, finally, recycling as the final option.

On the one hand, due to the rapidly growing production of electronic devices, digitalization is making a significant contribution to exacerbating the problems of the linear economy by increasing demand for strategic metals and adding to the amount of toxic electronic waste. On the other hand, digitalization can help to make loops visible and close coordination gaps. The WBGU therefore recommends a transformative strategy towards a circular economy that looks at the entire life-cycle of products at a global level and makes systematic use of digital technologies. Further essential components of this strategy include monitoring material flows, establishing regulation in the form of tax and contribution systems (Section 9.2.3.2), new business models, social innovations, and changes in the cultural practices of consumers.

Digital approaches should help monitor, analyse and, where possible, prolong the useful life of equipment, replace toxic and environmentally hazardous substances, prevent exports of electronic waste, and make products easier to reuse, repair and recycle. In order to start moving in the right direction, a global framework for action needs to be based on SDG 12, which defines 3R obligations. But, first and foremost, national regulations are needed which extend producer responsibility, integrate the circular economy into procurement and tendering systems, and provide incentives for social innovations.

For example, the collection, reuse and recycling rates of electronic waste and other equipment and the recovery of strategic metals can be significantly increased by developing a digitally supported, global monitoring system for electronic waste, and by tracking and avoiding raw materials from regions of conflict.

The worldwide introduction of a digital 'passport' for product waste or e-waste using concepts from the Internet of Things (IoT; Section 3.3.1) should be examined. In addition, (digital) options that encourage businesses and consumers to assume more responsibility should be used more and expanded. Ideas for social innovations in the population should promote a repair culture and raise 3Rs awareness in general, for example by supporting repair cafés and platforms for information, spare parts and second-hand products, and making it simpler to return appliances. Corporate approaches should be geared towards durable, repair- and recycling-friendly product designs (e.g. right to repair) and towards use-oriented business models (sharing economy, product-service systems). The use of digital sensor technology, robotics and AI in sorting plants for recyclable materials can significantly increase their efficiency. Further concrete recommendations are given in Sections 5.2.1 and 5.2.5.

9.1.1.3
Ensure sustainable land use and ecosystem protection

Sustainable land use is one of the most important issues for the future. Protecting soils and land from overuse and degradation is decisive in ensuring the supply of food and biomass to the growing global population. The goal of halting land degradation agreed in the United Nations Convention to Combat Desertification (UNCCD) should be vigorously pursued. At the same time, the agreement to stop the loss of biological diversity and ecosystem services enshrined in the Convention on Biological Diversity (CBD) must be implemented. Digital technologies and applications can make a contribution here, as long as the political will is there and the corresponding framework conditions are created (Section 8.2.3). This is often not the case at present, so that it will not be possible to achieve most of the CBD biodiversity goals (Aichi goals) unless considerable additional efforts are made. According to the Global Biodiversity Outlook (CBD, 2014), no progress is being made in key areas of biodiversity loss – fragmentation, overexploitation and loss of natural ecosystems, the spread of invasive alien species, and, not least, climate change. In fact in some cases the situation is deteriorating. Digital technologies (e.g. drones or sensors) should increasingly be used to assist in the implementation of goals and policies aimed at promoting the protection and sustainable use of biodiversity. For example, digital methods (e.g. drones or satellites to track herds and animals) can be used to counter acute poaching problems in Africa. Further recommendations on how ecosystem monitoring can be used to conserve biodiversity are made in Section 5.2.11.

At present, most farmers rely on monocultures and use large amounts of pesticides and nutrients; this puts pressure on ecosystems, their ecosystem services and their biodiversity. The aim should be to promote more small-scale, ecologically compatible farming methods and to use agrochemicals as sparingly as possible. In this respect, precision agriculture offers a wide range of possibilities. In developing countries, the opportunities offered by digitalized precision agriculture lie primarily in a combination of labour-intensive, manual activities to cultivate small areas (e.g. manual micro-fertilization and irrigation), access to the latest information and advisory services, and access to microfinance. Digital methods (e.g. digitalized land registers based on blockchain technologies; Section 3.3.5) can help secure the land rights of the local smallholder population. Recommendations on the arenas of precision agriculture and the digitalization of agriculture in developing countries can be found in Sections 5.2.9 and 5.2.10.

9.1.1.4
Promote global environmental awareness and sustainable consumption through digitalization

Digitalization can support sustainable consumer behaviour in a number of ways, and thus make a growing global environmental awareness more visible and more effective. To this purpose, credible and reliable knowledge, data and information in the sense of transformative education should be made widely available via the internet or public-service ICT (Section 9.2.3.1), for example on the ecological effects of the manufacture, transport, use and disposal or reusability of products. Reliable sources of information and supply can support consumers' decision-making and encourage products that are more sustainable, more resource-saving or more energy-efficient. The WBGU recommends making it obligatory for manufacturers and retailers to provide information in a digital format on the sustainability of products, e.g. the CO_2 emissions generated during the manufacture and transport of the product, the resources used and the product's social impact (e.g. child labour, occupational health and safety). This could be done, for example, by means of digital platforms, links to sales platforms, or codes on the products. Pre-set sustainability filters in online shops are also conceivable ('sustainability by default').

Whether information on sustainability really influences consumers' purchasing decisions depends not least on whether this information is trusted and whether shortcomings in the quality of the information can be sanctioned. Here, for example, an extension of manufacturers' or retailers' warranty obligations (Schlacke et al., 2016) could support sustainable purchase and usage decisions. A right to repair – including far-reaching obligations to disclose the information required for repairs conducted by third parties (Kurz and Rieger, 2018b) – also extends the possibilities for consumers to use a product sustainably.

Digital applications for networking and exploring resource-saving lifestyles can have positive effects on the environment in the sense of resource conservation. The WBGU recommends promoting the development and dissemination of digital tools such as platforms for resource-saving shared use, ideas like reusing, repairing, sharing and exchanging products, and suitable networking possibilities (Sections 5.2.2; 5.2.11). This addresses consumption practices and social innovations for implementing the circular economy and the 3Rs strategy of 'reduce, reuse, recycle'. Potential user groups should also be involved in product development as early as possible, for example when drawing up usage scenarios or designing software for platform cooperatives (Section 5.3.6). Platforms for sharing can also be created as part of a public-service ICT strategy (Section 5.3.5; Section 9.2.3.1; Peuckert and Pentzien, 2018:56).

Consumer-protection organizations should be strengthened both financially and institutionally in order to enforce consumer and environmental protection in an integrative manner via digital solutions, e.g. in online commerce. These associations have a control function which they can exercise via their right to issue warnings and to file collective action lawsuits. However, they can only also perform this function for new forms of digitalized consumption if they have enough personnel and institutional capacity.

The above recommendations can help in further developing the lighthouse initiative entitled 'Ways and building blocks of a digital agenda for sustainable consumption' of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the German Federal Environmental Agency (UBA). Further examples of recommendations can be found in the arenas on online commerce (Section 5.3.2.4), on global environmental awareness (Section 5.3.1), on consumer behaviour (Section 5.2.3), on electronic waste and the circular economy (Section 5.2.11) and on alternative economics (Section 5.2.2).

9.1.1.5
Involve companies in designing a digitalized, sustainable future economy

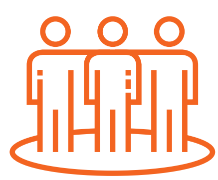
Companies exert a decisive influence on the sustainability of goods production through their raw-material and energy requirements, production methods, distribution logistics, and their handling of by-products and residual materials. As users of digital technologies, e.g. for optimizing material input and process organization, they also have particular potential for constructively combining digitalization and sustainability. They should therefore be more actively integrated than hitherto into shaping a sustainable, digital future economy (Section 4.2.2) that uses and leverages the value of innovative technologies for resource-saving, low-emission production methods. As 'agents of change', specialized service companies have long been offering companies technical and organizational environmental advice and helping them to make their production more energy- and resource-efficient (Schulz, 2005). If the development and use of efficiency-enhancing digital tools is specifically promoted by important actors like sustainability consultants (e.g. public authorities or industry associations providing such tools and best-practice recommendations free of charge), they will be able to support sustainable industrial and commercial production in large parts of the economy even more effectively in the future. The international expansion of initiatives that are already coordinating and systematically supporting collaborations between companies and environmental consultants with the help of digital platforms (e.g. the Austrian government's Öko-BusinessPlan in Vienna) can also help boost demand for corporate consulting on sustainability.

The WBGU also recommends extending incentive schemes (e.g. certificates) to producers themselves in addition to tax regulations (Section 9.2.3.2). Unlike the latter requirements, certificates can have a positive, motivating effect on corporate sustainability behaviour and potentially involve large sections of the workforce in initiatives to achieve certification. The aim here is to stimulate the global spread of an enhanced sense of responsibility on the part of the private sector for digitally supported sustainable production. Especially if companies can combine their environmental targets with marketing and competitive advantages, this motivates the use of digitalization for sustainable production. Incentives can be generated by new, special product labels for products of the digital economy (e.g. as in the case of the Blue Angel and bluesign), which become more attractive and credible with the help of digital documentation (e.g. using blockchains) or by integrating digitally optimized testing methods. The same applies to international seals of quality or audit-based certifications of sustainable action by companies when they introduce digital technologies (further development of approaches to corporate socio-environmental or digital responsibility; Loew and Rohde, 2013; Visser and Tolhurst, 2017). Companies, their products and services that have been certified in this way should be given preference in public tender procedures, e.g. in ICT infrastructure procurement. Also relevant in this context is the call for more eco-certified product ranges to support sustainable consumption (Section 5.2.3). The design and effectiveness of such seals of quality for sustainability could be monitored by an independent testing organization.

As far as the regulatory framework is concerned, in the EU Committee of Experts and in the standardization committees Germany should champion internationally valid EMAS and ISO standards to make comprehensive and systematic use of the potential of digitalization for saving resources in production processes. The standards for environmental management systems like EMAS and ISO 14000 can be made even more demanding and checked more effectively if digitalized monitoring and control procedures are applied and consistently integrated. The results of the conferences of the World Circular Economy Forum (2017 and 2018) offer starting points for establishing internationally valid standards on a digitally optimized certification strategy for corporate environmental management (Section 5.2.1).

Further starting points for Germany, integrated in the EU, can be found in the promotion of innovation and the economy. For example, BMBF or EU calls for tenders for international corporate cooperation projects, e.g. in product development or for joint R&D activities by companies and research institutions, can be directed specifically towards using digitalization on a broad front to make goods production more sustainable (e.g. enshrined in the Horizon Europe programme). The same applies to funding initiatives for spin-off companies that apply innovative ideas from research institutions, universities, colleges or established companies and implement them in an entrepreneurial way. Regional funding formats should also set priorities here (e.g. BMBF-supported cluster funding, incentives for innovation-oriented regional development, the Smart Specialization approach of EU regional funding; Foray, 2014; Morgan, 2017). New alliances and innovative companies can be formed that can establish the mutually beneficial interplay of digitalization and sustainability at the global level as a model for modern industrial development, raising it to a new, contemporary standard: 'Industry 5.0' (examples of recommendations on the field of global goods production are listed in Section 5.2.3).

9.1.2
Poverty reduction and inclusive development



Assessments of the potential of digital technologies for development cooperation (DC) range from highly 'techno-optimistic' notions that 'everything will be solved digitally' to those who consider digital change to be of little significance in solving the core problems of human development. The WBGU shows that digitalization dynamics influence the implementation of all 17 SDGs. This means that digital drivers of change must be systematically taken into account across sectors in cooperation with developing countries and emerging economies. Digitalization should become a cross-cutting task of DC. Digital expertise should therefore be significantly expanded in development ministries and organizations, but also in the public institutions of the partner countries. Special attention should be paid to the fact that, through automation, digital processes generate structural change in the international division of labour that will change the patterns of integration of developing countries into the world economy. At the same time, digital platforms are creating new employment opportunities in developing countries. Cooperation in economic, employment and innovation policy must systematically take these digital instruments of change into account. The digital possibilities for improving resource and climate efficiency and simultaneously reducing rebound effects, e.g. through price incentives, should also be mobilized. Cooperation with emerging economies will focus more on dialogue, scientific collaborations and cooperation to jointly shape global digital change: since developing countries and emerging economies are important partners in global governance, cross-border challenges of digitalization should be discussed and addressed. Against this background, the WBGU sets out below some examples of priorities in the areas of infrastructure and education, improved data applications in DC, urban development and mobility (Sections 5.2.7, 5.2.8).

9.1.2.1
Strengthen the analogue basis

The use of digital technologies to reduce poverty (SDG 1) can only succeed if the necessary analogue basis is in place (World Development Report, 'Digital Dividends'; World Bank, 2016). First of all, infrastructures need to be developed, affordable access to ICT created and digital skills promoted. A strategy to make use of digital technology's potential for rural development must, above all, close these analogue gaps to prevent the digital divide between the poor and rich parts of the world population from widening even further. An important measure for successfully exploiting the potential of digitalization for poverty reduction is therefore ensuring that DC has the corresponding resources and knowledge.

If these conditions are met, digitalization offers many opportunities for poverty reduction, especially in rural areas of developing countries and emerging economies, where the infrastructure is often underdeveloped. It facilitates, for example, improved access to educational programmes (Section 5.6.2), health services (online consultations), financial services (loans, payment systems by mobile phone), markets, weather information and agricultural advice (Section 5.3.2), government services (e.g. digital identities) and employment opportunities made available via digital platforms (Section 5.3.4). Blockchain-based solutions can simultaneously make the population less dependent on financial services that are hard to find in many places. However, if they are to be widely used, digital solutions must be adapted to local languages and cultural conditions.

9.1.2.2
Improve development cooperation and planning with digital technologies

DC instruments can potentially be improved using digital technologies. It is important here to combine data-driven approaches with local and context-specific understanding. Areas of application include humanitarian aid (e.g. combating epidemics or natural disasters), supervising bycatch and fishing quotas in the fishing industry, and replenishing stocks (e.g. vaccines). The use of digital technologies also offers great potential for monitoring – from environmental observation (Section 5.2.11) to measuring progress in development.

Data applications can also be used in development planning. For example, real-time data generated by digital technologies make timely decision-making and project management possible: ongoing development activities can be steered and adapted and any problems that crop up immediately solved. However, there are many barriers, such as a lack of trust in data quality, inadequate knowledge of the available data, data that cannot be suitably translated into information, and information that is not tailored to the actors' needs (Pawelke et al., 2017). Countering this requires the corresponding expertise, as well as institutional capacity and responsibility, e.g. data officers or data-protection officers. The use of data for development ultimately poses the same challenges to data protection and privacy as the use of data in general (Section 9.2.6).

9.1.2.3
Gear the digitalization of cities to sustainability and inclusiveness

Enshrine technological sovereignty in urban development

Cities and the worldwide power of urbanization are crucial for the Transformation towards Sustainability. At the same time, cities are key arenas of digital change (WBGU, 2016a; Section 4.2.5). In this context, urban digitalization must not only be seen as a technocratic optimization task; rather, any use of technology should be explicitly embedded in an ecologically sustainable and socially inclusive form of urban development. This means systematically combining the implementation of the New Urban Agenda (UN Habitat, 2016b) and the SDGs (particularly SDG 11: 'Sustainable cities and settlements') with urban digitalization policy. If the use of digital technologies in urban development in the interests of the common good is to succeed, municipalities and urban societies must retain formative sovereignty, build up technological sovereignty, and develop into platform providers. To this end, digital (technological) sovereignty should be robustly anchored in urban development processes. The 'right to the city', extended by a digital dimension, should be recognized, and corresponding civil-society and science-driven initiatives should be promoted. In addition, more personnel and institutional attention needs to be devoted to the digitalization issue. While many cities and municipalities have already taken this step, cities in developing countries and emerging economies in particular have a lot of catching up to do. Local authorities should make it a priority to create positions for data officers, data-protection officers and digital innovation officers, as well as competence centres for digitalization in municipal administrations (Sections 5.2.7).

Many ongoing projects on digital urban development are only partially related to sustainability issues and tend to be on too small a scale; or else their commitment to sustainability requirements are predominantly only rhetorical, without any consequences for project design. For example, the current lighthouse projects under the EU Smart Cities and Communities Initiative only address the topics of energy and mobility, without taking up other aspects of sustainable digital urban development. Although the innovation platform on the City of the Future (BMBF, 2018c) has the necessary objectives, the projects still seem relatively small-scale. In the WBGU's opinion, therefore, there is a need for regional, substantial support for real-world laboratories that can provide the necessary impetus for sustainable, digitally supported urban development. This should be accompanied by the development of sustainability indicators for cities that can, amongother things, map the SDGs and how they are affected by digitalization.

Create urban data spaces

An urban data space denotes "the space in which urban data are generated and processed" (Schieferdecker et al., 2018:219). This refers to all the data that are relevant to urban development, including data generated and collected in cities. Urban data spaces are thus the foundation of a participatory, scalable and future-oriented digitalization of the public space. A prerequisite for the development of an urban data space is an inventory of the municipal data pool and the local ICT infrastructure. Building on this, a strategy should be developed for the use of the urban data space based on the identification of the strategic fields of action that are central to urban development. From a global perspective, such an approach is also recommended for urban development policy, as well as for the implementation of the New Urban Agenda and the SDGs (Section 5.2.7).

If municipalities rely on individual manufacturers or operators to design their ICT infrastructures (Section 3.5.5), a cost-intensive dependency can arise. As a general rule, openness in the sense of standards-based interfaces, formats and services that are accessible not only to manufacturers or operators but also to a wide range of actors should be demanded when purchasing systems and products or when outsourcing, in order to avoid vendor lock-ins (Schieferdecker et al., 2018). Private providers that collect data in the public domain should be required to report to local authorities and submit aggregations of the data.

In order to involve all actors in urban development via urban digital platforms (Sections 3.6, 4.1), open interfaces and formats, as well as a conformity of standards for interoperable value-added services, should be mandatory requirements in the realization of urban digital platforms. Furthermore, every software component commissioned by the public sector should be made available as open-source software for use or further development by third parties. This is the only way to create a dynamic ecosystem of different products without creating a producer dependency that excludes potentially relevant actors from the urban digital platform (DIN SPEC OUP; DIN, 2016).

9.1.2.4
Embed the use of digital technologies into sustainable and inclusive mobility strategies

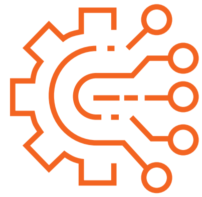
Sustainable mobility is an important aspect of the 2030 Agenda. In the following, the WBGU concentrates on one aspect: personal urban mobility. Solving key problems of urban transport systems (e.g. high CO_2 and air-pollutant emissions, land consumption, noise pollution, rising travel and transport times, and accident risks) is likewise not a purely technical matter; rather, the decisive issue will be how digital solutions are embedded into comprehensive concepts of sustainable urban mobility. However, digitalization plays an important role in the discourse on the future of mobility, since sustainability potential is attributed to a combination of intelligent transport technology, shared mobility (e.g. car sharing, bike sharing, ride-sharing services) or mobility as a service, electromobility and autonomous driving. Mobility systems should be developed at an early stage based on the guiding principle of sustainable mobility. Development should be guided by democratically legitimized institutions, not by vehicle manufacturers or digital companies; the well-being of people must be at the centre of attention. The WBGU therefore recommends (further) developing guiding principles and implementation plans for digitally supported, sustainable urban mobility at the level of the cities in cooperation with the national level. Such urban, spatial and transport planning should focus on health and quality of life.

Digitalization can make an important contribution to the promotion of sustainable mobility by making societal transport-sector costs transparent. The new digital technologies are making instruments available that can record and price external effects such as emissions, land consumption, loss of time, etc., in near real-time; they include intelligent traffic-control systems using time- and congestion-dependent toll systems or the corresponding pricing of mobility as a service. At the same time, unjustified subsidies must be reduced. However, these measures must be embedded into sustainable and inclusive mobility strategies, also because of their distributional impacts.

In order to preserve the formative sovereignty of public decision-makers in the field of sustainable mobility, measures should be taken to prevent individual private-sector actors from obtaining a monopolistic concentration of data and from gaining market-dominating positions (e.g. sharing providers, mobility-service providers), since access to data is increasingly a prerequisite for planning and controlling digitalized mobility. In addition, public actors must be enabled to collect and use digital data for specific purposes themselves. Particular attention must also be paid to data protection and to protecting people from surveillance. Position and mobility data are particularly sensitive – e.g. because even after anonymization they can, in certain circumstances, be used to identify the bearer and thus to assign further independent data sets to this person. Accordingly, privacy issues should already be routinely taken into account when planning such projects, and the protection of the individual from surveillance should be embedded in the digital solutions.

In developing countries and emerging economies, ensuring that poorer population groups have access to mobility services should also be a priority (SDG 11). In addition to access to public transport services, priority should be given to safety and to providing space for walking and cycling (walkability and bikeability). Among other things, this requires political attentiveness and investment in infrastructures for non-motorized transport, which should not be pushed into the background by a focus on superficially more visible, large-scale projects.

9.1.3
Work in the future and reducing inequality



The world of work and the labour markets face profound structural changes in the foreseeable future. Digital technological progress is fundamentally changing job requirements and job profiles in labour markets. What is especially different by historical comparison is the breadth of the skills and jobs affected and the speed with which the changes are taking place. This new scale of labour substitution coincides with an equally far-reaching structural change in some regions, caused by the phasing out of fossil energies made necessary by climate policy and the abandonment of technologies associated with the process. The WBGU believes that the main societal and political challenges that are already predictable today will lie in dealing with the impact of the structural-change processes on income distribution caused by digitalization and decarbonization. These are unfolding in very different dimensions: between human work and other, in some cases new factors of value creation, between work involving different qualifications, between generations, and between different regions and countries. Ultimately, the key challenge will be to avoid societal disruptions and simultaneously organizing societal change in such a way that the employment opportunities that will also exist in the future can fulfil the societal functions that gainful employment has today. However, the WBGU also sees this process as an opportunity to design more sustainable working environments. More detailed recommendations in these areas can be found in the arenas on 'Sustainable workplaces of the future' (Section 5.3.9) and the 'International division of labour' (Section 5.3.8).

9.1.3.1
Discuss work in the future as a sustainability task

The WBGU sees a need for action in the design and socio-political monitoring of the foreseeable structural change in qualifications and job profiles, so that those who are negatively affected are not left behind, and, overall, social cohesion is not endangered by the threat of inequality. This also includes maintaining the financial room for manoeuvre of the state and social security systems against the background of labour's increasing mobility, the possibility of falling employment levels, and other changes in the economic structure. A reform of the financing systems of the state and public institutions also appears advisable in order to reduce the tax incentives to replace human labour. In many countries, these result from the high level of taxation on earned income that still exists today, raising the general wage level and making labour more expensive relative to other factors. A revenue-neutral reduction in the tax burden on earned income could, for example, be achieved in the context of a comprehensive social-ecological tax reform involving appropriate pricing of environmental impacts and resource consumption (Section 9.2.3.2).

In addition, the WBGU recommends a continuous and fundamental examination of the societal functions of work. Even if people continue to work, the question is how employment will be embedded and organized in society in the future so that the societal functions attributed to gainful employment today may perhaps be guaranteed even more broadly and comprehensively than they are now. To this end, new, extended guiding principles of work must be developed and established in society. If today's forms of gainful employment become less important, a societal consensus will also be needed on new approaches and mechanisms for ensuring everyone's economic and societal inclusion (Section 9.1.3.3). However, new educational contents and formats are also needed to enable more people to experience self-efficacy and a meaning in life, without these being linked to work and gainful employment to the same extent as hitherto.

In addition to shaping and systematically reviewing such new blueprints for society, the WBGU believes that much attention should also be paid to the question of how the transition and the phase of necessary societal change can succeed without growing inequality and fears about the future jeopardizing social cohesion and, ultimately, political stability. On the one hand, an early debate serves to help society prepare and to safeguard it against the challenges posed by the double structural change brought about by digitalization and sustainability transformation. On the other hand, in the WBGU's view, it promises an opportunity to actively develop and establish new and broader possibilities for leading a self-determined life and for individual development within planetary guard rails.

9.1.3.2
Secure and promote social standards in occupational health and safety

In view of the increasing international mobility of labour, for example through the spread of digital work platforms, the WBGU regards securing and promoting occupational health-and-safety standards and social security for employees as a key element in shaping structural change in labour markets. In order to prevent the exploitation of workers and the bypassing of national regulations on occupational health and safety, the WBGU recommends an international initiative to develop and establish (minimum) standards of occupational health and safety and social security that are as global as possible and include the digital domain. On the probably long road to such an international agreement, national approaches and regulations must also be discussed and strengthened to oblige companies to comply with national minimum standards when outsourcing and relocating work, thus turning employees into quasi-self-employed workers. The targeted promotion of alternative, e.g. cooperative corporate forms can also potentially contribute to improving safeguards for social standards. Promoting a stronger organization of employees with the newly emerging status of quasi-self-employment is also conceivable in order to increase their bargaining power vis-à-vis companies.

In addition, the WBGU believes that in the discussion on occupational health and safety and on what constitutes 'decent work', new aspects that are becoming particularly controversial in the course of digitalization should be given greater consideration and included e.g. in the International Labour Organization's (ILO) definition of 'decent work' (ILO, 2018:9). Examples include possibilities such as workplace surveillance (e.g. recording work steps on the computer, etc.) and the safety and health of workers in times of new digitalized tools (technologies for improving human performance, e.g. exoskeletons).

9.1.3.3
Monitor and improve the functioning of labour markets

Apart from the financial ability to act of public institutions (Section 9.4), continuous monitoring of labour markets is necessary for an informed debate on the future of work and to shape structural change, for example through programmes of further education. Against this background, the WBGU recommends using the extended possibilities for collecting and processing information via digitalization specifically for these purposes, especially in developing countries. Furthermore, technical decision-assisting systems can be used to simplify search processes on labour markets and to reduce friction. For example, labour recruitment could be improved by introducing new search and matching algorithms that bring job seekers and potential employers together through an intelligent registration of occupations, qualifications and activities, despite increasingly differentiated occupational profiles. However, such approaches should only be pursued if it can be ensured that the decision-making assistance systems are non-discriminatory.

9.1.3.4
Develop and comprehensively test new distribution mechanisms

The WBGU sees the danger that, in the course of digital change, the remuneration of gainful employment will contribute less and less to ensuring economic inclusion and a balanced distribution of income, even if extreme scenarios of complete automation do not become reality. There is a threat of increasing inequality between and within societies and countries both from a growing disparity between the salaries of workers with different qualifications and from the declining importance of labour compared to other assets and factors, and correspondingly of earned income compared to profit income.

The establishment or further development of social security systems is necessary to be able to counter the threat of growing inequality, especially in the near future, and to be able to help people who cannot keep up with the pace of technological progress. New forms of social security such as time banks (Section 5.2.2.1) can provide support here. In the WBGU's view, the methods and scope of continuing vocational training should also be expanded and institutionally anchored more firmly; in view of the speed of technological and societal change, this is of great importance for securing economic inclusion (Sections 5.3.4, 9.1.4).

A combination of traditional social security and structural policy in the narrower sense of the word could fall a long way short of the mark, especially in the longer term, if the aim is to ensure broad participation by the population in value creation and avoid more extreme inequality. New concepts of redistribution and participation must therefore already be developed at an early stage and examined in feasibility studies. Such distribution mechanisms and their societal acceptance are key elements of new, expanded definitions of work and the drafts of society based on them. Possible approaches that need to be examined more thoroughly and systematically than hitherto are forms of an (unconditional) basic income or opportunities for broader participation in enterprises and their economic gains from digitalization, for example by establishing and promoting cooperative corporate forms (Section 5.2.2). Finally, the state can also contribute to the upgrading of societally important, but currently hardly paid or unpaid work by, for example, transforming such work into formal employment relationships or financially supporting them through tax relief. Just like the use of social security systems to cushion the effects of structural change in the shorter term, however, this presupposes a stabilization and strengthening of the state's financial room for manoeuvre, which must be achieved by reforming and adapting tax and contribution systems to the challenges of digitalization and exploiting its potential (Section 9.3.2.2).

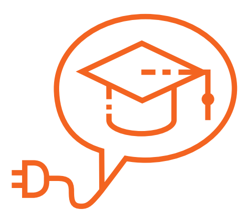
9.1.3.5
International division of labour: prepare for structural change

The changes in qualification requirements and the new, more extensive possibilities of automation as a result of digital technological progress also affect the economic integration of developing countries and emerging economies into global value chains. From the sustainability point of view, there is therefore a fundamental dimension of distributional effects between industrialized countries on the one hand, and developing countries and emerging economies on the other.

In the future, it will be possible for many of the activities outsourced to developing countries and emerging economies to be taken over by technical systems and relocated closer to domestic markets and end consumers Past development models in which locational advantages were exploited by the international division of labour will thus be called into question. At the same time, new access routes are being created by digital platforms and by the possibility of offering services worldwide, regardless of location. In the WBGU's view, more attention should be paid to this global dimension of structural change in the future. It should be examined more closely whether, and under what conditions, new, sustainable development models are generated by digital change and by newly emerging forms of work and employment relationships on digital platforms. A key factor will be to build up ICT infrastructures in developing countries and emerging economies to counter the danger of a new digital divide. This should be accompanied by the development of skills in handling and developing digital technologies, as well as corresponding investment in education and training.

In order to strengthen the opportunities for sustainable development, the WBGU furthermore believes that internationally applicable minimum standards of occupational health and safety should also be agreed on for digital platforms. Digitalization offers the potential here to globally check and enforce compliance with such obligations and standards.

9.1.4
Knowledge, education and digital literacy



People are socialized beings searching for meaning. Their education accompanies the development of personality, orientation in social and natural environments, and how they create and deal with change. "Since wars begin in the minds of men and women, it is in the minds of men and women that the defences of peace must be constructed," according to the constitution of the United Nations Educational, Scientific and Cultural Organization (UNESCO) of 1945. Therefore, in order to shape the future in a peaceful and sustainable way, people need educational content and formats that can meet the respective challenges. The requirements of education for sustainable development and global citizenship have been systematically recorded in the meantime, yet they have only rarely been consistently implemented. Today, demands for digital competence are growing louder. The WBGU proposes bringing the respective approaches together in a concept of future education; the corresponding resources must be earmarked and obligations enforced to ensure that this concept is systematically disseminated on a broad base.

9.1.4.1
Plan education for the digitalized sustainability society at an early stage

There is still a quite a lot of uncertainty about the effects of rapid, digitally induced socio-technical and societal change. As a result, the question of the most suitable educational ideal and suitable instruments and formats continues to gain in significance. Important, relevant skills are known from concepts of Education for Sustainable Development (ESD); these include multi-perspectivity and critical reflection, creativity, innovation capability, the ability to engage in dialogue, dealing with uncertainties, and self-control. They correspond in many respects to the outlined educational needs for dealing with digital change and increasingly complex work contexts. Media education is becoming more important here and should be enriched and extended by basic knowledge about digital technologies and their history, technology-impact assessment, and the qualities of digital information spaces. In this way, people can maintain their literacy (vis-à-vis socio-technical systems, their manufacturers and operators, as well as the latter's interests) and, at the same time, react flexibly and openly to new technical possibilities and developments. Personality formation, self-management skills and compassion not only help in dealing constructively with uncertainty, global solidarity and transformative developments, they are also discussed as unique features of humans compared to digital and digitalized technology, including AI. With this in mind, a future-oriented Education and Training Pact for the 21st century should be concluded at the national and international level. The prerequisite for this is that access to education within and between countries is guaranteed for all. The WBGU has developed more detailed recommendations here for the arena of education (Section 5.3.4).

9.1.4.2
Negotiate a Future Education Pact

In the context of the renewal of the World Action Programme on Education for Sustainable Development, Germany's Federal Government can use the coordination structures created between the federal and the state level to advance the integration of current skills requirements from different angles:

- *Transformation skills:* These are fundamental for a context of profound and rapid changes in what is familiar and for a resultant increase in the role of ethical-normative questions as orientation in shaping the new (e.g. philosophy, cognitive flexibility and complexity, critical, innovative thinking, and dealing with uncertainty and loss).
- *Sustainability skills:* These are oriented towards the aim that newly emerging technological, social, institutional and economic solutions should make human well-being possible within planetary guard rails, while respecting dignity and diversity. Examples include systemic thinking, the integration of scientific, social-scientific and technical knowledge, and dealing with multi-perspectivity and normative weightings.
- *Anticipation skills:* These are specifically geared towards reflection on how theories, concepts and assumptions about reality affect visions of the future and how these visions of the future in turn impact on actions and decisions in the present. Examples include the targeted search for divergent points of view, sensitivity to the structural power of established knowledge and practices, as well as empirical knowledge and learning through experience or simulation.
- *Digital skills:* These are important specifically for the new technical, organizational, social and (self-)regulatory challenges posed by digitalization. Examples include understanding digital technologies, methods and option spaces, handling digital media and sources of knowledge, digital business models, and the socio-technical and psychological effects of digitally mediated communication or control.

9.1.4.3
Take education seriously as an investment in the future

In addition to an Education Pact, in which the main content priorities are defined, a plan for its consistent implementation is also needed. Joint financing of the DigitalPact for Schools can only be a first step here, and its time period is too brief. With regard to the successful implementation of the decisions on ESD, there are proposals that include, for example, a roadmap of ten years and €14 billion in investment (Alliance for Future Education). A correspondingly larger undertaking is required for additional content and equipment. In the context of continuing vocational training, it is particularly important to strengthen future-oriented offerings in sectors and regions that are affected by intensive change processes. Germany continues to rank in the lower quarter among OECD countries in terms of its expenditure on education; the infrastructure quality and staffing levels are inadequate in many schools and day-care centres, and large fluctuations in equipment and quality have long been documented. For these reasons, the WBGU recommends a major investment initiative in future education that also systematically tackles inequalities in the field of inclusion in education. Effective evaluation procedures should be drawn up through close cooperation with pioneers from educational practice (kindergartens, schools, colleges, universities, further-education institutions, municipalities, civil society) and ensure a high level of ambition.

9.1.4.4
Provide prominent support for the Global Action Programme on Education for Sustainable Development

According to the review of SDG 4 – "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" – at the 2019 United Nations High-level Political Forum on Sustainable Development (UN, 2019), the focus in international cooperation should also shift from monitoring to implementation barriers and to seeking more institutional and financial support for achieving the educational goals.

9.1.4.5
Understand and organize knowledge as an integral part of shaping the future

Especially in times of societal upheaval with a high level of uncertainty about what changes are to be expected, the selection and quality of knowledge is of particular importance for the legitimacy of decisions and the anticipation of possible consequences. Public authorities are very important for the task of creating a societal, facts-oriented understanding of plausible, possible and desirable futures and their political and technological design. Results, especially on controversial topics, should be readily accessible to the public and presented in a way that is easy to understand. Institutions like the Science Media Centre are good as a first step, but no longer sufficient in times of more and more communication via social media unmediated by journalists. Furthermore, futures literacy and anticipation – disciplines that reflect on prevailing assumptions of reality as factors that will shape ideas and assessments of the future – should be incorporated, specifically promoted as a new research field and educational topic, and systematically integrated into the further development of futurology, forecasting and technology-impact assessment.

9.2
Digital revolution brings new sustainability challenges

The worldwide spread of digital technologies has given rise to specific risks, challenges and opportunities; although implicitly outlined in the 2030 Agenda's sustainability model, in many cases the scope of these factors has not been explicitly formulated (Section 8.3). The following recommendations on the topics of privacy, fragility and autonomy of technical systems, and economic and political power shifts show, by way of example, possible ways of meeting these challenges.

9.2.1
Big data and privacy

There is still no common understanding on how to handle data – either globally or within societies (Sections 8.3.1, 8.3.2). Data collection, data fusion, data trading and data use are largely not transparent. In many cases, decisions made on the basis of data evaluations cannot currently be tracked, and there is a lack of individual control over one's own data, their exploitation or resale. In return for seemingly cost-free services provided by (digital) companies, communication and behavioural data are collected and used whose value is unknown to the individual. Control over large quantities of personality profiles can furthermore open up possibilities for influencing societal and democratic decision-making that threaten the foundations of democratic processes. This not only poses a fundamental challenge to the market and to democracy, but ultimately also to people's dignity through a possible erosion of their autonomy (Christl and Spiekermann, 2016:118ff.). The WBGU rejects not only private but also (and especially) state mass surveillance, since it is in fact fundamentally contrary to its professed aim of protecting democracy and destroys its foundations.

In view of big data's contribution to the impression that the technical conditions for a totalitarian dictatorship have never been "as favourable as they are today"

(Grunwald, 2018:54), the development is showing its darker side: “Modern man has made his environment and his coexistence largely machine-readable, i.e. predictable” (Ullrich, 2017:188). It is therefore important to defend and preserve human and fundamental rights to privacy and freedom of opinion as the basis of free, democratic, peaceful and sovereign societies in the long term. For this it is essential to promote not only data protection, data security, informational self-determination and freedom from manipulation, but also data quality at national, European and global levels (Sections 9.2.1.1, 9.2.1.2), and to preserve and protect the digital public sphere and digital discourse spaces (Section 9.2.1.3). The protection of privacy and the democratic public sphere in the Digital Age should therefore be systematically taken into account in the implementation of the SDGs, and strengthened with the goal of enshrining the topic in a post-2030 process. Recommendations in this area can also be found in Section 5.3.2; for recommendations on self-care apps and handling digital health data, see Section 5.3.7.

9.2.1.1
Strengthen public- and private-sector responsibility for privacy protection

The WBGU endorses the recommendations on the protection of privacy and the strengthening of individual sovereignty submitted by the National Academy of Sciences Leopoldina (2018) and the Advisory Council for Consumer Affairs (SVRV, 2017). In particular, due to the complexity of the topic, states should recruit more appropriate personnel with broad interdisciplinary competence to data(-protection) authorities in order to optimally safeguard users’ data-protection rights vis-à-vis private and public actors. To improve the protection of citizens from the excessive use of data by state intelligence services, parliaments must be given more effective rights to monitor secret-service data collection.

The EU should perceive and develop data security and data protection as a future locational advantage; it should operationalize the level of protection offered by the EU’s General Data Protection Regulation (GDPR) in a practicable way and, where necessary, further develop it (Section 9.3.2.2). Civil society is an important voice for the enforcement of individual privacy protection. The WBGU therefore recommends supporting NGOs active in this field both through communicative exchanges with data-protection authorities and through scientific research (Section 10.2.4.3). NGOs should be empowered to contribute preventively by participating in preliminary procedures such as privacy and data-protection impact assessments or through complaint and redress mechanisms. While the responsibility must not be shifted onto individuals, each person should be able to contribute to their own privacy protection. First of all, this requires competence in dealing with ICT (Section 9.1.4). The WBGU sees a further opportunity for more user sovereignty in user-friendly, accessible technical tools for data sovereignty that enable people to monitor their own data. Examples include projects like mydata.org and decode, which develop technical tools for data management. Sufficient resources and capacity should be made available in technology development for the implementation of the principles of privacy and security by design, which are mandatory at least within the EU. Accordingly, the protection of privacy should already be consistently taken into account when planning ‘smart’ projects, e.g. by means of privacy and data-protection impact assessments. The individual’s freedom from surveillance must already be embedded in the technologies used (Kurz and Rieger, 2018a).

For a broad public discourse, especially on these topics, the informational literacy (Ullrich, 2014) of individuals and society as a whole should also be encouraged within the framework of a digital public sphere (Section 9.1.4). As part of a responsible innovation policy, digitalized communication should be designed for an international public sphere to serve the common good (Dabrock, 2018):41) and realized via public-service ICT (Section 5.3.5).

To ensure the consistent protection of privacy and the public sphere, “the German business community [...] should also commit itself to handling data in a responsible way” (Lukas, 2018:14). However, in the WBGU’s view, it should not do this alone – rather, even stronger EU-wide data protection legislation and application should “define what constitutes responsible data trading” (Lukas, 2018:14) – particularly in connection with its own European model (Section 9.3.2). A necessary prerequisite for this is a structural change from the big data concept to a concept of ‘smart data’ (Section 3.3.2), which is already laid down in legal requirements such as the EU-GDPR by principles such as earmarking and data economy and should be concretized in the sense of ‘data quality’ instead of ‘data quantity’.

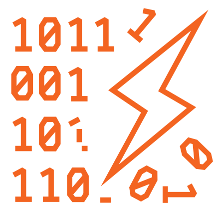
9.2.1.2
Create international protection of privacy law at the UN level

In the WBGU’s opinion, a United Nations Privacy Convention should be adopted (Section 8.3.1) covering the global human right to privacy (Article 12 of the Universal Declaration of Human Rights; Article 17 of the International Covenant on Civil and Political Rights). It should address detailed legal structures for handling data and protecting privacy both within and between countries. Privacy should also be understood as an integral part of sustainable development and placed on the agenda for the future development of global sustainability policy (Section 9.3.1). The initiatives established at UN level towards a global right to privacy (UN, 2017) should be further developed and supported. It should be noted in this context that, due to cultural diversity, notions of privacy vary greatly on a global scale, as do attitudes about what data should be collected, used or protected – and what methods should be used. This requires a discourse at the international level; local initiatives and the actors that promote the discourse in the respective countries should be supported to create broad multi-stakeholder governance.

9.2.1.3
Shape the digital structural transformation of the public sphere in a way that is innovative and oriented towards the common good

While on the one hand privacy is increasingly being 'made public', the public sphere in the Digital Age (e.g. in social media) is characterized by increasing privatization. Apart from greater risks of manipulation, the power of platform operators is already having a global impact on the right to freedom of expression (Cannataci et al., 2016), for example with regard to upload filters. From the perspective of global sustainability, however, digital structural change in the public sphere leads to a rather ambivalent picture – and not only in view of the partially unclear scientific data basis and related findings (e.g. in connection with filter bubbles or echo chambers; Fraser, 2010; Imhof, 2011). First of all, this is a fundamental transformation of the conditions governing the public sphere (Section 5.3.2). Although the digital structural change of the public sphere is not the only reason, it is accelerating its current crisis. The general functioning of media attention economies (Franck, 1998; Weischenberg, 2018) is at least as crucial. Two decades ago, this term was already being used to describe not only the increasing abundance of information as an individually "unmanageable flood" and an "ever-growing surge of stimuli", which were "especially designed to monopolize our attention" (Franck, 1998:49). The digital structural change of the public sphere has certainly not mitigated but has aggravated this situation, and the scarce resource of individual attention appears to be more contested than ever in the Digital Age. However, the focus is not on information, but on the novelty value, so that the pressure to be up-to-date is rising, as is the pressure of competition and the tendency towards personalized, conflict-laden and emotionally charged reporting (Weischenberg, 2018:30ff.). The WBGU therefore recommends that journalistic quality standards should not be subordinated to speed and reach, and that more support should be given to the cause of press freedom, which in some cases is massively threatened internationally. In addition to media competence and literacy, which are more likely to be located in the field of education policy, the WBGU recommends promoting corresponding emancipatory projects that seize the opportunities of digitalization to provide informed public discourse spaces and arenas (Section 9.4.4) in innovative ways (Puppis et al., 2017).

9.2.2
Fragility and autonomy of technical systems



The security and reliability of increasingly networked technical systems and processes are key prerequisites for a digitalized sustainability society. Initially, this applies in general to all ICT infrastructures (Section 9.2.2.1), and in particular to algorithm-based processes for decision-making or decision-making support (Section 9.2.2.2).

9.2.2.1
Security of digitalization as a prerequisite for the Transformation towards Sustainability

Enshrine security by design as a standard across the board

The WBGU strongly recommends insisting on security by design in the security-critical ICT field. This requires the further development of the corresponding expertise and an inter- and transdisciplinary exchange, as well as the (further) training of operators of digital infrastructures and ICT. Cyber-security should be incorporated and taught from the beginning of training. Both the state and the private sector must avoid a situation where gaps in cyber-security are not closed – supposedly in the interests of public security – in order to exploit them for active intervention. The fundamental right to guaranteed confidentiality and integrity of information technology systems is violated when gaps are intentionally kept open. Contrary to previous security-policy practices ranging from surveillance to future 'hack-backs', the state should do everything in its power to apply cyber-security methods and techniques across the board and to avoid anything that weakens them. Furthermore, the WBGU recommends a paradigm shift from globally increasing digital offensive strategies to a defensive cyber strategy. In the military and intelligence sectors, efforts should be made to internationally outlaw operations that "directly impair the sovereignty of a state, attack its ability to govern, and target critical civilian infrastructure such as power grids, production facilities, health and food supplies, and communications networks" (Kurz and Rieger, 2018a:252ff.). The WBGU would welcome a moratorium restricting a further cyber-arms race as a first step that sends an important signal. Subsequently, existing international agreements in the sense of a global digital peace policy should be extended, or new ones initiated.

Further develop BSI-KritisV and IT security law

The Ordinance on the Determination of Critical Infrastructures under the BSI Act (BSI-KritisV) covers critical infrastructures in the fields of energy, water, food, information technology and telecommunications, transport and traffic, health, finance and insurance. The WBGU advocates the further development of the BSI KritisV to include public-service ICT (Section 5.3.5) as a critical infrastructure. In addition, the IT Security Act, which was passed against the background of possible significant IT security incidents based on cyber attacks, should be further developed in such a way that malfunctions of different kinds must also be reported if the cyber-security and functional security of critical infrastructures is under threat. At present, for example, ordinary malfunctions do not need to be reported, provided they can be prevented by measures taken in accordance with state-of-the-art technology and can be overcome without major problems or increased resource expenditure, e.g. as with invasions of ordinary malware or hardware failures (BSI, 2019). Failures caused by errors of quality, configuration or operation are thus also excluded in this way. The current specifications should be adjusted in such a way that IT disruptions and IT failures are also reported in addition to significant IT security incidents. Furthermore, suppliers, manufacturers and operators of critical infrastructures, as well as public authorities, must be obliged to publish gaps in cyber-security and errors in ICT critical infrastructures in a way that is accessible to experts and manufacturers.

Develop a European register of technical systems, their failures and cases of damage

In order to improve the quality and security of ICT for the critical infrastructure available on the market, a parallel central European register should be set up in which they would be recorded in a differentiated manner on the basis of ISO standards. One advantage of such a register would be greater transparency and security, and that it would enable manufacturers and operators to continuously improve quality. It could simultaneously work as an early warning system to identify risks and avoid repeated damage. To maximize its neutrality, it should be operated and administered by a network of public bodies, and an authorization system should be used to assign access authorizations according to roles. Where appropriate and possible, the register should also be accessible to the wider tech community. In addition, a European failure and damage register should be established covering ICT failures and ICT damage to facilities, installations and parts of critical infrastructure, including public-sector ICT. It would also be worth considering the inclusion of reports of major IT malfunctions and failures in public administrations and digital service providers. The register should also be run and administered by a network of neutral public bodies, and full access should be reserved for an authorized circle of experts. However, extracts from the register should be accessible to the wider tech community or the public. Authorization systems should be used for this purpose.

9.2.2.2
Use of automated decisions

Digital technologies are taking on increasingly complex monitoring and control tasks, and societies and individuals depend on their reliability. Decisions in core areas of society should only be transferred to automated systems in ways that are methodically and democratically safeguarded and understandable for the people affected (Section 8.3.3).

Big data and algorithmic decision-making processes – create legally enforceable rights

There is a need for more transparency on procedures, participation by civil society, better information for the people affected, and state supervision of algorithmic decision-making. In principle, this is a political, not a purely technical process that is determined by ideas, norms and interests, especially in core areas of society. Accordingly, there should be a broader discussion on obligations relating to information and labelling for those responsible for decision-making, on the preventive monitoring of technical systems in critical areas of application under which the supervisory authority reserves the right to grant authorization, and liability rules. These should then be established. This also applies if a decision is only partially automated. First approaches would be the right to counterfactual explanations (Wachter et al., 2017) and to rational algorithmic decision making and decision-making support (Wachter and Mittelstadt, 2018b).

In the case of algorithm-based decision making and decision-making support or similar automated processes, only audited processes or certified procedures should be used, especially in core areas of society. State regulation and, if necessary, explicit licensing of digital solutions in socially critical areas of application should ensure that there is no threat of (fundamental) rights violations or other societal dangers. Furthermore, the individuals or legal entities affected must be given a legally enforceable right to a rational justification for decisions. The WBGU recommends that in automated decision making and decision-making support and the use of AI in core areas of society (Campolo et al., 2017; Villani, 2018), the ultimate decision-making sovereignty (and responsibility) should be left with human beings, especially in order to avoid discrimination. Further recommendations on scoring in particular can be found in Section 5.5.5.

Strengthen liability, information and labelling obligations

In the context of democratic processes and multi-stakeholder participation, the WBGU recommends developing criteria, standards and limits for the transfer of automated decision making and decision-making support to technical systems in such core areas of society as justice, health, welfare, finance and education – and for demands on traceability and suability when automated decisions are vetted – that go further than purely technical explanations.

Instead of simply subjecting algorithms to regular testing and certification (Djeffal, 2018; SVRV, 2017) – in a similar procedure to today's auditing companies – the existing ICT-related certification authorities might be authorized to develop quality criteria for systems involving algorithm-based decision-making processes and to establish appropriate auditing and certification procedures. In this context, regulations on (and potentially a tightening of) the responsibility and liability of private actors should be implemented as an additional incentive to develop resilient and secure systems (Scherer, 2016). There should also be clear quality and security labelling of software-based products and services (Kurz and Rieger, 2018a:256ff.; Table 4.2-2). Susceptibility to crises and the risk of systemic failure increase as the number of decentralized, independent components for algorithm-based decision-making support or decision-making systems decreases, as would result from increasing monopolization or market concentration. In the context of resilience, therefore, accompanying measures to maintain and strengthen competition and increase diversity are similarly important, also for security-critical components (based on standards, open interfaces and interoperability; Section 9.2.3). Against this background, the problem of systemic importance (too big to fail), familiar from the financial sector, must also be addressed with regard to the required regulation and strengthening of private-sector liability, since it may otherwise prove to be infeasible for very large, systemically important companies.

9.2.3
Economic and political power shifts

Digital technologies are shifting power and influence between states, companies and citizens (Section 8.4.1). As a result of strong network effects and economies of scale, digitalization today is largely being shaped by a small number of mostly private-sector stakeholders. Individual countries, too, are already making intensive use of digital technology to boost their state power. Digitalization will exacerbate existing social inequalities unless all people are given equal opportunities to share in its potential.

9.2.3.1
Create public-service ICT infrastructures and digital commons

A central aspect in achieving the Transformation towards Sustainability is substantive inclusion for all people ('normative compass'; Chapter 2). The WBGU argues that, in the Digital Age, access to digital infrastructures is a key prerequisite for a decent life and for participation in societal development, in addition to classic basic public services such as education, health care and security. The state therefore has a responsibility to ensure general access to public information and communication services for all – particularly for disadvantaged population groups – as part of the provision of basic public services (Section 5.3.5). This includes part of the internet, as well as social platforms that can offer data, information, knowledge and educational services, provide citizens' services (Hanafizadeh et al., 2009:388ff.), perform public functions, and are publicly or privately run. The respective characteristics – content, quality and security – of public-service ICT must be differentiated according to sectors.

In order to make the added value of a society permeated by ICT usable for different purposes and for as many people worldwide as possible, the WBGU first advocates the establishment and expansion of neutral ICT network infrastructures with open international standards and interoperable interfaces and formats. In addition, the conception of modular and replaceable technical components should be promoted to avoid dependencies on individual manufacturers and infrastructure providers and thus guarantee both reparability and digital (technology) sovereignty (Schieferdecker et al., 2018). Public procurement can play a key role here. The components of public-service ICT must also be adapted to local circumstances and political objectives (UNCTAD, 2018); the WBGU recommends an open dialogue and cooperation between different stakeholders (local authorities, business, academia, civil society) to promote a rapid, user-centred introduction and improvement of public-service ICT offerings (The Earth Institute and Ericsson, 2016:96ff.). In addition, open source software should be developed in line with such principles as interoperability, reusability, security and scalability, and used and promoted in public procurement in public-sector ICT infrastructure projects wherever appropriate and possible (Schieferdecker et al., 2018). As a general rule, the WBGU recommends, when setting up and developing public-service digital infrastructures, focusing on their public-welfare orientation, so that public funds are used above all to create public goods. Societal controllability, discrimination-free access and sustaining the natural life-support systems should be guaranteed and become guiding principles for public procurement in addition to efficiency, security (incl. trustworthiness) and resilience. The German Federal Government should also work both nationally and internationally to secure and strengthen net neutrality and promote equal access to the network in rural and structurally weak regions. At the same time, in the spirit of green IT, the ecological footprint (e.g. resource and energy efficiency, recyclability) should already be minimized at the development stage, i.e. the natural life-support systems must be respected and sustained during the development, expansion and operation of public-service ICT infrastructures and services. In addition, the importance of digital commons (Section 5.6.2) – such as free education in the sense of open education and open educational resources, generally accessible knowledge via open access and open (government) data, and the digitalized cultural and natural heritage in a digital sustainability society – and the need to make them available and secure must be placed on the political agenda both nationally and internationally. Digital commons must be organizationally, technically and legally secured, e.g. with a view to legal certainty in licensing or the long-term preservation of knowledge. The central aim is to ensure inclusive and equitable access to digital commons by means of open, barrier-free formats and improved findability and retrievability (e.g. by means of international metadata standards) and to promote broad participation in the creation and further development of digital commons, e.g. via flagship projects. Furthermore, quality assurance and qualification measures must be taken to ensure the provision and use of high-quality digital commons. More detailed recommendations for action on public-service ICT and digital commons can be found in Section 5.3.5 (arena on public-service ICT) and Section 5.3.10 (arena on digital commons).

9.2.3.2
Reform tax and contribution systems

The WBGU believes that governments and public institutions have an important formative role – also, indeed especially, in the Digital Age – be it in the provision of digital commons or public-service digital infrastructures, in shaping broad structural change in the social and educational policy field, or to ensure economic inclusion and to contain any risks of developments towards inequality. Doing justice to this role requires stable longer-term financial leeway for states and public institutions.

However, in the WBGU's view, the structural changes in the labour markets, combined with the increasing economic importance of intangible assets like data and digital services, give rise to considerable doubts as to whether today's tax and contribution systems will be able to provide such a financial base in the longer term (Section 5.3.3). In the WBGU's opinion, the financing of the state and public institutions should be linked as far as possible to the design of the framework conditions that are needed for sustainable development and for the form of digitalization needed to achieve this goal. Up to now, however, this link has not been made in the discussion about the challenges posed by digitalization and possible reform steps. There is no doubt that new regulations must be found to tax internationally operating companies appropriately. The risk of erosion of the financial base of countries in the course of digitalization and possibilities for a further harmonization of international rules on taxation should be, and are already being, intensively discussed and explored today (e.g. BEPS project at the level of the OECD and G20; OECD, 2015d). However, taxes and contributions also have a strong steering effect, which the WBGU believes should be used specifically to promote sustainable development and to shape a sustainable Digital Age. The guiding principle for the future design of tax and contribution systems should therefore be to burden production methods and consumption patterns that run counter to these goals and, conversely, to correct current tax burdens that are not in line with the goals of sustainable development. Generally speaking, the WBGU sees three overarching starting points for reforms.

Tax natural resources and external effects that are not appropriately priced

The WBGU believes that the very far-reaching possibilities for monitoring and analysing environmental changes should be used to consistently gear tax and contribution systems towards the goals of sustainable development and, in particular, to protecting natural life-support systems: environmental influences and damage, and the general societal consequences of private actions, should be comprehensively priced if these factors are not, or not adequately, covered by market prices. With such a (re)orientation of taxes and contributions, individual actors, be they companies or private actors, can be given prompt (price) signals on the societal consequences of their actions in line with the polluter-pays principle. This steers the actors' attention directly to the protection of the natural life-support systems and, in addition to adjustments in production methods and consumer behaviour, brings further technological development much more into line with the objectives of sustainable development than it has been up to now. Although this reorientation of taxes and contributions affects all actors in principle, it also addresses in particular energy and resource consumption by digital applications and devices and thus a central challenge of digitalization for sustainable development and protecting the natural life-support systems. At the same time, sources of finance are tapped that are not directly tied to gainful employment, thus avoiding an erosion of the state's financing base or at least an increasingly unequal distribution of the financial burdens of the state and social systems.

Ease the tax burden on labour

Such alternative sources of finance create scope for the second central reform approach: the WBGU believes that the current high tax burden on (gainful) employment in many countries should be reviewed and, where appropriate, corrected. This tax burden not only raises (distributional-policy) questions about the future financing of public systems and institutions, it also creates strong and one-sided incentives for companies and employers to exploit and expand technical automation possibilities. Further automation should not be rejected on principle; indeed it can be societally desirable, for example in the case of extremely dangerous work. Particularly in the short term, however, a very one-sided focus on the broad substitution of (gainful) employment instead of, for example, the protection of natural resources, is not in society's interest. It threatens social cohesion and offers too little room for the societal change needed to ensure that the societal functions of gainful employment will also be guaranteed in the future – or perhaps even more comprehensively than they are today.

Reform corporate taxation

Without doubt, the appropriate taxation of corporate profits is key to maintaining the financial capacity of states to act. Problems for nation-state financing caused by international tax competition and the aggressive tax planning of international corporations already existed before digitalization. However, digitalization aggravates these problems by generally promoting the internationalization and mobility of entrepreneurial activities and making the geographical allocation and determination of taxable assets more difficult since value is shifted to intangible assets such as data.

Despite concerns about a growing imbalance between the possibilities that a country has to levy taxes on the one hand, and the scale of business activities and earnings of non-resident, internationally operating companies – especially those of the digital economy – on the other, the WBGU does not believe that special regulations should be pursued for companies in the 'digital economy'. Such distinctions between representatives of the digital and non-digital economy not only often contradict the internal logic of existing corporate taxation systems, they appear, above all, arbitrary and increasingly unclear over time in view of the widespread impact of digitalization.

Instead, reforms within the existing system of corporate taxation are conceivable in principle, as is a fundamental departure from the current source-country principle of corporate taxation towards the destination-country principle. Within the existing system, which ties the right to tax to the place of value creation, new regulations must be found for the international allocation of company profits and value contributions. One starting point is the further elaboration of the concept of digital production sites. In addition, criteria, which cannot yet be anticipated in full, must be developed for determining the proportion of value added generated locally in a particular country. If minimum tax rates could be agreed at the international level (e.g. G20), international tax competition could be curbed.

A more far-reaching step towards reform would be to move the taxation of corporate income more towards turnover taxation. Including the non-monetary exchange of data for services in a company's assessment for turnover tax would represent a first step in this direction. This could also be introduced while maintaining the current principles of company taxation, although its practical implementation raises complex issues regarding the full assessment and valuation of these barter transactions. On the other hand, a very fundamental reform of company taxation that is being discussed is the introduction of a destination-based cash-flow tax. This would generally link taxation to the sales generated and to the location of the end consumer, and thus no longer to the place of value creation or to the increasingly mobile place of profit generation. Such a step would clearly go much further than the reform steps currently being discussed at EU and OECD level. However, since it would significantly reduce and curb incentives for transferring profits, and with it international tax competition, the WBGU believes that this concept and its legal and economic implications should definitely be examined further.

9.2.3.3
Forestall monopolization tendencies and strengthen competition on digitalized markets

The advance of digital technologies in the economy and society has a fundamentally ambivalent impact on economic concentration and competition. However, big economies of scale and network effects and the growing importance of data for successful products and services, as well as more radical innovations, lead to expectations that there will be ever stronger concentration on a few dominant actors; this is already becoming apparent today since many digitalization processes are still unregulated. The WBGU believes that strong economic concentration should be avoided for a number of reasons. It has distributional effects that exacerbate the dangers of greater inequality between countries, but also within societies. From a systemic perspective, it impedes the innovation-promoting and system-stabilizing forces of competition between decisions by different, independent actors and information-processing systems. Finally, at the political level, there is the danger that societal decision-making processes and the formative role of the state will be undermined if individual private-sector actors become too dominant, especially since the formative power of these actors can be significantly increased by digital technologies. In order to curb such concentration processes, the WBGU believes that competition or cartel law should be further developed and, if possible, international harmonization should be sought. However, this evolution of *ex-post* control is not sufficient. In addition, efforts are needed to effectively address the structural drivers of economic concentration – which are based on the interaction of economies of scale and network effects on the one hand and the importance of intangible assets such as data on the other.

Develop effective approaches to competition control and coordinate them internationally

It is widely recognized that competition law needs to be further developed to achieve more effective control and sanctioning of market power and its abuse in an increasingly digitalized, data-driven economy. First steps have been taken and further adjustments are already the subject of intense discussion. The WBGU believes that this discussion should definitely be continued in greater depth. Against the background of international companies and platforms, there should also be efforts to internationally harmonize competition-law procedures and requirements.

In the WBGU's opinion, priority should be given to further developing competition-law regulations and procedures for determining market power and its abuse. In particular, they should focus on how companies use the data they collect and link to create and defend dominant market positions, quite apart from the question of pricing products and services. The WBGU also supports the idea that scientists and antitrust authorities should soon start examining the possibilities of (implicitly) collusive behaviour using algorithm-based, autonomous decision-making systems. The WBGU regards a stronger interlinkage between competition law and data protection/privacy protection as a significant extension of the scope of control possibilities under competition law. This should be further explored to make efforts to sanction the misuse of market power to circumvent data-protection provisions more effective. The WBGU takes a critical view – not only from the point of view of competition law but also from the sustainability perspective – of individual companies combining different business segments under one roof if the data linked in this way are used to restrict access to relevant basic goods, to threaten areas of privacy that deserve particular protection, or, for example, to undermine principles of solidarity and risk-spreading in the insurance sector. In the context of the regulation of well-known industries with strong network effects, such as the energy industry, the WBGU recommends at the very least considering whether the combination of certain business segments or operations under the umbrella of a single company should not be prohibited under antitrust law, or, if this is not possible, whether the possibilities for such an antitrust divestiture should be created. This could protect abuse-free access to relevant services, e.g. access to credit, which can be jeopardized by linking comprehensive personality profiles from social networks or major e-commerce platforms with offers of financial services. Here, too, international criteria and regulations should be sought wherever possible.

Address the role of data in the concentration of power

In addition to the need for an effective control of possible abuses of market- dominating positions, the WBGU sees the combination of economies of scale and network effects on the one hand and the feedback effects from the accumulation of data on the other as fundamental structural drivers of concentration on data-rich, data-driven markets that require further regulatory intervention. Here, competition legislation that acts as an ex-post control instrument focused on specific, individual cases where existing market-dominating positions are abused, does not go far enough. Rather, the WBGU agrees with the view that regulated access to data should be developed and enforced to break up self-reinforcing positions of power and to dismantle barriers to competition achieved by restricting data availability. Such forms of regulation necessarily face conflicting priorities: on the one hand the advantages of openness and broad data availability and, on the other, the need to protect privacy and possible (private) economic incentives for data collection. Furthermore, because the areas and contexts from which data are collected are so heterogeneous, there is no chance of a blanket regulation of data access. Free or at least clearly regulated, non-discriminatory and (in terms of interoperability) standardized access should, however, be enforced in the case of data that are relevant to competition in the further development of products and services, do not relate to any individual person, and tend to be collected as a by-product of other economic activities. Before comprehensive, governmental frameworks can be created regarding data access in digital market economies, approaches must first be developed that allow a more precise definition and delimitation of the (societal) value of data and their relevance for competition and innovation. In the WBGU's view, however, individual areas can already be identified today in which society's interest in a broad, regulated availability of data is particularly high. This applies, for example, to data from public spaces (smart cities) or to the digital commons that are yet to be created.

9.3 World order of the Digital Age

Efforts are needed in politics and society in order to place digitalization at the service of sustainable development and to counter risks, meet challenges, and seize opportunities. The enormous speed of digitalization processes requires adaptive governance; the various levels of governance will require an increase in capacity to meet this challenge. First, there is a need to strengthen international governance capacities to deal with the issue of sustainable digitalization and digitalization for sustainability (Chapter 8). The following recommendations provide some initial ideas for reaching an understanding on a common digital future. Second, the EU is called upon to develop its values, develop its path towards the digital future, and play an active role in shaping it (Section 8.5).

9.3.1 Global governance for sustainably shaping the Digital Age

Internationally, an understanding of sustainability has evolved over the last decades as a vision of global, long-term well-being; this is expressed by the 2030 Agenda, the Paris Agreement on Climate Change, and other multilateral pacts and agreements in the field of environment and development. By comparison, efforts to reach an international understanding on a regulatory framework and on cooperation in the field of digitalization and the application of digital technologies are still in their infancy (Section 8.1). The key challenge for the international community today is to develop a common vision for a sustainable, digitally supported future, and to reach an understanding on common guiding concepts, principles and regulatory frameworks. Just as the Brundtland report on 'Our Common Future' launched a global understanding of sustainable development by integrating environmental and development issues, a new stimulus is needed today for a global understanding of *our common digital future*. This requires stronger global governance capacities (Section 8.4).

9.3.1.1 Call a UN summit on 'Sustainability in the Digital Age'

Germany and the EU should champion a UN summit on 'Digitalization and Sustainability' (UN Conference for a Sustainable Digital Age, Section 8.4.3) in 2022 (30 years after UNCED in Rio). The central theme of the conference with a global perspective would be agreeing on the necessary fundamental steps to be taken to achieve digitally supported sustainable development and avoid unsustainable consequences of digital change. Suitable thematic priorities include the use of digital technologies to support the implementation of the SDGs and new challenges to global sustainability policy after 2030. The global summit should take into account the recommendations of the High-level Panel on Digital Cooperation and the results of the world summits on sustainable development held since 1992 (UNCED 1992, Millennium Summit, 2000, WSSD, 2002, UN Conference on Sustainable Development 2012, and the World Summits on the Information Society in 2003 and 2005). A key outcome of the UN summit could be the adoption of a charter for

Box 9.3.1-1

'Our Common Digital Future' – A Draft Charter for a Sustainable Digital Age

Preamble

Conscious of the responsibility of all societies for our common digital future,

conscious of the urgent need for decisive action to limit anthropogenic climate change and sustain the natural life-support systems, and conscious of the responsibility of humankind in the new geological epoch of the Anthropocene,

endeavouring to work towards a humanistic vision for a networked global society of the Digital Age in which civilizational and human potential can fully unfold,

recognizing the Universal Declaration of Human Rights, the report of the World Commission on Environment and Development, the United Nations Conference on Environment and Development, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, the United Nations-sponsored World Summit on the Information Society, the United Nations 2030 Agenda with its Sustainable Development Goals, the Paris Agreement and similar processes launched by informal initiatives,

the undersigned acknowledge and commit to the implementation of the following goals, principles, freedoms, rights and obligations.

Goals and principles

1. Human *dignity* shall also be inviolable in digital space. Everyone shall have the right to digital identity, sovereignty, data protection and privacy. This shall also include the right to evade digitalization in the private sphere and the right to be informed if an interaction partner is not a human being but a technical system.
2. The development of digital technologies and digitalized infrastructures shall always be geared towards sustaining the *natural life-support systems*. The planetary guard rails must be observed, global and local environmental problems must be avoided. The polluter-pays, cooperation, integration and precautionary principles must be observed as guiding principles.
3. The development of digitalized infrastructures shall always be oriented in such a way that it is *accessible to all* and offers equal opportunities for societal participation and realization. For the underlying technologies such as microelectronics, tele- and data-communication networks, data processing and artificial intelligence, information on the basic functions should be accessible to all worldwide.
4. The rights of the individual to the *protection of individual freedom of development* in the digital space shall be guaranteed. These rights shall include informational self-determination, the protection of freedom of expression and digital identity, the protection of minorities and protection against discrimination. All people shall have the fundamental right to inspect and correct data stored about them, to determine their use and to have them deleted. These rights shall be legally enforceable.

Digitalization at the service of sustainability goals

5. The potential of digitalization should be used worldwide to achieve the *goals of sustainable development* (2030 Agenda and beyond). Solutions based on digital technology should be considered in societal decisions involving the goals of sustainable development.
6. The development of digital technologies and digitalized infrastructures shall always take the environmental and social impacts into account. The *planetary guard rails* must be observed.
7. Digitalization shall be used specifically to monitor the *UN's sustainability goals* and thus to safeguard social and ecological standards.
8. All countries shall contribute to the development of *digital commons*, to the cultural and natural heritage and to the global state of knowledge, and shall ensure their protection and universal accessibility across generations.

Avoid systemic risks

9. All states and companies shall actively work to minimize *risks to critical infrastructures*. They shall be obliged to inform each other about errors and vulnerabilities and to ensure that these are remedied. Responsibility for damage shall always be clearly defined.
10. The use of digital technology involves obligations. Its use should at the same time serve the *common good*. Digital solutions may not be used to oppress people, to monitor them without cause, or to exercise social control.
11. All states shall have a duty to provide appropriate support for people affected to adapt to the *changes in the world of work* caused by digitalization according to the principles defined above.
12. Human *decision-making sovereignty* in the use of artificial intelligence and algorithm-based automatic systems in societal decision-making processes shall be guaranteed. Human beings shall retain the right to make the final decision. Automated decision-making and decision-making support must always be traceable, and shall take place only within a clearly defined framework and with the option of making corrections. The responsibility for automated decision-making and decision-making support shall always be clearly defined.
13. All states shall have a duty to preserve the *right of the individual to Eigenart and imperfection*. Societal pressure to optimize the human body through technology shall be countered. All states shall agree on binding rules and ethical guidelines at the multilateral level.
14. *Cyberattacks* shall be subject to the Geneva Conventions on Armed Conflict and their additional protocols, which must be supplemented to include attacks on critical infrastructures. The use of fully automated *autonomous weapon systems* shall be prohibited. The protection of the civilian population shall have the highest priority.

Prepare for procedural challenges

15. All states and companies shall develop *ethical guidelines* on the conception, development and application of digital technologies and solutions with regard to human dignity and sustainability goals and shall create the necessary legal and organizational frameworks for their implementation.
16. All states shall create *institutions* that give advice on the use of digital technologies when they impinge directly on human dignity, the natural life-support systems, the inclusion of all human beings, or the individual's *Eigenart*.

All states shall create the conditions for *civil society* to participate in these processes at an early stage.

17. Through *technology-oriented future-proof education*, all states shall enable their citizens to participate in the use of digital technology, to develop an awareness of global responsibility and a holistic understanding of their options for action in the Digital Age, and to actively participate in shaping future developments of digital technologies and digital infrastructures. This shall include in particular education for sustainable development.
18. All states shall *cooperate* at a multilateral level in accordance with the objectives and obligations agreed in this Charter.

the international community (Box 9.3.1-1). Such a declaration should set out the fundamental goals and principles for the sustainable design of the Digital Age, call for a form of digitalization that is in line with the sustainability goals, point out systemic risks to be avoided, and identify key political starting points for policy-making (Box 9.3.1-2).

To prepare for the proposed UN Summit, the WBGU recommends immediately setting up a 'World Commission for a Sustainable Digital Age' modelled on the Brundtland Commission. The World Commission's task should be to develop the goals, long-term strategies, and a vision for the future of digitalized sustainability societies. In particular, it should identify the risks posed by digital technologies for the Transformation towards Sustainability and describe ways of containing them. At the same time, the World Commission should stipulate the conditions that will allow the potential of digital technologies for sustainable development to unfold.

9.3.1.2
Ensure that the issue of digitalization is well anchored in the UN system

The WBGU sees various possibilities for a stronger institutional anchoring of the topic of digitalization and sustainability in the UN system (Section 8.4.4). First, all UN organizations and institutions working on sustainability issues (e.g. UNDP, UN Environment, UN-Habitat, IOM, UNCTAD, as well as the World Bank and regional development banks) should systematically incorporate the issue of digital change into their work and strategy-building processes. In addition, digitalization should be firmly established as a cross-sectional issue. An appropriate way of doing this would be to set up a mechanism to ensure cooperation between agencies and system-wide coordination ('UN Digitalization', analogous to the existing UN Energy).

9.3.1.3
International legal framework as an indispensable element

International law is an important component of global governance – also in the Digital Age (Section 8.4.5). In addition to negotiating a United Nations Privacy Convention (Sections 8.3.1.3, 9.2.1.2), Germany's Federal Government should champion opening a global discourse space for new sustainability issues connected with digitalization; this would also include the negotiation of a 'UN Framework Convention on Digital Sustainability and Sustainable Digitalization'. The latter would be the most visible measure, but certainly also the most complex task in terms of negotiation. In particular, new topics should be placed on the international community's agenda, including digitalized infrastructures and internet governance, participation in digital assets such as data, the protection of human decision-making sovereignty in dealing with algorithm-based decision-making, AI and automation, and the future of human beings in the relationship between humans and machines.

Starting points for international agreements on cooperation in these and other new fields of global governance could be principles known from environmental law, such as the precautionary principle, the polluter-pays principle, the cooperation principle and the integration principle. For example, technology-impact assessment should be enshrined as a fixed component and preventive controls by the authorities should be ensured in research, development and the application of autonomous and self-learning systems (precautionary principle). According to the cooperation principle, companies should be turned into promoters of a digitally supported Transformation towards Sustainability, e.g. through corporate eco-digital responsibility, incentives (privileging), and a public discourse on the transfer of state or private decisions to technical systems (cooperation principle). Liability gaps should be closed and responsibilities (product responsibility) assigned (polluter-pays principle). Old and new sustainability issues (ecology, privacy) should be integrated as cross-sectional issues into all areas of digital change (integration principle). The integration principle can also be applied to digitalization itself, which should be considered in all processes as a new cross-sectional topic and in the function of a tool and as a source of new challenges.

Box 9.3-1

Avoiding systemic risks in the Digital Age

In order to be able to exploit the potential of digitalization, we must be aware of the possible systemic risks in the Digital Age. Digital systemic risks include conceivable, large-scale changes in our societies, each of which could in itself trigger destabilization in those societies. Knock-on and cumulative amplifying effects would multiply accordingly and have a broad-based impact.

While some of these threats are undisputed (e.g. labour-market disruptions), the magnitude of the changes is uncertain. The probability of other systemic risks occurring is significant (e.g. breaching planetary guard rails, digital authoritarianism, further power gains by major digital corporations), while the likelihood of other risks occurring is relatively low from today's perspective (e.g. acceptance of human enhancement to create an optimized *Homo sapiens*). However, even the latter systemic risks must not be neglected because, in a worst-case scenario, they would have a major impact on the future of civilization. The WBGU identifies the following systemic risks in the Digital Age:

- the breaching of planetary guard rails as a result of digitally driven, resource- and emissions-intensive growth patterns,
- the disempowerment of the individual, threats to privacy and an undermining of the digitalized public sphere through digitally empowered authoritarianism and totalitarianism,
- an undermining of democracy and deliberation by normatively and institutionally non-embedded, automated decision-making or decision-making support,
- dominance by companies that can elude government control, driven by further data-based power concentration,
- disruption of labour markets by the comprehensive automation of data-driven activities and the danger that human labour will become increasingly irrelevant to the economy,
- a deeper division of global society as a result of limited access to, and use of, digital potential, mainly by wealthy minorities in the global society,
- abuse of the mechanization of humanity on the basis of human-enhancement philosophies and methods.

It is also important to bear in mind that the digital upheavals are being experienced by societies that are already unsettled by globalization, the rise of new powers, refugee flows and forms of authoritarian populism. The bow-waves of digitalization are colliding with the current crisis in Europe and the West, as well as with frontal attacks on a multilateral world order based on cooperation and rules. The systemic risks of the Digital Age could overlap with and reinforce the centrifugal forces that already exist in many societies.

9.3.1.4
Appoint a scientific panel on digitalization and sustainability

Scientific advice for policy-makers, technology-impact assessment and the broad-based integration of foresighted expertise on long-term developments and feedback between ecological and digitalized socio-technical systems should be institutionally strengthened in order to establish 'anticipatory governance'. The example of the IPCC has shown that pooling scientific expertise is an important prerequisite for fact-based policy-making for political decision-makers. The WBGU proposes setting up an intergovernmental or international scientific body to prepare regular assessment reports on the state of scientific knowledge on all socio-technical and ecological aspects of digital change that are relevant to sustainability. Building on experience gained to date, such a body could be structured similarly to the IPCC or IPBES (Section 8.4.6).

9.3.2
The EU as a pioneer of a digitalized sustainability society

As the world's largest single market, having its own model of a digitalized sustainability society would give the EU an opportunity to make an international name for itself as a "sustainable environment in which to live and work" (RNE, 2018a; Section 8.5). Against this background, the German Federal Government should, within the framework of its EU Council Presidency in 2020, commit itself to developing a common European vision and strategy for a digitally supported sustainability society and to firmly establishing sustainable development itself as a guiding principle for European digitalization policies. The point of departure for a European path towards digitalized sustainability societies is the assurance of common values. The WBGU regards a new humanism for the Digital Age as a guiding principle for European development (Chapter 7). Essential elements of such a value system are also set out in the Charter (Box 9.3-1).

9.3.2.1
Setting the course for the digitalized sustainability society

An important step for the European model is to integrate the interaction of sustainability and digitalization into EU policies (Section 8.5.2). The overarching EU strategy should express this objective, with a clear focus on the 2030 Agenda and a strong prioritization of known and new sustainability issues involved in the digital revolution. A European vision of a sustainable digital future would, in addition to the goal of creating a digital internal market, focus in particular on sustaining natural life-support systems and protecting other interests of the common good. The WBGU sees energy policy, the mitigation of climate change, and the circular economy as priority areas. In addition, the social dimension of both transformation processes is an important element of successful integration (Box 8.5-1).

The principles of environmental law (precautionary principle, polluter-pays principle, cooperation principle and integration principle; Sections 8.4.2 and 9.3.1.3) can be used to further develop the digital agenda. They can also provide guidelines for a sustainable framework for digitalization processes. Up to now, the decisive drivers of digital change have been economic interests and state surveillance and control. Sustainable digitalization policy should above all pursue interests of the common good.

Digital change, its opportunities and risks should be systematically included in the current preparations for the EU Environment Action Programme and the EU Decarbonization Strategy for the Paris Agreement. The development of an 'EU Strategy for Sustainability in the Digital Age' also opens up the possibility of placing new sustainability issues – such as privacy protection, digital inclusion, the sovereignty of human decision-making and the unique features of human beings in the human-machine relationship – onto the sustainability agenda (Section 8.3). With an 'EU Strategy for Sustainability in the Digital Age', the EU could furthermore play a pioneering role in the further development of the 2030 Agenda. Europe can thus give new impetus to global digital development (Section 8.4; Box 8.5-1).

To make this vision a reality, investment and innovation should be steered in this direction, for example by building up a sustainable European ICT infrastructure and testing digital technologies in cities, municipalities and regions (Box 10.3.2-1). Looking into new indicators and guiding concepts for measuring and evaluating economic success offers potential for promoting change towards the common good (Section 8.4.1). Important example projects include the provision of public-service ICT and participation in digital commons (Section 9.2.3.1). Education and research are key prerequisites for the development of concrete elements for the success of this model (Section 9.1.4, Chapter 10).

9.3.2.2
Enhance data protection and ethics in technology design as a competitive and locational advantage

Instead of conforming to a kind of global competition that contradicts its own values, the EU, as a powerful actor, can go on the offensive and introduce its own rules in order to change global competition itself in the longer term. The protection for privacy created by the EU-GDPR should be seen as a locational advantage and consistently expanded (Section 9.3.2.2). Participating in international competition with China and the USA on training-data-intensive machine learning at the expense of privacy would be a mistake; it would undermine the European system of basic values. Instead, sustainability, fair production conditions, privacy and cyber-security in technology design and at work (ethics by, in and for design, privacy by design, security by design, sustainability and fairness by design) should become central action-guiding elements of a future European digitalization model. The most important reference here is the EU-GDPR and the development of sustainable data handling. The responsible handling of data and privacy would put the EU in a unique position if consistently enforced and not watered down in global competition. The EU should therefore create a competitive advantage and, at the same time, perceive sovereign data protection and ethically reflected technology design as locational advantages.

As a first interpretation proposal for handling personal data, the EU-GDPR is the strictest standard worldwide. It needs to be decisively implemented, enforced and constantly further developed. It aims to protect natural persons when their personal data are processed and transferred, thereby protecting the fundamental rights and freedoms of natural persons. In the WBGU's view, the question of whether these protection objectives are achieved will depend to a large extent on the consistency of their enforcement, concrete application and further development, e.g. by data-protection authorities and the courts. In addition to strengthening law-enforcement authorities in the Member States, the EU-GDPR should recognize and support civil-society actors in their important role as cooperation partners in its enforcement. A debate on privacy should be initiated and supported throughout society. The WBGU recommends vigorously countering excessive surveilling and profiling. This requires, among other things, a powerful ePrivacy Regulation (ePR). The German Federal Government should therefore work at the EU level to lift the blockade on the ePR and implement it in the interests of its citizens. The negotiation process on the ePrivacy Regulation, which is currently largely blocked, should be accelerated in the public interest. This and the further development of the EU-GDPR would also send an international signal to third countries, especially to developing countries (Kuner et al., 2017). Effective data-protection instruments should be successively established as international standards via multilateral processes. In the Digital Age, data processing is not only the cause of violations of privacy, but also of concentrations of power and undesirable economic developments. The EU should therefore put data protection, together with data obligations, on the agenda – also in relation to non-personal data.

9.3.3
Actor constellations for digitalized sustainability societies

In order to steer digitalization towards sustainability, alliances of actors are needed that promote normative guidance, regulatory frameworks and fair market structures in society. Combining digitalization with sustainability objectives is a political process, not a technological one. The WBGU has examined the actor groups, viz. individuals, business and enterprises, civil society, tech communities, cities and municipalities, states, transnational actors, and the international community of states (Chapter 4). Trends can be deduced as to which groups of actors will gain influence and room for manoeuvre through digitalization and which will lose it. From the target perspective of a Great Transformation towards Sustainability, it is necessary to involve actors with the power to shape transformation and to open up room for manoeuvre for pioneers of change. Specific recommendations have already been made on some actor constellations in Sections 9.1 to 9.3.

The WBGU adheres to the concept of polycentric governance, which focuses on the interdependence of actor groups. The following recommendations aim to enable a wide range of actors to assume responsibility for the Transformation towards Sustainability in the Digital Age (polycentric responsibility architecture; WBGU, 2016b). Within a polycentric responsibility architecture, strong actors such as states or international organizations can generate impetus and actively strengthen other actors, e.g. in order to form coalitions or counterweights to powerful players. Some of these potentially strong actors have yet to develop the ability to shape digital processes. To this end, digital competencies should be developed and linked to the requirements of sustainability transformation.

9.3.3.1
Develop civil-society networks for individual and public-interest concerns

Since individuals in the digitalized world are exposed to numerous prestructurings and complexities, they need custodians of their collective interests who represent non-commercial interests (e.g. consumer-protection organizations). Existing organizations only provide individuals with limited protection from possible violations of individual rights by digital applications. For example, the interests of data-generating users vis-à-vis commercial companies that exploit their data have so far not been safeguarded by custodians such as trade unions. This requires the development of new forms and representation rights. Civil-society organization and civic involvement are particularly crucial in the Digital Age as a link between the individual and society, but also as a counterbalance and supervisory entity that monitors state and economic power. Strong networks of civil-society actors can become a critical sensorium, both nationally and globally, for ecological, societal and human-rights grievances, and in this sense be promoted and institutionalized all over the world.

9.3.3.2
Win over tech-communities as allies for the Transformation towards Sustainability

Due to the ever-increasing influence of the tech communities (Section 4.2.4), discourses relevant to sustainability should be systematically and institutionally promoted among this actor group. The discussions within the tech community on values by design, corporate social responsibility, the responsible use of technology, and the development of a professional ethic offer good starting points for leveraging potential for the ability to act, shape and plan when moving towards sustainability transformation. These contents should also become an established part of education and further training. Alongside a strengthened form of corporate social responsibility, technological social responsibility should also be established so that tech communities increasingly become pioneers of the Transformation towards Sustainability. The Corporate Digital Responsibility Initiative launched by the Federal Ministry of Justice and Consumer Protection (BMJV) has taken a first step towards defining possible principles of digital responsibility in Germany. This can be further developed.

A 'Weizenbaum oath' (Section 4.2.4) could serve as a professional ethic for the sustainable design and use of digital technologies. It could commit the tech communities to general principles that guide the development and application of digital technologies. These principles, too, should be an established part of the education and further training of experts.

9.3.3.3
Mainstream technical knowledge and modernize state institutions

The digital and sustainability competencies of public actors need to be strengthened in a targeted way for the Transformation towards Sustainability. In order to fully tap into the sustainability potential of digitalized state action, an understanding and technical knowledge of the opportunities and risks of digitalization should be enshrined in all government institutions from the local to the national level and across all relevant subject areas (mainstreaming). Moreover, states should increasingly act together and cooperate multilaterally in order to (re-)gain their ability to act. They should ensure that civil rights are not restricted and that privacy is not violated. In the Digital Age, states have a special obligation to offer protection from threats to human dignity and must prepare themselves to be able to meet this obligation.

9.3.3.4
Use the resources of transnational and international organizations for sustainability

In the best-case scenario, digital interconnectedness, virtuality, and knowledge growth can be positive drivers for the formation and diversification of transnational structures that have already been set in motion and which, in the long term, will cumulate into a kind of critical global society or global environmental awareness. This requires the mainstreaming of sustainability topics in transnational networks and organizational structures dealing with digital and digitalized infrastructures (e.g. ICANN). This perspective could be actively introduced by state or civil-society actors. International sustainability-governance organizations, which represent a key global knowledge resource with their fact-based reporting, should in the future take on a new role in the sense of informational quality assurance. In addition, international organizations, resources and networks should form a bridge between transnationally organized units and states. A compatible model example of this is the work of the UN Climate Secretariat (Section 4.2.7).

9.4
New normative questions – the future of *Homo sapiens*

New ground is repeatedly being broken as the capabilities and proficiencies of technical systems are continuously further developed, human abilities extended by technical systems, and attempts made to confer human-like abilities on technical systems. This raises fundamental ethical questions that must be discussed by society as a whole. Currently, images of utopian or dystopian science fiction abound in the discourses on cooperation and collaboration between humans and machines, and on the physical (and social) mechanization of humans through digitalization (Chapter 6). Yet the emotionally charged atmosphere and the focus on a distant future distract from the fact that borderlines are probably already being crossed today that require immediate regulation (Section 9.4.1). The WBGU's normative compass, which has been extended to include human dignity, can provide orientation on topics that currently still seem futuristic. Today, there are already concrete challenges to the protection of individuals from objectification (Section 2.3.2), to enabling self-determination and the free development of personality, and to diversity as the basis of creativity and an opportunity for necessary transformations in society. Developments that are already emerging inevitably lead to questions as to which technical developments we want to – and which we do not want to – realize in the future, taking their possible consequences into consideration. This requires the creation of discourse spaces and early warning systems (Sections 9.4.2, 9.4.3).

9.4.1
Brain-computer interfaces: incorporate data protection and shut-down options

Although assessing the development of brain-computer interfaces (BCIs) and neuroprosthetics is often speculative, in the meantime these technologies are considered significant by major investors. Correspondingly large research budgets and activities in the private sector are not without implications for research ethics and society, however, because the "meaningful, marketable and clinically usable development of brain-computer interfaces and brain-stimulation devices is only possible with equal and intensive cooperation between physiological, engineering and clinical disciplines" (Birbaumer, 2017:8). In this context, the fact that the development departments of corporate groups often employ medical engineers without any clinical training or experience and without access to clinical groups is regarded as problematic in view of the lack of interdisciplinarity (Chapter 10); the same applies to decisions to make and design developments based on profit expectations and the availability of new technological options without reflecting on the ethics. Digitally controllable prostheses and implants are already being used for curative purposes today, in some cases without mandatory encryption or switch-off functions (Clausen et al., 2017). There is an urgent need for action here.

Although technologies for reading thoughts are still rudimentary, and emotions cannot yet be read at all (e.g. by using scientifically questionable commercial EEG devices), such developments are theoretically possible in the foreseeable future (Topic box 5.3-2; Birbaumer, 2017). The WBGU therefore believes that the foundations must now be laid for regulating the use of such developments, which may possibly be pushed in ethically problematic directions for commercial reasons. Since the rapid development of new sensors and machine intelligence could make 'mind-reading' possible within a few decades, at least in a limited form, it is important to already oblige manufacturers today to install an emergency shut-down switch. The maximum safety and resilience of such systems must also be guaranteed (Birbaumer, 2017:32). In this context, cybersecurity (Section 3.3.4) would be a new, additional guarantor of mental integrity.

In view of the foreseeable quantitative increase in neuro data, the WBGU continues to recommend creating an individual right to privacy in the 'default-opt-out' mode, strictly regulating the commercial use and passing on of data, and extending existing international obligations (e.g. UN Declaration of Human Rights) by adding corresponding 'neuro-rights' (Yuste and Goering, 2017: 161ff.). The rapid and, in some cases, already very advanced research and development in this area shows that spaces and institutions urgently need to be created for early discussions on setting possible borderlines and imposing moratoria (Section 9.4.3).

9.4.2 Licensing standards and 'early warning systems' in the field of human-machine interaction

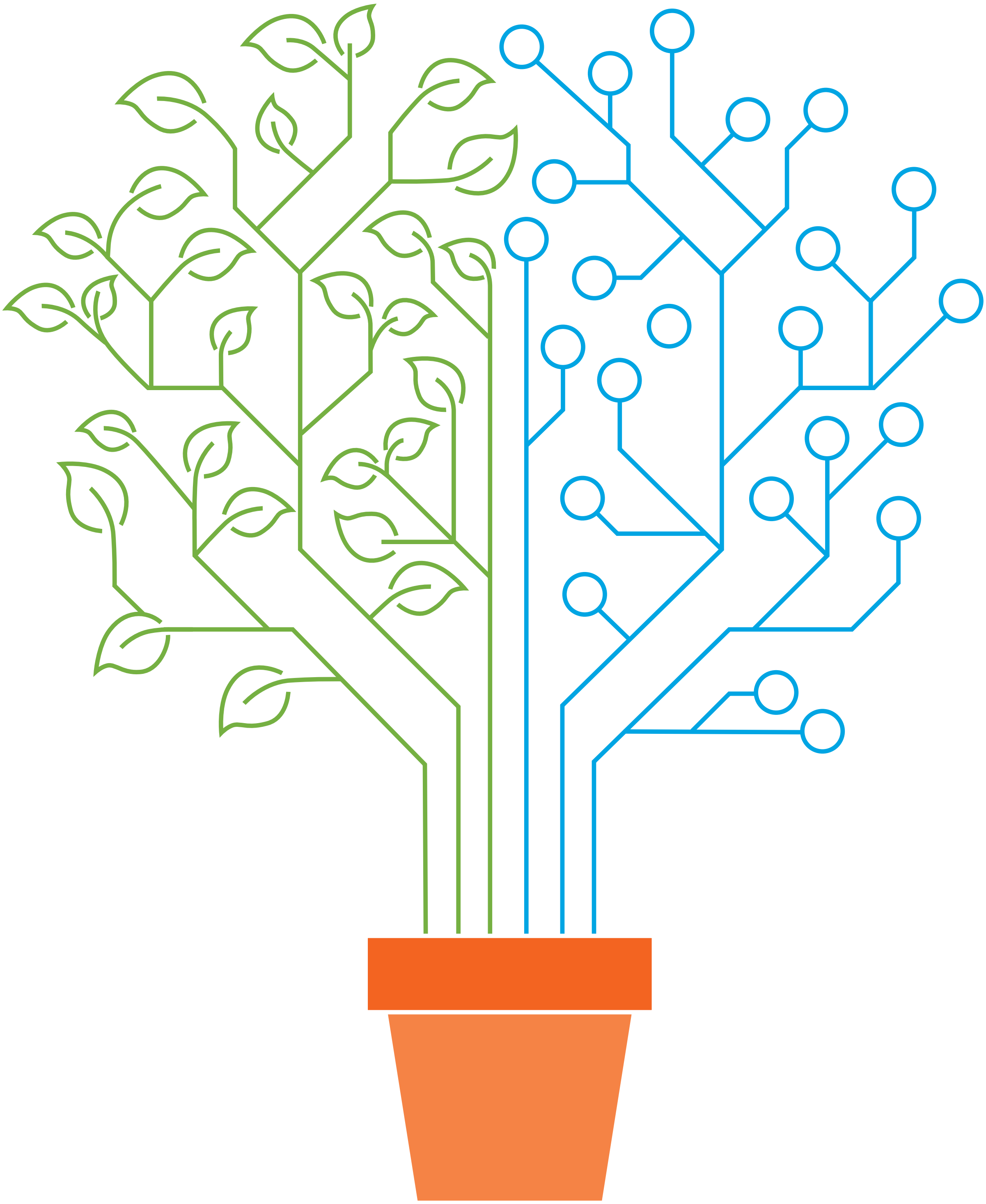
Not only does the physical technologization of human beings by machines raise fundamental questions; the intensification and redesigning of human-machine interaction also requires foresight and the containment of possible dangers relating to social policy, individual freedom of knowledge and decision-making autonomy (Box 4.3.3-1; Topic box 5.3-2; Birbaumer, 2017:25ff.). Today, Alexa and Siri are already becoming part of more and more people's everyday lives in industrialized countries. In view of people's tendency to anthropomorphize autonomous systems, urgent societal questions arise here. In some cases, we interact with autonomous systems without knowing it (avatars, bots, service robots), which is why the WBGU strongly recommends a labelling requirement for communication with a machine 'counterpart'. Furthermore, (partially) autonomous robots are already being used today in vulnerable areas, e.g. in nursing care, with patients suffering from dementia (Paro therapeutic robot) or in children's rooms (e.g. networked toys with audio-visual tracking functions). Due to the potentially far-reaching consequences for mental integrity, the WBGU recommends laying down appropriate general licensing standards for all socio-technical innovations, i.e. products and services related to human-machine interaction. In order to keep pace with rapid developments driven by strong commercial interests, new and more anticipatory forms of technology-impact assessment need to be developed, as well as early warning systems for particularly vulnerable target groups (children, adolescents, etc.).

9.4.3 Continuously adapt our understanding of the relationship between humans, machines and the environment

Man-made digital technologies not only make it possible to irreversibly change the planet, they also influence and change human beings and the prevailing ideas of what it means to be human (Chapter 7, Section 8.3.4). The relationship between humans, machines and the environment is dynamic because all three components can be changed by technology and society. Nevertheless, technology is and will remain the work of human beings even in the long term. A critical and responsible anticipation of the future potential and risks of technological developments therefore requires a different, broader understanding of the future instead of a one-sided technology-oriented one. In addition to an education pact (Section 9.1.4.2), the WBGU recommends backing this up scientifically by further developing the necessary principles of futurology, forecasting and technological change (Chapter 10). Due to their societal significance, we see here a strong obligation to make the research results accessible to societal discourse, for example through new formats of knowledge transfer such as opportunities to experiment, road shows or testing in real-world laboratories.

9.4.4 Create effective and inclusive discourse arenas

A further building block is the creation of arenas of discourse by Germany's Federal Government – offering spaces for discussion in which civil society, scientists, businesspeople and policy-makers can exchange views on values, goals, and the limits of digital change (Section 7.4). The aim of this instrument is to organize societal discourse in such a way as to raise awareness of the new ethical questions emerging in the context of digital change – and to develop answers for society. These arenas should be organized in several interconnected and complementary formats. Their results should be incorporated into parliamentary procedures, for example through statements (oral or written) to relevant Bundestag committees (e.g. on the Digital Agenda). In addition, an interministerial or state-secretary committee for sustainable digitalization could be established.



Research Recommendations 10

The WBGU sees technological progress not as an end in itself, but as a means of achieving societal goals. Against this background, it proposes combining sustainability and digitalization research in order to close knowledge gaps. It also presents concrete proposals for the further development of existing research structures and makes research recommendations on various aspects at the interface between digitalization and sustainability.

The WBGU is oriented towards the questions of a global societal future within planetary guard rails. Research and innovation are of great importance in shaping a constructive role of digitalization for sustainable development. The WBGU sees technological progress not as an end in itself, but as a means of achieving societal goals, in particular a decent life for all. In line with its normative compass (Chapter 2), the WBGU therefore expressly welcomes the corresponding basic convictions of the BMBF's digital strategy (2019) and their forthcoming implementation.

In this report, the Transformation towards Sustainability is considered together with the power of digitalization and how it can be shaped. For sustainable development in the Digital Age, sustainability issues should be embedded in innovation and research policy on a broad societal level and should have international appeal on the sustainable design of the entire innovation system at both the national and European level. *Transformation research* aimed at better understanding the importance of digitalization for fundamental societal change processes plays an important role here, as does *transformative research*, which, with its research findings, initiates and catalyses transformation processes towards sustainable development (WBGU, 2011:22ff., 322). The contribution of science lies not only in stimulating relevant discourses but also in providing sound technical foundations for them in order to develop new technologies for digitalized sustainability and prepare them for application.

Although it is already understood that radical societal changes are to be expected on the way to the Great Transformation towards Sustainability and to digital change, current research in the context of digitalization continues to focus on technological development, e.g. big data, artificial intelligence (AI) or autonomous systems – as shown by a mapping of the discourse landscape carried out by the WBGU (Box 10.3-1). The content and direction of this research are primarily determined by economic potential, not least in the context of international competitiveness. Ecological and social research issues, the latter with the exception of the thematic blocks of knowledge, education and digital literacy, are addressed to a much lesser extent. This also applies to the major questions of the future for the further development of society and people in the context of digital change (Chapter 7).

Compared to the speed and breadth of digital change, there is therefore still not enough reliable knowledge about the impact of digital technologies on the Earth system, societies and people. As a result, socio-political discourses on the effects of digitalization – for example with regard to work in the future or energy and resource consumption – are characterized by contradictory assessments and a lot of uncertainty. Equally, research has only just begun on the potential and risks of digitalization for achieving the internationally agreed sustainability goals (UN Sustainable Development Goals – SDGs; UNGA, 2015) and the question of how digitally supported educational measures can promote knowledge and action for the Great Transformation towards Sustainability (UN, 2018c).

This status quo suggests both a reorientation of the current research foci on digitalization towards sustainability and the further development of sustainability research related to digitalization. In line with the Three Dynamics of the Digital Age (Chapter 7), the WBGU proposes the following overarching lines of research to fill existing gaps in knowledge and to gain more insight into the potential and risks of digitalization for a transformation to a sustainable economic and societal structure:

- *Research on digitalization for sustainability (First Dynamic)*: How can digital technologies, digital and digitalized infrastructures, as well as digitalized systems and end devices themselves be made sustainable, especially with regard to their energy and resource consumption and the establishment of a circular economy? How can digitalization be used as an instrument to implement the SDGs and to mitigate climate change?
- *Research on sustainable digitalized societies (Second Dynamic):* How can societies be preserved that are able to assess the system-changing impact of digitalization on the Earth system, society, business, human beings and technical systems, and capable of taking action, proactively and sustainably shaping that impact, and countering any unintended consequences? Important tasks for research include studying systemic risks and potential, developing new forms of inclusion in the context of work in the future, shaping human-machine interactions, and empowering the individual in digitalized sustainability societies. Research funding on the impact of AI on the digitalized sustainability society should be significantly increased.
- *Research on the future of Homo sapiens (Third Dynamic):* In the Digital Age, being human is in itself also becoming a topic of sustainable development. To what extent should old and new ideas of what it means to be human be questioned in the light of a possible intertwining of humans and technology and the increasing cooperation between humans and machines? How can the preservation of human dignity be ensured?

Last but not least, the science system itself must face up to digital change and develop accordingly. A focus on sustainability goals in almost all disciplines places new demands on their structural design. There is a greater need for discourse and spaces for reflexion within the scientific system in order to make possible differentiated, joint and timely discussion of ethical and sustainability issues at various levels of society, and to develop proposals for suitable framework conditions.

First, Section 10.1 explains the overarching objective with regard to the Great Transformation towards Sustainability (WBGU, 2011). On this basis, Section 10.2 makes concrete proposals for the further development of existing research structures. In the design of current programmes, it is often difficult to position projects at the interface of sustainability and digitalization. Institutes and programmes are presented which have taken the first steps towards exploring the interface between sustainability and digitalization, or which would lend themselves to bringing about a closer intersection of the two areas. Furthermore, proposals are made for existing programmes and institutions at the interface of digitalization and sustainability as well as for actors in the science system that take into account the increased necessity for interdisciplinary exchange and the integration of science-related actors. Finally, Section 10.3 explains the research recommendations in terms of content along the overarching research lines described at the beginning.

10.1 Overarching research priorities

At present, scientific and public uncertainty about the impact of digitalization on the Earth system, societies and people is out of line with the current dynamics, breadth and intervention depth of digital developments. The research recommendations in this report are therefore also concerned with maintaining and promoting global society's ability to understand, innovate, and engage in discourse, in order ultimately to preserve – or, where necessary, regain – its ability to shape and act (Section 7.5). Science and research have a key role to play here. Critical analyses, reflection and opening realms of possibility and discourse on digital change are therefore indispensable components for shaping a sustainable Digital Age; they should be understood as promoters of – and not obstacles to – innovation and competitiveness.

In the WBGU's view, perhaps the greatest challenge for research funding lies in creating conditions at diverse, interacting levels for a differentiated, joint and timely discussion of ethical issues, and in conceiving societal framework conditions for sustainable digitalization and safeguarding it in the future. In this context, it is important to further increase reflective potential not only in science itself, but also in the many different public arenas of the digitalization discourse. To this end, new formats for science communication could be set up beyond existing ones, e.g. in the field of art, to increasingly activate scientific expertise for public discourses. Accordingly, in order for a Great Transformation to be successful (WBGU, 2011), it is important to promote both transformation research for a better understanding of how to shape digitalization, and transformative research using the instruments of digitalization. Digitalization should be established as a new cross-cutting topic in all existing sustainability-research initiatives, and the sustainability target system should be embedded in all digitalization research.

Transformation research 'specifically addresses the future challenge of transformation realisation. This discipline explores transitory processes in order to come to conclusions on the factors and causal relations of transformation processes. Examples from history could provide the basis for analysing observed transformative moments' (WBGU, 2011: 22). In the context of digitalization, such research helps us to comprehend what the relevant drivers are for understanding the 'key questions for a digital, sustainable society' (WBGU, 2018a). Against the background of the Three Dynamics, methods of technology-impact assessment and futurology are important building blocks of transformation research.

At the same time, digitalization offers instruments for raising empirical and long-term research to a new level of quality. For example, monitoring in Earth observation, social platforms in behavioural research, and Industry 4.0 for the circular economy – they all make it possible to comprehensively recognize dependencies, complex relationships and implications. Data analyses, time-series analyses, pattern recognition, modelling, simulations and forecasts are orders of magnitude better than ever before – in terms of coverage, precision, repeatability and traceability – thanks to the accuracy of observation possibilities, as well as the topicality, scope and duration of the observations. Such instruments make even such extensive tasks of observation and analysis as the further development of the SDG indicators feasible in countries and worldwide. A first SDG indicator framework was already presented with the SDGs. However, this has not yet been fully implemented due to content-related and operational difficulties. Developing it further with a view to implementation should therefore be a subject of research. In combination with the communitization of research data and findings as digital commons, the SDG-oriented knowledge base can thus also be established, expanded and made universally accessible.

In the context of digitalization, *transformative research* develops on the one hand direct, digital-based methods and solution modules for sustainability-related challenges (e.g. innovations for decentralized energy-supply systems, automated driving in the context of sustainable mobility, precision agriculture, circular economy); on the other hand, it initiates societal debates on the sustainability potential and risks of digitalization by creating a suitable framework and sensitizing people to the interrelation of different issues. Furthermore, both can develop further with digitalized methods and instruments.

The intertwining of sustainability and digitalization research, in which transformative research cannot get by without the SDG target system and ICT innovation dynamics, should be accompanied by educational research for the digitalized sustainability society. Not only the manifestation and strengthening of digital and sustainability competencies should be examined here, but also, in particular, the transfer of transformation competencies to deal with the upcoming tasks and options of the Transformation. A canon for the education and further training of digital, sustainability and transformation skills should be prepared and scientifically accompanied by transformative educational research as a foundation in the digitalized sustainability society.

10.2 Research structures – transformation research and transformative research in the Digital Age

The German science system should be further developed in terms of both structures and programmes in order to process and provide the knowledge required for digital development, and to strengthen the role of science as a space for discourse and reflection. The SDG target canon should be mainstreamed in every relevant discipline, but especially in digitalization research because of the dynamics of ICT innovation. Table 10.2-1 provides an overview of the ideas the WBGU is suggesting for basic research on transformation processes in the Digital Age and transdisciplinary, application-oriented research for digital change. Proposals are made both for existing research programmes (Section 10.2.1) and for established actors in the science system (Section 10.2.2). Institutional capacity in Germany should also be further expanded (10.2.3), also in view of the fact that the German Federal Government, together with the Länder and industry, is still missing its target of allocating 3.5% of GDP to research and development – it is 0.5% short (BMBF, 2018a). Further research recommendations can be found under the respective arenas (Chapter 5). Box 10.3-2 gives an overview of the topics.

10.2.1 Extend research programmes and strategies at the interface between digitalization and sustainability

In view of existing environmental and sustainability problems and the dynamics of digitalization, there is an

Table 10.2-1
Further development of the German research system to meet the challenges of digital transformation in the Anthropocene. Source: WBGU

Strengthening transformation research	Strengthening transformative research
Basic research on transformation processes in the Digital Age	**Transdisciplinary and application-oriented research for digital change**
Set up research institutes on the basic issues of digitalized sustainability Ideas for the further development of basic research: › set up a DFG Senate Commission on 'Sustainability in Digitalization Research' › guidelines for universities and R&D	Relate research programmes on sustainability and/or digitalization reciprocally and develop them in a transdisciplinary way: › Horizon Europe › Future Earth › High-Tech Strategy 2025 › BMBF-FONA › Energy research programme Stimuli for sustainable digitalization in industrial research: › Sustainability lines for R&D › Sustainability-oriented target indicators

urgent need to generate knowledge to guide action. However, there are currently only a few existing research programmes and strategies that explicitly place digitalization and sustainability at the core of their activities. Existing transformative research programmes to accompany digitalization should be re-launched or further developed at the European and national level.

10.2.1.1
Horizon Europe: centrally enshrine digitalized sustainability in Europe

The EU bundles its research-funding programmes in time-limited Research Framework Programmes administered by the European Commission. In 2021, the current framework programme EU Horizon 2020 – with a funding volume of €77 billion the largest research and innovation programme in the world (BMBF, 2018a: 39) – will be superseded by its successor programme Horizon Europe (2021–2027). As stated in the High-Tech Strategy, the German Federal Government should work to ensure that the SDGs and the Paris Agreement are enshrined in the new EU Research Framework Programme. This programme is based on three pillars which can are a good match with this report: (1) open science, (2) global challenges and international competitiveness, and (3) open innovation (Figure 10.2.1-1).

However, in view of the interdependence of digitalization and sustainability, the WBGU recommends that these three pillars of a 'European Research Area' should be conceptually combined more closely and that the Federal Government should take a corresponding position on the further implementation of the 'Responsible Research and Innovation' paradigm (RRI; Lindner et al., 2016). This would also have to be embedded in general incentive structures and not only, as with 'Horizon 2020', in the comparatively low-budget sub-programme 'Science with and for Society'. This could be a way of directly strengthening the responsibility of European and German science in view of the challenges of digitalization relating to global sustainable development. Just as securing industrial competitiveness in the second pillar can only be meaningfully considered in conjunction with global sustainability challenges, open science and innovation cannot be implemented separately from responsible technology design. In the Federal Government's position paper on 'Horizon Europe' (2018b: 5), the envisaged 'broad concept of innovation' explicitly refers not only to technological but also to social innovations and, in addition to increased value creation, also emphasizes the need to overcome societal challenges in line with the precautionary principle.

In line with the demand stated there that SDGs "are also included in the clusters as a guideline for topic selection and tenders," the WBGU recommends developing and introducing an overarching 'mission' specifically oriented towards sustainable and sustainability-enabling digitalization. In the report 'Mission-Oriented Research & Innovation in the European Union' (Mazzucato, 2018), on which the European Commission's current proposal is based, not only is there a clear reference to digitalization in many places, but the SDGs also play a key role. A corresponding, mission-oriented systemic policy uses 'frontier knowledge to attain specific goals' or 'big science deployed to meet big problems' (Mazzucato, 2018: 4).

Figure 10.2.1-1
Three pillars of Horizon Europe.
Source: European Commission, 2018d (own translation)

Given the complexity and specialization of today's science, openness and collaboration are becoming critical success factors. This applies both within the diversity of Europe and in global competition, especially with economically strong states such as China or the USA. In line with the WBGU's transformative perspective (2011), the WBGU therefore recommends that mission-oriented research on fundamental global challenges (Grand Challenges) be implemented structurally in the next Research Framework Programme. The aim is to gear scientific investment towards making such research possible in an interdisciplinary, focused and problem-oriented manner in conjunction with basic and applied research (Mazzucato, 2018: 5ff.).

On this basis, the WBGU furthermore proposes the creation of a 'Digital Sustainability Knowledge and Innovation Community' (KIC) at the European Institute of Innovation and Technology (EIT; European Commission, 2018d) as a cooperative community for knowledge and innovation together with industry, in order to implement major changes, e.g. towards a circular economy.

The WBGU further recommends that the German Federal Government should focus the negotiations on the next Framework Programme (FP9, beginning on 1 January 2021) more strongly on the sustainability of digitalization and digital sustainability, in order to make important contributions to the sustainable development of the EU, as laid down in the current position paper (Bundesregierung, 2018c: 2).

10.2.1.2
Future Earth: extend sustainability research in the direction of digitalization

In view of the interdependencies between digitalization and sustainability identified in this report, the WBGU recommends integrating digitalization as an important building block into the international Future Earth research programme, which is geared towards the transformation to global sustainability. In this context, a global project on 'eSustainability' should be initiated. A new inter- and transdisciplinary type of science (in line with the WBGU's ideas presented in Section 10.2) is already a central element of the vision for 2025 (Future Earth, 2014). 'eSustainability' can contribute significantly to achieving the SDGs, and not only through increased output on the central topics of Future Earth; it can also promote the realization of a corresponding new collaborative scientific culture that transcends current limitations and creates the necessary prerequisites for it. The WBGU further recommends the creation of a knowledge action network on 'Digitalization' in order to firmly establish this and other projects at the interface of sustainability and digitalization as pillars of research strategy and to continuously expand them.

10.2.1.3
High-Tech Strategy 2025: bring digitalization and sustainability together

Since 2006, the High-Tech Strategy (BMBF, 2018b) has concentrated the German Federal Government's research and innovation policy across all ministries. The further developments introduced in 2010, 2014 and 2018 successively shifted the Strategy's focus – which was originally purely technical and economic – more towards societal challenges. Since 2014, there have been occasional references to social innovations, as well as to research in sustainability, social sciences and the humanities. The 2018 revision further strengthened these aspects, a fact that the WBGU welcomes. Digitalization is treated as a central cross-cutting issue in the High-Tech Strategy and is to be promoted in all six fields of action. Sustainability, however, is kept thematically more sectoral in the context of climate-change mitigation and energy. Although the High-Tech Strategy states that the Federal Government is committed to anchoring the SDGs and the Paris Agreement in the new EU Research Framework Programme, they are not mentioned in the High-Tech Strategy itself. The High-

Tech Strategy 2025 sees itself as a learning process that takes up ideas on the implementation and further development of the strategy. To this purpose, the WBGU recommends giving sustainability aspects even greater consideration in the High-Tech Strategy, and consistently combining them with the power of digitalization. The following concrete measures are recommended:

1. Sustainability – like digitalization – should be positioned in the High-Tech Strategy as a cross-cutting topic that is promoted equally in all fields of action. Furthermore, digitalization for sustainability, in the sense of developing digitally supported solutions oriented towards the SDGs, should be added as a concrete mission in the High-Tech Strategy.
2. Growth targets should not take precedence over welfare and sustainability. With regard to international competitiveness, the aim must be to combine political thinking on competitiveness and sustainability. Instead of focusing on the concept of growth and international competitiveness, the High-Tech Strategy should therefore focus on the concept of welfare and the sustainability goals as a new global development paradigm. Social and ecological dimensions of innovations as strategic elements for achieving welfare goals should be further strengthened.
3. Sustainable digitalization – i.e. secure, resource-saving and energy-efficient digitalization – should be added to the High-Tech Strategy as a concrete mission. Solutions for a sustainable consumption of required resources and energy should already be taken into consideration in the development and operation of digital and digitalized infrastructures and applications.

10.2.1.4
FONA⁴: create link with digitalization

The BMBF Framework Programme on 'Research for Sustainable Development' (FONA) develops decision criteria for future-oriented action and innovative solutions for a sustainable society. The Fourth framework programme (FONA⁴) should be used to introduce the topic of digitalization into the sustainability research programme. It should take into account in particular the possible role of digitalization as an instrument for effectively implementing the sustainability goals, e.g. through improved monitoring or the simplified exchange of environmental data.

This strategic reorientation places new demands on the preventative research already set out in FONA³ (BMBF, 2015), since new digital preventative topics such as data security, protection of privacy and stability of infrastructures are thus also gaining relevance in sustainability research. Accordingly, preventative research should be further developed within FONA⁴. The same applies to the socio-ecological research conducted within FONA, which takes up topics involving societal negotiation processes and value discussions in order to find possible solutions for the transition to a sustainable society. Linking FONA with digitalization topics will lead to more discussions on values.

10.2.1.5
German Federal Government's Energy Research Programme: strengthen sustainability impacts and the international perspective

The Energy Research Programme describes the content and instruments of the Federal Government's research funding in the energy sector. It has only recently been fundamentally revised, and the current seventh edition has been adapted to changed framework conditions and new challenges in the implementation of energy- and climate-policy objectives in Germany. The Energy Research Programme takes up many technologies and approaches to protecting natural resources that are also important to the WBGU, such as technologies for capturing CO_2, and processes and materials for closing material cycles. In the WBGU's view, it is important to emphasize that the revision significantly strengthened the programme's orientation towards systemic research questions and cross-system research topics. These include interdisciplinary research on the necessary socio-economic prerequisites for the successful application and dissemination of new technologies, and on the practical testing of technologies and regulatory measures in real-world laboratories.

In addition to this enhanced focus on interaction between society and technology for the successful application of new technologies, the WBGU welcomes the fact that the revision has explicitly integrated digitalization and its consequences for the energy sector as one of the cross-system research topics – as well as in many other areas, for example in connection with new mobility concepts, intelligent buildings and particularly in connection with sector coupling. This has remedied a major flaw in the previous Energy Research Programme. The current programme lists a wide range of technical and non-technical developments in the course of digitalization and a multitude of possible application areas and potential for digital technologies. Critical questions – such as the consequences of increasing networking for the security and resilience of the energy system and data protection – are not ignored either.

However, the societal and ecological implications of digitalization for sustainable development ensuing from the energy sector are hardly covered by the Energy Research Programme. In line with the guiding principle of this report, technologies and digitalization should be placed at the service of sustainability. When developing technologies, therefore, the WBGU recommends considering not only market potential, but also societal and environmental sustainability impacts within the framework of projects. For example, it could be made obligatory to discuss these aspects when filing applications for new project proposals. Such a regulation would lay down the integration of sustainability aspects as a standard, deviations from which would have to be justified. Moreover, the WBGU takes a critical view of the very one-sided focus on Germany and industrialized countries. This orientation neglects the special societal and structural prerequisites in developing countries and emerging economies for the design of sustainable energy systems. Societal and structural prerequisites in developing countries and emerging economies for designing sustainable energy systems should be given greater consideration in research funding, both in the development of new energy technologies and in studies on the necessary framework conditions for a successful and rapid implementation of technologies.

10.2.2 Recommendations to existing actors in the science system

Since both digitalization and sustainability are cross-sectional topics, and are furthermore highly interdependent, both should be put on the agenda and disseminated by the key actors in the science system. By means of an inter- and transdisciplinary mainstreaming of these topics, it is possible to establish and gradually expand a broad understanding of sustainability in the sense of the SDGs and to show how research linked to digitalization within science itself and in exchange with business and society can be made sustainable.

10.2.2.1 DFG: set up a permanent Senate Commission on Sustainability in Digitalization Research

The intertwined fields of sustainability and digitalization are a rapidly developing scientific topic that is controversially discussed in politics and society where a recurring need for legal regulation with clear relevance for research is to be expected (DFG, 2018). The WBGU recommends that the DFG set up a standing Senate Commission on Sustainability in Digitalization Research to clearly define and pool the relevant competencies within the DFG. The Senate Commission would have the task of drawing attention to digital developments that raise scientific, ethical, legal and social questions, or conflict with the aim of sustaining natural life-support systems. It should observe digital change carefully and proactively in order to initiate new public debates in good time and indicate areas that require research. The Senate Commission on Sustainability in Digitalization Research should also point out gaps in public and research-policy discourses.

10.2.2.2 Universities and colleges: formulate and develop guidelines

Universities and colleges can send important stimuli to society not only as places where research and teaching are bundled, but also as actors within society. Some universities and colleges have already drawn up official sustainability guidelines specifying, for example, the assumption of ecological and social responsibility in their research, teaching and administration. Universities and colleges should create, enhance and implement guidelines for their own practice on the sustainable use of digital methods and tools in university and college activities. To this purpose, they should seek ways to share and exchange know-how with faculties engaged in research on digitalization. The topic of digitalization should form an additional part of the BMBF's Sustainability at Universities (HOCH^{N}) project.

10.2.2.3 Academies of science: intensify references to sustainability

Another central pillar of the German science system, the Union of the German Academies of Sciences and Humanities, is an important player with a leverage effect in the shaping of national science practice. The topic of digitalization is already very present there with working groups on Digital Humanities, the creation of a National Research Data Infrastructure (NFDI) and digitalization centres. In the WBGU's opinion, it would be desirable to further intensify references to sustainability and to simultaneously promote the realization of positive visions of open and inclusive science beyond the pillar of Open Access (Section 10.2.4.1). The WBGU welcomes the initiatives on this that have already been launched, such as those at the Berlin-Brandenburg Academy of Sciences and Humanities, and recommends their expansion.

In the field of engineering sciences, the WBGU welcomes the 'Germany decoupling' initiative of the German Academy of Engineering Sciences (acatech) and suggests the systematic integration of the circular economy into all resource-related research fields (acatech, 2017). This applies in particular to the increasing volume of electronic waste (Section 5.2.5), but also to other material flows. Studies should be conducted on the causes of the growing demand for material and on strategies to avoid it, on the possibilities of sustainable product design, on substituting materials with biodegradable ones, and on making products easier to repair. Such topics should become more widespread in engineering research and teaching. The practicability and potential of specific material and component cycles should also be looked at, as should cycle-oriented consumer practices and business models.

10.2.2.4
Business: integrate ethics and sustainability aspects into in-house corporate R&D

Two thirds of annual research and development expenditure in Germany is financed by the private sector with the primary aim of going straight into application and achieving commercially exploitable results. It concentrates primarily on the high-value technology sectors (BMBF, 2018). In order to encourage responsible innovation, the WBGU recommends systematically incorporating ethics and sustainability in the sense of Responsible Research and Innovation (RRI, Lindner et al. 2016) into private-sector high-tech development. To this end, companies should on the one hand develop guidelines that consistently integrate ethics and sustainability into their in-house research activities; on the other hand, they should offer appropriate training and further-education programmes to empower developers to critically engage with conscious (e.g. privacy by design) and unconscious (e.g. gender stereotypes) assignments of values in technologies, for example in the development of AI and algorithms. Furthermore, support should be given to research linking design ethics with professional ethics (such as the IEEE initiative on 'Ethically Aligned Design').

Research funding should provide companies with corresponding incentives. In future funding lines, the BMBF and the EU should make the integration of ethics and sustainability into corporate research a prerequisite. This would make it possible to link research funding in relevant areas to the collection of corporate data on resource flows and energy consumption, and to the development of systems that monitor, warn about, and forecast breaches of existing environmental regulations; the aim is to integrate sustainability requirements more firmly into production processes. In the case of funding approaches for R&D collaborations at the federal and EU level, incentives should be offered when consortia are created to bring specialists in digitalization together with experts in sustainable production approaches within a project framework. In addition, the EU should support the further development of regional innovation systems that focus on the systemic-synergetic interlinking of digitalization skills and sustainability transition management.

10.2.3
Establish research institute(s) on the fundamental issues of digitalized sustainability

The institutional capacity of German environmental and sustainability research has been successively expanded over the past decades, and the level of research expenditure by the Federal Government (more than €1.4 billion) is very high by international standards (BMBF, 2018a: 287). Research activities on digitalization have also been further expanded, especially in recent years. The Weizenbaum Institute for the Networked Society (2017) or Cyber Valley between Stuttgart and Tübingen, with its International Max Planck Research School for Intelligent Systems (2017) are just two examples of start-ups and boosts to capacity in recent years. However, there has been no systematic interlinkage of programmes between the two thematic blocks of digitalization and sustainability.

As a first step in this direction, an institute was founded in 2017 with the world's most comprehensive funding for basic research at the interface between the internet and society: the Weizenbaum Institute for the Networked Society researches the ethical, legal, economic, sociological and technical aspects of digital change from a social-science perspective. In addition, a cross-sectional department on digitalization and sustainability incorporating different research groups was set up, which could provide initial stimuli for a further research institute.

10.2.3.1
New research institutes at non-university research institutions

The WBGU sees a further need for financially independent research centres which, although they have a technological knowledge base, do not themselves develop technology, but rather look into the implications of developments for present and future generations. The WBGU therefore encourages the establishment of research institutes, e.g. at the Leibniz Association, Helmholtz Association, Fraunhofer-Gesellschaft or Max Planck Society, or as federal or state government institutes. From a sustainability perspective, these should close current and future research gaps (Section 10.3) as quickly as possible and set new standards not only in terms of the quality but also the speed of research. On the assumption that technology should never be designed, developed or implemented without considering the implications for society, the WBGU recommends that potential and impact research, especially with regard to global environmental impacts, be established and promoted at the institutes.

10.2.3.2
Implement initiative for a new Max Planck Institute for 'Geo-anthropology'

An article sponsored by the Max Planck Society in the journal Nature (Rosol et al., 2018) encourages the creation of a new branch of interdisciplinary research on 'geo-anthropology'. The aim is to systematically analyse global change in the Anthropocene and to bring together expertise from the natural sciences, humanities and engineering in an interdisciplinary way in order to develop prospects for sustaining the natural life-support systems. Transformation processes in the Digital Age can be better understood with the help of such basic transformation research (WBGU, 2011). The WBGU therefore supports the initiative for a new Max Planck Institute in the field of 'geo-anthropology' (Rosol et al., 2018).

10.2.4
Further develop the science system and establish new forms of cooperation between science and society

In view of the question raised from the perspective of transformative research (Section 10.1) as to whether "the institutions, the internal structures of universities and scientific institutions, the reputation systems, the quality assurance systems, the financing structures or the career biographies in today's science system are still appropriate for suitably relating knowledge generated within the science system to society and its challenges" (Schneidewind, 2015:89), the WBGU believes there is a need both for the consistent further development and implementation of open science and for new forms of cooperation between science and society.

10.2.4.1
Open scientific structures for the joint production of knowledge

The WBGU shares the European Commission's programmatic orientation towards open science as a collaborative approach with new possibilities for generating, teaching and communicating knowledge based on digital infrastructures and collaborative tools. This approach aims for a systemic switch in all areas of scientific work – e.g. from standard practices in the academic publication of research findings to the use of all the available knowledge generated in shared exchange from the beginning of the research process (European Commission, 2016:33). On this basis, the WBGU recommends:

- *Make science as open and inclusive as possible:* The WBGU recommends working towards a further opening of research practice beyond the current incentives, involving not only data, methods and results, but also the entire process of scientific work. At the same time, inclusion should be promoted both within science and in areas close to science, e.g. through citizen science. In this way, applied scientific work can be accelerated, established more firmly in society, and geared more towards the common good. Increases in efficiency on the one hand, and the democratization of scientific knowledge from its creation to its dissemination on the other, are not mutually exclusive but can be mutually beneficial. At the same time, societal needs in the sense of the common good can be addressed more directly by research in this way (Arza and Fressoli, 2017:468).
- *Bring together sustainability, digitalization and open science:* In this context, the digitalization of research practice must be consistently enhanced with sustainability goals, and sustainability-oriented research must be supported digitally. To this end, the great potential of open and inclusive science can be exploited within the framework of current developments such as the European Open Science Cloud (EOSC) and national research data infrastructures (RfII, 2018a, b), but also beyond this. The WBGU believes that the principles of the GO FAIR initiative for research data – Findable, Accessible, Interoperable and thus Reusable (FAIR) – which up to now has only been established in Germany, the Netherlands and France, should not only become the standard for the EOSC (Nature, 2017:451) and internationally, but also take sustainability into account in its infrastructure design. In addition, every publicly funded R&D project proposal should explicitly answer not only questions on data protection and ethics, but also standardized questions on sustainability. The research worthiness of a project should take into account its contribution and relevance to the sustainability goals.
- *Expand science studies into open science:* Concepts associated with open science – such as open access, open data, open source, review, education and citizen science – will inevitably remain the subject of intense debate (Bartling and Friesike, 2014). In detail, many research questions on concrete implementation are still open, which is why the WBGU believes that targeted research funding of open science and its associated concepts is necessary. Specific programmes in science research would need to be launched in order for science to be actively involved in accompanying and shaping further development.

10.2.4.2
Digitally supported science in and with the public – from local to global

The inclusive nature of future open science also affects the public discourse on science (knowledge communication), including feedback channels relevant to democracy and literacy, e.g. data journalism based on open data, transdisciplinary formats and citizen science. This inclusion of others can only succeed if mediated via appropriately networked technical infrastructures for science (e.g. research information systems or research data infrastructures), which to date have been dominated by a small number of mainly private providers. By contrast, digitalized infrastructures in the public sector (Section 5.3.5) could be linked to corresponding scientific repositories for organizing society's knowledge archive (Section 5.3.10) and transdisciplinary discourse. For this purpose, the national initiatives on research data infrastructures must be networked at the European and international levels and go beyond research data. Inclusiveness in this sense also means that the scientists themselves are involved in building and operating the digital research-data infrastructures, which gives them greater freedom but also means additional work. At this point, it is therefore crucial to create corresponding incentives – which have been lacking up to now (Borgman, 2010; Klump, 2012) – for example in the form of corresponding career paths without detrimental effects on scientific careers, or explicit research funds for the conception, implementation and application of sustainability research software. Furthermore, the potential of international research collaborations facilitated by digital and digitalized infrastructures could be exploited with the greater involvement of developing countries and emerging economies in the sense of worldwide knowledge development and communication. With regard to global social and digital inequality, this could further counteract the systematic distortion of scientific work and scientific communication that happens to the detriment of researchers in those countries (Asamoah-Hassan et al., 2017). In this context, barriers between different scientific language areas (both cultural and discipline-related) could similarly be further reduced through the use of natural (including artificial) language processing (an AI application).

10.2.4.3
Digitally supported transdisciplinarity and interdisciplinarity for solving societal challenges

The success of modern science is largely based on the specialization of research fields and the differentiation of disciplines. A newly emerging digital spectrum of methods and new digital instruments open up possibilities for the further differentiation of the scientific disciplines and for new disciplines at the intersections. However, cross-disciplinary exchange is of particular relevance for sustainable digital development. Although the STEM disciplines (science, technology, engineering and mathematics) are essential to gain expertise on how technologies can be shaped and on socio-technical systems, a technical focus alone is not enough to be able to act with foresight. The knowledge that constitutes a mature society (culture, ideas and values, etc.) is developed in particular by the humanities and social sciences. For example, important questions about the future, such as how to handle data or the increase in networking, can only be answered in an interdisciplinary way and in a dialogue with society (Mainzer, 2016:225). In addition, innovative discourses on reciprocal links between digitalization and sustainability are increasingly being conducted outside of science, for example among NGOs, think tanks and private companies. Transdisciplinary research that wishes to build a new relationship between science, society and nature (Krohn et al., 2018) is therefore, in the WBGU's view, an important building block of scientific culture in the Digital Age. Digital instruments and cooperation formats (Section 10.2.4.1) should be developed and used for the new forms of collaboration. This makes it possible, for example, for participants in political discourses to be better informed. Such formats can provide evidence-based information about the potential effects of digitalization and the limits of the current state of knowledge (Section 5.3.2). Furthermore, a large number of perspectives are brought together in a targeted manner in order to gear the development of knowledge more closely to the common good and promote a sustainable Digital Age in a dialogue with society. The ability of people to imagine their futures (futures literacy) is a core competence in this context (Section 5.3.4).

10.2.4.4
Organize a relevant proportion of research in an inter- and transdisciplinary way and integrate epistemology more closely into scientific training

The WBGU recommends a significant increase in the proportion of research funds used for inter- and transdisciplinary research. Amounts of up to 20% of public research funding are recommended in the discourse on transdisciplinary research. Transdisciplinary processes offer in particular potential in co-designing and in the joint production of knowledge by scientists and societal stakeholders with a view to developing problem definitions and dealing with unintended side-effects for sustainable digitalization. For example, a comprehensive European Expert Round Table process (Scholz et al., 2017) identified a total of 42 unintended, possible negative effects of digitalization in ten overarching topic areas.

In order to support exchange across different scientific disciplines, it is advantageous to have insights into the epistemological prerequisites and limits, and into how knowledge and other forms of conviction come about. The WBGU recommends that epistemological and scientific theory be enshrined more firmly in academic education, for example by integrating such courses more closely into existing post-graduate programmes. In view of their reflective core competence and interdisciplinary capacity for discourse, aspects from the perspective of the humanities and social sciences, particularly philosophy and the history of science, should also be reinforced.

In addition, the WBGU recommends that any academic training in digitalization-oriented or digitalization-related occupations be extended to include explicit components of digital ethics and the methods, processes and tools of their implementation (ACM Code of Ethics, IEEE CS/ACM Code of Ethics and Professional Practice, etc.).

10.2.4.5
To influence public discourse more strongly, provide third-party funding and expand the freedom of researchers

Especially in the field of 'digitalization and sustainability', scientists and scientific institutions are called upon as 'public intellectuals' to raise awareness of sustainability potential, as well as the opportunities, risks and challenges of digitalization. Commitment to the synthesis of scientific findings, their transfer and scientific communication should play a greater role within the research structures in assessing academic performance and appointing professors. The WBGU therefore recommends the provision of additional third-party funding for which both scientists and civil-society actors can apply, in order to have a greater impact on public discourse beyond scientific incentives. An additional incentive could be provided by extended freedoms, such as a reduction in teaching obligations and administrative tasks, which could be made more efficient through digitalization.

10.3
Research recommendations on content

In preparation for the following overview of a possible design for an inter- and transdisciplinary research agenda at the intersection of digitalization and sustainability, the WBGU has evaluated the research recommendations contained in recent reports and scientific publications (Box 10.3-1).

The recommendations on socio-technical research listed here focus on the societal embedding of innovation dynamics for sustainable development. Further research recommendations can be found in the respective topic arenas (Box 10.3-2). Using examples, the WBGU thus believes it is possible to outline the initial contours of future research agendas. This approach embodies a new, integrative perspective that does not claim to provide complete, detailed coverage of the respective subject areas. Even in the relevant discourses on recommendations for action (Chapter 9), the topics of digitalization and sustainability have so far only been interlinked to a limited extent. For example, sustainability and environmental aspects have hitherto been under-represented in the German Federal Government's current key issues paper on AI (Federal Government, 2018b). By way of contrast, the current Federal Research Report (BMBF, 2018a) often addresses these aspects, but as a rule does not relate them to the innovation concept proposed there. The WBGU advocates a research and innovation agenda geared to the major issues of the future, in which SDG-related sustainability issues become an integral part. Based on the 'Three Dynamics of the Digital Age' (Chapter 7), the following section is divided into recommendations for the use of digitalization for sustainability (Section 10.3.1), for sustainable digitalized societies (Section 10.3.2) and for the future of *Homo sapiens* (Section 10.3.3).

10.3.1
Research on digitalization for sustainability

The line of research entitled 'Research on sustainable digitalization' deals with the question of how digital technologies and the development of digital and digitalized infrastructures can be shaped in a sustainable way, especially with regard to their consumption of energy and other resources and the establishment of a circular economy. Another question is how digitalization can be used as an instrument for implementing SDGs and for climate protection. Both lines of research are part of this section.

10.3.1.1
Research on the ecological footprint of digital solutions and the recycling of products, components and raw materials

In view of the expansion of the infrastructure and the increasing number of devices and their short lifespan, the demand for material resources and energy consumption are expected to increase further as a result of digitalization. At the same time, particularly in the case

Box 10.3-1

WBGU analysis of research and recommendations on artificial intelligence

Preparations for writing this report's two chapters of recommendations included reviewing already existing research recommendations. Corresponding text passages from 45 source documents that implicitly or explicitly position digitalization in the context of sustainability were condensed into compact statements in a qualitative-interpretive discourse analysis. The entire analysis, covering both action and research recommendations, is available for download on the WBGU website. In some cases, these recommendations are repeated several times in different sources. The results show that, internationally and nationally, there is currently a strong emphasis on research recommendations formulated from a technical perspective, and that direct references to sustainability are rarely explicit. The topics were structured in line with the categories of the stirring paper on digitalization and sustainability, which preceded this report (WBGU, 2018a). With the exception of the thematic block on knowledge, education and digital literacy, it is relatively rare for social and ecological research questions to be addressed; the same applies to important issues about the future such as the further development of humanity and associated risks. Some such approaches are formulated for AI research, which is addressed in the publications examined as follows:

- researching the opportunities and risks of AI more closely;
- ethical reflection as a prerequisite for research funding on AI;
- more ethical and legal research on AI;
- gearing AI research to the common good;
- interdisciplinary research on AI standards;
- establishing the precautionary principle for AI and robotics using technology-impact assessment;
- proactively anticipating the dual use of AI and robotics, developing best practices;
- using AI for a more ecological economy using green AI/open ecological data;
- more research on the use of AI in the world of work;
- research on strategies against AI bias;
- developing the international coordination of AI research;
- evidence-based AI research;
- no militarily motivated AI arms race in research.

The list shows that this text corpus, which is specifically tailored to the topic of the report, already addresses some approaches to sustainable digitalization research involving AI. In this chapter, the WBGU takes up these approaches in a thematically broader and more concrete form. It should be noted, however, that the previously analysed material can only be selective and is not representative, as further publications are constantly appearing. AI was chosen as an example topic at this point because it is a research area with a disproportionately fast rising number of publications (Figure 10.3-1). In the last ten years, the number of AI publications has increased nine-fold, while the number of publications in computer science has risen six-fold and the number in all disciplines has almost tripled, as the Scopus database shows (scopus.com). Although this database, despite its size, does not reflect the global research landscape in a representative way (corpus bias), statements on general trends can be made without any bibliometric or scientometric concerns.

AI publications mainly appear in computer science journals (Figure 10.3-2). This suggests that a technology- and application-oriented perspective dominates in which digitalization and sustainability are still (too) seldom linked. In view of the increasing use of AI technologies in core areas of society, the WBGU believes it would be desirable if the expected future growth of AI publications were to contain a higher proportion of AI publications produced outside computer science in a broader context and with an explicit consideration of sustainability. With regard to interdisciplinarity, Figure 10.3-2 shows a clear imbalance between AI-related publications within and outside the computer sciences.

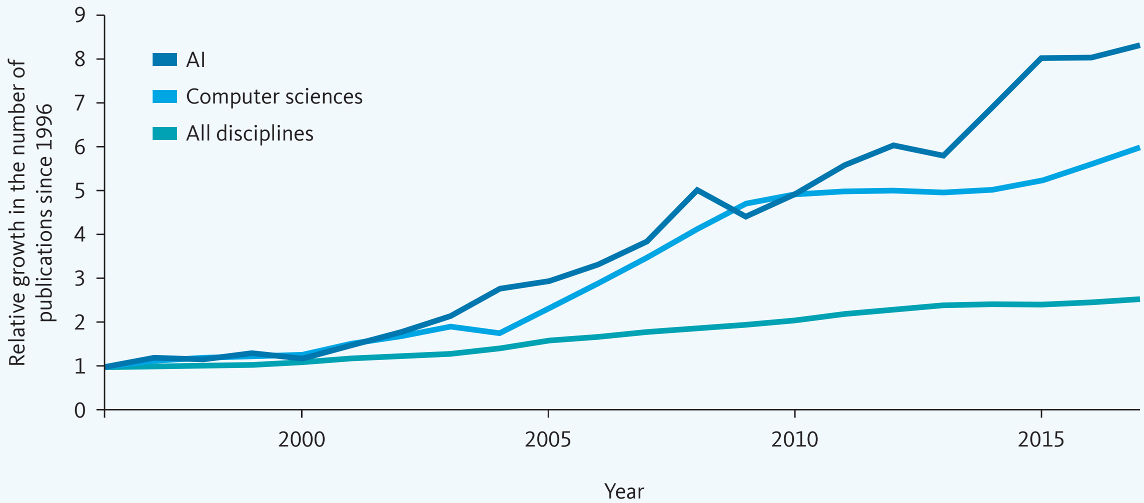


Figure 10.3-1
Growth in the number of publications on AI compared to computer science and publications as a whole.
Source: WBGU, own diagram based on the Scopus database (scopus.com)

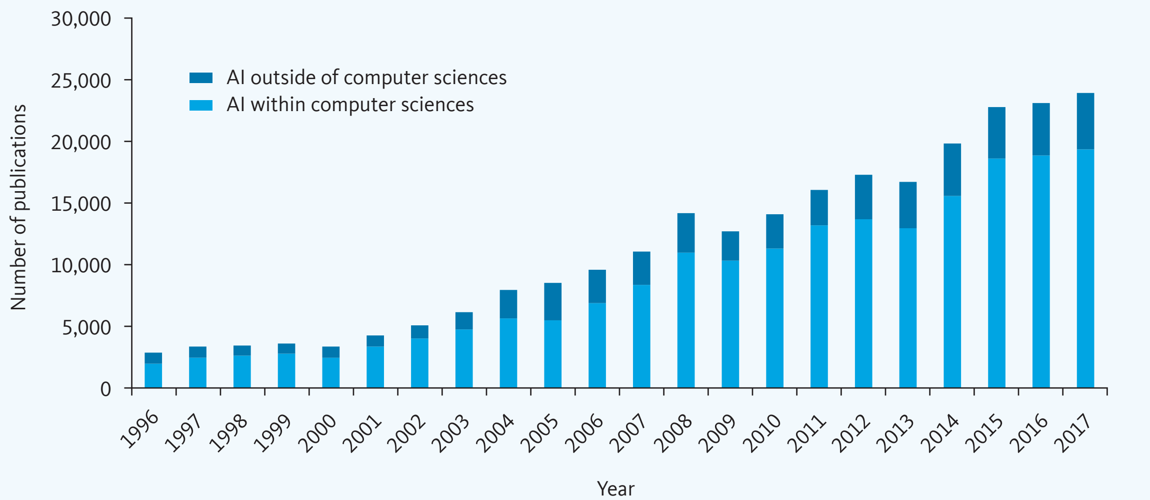


Figure 10.3-2
Number of scientific publications on AI.
Source: WBGU, own diagram based on the Scopus database (scopus.com)

of electronic waste (e-waste), achieving closed material cycles is still a long way off for critical raw materials (e.g. strategic metals, rare earths; Section 5.2.5). Moreover, the information available on the ecological effects of digitalization is far from sufficient. A qualified assessment of the development of the global demand for energy and digital resources is hampered by insufficient data (Köhler et al., 2018). Corresponding research projects should be carried out to improve our understanding of the ecological footprint of digital technologies and their use. The WBGU therefore recommends a broad-based, transformative research offensive consisting of the following components:

1. The collection of data on the physical composition of the ICT hardware and an assessment of future resource needs for the development of technical infrastructures (servers, data centres, etc.) and devices, as well as the development of a global roadmap for phasing out toxic substances.
2. Research into improved approaches to avoiding or reducing e-waste by resource-saving device development, the optimization of product architecture, improved target orientation and accessibility of information about re-use (e.g. second-hand market, sharing and services) and reparability, and even material substitution and the development of biodegradable electronics (Section 5.2.5).
3. Development of innovative processes for the digitally supported, safe and lucrative further processing of e-waste (remanufacturing), technical solutions for recycling reusable materials from e-waste, such as strategic metals or rare earths, and the development and promotion of corresponding digital platforms in order to significantly increase levels of reuse and recycling.
4. Social science research should contribute to sounding out the theoretical and practical limits of the circular economy and assessing the need for further measures such as efficiency and sufficiency strategies. In addition, scientific studies – incorporating nationally or regionally specific impact and success factors – on economic incentives to reduce the demand for products at the beginning of the design phase and to prolong product lifecycles are recommended.
5. Research to determine and minimize the resource requirements and energy consumption of individual technologies, e.g. blockchain or deep learning; development of tools to analyse lifecycles taking these factors into account.
6. Early integration of behavioural sciences, e.g. environmental psychology, into the research and development process of new technologies, since new solutions (e.g. smart homes or smart grids) do not automatically lead to more efficient use and resource conservation unless the motivation for behavioural changes is triggered (Schultz et al., 2015).

More specific recommendations on the relationship between digitalization and electronic waste can be found in Section 5.2.5.

Box 10.3-2

Arenas of digital change

Further research recommendations are made on various topics in the arenas of digital change (Chapter 5). Here is an overview of the topics with the corresponding references to make them easier to find.

- Sustainable Industry 4.0 and the circular economy – how digitalization is changig industrial metabolism (Section 5.2.1)
- New forms of digital economy: approaches to sustainable economic activity in the Digital Age (Section 5.2.2)
- Digitalization of consumption and sustainable consumer behaviour: promotion of solidarity-based lifestyles (Section 5.2.3)
- Sustainability in online commerce: status quo and prospects (Section 5.2.4)
- Digitalization: from the electronic waste problem to a solution for the circular economy? (Section 5.2.5)
- Digitalization for climate-change mitigation and the energy transformation (Section 5.2.6)
- 'Smart city': sustainable urban development with digitalization? (Section 5.2.7).
- Sustainable urban mobility in the Digital Age (Section 5.2.8)
- Precision agriculture: the next step towards industrialized agriculture? (Section 5.2.9).
- Digitalization in agriculture in developing countries (Section 5.2.10)
- Digitally enhanced monitoring of ecosystems and biodiversity (Section 5.2.11)
- Digitalization as an opportunity to promote a collective global awareness of sustainable development (Section 5.3.1)
- Digitalization and public discourse: the end of rational argumentation or the chance of a global agora? (Section 5.3.2).
- Challenges of the scoring society (Section 5.3.3)
- From education for digitalization and sustainable development to future-proof education (Section 5.3.4)
- Public-service ICT as part of basic public services (Section 5.3.5)
- Digital technology as a gender bender? (Section 5.3.6).
- Digital self-tracking: between empowerment and loss of control (Section 5.3.7)
- International division of labour and digitalization: consequences for developing countries and emerging economies (Section 5.3.8)
- Sustainable working environments of the future (Section 5.3.9)
- Digital commons (Section 5.3.10)

10.3.1.2
Digitalization as a key factor in decarbonization

The goals for climate-change mitigation agreed in the Paris Agreement require not only the decarbonization of the global economy, but also, in the long term, the actual removal of CO_2 from the atmosphere (IPCC, 2018). Research on digitalization's contribution to the global energy-system transformation should therefore be organized in a systemic way, i.e. going beyond the sectors of energy, mobility and heating. The WBGU recommends resolutely pursuing the vision of an energy system that is based 100% on renewable energies and enshrining it as a central research mission. A further focus should be research into cost-effective and robust solutions for a reliable power supply in off-grid regions in emerging economies and developing countries. A wide variety of digital technology applications are of importance here, e.g. for mini grids based on renewable energies (IRENA, 2016). Finally, greater emphasis should be placed on the reliability and stability of the energy supply, as well as on privacy and data protection, in the course of digitalization. Furthermore, smart grids, smart meters and other intelligent applications lead to new complexities of energy supply and use, the implications of which are a further research topic. Specific recommendations on the impact of digitalization on climate-change mitigation and energy-system transformation can be found in Section 5.2.6.

10.3.1.3
Sustainable Industry 4.0 and resource-conserving industrial metabolism

The consumption of materials and energy should be digitally optimized, economically used, and based consistently on the circular economy and recycling. In addition to this, industrial metabolism – i.e. the material and energy flows connected with goods production – should be designed in such a way that the natural life-support systems are sustained, e.g. that significant contributions can be made to reducing greenhouse-gas emissions. Within existing research initiatives on Industry 4.0, application-oriented proposals should be systematically developed for an improved coordination of material flows through the digital networking, control and monitoring of manufacturing processes. Above all, projects should sound out the potential of additive manufacturing processes (3D printing) for forms of goods production that conserve resources and offer improved recycling potential in logistics and material use. Beyond the research objectives of the sustainability-oriented, further developed digital coordination of industrial value chains, ideas should be generated on how completely new, regenerative 'technical ecosystems' of digitalized goods production can be established (Moreno and Charnley, 2016). Research should also be carried out into ways of using ICT (e.g. IoT) to improve links between production-, product- and use-related data within cross-company value-added systems, and to evaluate them using AI in order to identify new potential in a circular economy for a comprehensive tracking and monitoring system of resource flows – and to market these via digital platforms. More specific recommendations on the influence of digitalization on industrial metabolism can be found in Section 5.2.1.

10.3.1.4
Research on digitalization for global food security and nature conservation

Research and development on the digitalization of agriculture should be oriented towards the goal of globally sustainable land use. Germany's Federal Government should launch a research programme on sustainability, resource conservation and diversity in agriculture (e.g. crop rotations, biodiversity) using digital solutions. In particular, the focus should be on the potential benefits and risks of a digitalized industrial agriculture, a decidedly sustainable precision agriculture, and the framework conditions and incentives that this requires (Section 5.2.9).

In the context of developing countries and emerging economies, the potential for efficiency gains in smallholder agriculture should be explored through improved access to information and knowledge and the removal of barriers to the adoption of digital innovations at the level of smallholder and medium-sized farms (Section 5.2.10).

Given the rapid pace of technological development, the medium- to long-term potential benefits and risks of digitally supported nature conservation have not yet been sufficiently researched (Section 5.2.11). The focus should be on contributions to global and comprehensive biodiversity monitoring (e.g. remote sensing, tracking, image recognition and analysis, data management) and on digital support for practical nature conservation (e.g. inventories of endangered ecosystems and species, combating poaching).

10.3.1.5
Use digitalization for sustainable urban development

In its last flagship report (WBGU, 2016a: 423ff.), the WBGU presented comprehensive research proposals on sustainable urbanization and referred to technological transformation processes (WBGU, 2016a: 48ff., 368, 373). Urban areas have become the central organizational form for almost all human societies, and each is seeking 'its own way' towards a sustainable future. In order to integrate digital solutions and use digital modelling, simulation and prognosis for urban sustainability, funding should be provided for empirical (case) studies and real-world laboratories that look critically and constructively at the economic, social and ecological implications of digital smart-city and smart-community approaches and study them empirically and in detail on location. In the same way, international comparative studies on significant differences in motivation, measure portfolios, actor structures and implementation dynamics of smart-city approaches in different countries or regions should be conducted to advance international learning processes on sustainability issues in urban strategy and project development. There should be a special focus on the contribution of different ICT applications (e.g. for mobility, housing, work, security, environmental monitoring) to achieving environmental objectives and on their acceptance, the aim being to assess their potential for use and dissemination across different population strata. For only if the new digital possibilities are used widely can significant digitalization-related environmental effects be achieved (e.g. savings in energy and water requirements, more efficient use of many other material resources, emissions reductions). The development of technology is currently taking place mainly in industrialized countries; however, just under 90% of urban population growth up to 2050 is expected to take place in Asia and Africa (UN DESA, 2015). Therefore, digital technologies for urban development should be studied against the background of different contextual situations and cultural areas. In this way, best practices can be identified and sustainable solutions implemented. More specific recommendations for action on sustainable urban development through digitalization can be found in Section 5.2.7.

10.3.1.6
New development models for developing countries and emerging economies

There is a need for research into the question of which new development models might arise for developing countries and emerging economies in the course of digitalization. Digital technologies can, for example, help overcome institutional problems in developing countries and emerging economies or open up access to markets and necessary services (e.g. financing). In this context, research needs to be done to determine which instruments of innovation and economic promotion can be used to establish or secure the inclusion of these countries in the digital economy. Initially, the conditions should be studied under which developing countries and emerging economies can exploit this new development potential for themselves. It would also be necessary to analyse what development cooperation can achieve in terms of possible new development models and opportunities. Similarly, the effects of digitalization on trade structures and the division of labour, and thus, in a broader sense, on a fundamental development model of recent years, are not clearly foreseeable to date. Studies have hitherto been limited to the presentation of individual cases. There is therefore already a considerable need for research on the fundamental question of the future and future design of global value chains and the international division of labour. Moreover, further recommendations for action, also for future development cooperation, would also require a deeper understanding of the factors that determine whether and when work steps are automated and, for example, relocated back to industrialized countries (Section 5.3.8). At the same time, digitalization enables a more intensive exchange of research results and processed experience (Pawelke et al., 2017:11), which, in the WBGU's view, should be promoted particularly to make digitalization sustainable in developing countries and emerging economies and to encourage specific innovation in local contexts.

10.3.2 Research for digitalized sustainability societies

The overarching line of research entitled 'Digitalized Sustainability Societies' should deal with the question of how societies can interpret the system-changing impact of digitalization on the Earth system, society, economy, human beings and technology, make it sustainable and counter any emergences that occur.

10.3.2.1 Work in the future: develop new forms of inclusion

At present, it is mainly gainful employment that ensures broad societal and economic inclusion: at the same time, it is of key importance to many people's self-esteem. The partial substitution of manual and intellectual gainful employment by intelligent machines thus touches on very profound aspects of societal cohesion and personal life. It raises questions about further developed forms of work, for example a shift in emphasis to social work, but also about possible alternative life goals, styles and designs. Up to now, not enough ideas have been developed on alternative and simultaneously incentive-compatible mechanisms of distributing work, income and prosperity that offer suitable incentives for participation in society and the economy as well as for (further) education, research and development; the broader societal implications of such mechanisms have not been examined either. Furthermore, there is the question of the political consequences of a societal change caused by a further developed understanding of work; e.g. what might be the consequences of ensuring economic inclusion via broad redistribution mechanisms for the stability and functioning of democratic political systems? The specific challenges in developing countries and emerging economies, and changes in the international division of labour, should be described in more detail and taken into account when studying these questions. More specific recommendations on the field of digitalization and work can be found in Sections 5.3.8 and 5.3.9.

10.3.2.2 Develop financing concepts for the state and social systems

Today, the financing of state systems is still predominantly based on the taxation of the (hitherto primarily immobile) factor labour. The social security systems in many countries are also institutionally coupled to gainful employment. Existing tax and contribution systems must be fundamentally reviewed, both with a view to the future efficiency and financial room for manoeuvre of the state and social security systems, and with a view to possible distortions of the price of labour compared to production factors such as (financial) capital or data. At the same time, there is a considerable need for research into how alternative systems of taxation can be designed that preserve the state's financial leeway for action if, in the course of digitalization, value creation shifts further to intangible assets such as data, human labour becomes more easily substitutable and even more mobile, or if, in the extreme scenario, human labour is completely performed by machines (Section 5.3.9).

10.3.2.3 Research on the design of human-machine interactions

The WBGU recommends early and comprehensive research into the possible effects of interaction with (partially) autonomous technical systems. Possible research questions are as follows: How must such systems be designed to support desirable interaction and what possible negative implications need to be considered? Living together with autonomous systems raises diverse questions about the effect of interaction with such systems: what forms of interaction are desirable? How must systems be designed to promote appropriate and safe interactions and prevent dysfunctional interactions? Which groups need to be differentiated (e.g. children or mentally handicapped persons)? Social sciences, especially psychological research, must be integrated into socio-technical developments at an early stage.

Box 10.3.2-1

Real-world laboratories

There are no universally valid blueprints for making global digital transformation sustainable in the diverse areas of life. In view of the many unpredictable and rapid technological developments, this creative process remains a search and learning process involving many uncertainties. The special challenges of digital change are, on the one hand, that it affects societies in a complex way, so that foreseeable effects take place beyond established forecasting areas. On the other hand, it is necessary to shape and regulate before all the effects are foreseeable. In these real-world conditions, it is important that Europe's digital innovative capacity is geared towards the SDGs. In view of these challenges, the WBGU recommends that the EU set up 'European labs for a sustainable and digital future'. In real-world labs, scientists and actors can experiment and try things out to jointly generate knowledge and work out problem solutions on how best to make the digital transformation sustainable. Real-world labs make it possible to experiment with innovations within a protected framework and, at the same time, gain more comprehensive knowledge faster.

Real-world labs (also known as 'living labs' or 'citizen science projects') are currently being carried out in several European countries; some of them are transnational (Deutscher Bundestag, 2018). Real-world labs have not yet become established at the EU level, although they offer significant opportunities for further developing a European vision, strengthening European innovation, and improving quality of life for European citizens. In the research context, European real-world labs could be linked to the activities of the European Institute of Innovation and Technology (EIT) within the framework of Innovation Communities (such as 'EIT Climate-KIC'). In addition to further developing the EIT's existing transdisciplinary innovation and research approaches into holistic European real-world labs, the WBGU also recommends setting up such laboratories on new topics, such as the sustainable future of work.

Real-world lab on the 'Sustainable Future of Work'

Labour markets are an important guarantor of social inclusion. Especially younger population groups and migrants are increasingly affected by new employment and work realities, such as new work, platform-based employment contracts, and the blurring of working hours and work location in gainful employment. This opens up both opportunities and risks for a person's quality of life, for social cohesion, and for the orientation towards a future-proof concept of sustainable work (Section 5.3.9). A European real-world lab on the 'Sustainable Future of Work' could experiment with new forms of social security (e.g. ecological transformation income; Swaton, 2018) and organization under labour law that also take into account the special challenges of transnational working and living environments in the EU. The real-world lab would thus also play a pioneering role in the ongoing expansion of the EU's social pillar. At this interface of sustainability and digitalization challenges, it is necessary to pool the energies of science, business, university and college education, and civil society in order to test new future models.

10.3.2.4 Technical and experimental impact assessment for dealing with major uncertainties

Due to the dynamics of digital transformation processes, dealing with uncertainties, for example unexpected or unintended side effects (or 'unseens'), poses a particular challenge. The WBGU recommends testing innovations and (new) regulatory instruments in real-world laboratories in a temporary, spatially delimited, legally adapted (experimental clauses, special permits, etc.) and well-secured field with open-ended results (Box 10.3.2-1).

In addition to real-world laboratories, further experimental spaces should be strengthened (e.g. governance barcamps), which are explicitly focused on considering possible consequences. The development of capacities for IT-oriented governance research and IT-supported governance formats is of great importance here.

10.3.2.5 Research on sustainable handling of data

The effects of the European General Data Protection Regulation (EU-GDPR) in practice should be empirically tested and proposals for further development elaborated. For example, there should be research on how data-access regimes or a data-sharing obligation might be designed in detail. The technical, procedural and regulatory requirements for protecting personal data must be taken into account here, also with a view to the risk of the future 'de-anonymization' of currently non-personal data. What form should monitoring by corresponding supervisory authorities for digital products and services take, e.g. with regard to the enforcement of data obligations, data protection, data-security standards or possible discrimination against users? There should be studies on how to identify, measure and trace the added value of data availability and the availability of certain digital products and services for society and the public. Research should also be conducted into how public, data-based goods (Section 5.3.10) can be made available in sufficient quality and quantity.

10.3.2.6 Research on social platforms

New developments in social platforms should be continuously accompanied by research, e.g. with a view to how group dynamics, self-representation or the sharing of personal information (e.g. fitness and exercise data on fitness platforms, opinions or similar private information) can affect people's well-being, quality of life and social interactions (Section 5.3.7). In addition, there should be research on which quality criteria are to be applied to social platforms, their services and applications, and how these are to be communicated, checked and improved. Both here and in general, targeted education (Sections 5.3.4, 9.1.4) and corresponding educational research are needed to enable people to deal competently and responsibly with new technologies and the high dynamics of (technical) progress. The possible impacts of social platforms on sustainable and environmentally conscious behaviour should also be explored in greater depth (Section 5.2.3).

10.3.2.7
Educational research on empowering the individual in a digitalized sustainability society

In order to teach transformation knowledge and action, the WBGU recommends investigating how (digitalized) educational measures can promote knowledge and action for the Great Transformation (WBGU, 2011), ideally through an institute for educational research on and in the sustainable Digital Age. This would focus in particular on research to promote creativity, cooperation and innovation as well as environmental awareness and futures literacy. Transformative education needs to be strengthened to constantly expand the ability to reflect. Parallel to this, further spaces for reflection could be created within the framework of collaborations with existing institutions, for example in the fields of science fiction, art, culture and the integration of forms of knowledge. Furthermore, research is needed to enable the inclusion of disadvantaged groups with the aim of investigating and evaluating which digitalized educational opportunities also make it possible to include disadvantaged groups (particularly with regard to gender, age, origin) and how knowledge acquisition can be digitally promoted. Support should also be given to studies that address the impact of digitally mediated content on learners' skills. This is very likely to require a shift in the focus of education policy. Abilities must be strengthened that empower people to lead a self-determined, meaningful life without today's labour-market structures. These skills include social-interaction skills, empathy, creativity, keen perception and an ability to adapt quickly (in the sense of a well-developed ability to react to unexpected events, etc.), but not so much the ability to teach detailed knowledge. More specific recommendations on education in the Digital Age can be found in Section 5.3.4.

10.3.3
Research on the future of *Homo sapiens*

A superordinate line of research entitled 'Research on the future of humankind and the preservation of human dignity' should deal with the question of where the limits of old and new ideas on what it means to be human lie, in view of the interdependence of humans and technology and the design of machines with (initially supposed) human characteristics. As a general rule, individuals or groups who wish to evade digital developments should also be taken into account in all future developments; this also applies explicitly with regard to research ethics.

10.3.3.1
Digital anthropology: how is the idea of what it means to be human changing?

In the Digital Age, being human is itself becoming a topic of sustainable development. The physical and social fusion of humans with digital technology on the one hand, and the humanization of technology on the other, raise the question of the *conditio humana* in a new and controversial way. In philosophical thinking beyond anthropocentric humanism with the human being at the centre, it therefore needs to be continuously analysed in the future how the concept of what it means to be human develops dynamically in relation to the environment and increasing technical possibilities (Coeckelbergh, 2013b, 2017), in order to be embedded into the real world or into its 'natural' body. The WBGU strongly recommends that human dignity (Chapter 2) be placed at the centre of corresponding anthropological and ethical debates and enshrined in responsible research and development.

10.3.3.2
Research the effects of digitalization on cognition, emotion and social life

Since digitalization, and in particular the many forms of interaction between humans and machines, will continue to influence key aspects of life such as cognition, emotion and social life in the future, it is necessary to conduct and provide targeted funding for interdisciplinary research into these aspects (SVRV, 2017: 17ff.). Behavioural changes at the psychological and social levels must be systematically investigated in this context. In the WBGU's view, this should also be explicitly done in a positive sense for sustainable purposes, such as promoting a 'global awareness for sustainable development' (Section 5.3.1). Other relevant issues include the effects of multitasking (especially in children) on cognition (i.e. processes of attention, remembering, thinking, problem solving and creativity), the influence of digital media use (e.g. social networks) on the sense of social belonging and emotion management, and the effects of workplace surveillance and health and safety in times of the technologization of human beings.

10.3.3.3
Exploring the future of human civilization

In the course of increasing international networking, the WBGU recommends using an interdisciplinary approach in order to research emerging risks to human civilization. In general, in view of the dual-use character of technologies such as AI and robotics, responsible innovation, research on ethics, technology-impact assessment and proactive technological change must be expanded internationally in line with the precautionary principle. To this end, new international cooperation formats should be researched, also taking into account limits of development that will become necessary in the future.

Timely implementation of the recommendations for action and research will make it possible to exploit the potential of digital change for the Great Transformation towards Sustainability and to contain its risks. This WBGU report is intended as an stimulus for long-awaited discussions and initiatives on all levels and with all actor groups.

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11

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Glossary

12

Additive manufacturing / 3D printing
refers to various processes in which the desired component is successively constructed on the basis of a digital 3D model by the targeted layer-by-layer application of the raw material (Caviezel et al., 2017: 9). The term '3D printing' is also commonly used since the manufacturing process has some similarities with 2D printing (Bourell, 2016: 2). → Section 3.3.5.4

Anthropocene
means the 'age of man' and is partly derived from the concept of geological ages like the Palaeocene or the Holocene. The term was coined in 2000 by Nobel Prize laureate Paul Crutzen together with Eugene Stoermer and refers to a geological era in which the effects of human activities on the environment have reached a global dimension. This leads to – in some cases considerable – changes in ecosystems, even to the extent of their destruction. Further important changes caused by humans include climate change and ozone-layer depletion in the Antarctic. → Chapter 2

Actuators
are electrotechnical assembly units that convert IT signals into changes in physical quantities, e.g. by means of mechanical movements. In this way, they actively influence their surroundings and control objects (Hoepner et al., 2016: 10).

Algorithm
In general a sequence of instructions for solving a given problem (or, to be more precise, class of problems). Algorithms are always explicitly and well defined, although the respective manifestation of the sequence of instructions in a specific application along concrete data and calculations cannot always be traced. Mathematically, an algorithm corresponds to a calculable function; in terms of information technology, an algorithm is a deterministic set of instructions for a computation. → Section 3.2.3

Artificial intelligence (AI)
refers to "a discipline within computer science that deals with the development of software systems which provide functions whose execution requires what is typically referred to as intelligence" (Burgard, 2018). As in the case of 'intelligence', there is still no uniform definition of artificial intelligence (AI); it is understood in many different ways. Basically, intelligent systems are characterized by the ability to solve problems (to some extent) autonomously and efficiently (Mainzer, 2016: 2). → Section 3.3.3

Autonomy
describes a → core characteristic of the → Digital Age, according to which technical systems independently make decisions and control and optimize complex processes. They can help make better-informed economic, political and social decisions, but also lead to a loss of societal control or an abuse of power – or undermine privacy and freedom. → Section 3.4.3

Big data
is a generic term for developments of methods, technologies and solutions for collecting, preparing, storing and analysing large quantities of structured or unstructured data. In this way, large-volume, heterogeneous, volatile, even not clearly defined quantities of data can be processed in an ever shorter period of time. As a complex socio-technical phenomenon, big data forms the basis for using exponentially increasing volumes of data along the digitalization process to generate added value. → Section 3.3.2

Big Five
refers to the five dominant digital corporations Google/Alphabet, Apple, Facebook, Amazon and Microsoft (also known as GAFAM), which are among the five most valuable corporations in the world in terms of market value (Barwise and Watkins, 2018: 21).

Blockchain / Distributed-ledger technology
These terms refer to methods in which an expandable list of data sets (the 'blocks') are concatenated (the 'chain') using cryptographic methods. The more general distributed-ledger technologies ('distributed registers') are regarded as an innovation with far-reaching societal and technological changes (Schlatt et al., 2016) for cryptocurrencies, cadastres, health data, elections. → Section 3.3.5.5

Core characteristics of the Digital Age
identify the five essential characteristics of → digitalization in the civilizational context and make it possible to understand development trends and the direction of digital change. They comprise (1) → interconnectedness, (2) → cognition, (3) → autonomy, (4) → virtuality and (5) the → knowledge explosion. The WBGU has furthermore analysed the technologization of human beings (→ Figure 3.4-1), but has not (yet) named it as a core characteristic in terms of its effect and breadth. → Chapter 3.4

Cognition
refers to a → core characteristic of the → Digital Age according to which technical systems can perceive, learn, analyse, evaluate and act → autonomously using the methods of the → Internet of Things, → big data and → artificial intelligence. Such systems will fundamentally change our human self-image, the economy, labour markets, learning processes, our knowledge, our interaction with technology, society and nature. → Section 3.4.2

Circular economy
refers to an alternative to the dominant 'linear' value-added chain in which raw materials are extracted by mining, processed into products and, at the end of their useful lives, either incinerated or dumped in landfills as waste (EMF, 2014). The '3Rs strategy' (reduce, reuse, recycle) called for by the UN, among others, is regarded as one of the guiding principles of the circular economy. → Section 5.2.5

Cybersecurity
Also known as information security, cybersecurity refers to the entire field of security in information and communication technology and describes the aim of reducing the risks from the use of ICT caused by threats and vulnerabilities to an acceptable level by taking appropriate security measures (BSI, 2019a). By contrast to safety (functional security), cybersecurity refers to the protection of the internal values of a system, i.e. internal protection, which can also cause immaterial damage externally in the event of misuse, for example when a → person's privacy is violated. → Section 3.3.4

Data protection
refers to measures to protect natural persons from violations of their rights of personality and comprises measures to protect against abusive data processing and handling, to protect people's right to informational self-determination, to protect their privacy in data processing and handling, or to ensure self-determination over personal data. → Section 3.3.4

Data security
Part of → cybersecurity relating to measures to protect technical systems, particularly to protect data from loss, destruction or manipulation by unauthorized persons; in the case of personal data it thus also relates to → data protection. Data security is challenged by vulnerabilities in software and by malware, identity theft and targeted complex sociotechnical attacks (Rescorla, 2005). → Section 3.3.4

Decarbonization
describes the transition process from high-carbon energy sources (coal) to less carbon-intensive (oil and natural gas) and increasingly to CO_2-emissions-free energy sources (solar, wind and hydroelectric power). → Section 5.2.6

Digital commons
are all digitized data assets, information assets and knowledge assets which, as non-rival resources, should be made as broadly, i.e. publicly, accessible as possible in the common interest, → following the idea of commons in general. → Section 5.3.10

Digital divide
refers to the spatial and social-group-specific differences in access to digital services and the (broadband) internet, as well as corresponding differences in skills for dealing with ICT. → Section 5.3.5

Digitalization
The WBGU has a broad understanding of digitalization as the development and application of digital and digitalized technologies that dovetail with and augment all other civilizational technologies and methods. → Chapter 3.1

Digitization
is the process of converting information from analogue to digital form.

Digital Age
is a term used to describe the new social order that, since the introduction of electronic data processing in the 1950s, has emerged with new groups of actors and a more flexible and globalized → polycentric architecture of responsibility. → Chapter 4

Distributed-ledger technology
→ Blockchain

Dynamics of the Digital Age
clarify the option spaces and areas where action is needed in the context of → digitalization and the → Great Transformation towards Sustainability: (1) 'digitalization for sustainability', in which sustainability can be digitally supported, and/or ecological and societal disruptions can arise, (2) 'sustainable digitalized societies', which require a new humanism and are intended to prevent digitally empowered totalitarianism, (3) 'the future of *Homo sapiens*', which is about strengthening the self-confidence of *Homo sapiens* in the conflict over the borderlines between humans and machines. These three Dynamics are already emerging in parallel today, albeit at different levels of intensity; there is no strict chronological sequence. → Chapter 7

Global (environmental) awareness
refers, according to the WBGU, to → digitized knowledge and a global, individual awareness of actions for preserving the Earth system and the development of → solidarity-based lifestyles. → Section 5.3.1

Governance
refers to regulatory and control structures at various levels that are established by state actors, non-state actors, or jointly by both actor groups. The concept was developed originally to make a distinction from the term 'government'. It expresses the idea that political control is exerted not only hierarchically by the state, but also by civil-society actors such as non-governmental organizations and private companies. → Chapter 8

Great Transformation towards Sustainability
is a comprehensive change towards sustainability that takes the → planetary guard rails into account; it involves a restructuring of national economies and the global economy within these guard rails in order to avoid irreversible damage to the Earth system and ecosystems and the impacts this would have on humanity (WBGU, 2011).

Interconnectedness
refers to a → core characteristic of the → Digital Age, according to which technical systems, as well as people, things, processes and organizations are networked omnipresently on different levels of action. This creates qualitatively novel, border-crossing economic, social, cultural, institutional and political networking structures with interdependent infrastructures and processes. → Section 3.4

Internet
is a worldwide network of information and communication networks and computers that enables the use of services such as WWW (hypertext documents), email (electronic mail) or messaging using a wide variety of mobile devices. Data are exchanged via standardized internet protocol stacks; for example, versions 4 and 6 of the internet protocol (IPv4, IPv6) are central. → Section 3.3.1

Internet of Things – IoT
refers to the increasing interconnectedness and thus fusion of digital and physical infrastructures (Horvath, 2012: 1). From a technological point of view, the IoT refers to objects or things of any kind that are given a distinct identity by means of physical identity carriers such as barcodes, QR codes, RFID or smartcards and which can be networked with the internet or with each other via communication technologies such as → Bluetooth, near-field communication or mobile telephony (Fraunhofer FOKUS, 2016: 4). → Section 3.3.1

Interoperability
describes the ability of different ICT-based systems to communicate and collaborate with each other. Ensuring interoperability is particularly important in telecommunications and the digital platforms based on them, as well as in the → Internet of Things (Schieferdecker et al., 2018).

IT platform
From a technical point of view, this refers in the broader sense to software that serves as the basis for the development of applications; in a narrower sense it refers to the technical basis for the development, marketing and implementation of smart services via online marketplaces and digital ecosystems (Engels et al., 2017). The WBGU speaks more generally of ICT platforms that also include communication and → interconnectedness.

Knowledge explosion
refers to a → core characteristic of the → Digital Age, according to which digital methods modernize all kinds of quantitative and qualitative research and offer new approaches for understanding and shaping our natural and societal realities by means of data acquisition

and processing, modelling, simulation and visualization. It is also the basis for a global exchange and an awareness of the → global (environmental) awareness. → Section 3.4

Machine learning
refers to "procedures in which computer algorithms learn from data – e.g. to recognize patterns or show desired modes of behaviour – without each individual case having been explicitly programmed" (Burchardt, 2018: 13). The basis for this is large amounts of already categorized training data; their quality and design can distort the result. For example, "certain cultural influences or prejudices on the part of the developers [...] can be reflected in the training data" (Welzel and Grosch, 2018: 4). → Sections 3.3.3, 3.2.4

Monitoring
refers to the systematic observation (called surveillance in Earth observation) of objects, processes or environments, for example to record their properties, behaviour or compliance with threshold values. It can collect data to gain knowledge or form the basis of control processes. → Sections 3.3.5.1, 5.2.11

Normative compass
identifies the central dimensions to be taken into account in the → Great Transformation towards Sustainability (1) 'sustaining natural life-support systems': complying with planetary guard rails and avoiding or solving local environmental problems, (2) 'inclusion': ensuring universal minimum standards for substantive, political and economic participation, (3) '*Eigenart*': recognizing the value of diversity as a resource for successful transformation and as a condition for well-being and quality of life (WBGU, 2016a). Up to now, human dignity has been the WBGU's implicit normative starting point. It cannot be realized without the three compass dimensions; however, it is being increasingly challenged in the Digital Age. For this reason, the WBGU explicitly names the inviolability of, respect for and protection of dignity as guidance in the spirit of the Transformation towards Sustainability. → Chapter 2

Open data
refer to data that are made available for free use for the common good without any restrictions, including further distribution and sharing (Schieferdecker et al., 2018). → Section 10.1.1

Open source
refers to software whose source code is disclosed and freely accessible. Depending on the terms of use, the software can be freely used or modified by users (Schieferdecker et al., 2018). → Section 10.1.1

Path dependency
refers to situations in which an ongoing development is determined by historical developments or decisions and thus follows a path whose structure becomes increasingly rigid over time (lock-in effect). For example, the fact that one technology and not another becomes dominant is not necessarily due to its superiority, but may be the result of historical coincidences and a self-reinforcing process.

Planetary guard rails
are quantitatively defined damage thresholds whose transgression would have intolerable or even catastrophic consequences. They are scientifically deduced, but always contain an evaluating component. One example is the climate-protection guard rail, which means that an increase in the global mean temperature by more than 2°C above the pre-industrial level should be prevented. Sustainable development pathways do not transgress these guard rails. The approach is based on the realization that it is hardly possible to define a desirable, sustainable future in terms of a state to be achieved. It is, however, possible to agree on the definition of an area that is recognized as unacceptable, and which society wishes to avoid. Compliance with the guard rails is a necessary, but not sufficient, criterion for sustainability (WBGU, 2007: 16, 2009: 14). → Section 2.2.1.1

Polycentric responsibility architecture
also called polycentric → governance, characterizes governance systems in which vertical and horizontal governance structures are interlinked across different levels. Thus, responsibility does not emanate from one location only, but is distributed across different actors and institutions at the various levels of governance (WBGU, 2016a: 381ff.). → Chapter 4

Precision agriculture / Precision farming
is a form of agriculture in which, in field crop production, fertilizers, pesticides and water are applied precisely according to the needs of the plants and soil quality using digital systems (Gebbers and Adamchuk, 2010). The means used for this purpose include → sensor technology (e.g. devices for measuring soil moisture and nutrients), → monitoring (e.g. digital collection and evaluation of meteorological data, use of drones for image recognition), satellite-supported position determination (e.g. digital maps of areas), and → actuator technology (e.g. for dosing fertilizers) for the intelligent control of agricultural machinery (Walter et al., 2017) → Section 5.2.9

Privacy
refers to the right of individuals, groups or institutions to decide when, how and to what extent information about them is passed on to others (Westin, 1970).

Private life
refers in the legal sense, pursuant to Article 7 of the EU Charter of Fundamental Rights, to "the identity and development of the person, as well as to the right to establish and maintain relationships with other persons and the outside world" (Sydow, 2018). The protection of → privacy is legally addressed with the concept of protecting a person's private life and has the task of guaranteeing the narrower personal sphere of life and preserving its basic conditions, which cannot be fully covered by the traditional guarantees of freedom (BVerfG, 1969; BVerfG, 1973). → Section 8.3.1

Prosumers
A word uniting the terms producer and consumer, combining the two market roles in one person. The term was coined on social platforms where users both provide their own information and consume it. It can also be found in private households that generate their own renewable energy (e.g. with a photovoltaic system) and consume this electricity themselves as well as feed it into the grid – and consume electricity from the utilities as soon as their own supply runs out.

Public-service ICT
refers (according to the WBGU's understanding) to information and communication technologies that are of key importance to society as a whole and where the state has a special responsibility for their realization. It includes a public-service part of the → internet, including social platforms, via which public data, information, knowledge, and educational and citizens' services are accessible and subject to key principles such as net neutrality (which is increasingly under threat), inclusivity and accessibility. → Section 5.3.5

Quantum computing
aims to develop quantum computers (Aharonov, 1999; Feynman, 1986) which, unlike conventional computers, are based on a "completely new way of calculating: [...] while in a classical computer a bit is set to either 0 or 1, a quantum bit (qubit) can assume both values simultaneously, i.e. it can be in two states at the same time" (Homeister, 2015: 1f.). A qubit is a two-state quantum system which can, in principle, assume an infinite number of states, but two of which can be reliably distinguished by measurement. On this basis, there is a great speed advantage in certain problem areas compared to classical computers, which could, for example, allow complex climate models to be calculated more efficiently. For the time being, however, classical computers could not be replaced in the vast majority of applications, but only in specifically calculation-intensive areas. → Section 3.2.6

Resilience
refers in the technical sense to the ability of systems to deal with, prevent, protect themselves from, cope with and adapt to adverse events, i.e. human or technical disasters (e.g. terrorist attacks, major industrial accidents) or natural disasters (e.g. extreme weather events, earthquakes, volcano eruptions; Scharte et al., 2014: 121f.) and thus their ability to work towards "minimizing potential or existing damage to the physical and material well-being of the population" (Scharte et al., 2014: 54). → Section 3.3.4

Robotics
"deals with the design, creation, control, production and operation of robots, e.g. industrial or service robots. In the case of human-like robots, it is also a question of the production of limbs and skin, facial expressions and gestures, as well as natural language abilities" (Bendel, 2016: 191f.). The aim is to "promote the development of systems that advance the automation of human activities" (Kehl and Coenen, 2016: 120). However, the degree of human-machine interaction often varies just as much as e.g. industrial robots, telerobots or drones differ from human-like robots. → Section 3.3.5.3

Scoring
is generally used to assign a numerical value to a natural person in his or her role as a consumer, citizen, employee, etc. Scoring can also refer to the aggregation of different characteristic values to form a single value – often using a statistical procedure. → Section 5.3.3

Sensors
are electrotechnical units which can be used for the qualitative or quantitative measurement of certain physical, chemical, biological or information-technical properties and quantities (such as acceleration and force, heat, temperature, humidity, pressure, sound intensity, light intensity, and electric and magnetic fields; Gayetskyy et al., 2005: 2). They are "technical sensory organs" that make it possible to make a digital image of their environment (Hoepner et al., 2016: 10, 101).

Smart grids
refers to the IT networking and control of electricity generators, storage facilities, consumers, infrastructure and equipment such as energy-transmission and distribution networks for electricity supply. This enables the

interconnected components to be optimized (WBGU, 2011).

Solidarity-based quality of life
is defined by the WBGU as a quality of life that is not only oriented towards one's own needs and those of one's immediate environment (e.g. family), but also takes into account the principles of intra- and intergenerational justice (WBGU, 2016a).

Social cohesion
refers to cohesion among members of a social structure and thus relates to the relationships between the group members. Group cohesion is measured by the attraction exerted by the group on the individual members. It is believed that social cohesion has an impact on solidarity among the group members and strengthens the group vis-à-vis outside influences. In the political context, strengthening social cohesion is seen as a goal of social policy.

Sustainable development
was defined in 1987 by the Brundtland Commission as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs and choose their life style. Today, there are many definitions of sustainability. What they all have in common is that economic, social and environment-friendly development must be advanced at the same time.

Sustainable Development Goals (SDGs)
→ 2030 Agenda

Transformation
→ Great Transformation towards Sustainability

Transformation research
deals with the framework conditions of the → Transformation and possible ways of shaping it. It analyses the underlying drivers, causal relations, processes and dynamics of historical and current transformations in order to draw conclusions from these analyses for future transformations. In order to understand system contexts and adequately take them into account, transformation research needs to be inter- and transdisciplinary in orientation (WBGU, 2011, 2016a).

Transformative research
aims to develop solutions for specific problems of societal change in the form of technical and social innovations and to disseminate them in society and the economy. The transdisciplinary involvement of societal actors and businesses in the process of generating knowledge increases the chances of the subsequent application and acceptance of the resulting innovations (WBGU, 2011, 2016a).

Turing test
refers to a thought experiment by the British mathematician and AI pioneer Alan Turing from 1950, in which a person is connected either to a real person or to a computer without knowing with which of the two they are currently interacting. If it was impossible to distinguish between human and machine, the computer would have passed the 'test'. Contrary to the reception over the last decades, Turing's intention was not to practically test computers for 'intelligence', but only, in the context of his time, "to gain clarity about what is understood by a 'thinking machine' and what its existence would mean" (Walsh, 2018:69). → Section 3.3.3

Urban data
refer to all types of data that are relevant in an urban context, regardless of the specific data location, data retention, intellectual property rights or licensing regulations to which these data are subject. Urban data may also include data beyond the immediate municipal context (Schieferdecker et al., 2018). → Section 5.2.7

Virtuality
refers to a → core characteristic of the → Digital Age, according to which new spaces for human societies emerge in the virtual world. In this way, the Earth system, ecosystems and distant cultures can be directly experienced, and a connection to nature simulated, while real nature increasingly degenerates. → Section 3.4

Virtual worlds
refers to augmented realities (AR) and virtual realities (VR). AR describes an interactive environment in which end devices (e.g. smartphones, special glasses, PCs or televisions) are used to overlay virtual content with the correct perspective in the user's environment, thus augmenting reality (Dörner et al., 2016:33). While AR applications enhance reality, VR applications go one step further. Here, the real world is faded out and a completely new world is created (van Looy, 2017:57). Such a virtual reality is "a world simulated by computers and its software which is conveyed to users using special techniques and interfaces and with which they can interact" (Brockhaus, 2017). → Section 3.3.5

2030 Agenda
refers to the action plan for people, planet, prosperity, peace and partnerships adopted by all UN member states in September 2015 (UNGA, 2015). The 17 Sustainable Development Goals (SDGs), which link ecological, social and economic dimensions of sustainability, will be at the core of effective implementation up to 2030. The 2030 Agenda is universally valid, i.e. for all countries, but not legally binding. Its adoption is regarded as a multilateral milestone and a central point of reference for global efforts towards an inclusive, responsible and low-carbon way of life and economy worldwide. → Box 2.1-1

Towards Our Common Digital Future

In the report "Towards Our Common Digital Future", the WBGU makes it clear that sustainability strategies and concepts need to be fundamentally further developed in the age of digitalization. Only if digital change and the Transformation towards Sustainability are synchronized can we succeed in advancing climate and Earth-system protection and in making social progress in human development. Without formative political action, digital change will further accelerate resource and energy consumption, and exacerbate damage to the environment and the climate. It is therefore an urgent political task to create the conditions needed to place digitalization at the service of sustainable development.

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ISBN 978-3-946830-03-0