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German Advisory Council on Global Change

Towards Our Common Digital Future

Recommendations

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Recommendations for action

9

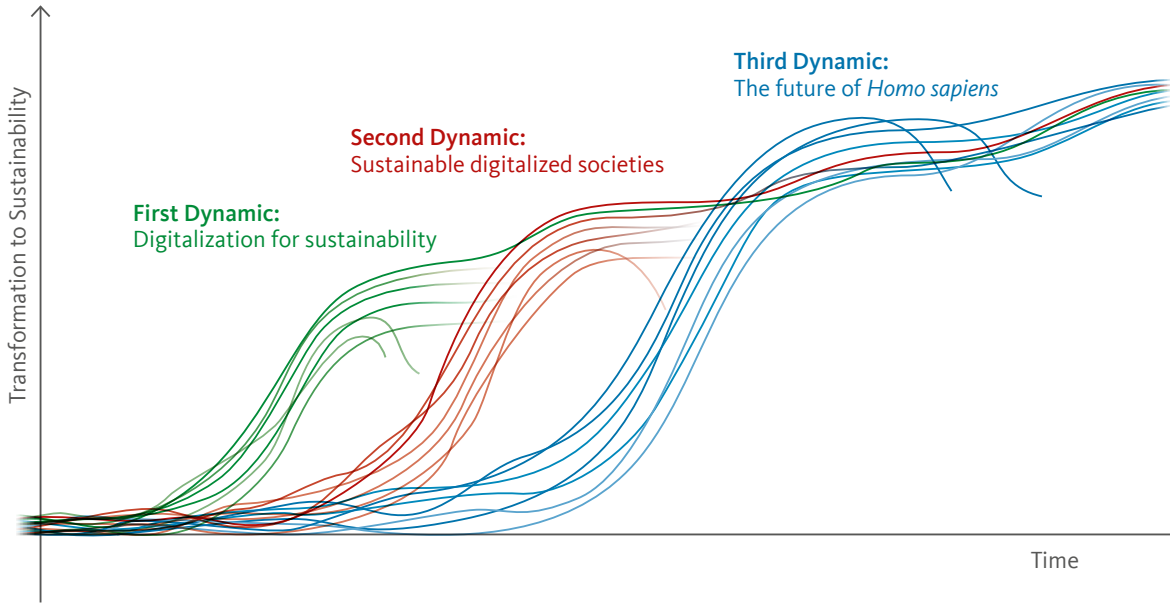
The WBGU recommends that digitalization should be explicitly placed at the service of sustainability. Unless it is actively shaped, global digital change involves the risk of further accelerating the threat to humankind's natural life-support systems. Without regulation and democratic control, it can 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 (Fig. 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).

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



↑ 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

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, 2018b). 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 competition 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

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.

New approaches to sustainable business management

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 in a 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.

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 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

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 'DigitalPact 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.

Quantified self

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..

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. 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 natural life-support systems

Sustaining 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 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, 2016). 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

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, 2018b).

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 par-

ticipate 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.

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. 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, remanufacturing) 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. 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. Forexample, 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, 2018) – 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 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 ÖkoBusinessPlan in Vienna) can also help boost demand for corporate consulting on sustainability.

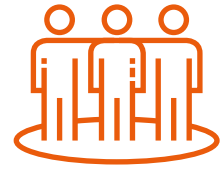
The WBGU also recommends extending incentive schemes (e.g. certificates) to producers themselves in addition to tax regulations (Section 9.2.3.2). Unlike the latter requirements, certificates can have a positive, motivating effect on corporate sustainability behaviour and potentially involve large sections 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). 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 5.4.1, 5.4.2).

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, 2018b) 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" (Fraunhofer, 2018: 237). 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 5.4.1).

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 (Fraunhofer 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).

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, 2018b: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 labour 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. 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. 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 (Spiekermann and Christl, 2016:118 ff.). 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, 2018b: 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, 2018).

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'.

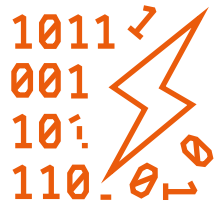
9.2.1.2
Create international protection of privacy law at the UN level

In the WBGU's opinion, a United Nations Privacy Convention should be adopted 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 so-called filter bubbles or echo chambers; Fraser, 2010; Imhof, 2011). First of all, this is a fundamental transformation of the conditions governing the public sphere. 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 so-called '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, 2018:252ff.). 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, 2017). 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.

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, 2018).

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 (AlgorithmWatch, 2017; 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, 2018: 256 ff.; 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. 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, 2015). 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 so-called 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/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. 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.

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.

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) 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 the international community. 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).

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. First, all UN organizations and institutions working on sustainability issues (e.g. UNDP, UNEP, 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 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. In addition to negotiating a United Nations Privacy Convention (Section 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/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.

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.

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). 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 9.4-1).

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. 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 10.3-3). 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

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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.

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

Box 9.4-1

'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

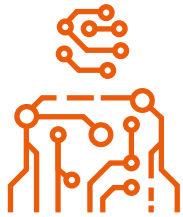
15. All states and companies shall develop *ethical guidelines* on the conception, development and application of digital technologies and solutions with regard to human dignity and sustainability goals and shall create the necessary legal and organizational frameworks for their implementation.
16. All 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.

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 (BCI) 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 (Birbaumer, 2018; 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 (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, cyber security

(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: 161 ff.). 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 (Birbaumer, 2018: 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). 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. 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 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: 23 ff.). 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; UN General Assembly 2015) and the question of how digitally supported educational measures can promote knowledge and action for the Great Transformation towards Sustainability (UN, 2018a).

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. 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 "focuses on the forthcoming task of shaping the Transformation. Here, transitory processes are explored in order to come to conclusions on the factors and interdependencies of transformation processes. Examples from history can serve as a basis for analysing observed transformative moments" (WBGU, 2011:23). 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, 2018b). 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 arena topics (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 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

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

(BMBF, 2018b) – 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 (Fig. 10.2-1).

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 EU 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).

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: 5 ff.).

On this basis, the WBGU furthermore proposes the creation of a 'Digital Sustainability Knowledge

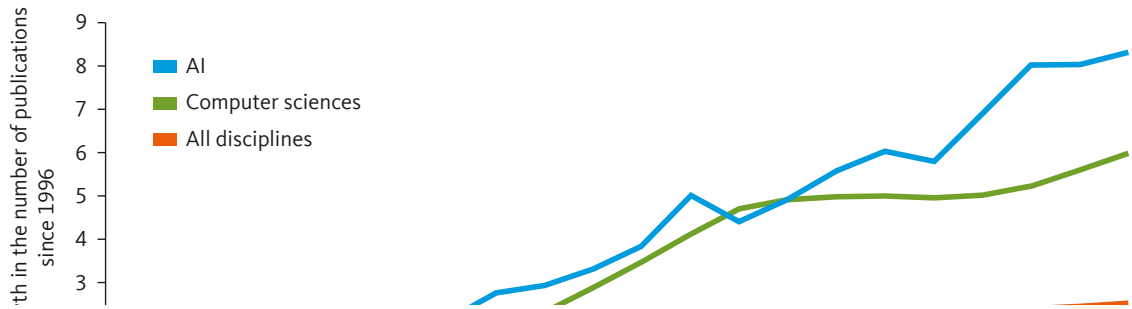


Figure 10.2-1
Three pillars of Horizon Europe.
Source: European Commission, 2018h

and Innovation Community' (KIC) at the European Institute of Innovation and Technology (EIT; European Commission, 2018h) 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 European Union, as laid down in the current position paper (Bundesregierung, 2018b: 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, 2018a) 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 interna-

tional 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
FONA[4]: 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 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 CO2, 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 so-called 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). Research activities on digitalization have also been further expanded, especially in recent years. The Weizenbaum Institute for the Networked Society (2017) 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 f.), 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 (incl. 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 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, 2018c). 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 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:

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, 2018b). 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 (Fig. 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. 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 (Fig. 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.

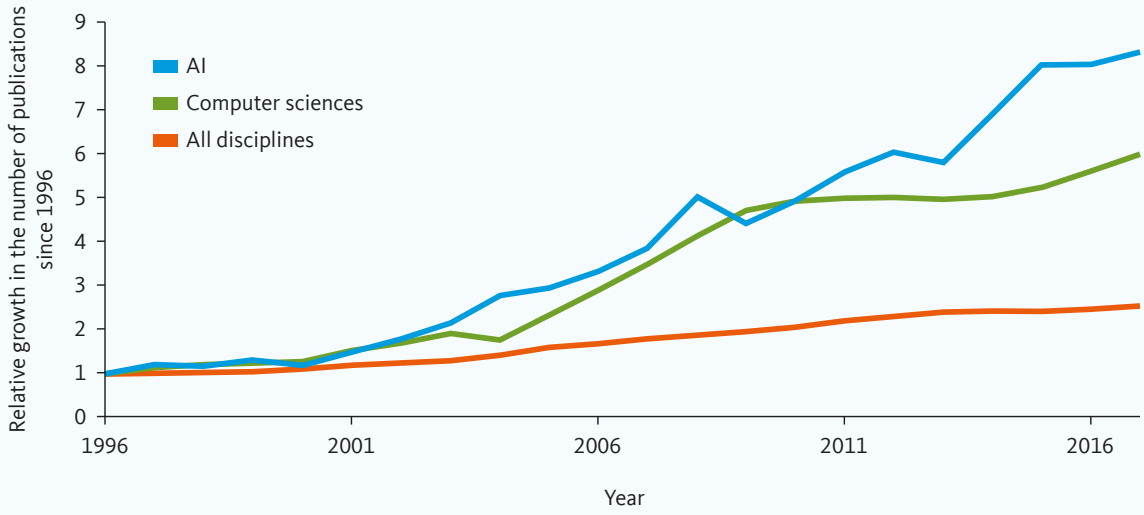


Figure 10.3-1
Growth in the number of publications on AI compared to computer science and publications as a whole.
Source: WBGU, own diagram based on the Scopus database

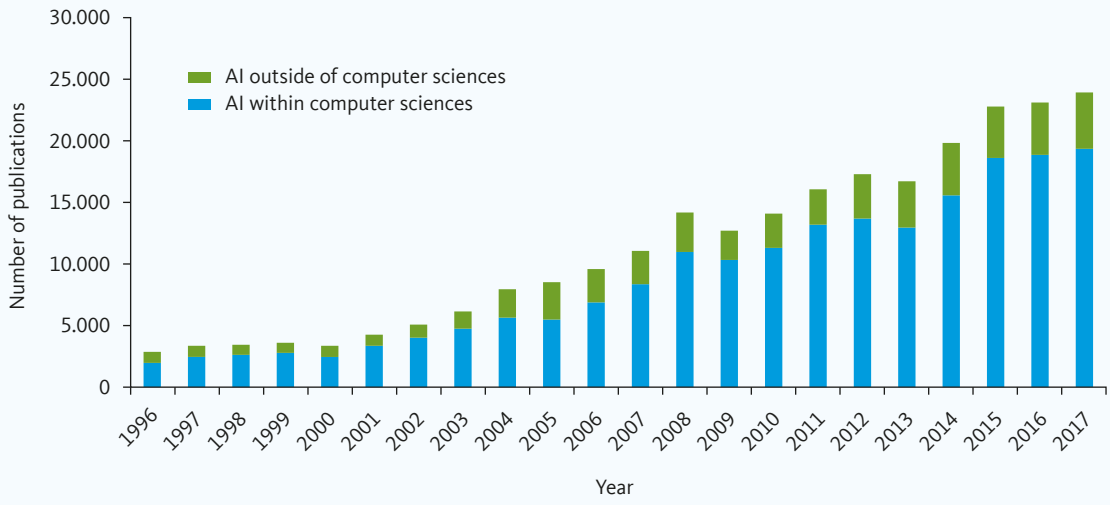


Figure 10.3-2
Number of scientific publications on artificial intelligence.
Source: WBGU, own diagram based on the Scopus database

- 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.
- 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 repairability, and even material substitution and the development of biodegradable electronics (Section 5.2.5).
- 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.
- 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.
- 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.
- 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.

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

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 circular economy – how digitalization changes industrial metabolism (Section 5.2.1)
- New forms of (digital) economy: new approaches to sustainable management in the Digital Age (Section 5.2.2)
- Digitalization of consumption and sustainable consumption behaviour: promotion of solidarity-based lifestyles (Section 5.2.3)
- Sustainability in online trading: status quo and future prospects (Section 5.2.4)
- Digitalization as the cause and solution of the problem of electronic waste in the context of a (global) circular economy (Section 5.2.5)
- Digitalization for climate-change mitigation and the energy-system 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 supported 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).
- Quantified self: between empowerment and control loss (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)

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: 451 ff.), the WBGU presented comprehensive research proposals on sustainable urbanization and referred to technological transformation processes (WBGU, 2016a: 51 ff. and pages 53, 54, 393 and 399). 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, 2014). 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 (DC) 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 DC, 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 (GIZ, 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.

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 10.3-3).

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 the sustainable Digital Age

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 digitalized sustainability era. 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, 2013, 2017, 2018), 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: 17 ff.). 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

Box 10.3-3

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 sustainable development goals. 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.

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.

The German Advisory Council on Global Change

(Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen – WBGU)

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- reviews and evaluates national and international research in the field of global change,
- provides early warning of new issue areas,
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- monitors and assesses national and international policies for the achievement of sustainable development,
- elaborates recommendations for action, and
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