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German Advisory Council on Global Change

Summary

Towards Our Common Digital Future

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Summary

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

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

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

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

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

Conservation and creation in the Digital Age

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

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

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

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

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

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

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

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

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

First, however, we consider it important to put this

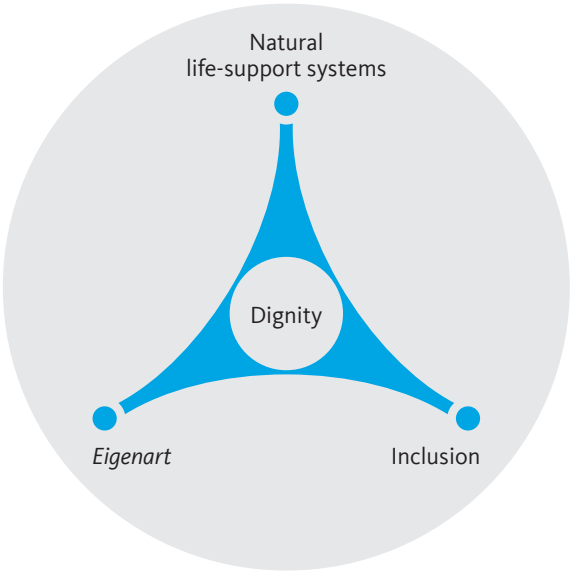


Figure 1
Normative compass for the Great Transformation towards Sustainability in a digitalized society. The transformation can be achieved by interaction and a balance between the following three dimensions:

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

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

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

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

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

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

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

In its report, the WBGU has examined these questions and reaches a double conclusion. On the one hand, it must be plainly stated that the digitalization of business and everyday life has so far been only marginally

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

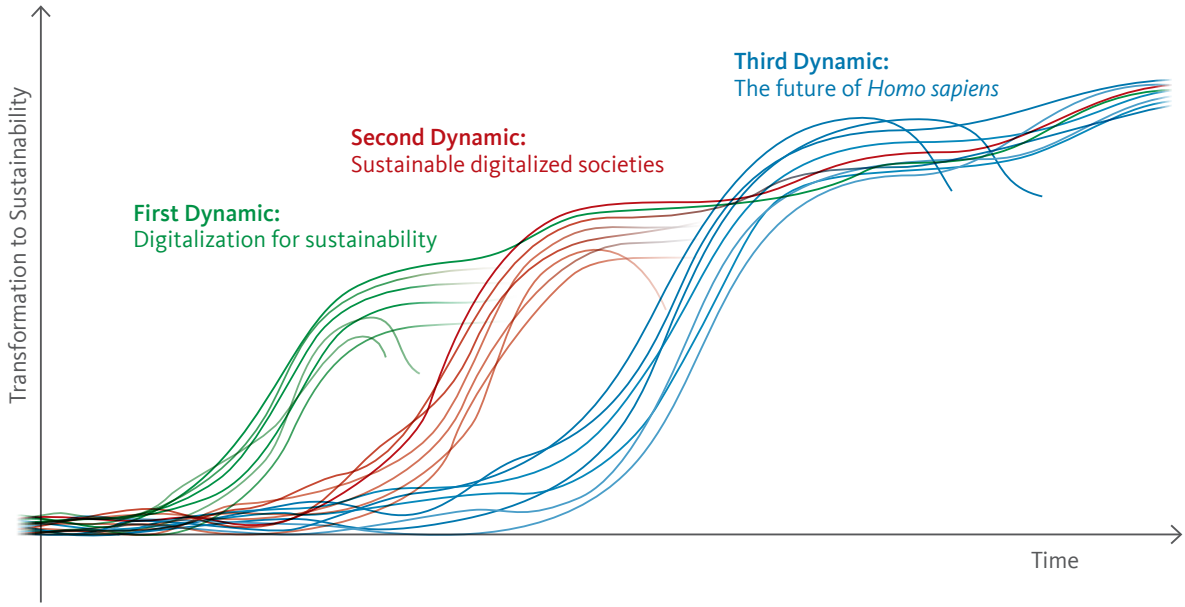
On the other hand, what is not yet possible can – and must – become possible. After all, digitalization offers an enormous range of possibilities for supporting the Great Transformation towards Sustainability (WBGU, 2011) – from sensor systems to self-organized system optimization. The WBGU has defined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

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

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

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

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



↑ Digitally support sustainability

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

↓ Ecological and societal disruption

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

↑ New humanism

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

↓ Digitally empowered totalitarianism

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

↑ Strengthen *Homo sapiens*' self-confidence

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

↓ Blurring of borderlines between humans and machines

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

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

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

path in the tradition of the Enlightenment and humanism that seems appropriate. A Europe acting jointly could introduce this into the global negotiations and set an example together with like-minded states.

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

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

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

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

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

1. Humankind finds itself

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

2. Humans create companions for themselves

The more advances AI makes in ever broader application areas, the more diverse and intimate will be the points of contact, interfaces and hinges between technology and people. This can lead to symbiotic connections, which, however, may turn out differently than imagined in the popular 'cyborg' dreams. It is also possible that AI-enabled entities emerge that will become well-integrated, loyal companions of humans in societies that are more liveable than those of today. For example, in the medium term, digital assistants could liberate us more and more from monotonous activities (e.g. by taking on logistical tasks), support us in learning and understanding (e.g. by synthesizing and interpreting the overwhelming wealth of information), and ultimately help us to value ourselves and our environment more highly (e.g. through diagnostics and mirroring). Such a prospect encounters far less scepticism in

the East Asian cultural sphere than in Western societies, for example, and promotes a world view that does not categorically isolate humans from nature and technology.

3. Humans invent their masters

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

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

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

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

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

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

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

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

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

Combine digitalization and sustainability research (p. 23)

Using digitalization to implement the 2030 Agenda

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

A double course correction is needed

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

Sustain natural life-support systems (p. 17)

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

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

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

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

Promote poverty reduction and inclusive development (p. 18)

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

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

Up to now, digital expertise has been severely underdeveloped in ministries, parliaments, municipal administrations, non-governmental organizations, sustainability research institutes, the media and international organizations. Creating the sheer ability to shape and plan requires a push for modernization in all the areas mentioned, in order to create digital expertise and bring it

into line with the requirements of the sustainability transformation. If this does not succeed, technology-oriented and short-term self-dynamics will prevail; then it will no longer be possible to link the digital transformation with the sustainability transformation. Public institutions need to make comprehensive modernization efforts, like those carried out in the early 1970s, supported and accompanied by extensive scientific research programmes (Scharpf, 1972; Mayntz et al., 1978). Back then, the aim was to prepare public institutions to dovetail economic, technological, social and environmental developments and to expand societal inclusion; today, the aim is to create comprehensive digitalization expertise and to combine this with sustainability transformations.

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

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

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

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

At the same time, developments that are of great importance are conceivable and possible, specifically

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

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

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

Avoiding systemic risks in the Digital Age

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

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

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

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

It is also important to bear in mind that the digital upheavals are being experienced by societies that are already unsettled by globalization, the rise of new powers, by forms of authoritarian populism and the flow of refugees. The bow waves of digitalization are colliding with the current crisis in Europe and the West and with frontal attacks on a multilateral world order

based on cooperation and rules. The systemic risks of the Digital Age could overlap with and reinforce the centrifugal forces that already exist in many societies.

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

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

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

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

Protect privacy (p. 20)

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

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

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

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

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

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

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

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

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

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

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

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

Establish and secure digital commons (p. 21)

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

Provide public-service ICT (p. 21)

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

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

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

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

Gear digitalization towards the common good (p. 17)

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

An overview of the report

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

Sustainability in the age of digitalization

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

Box 1

Arenas of digital change

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

Industrial metabolism

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

New 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.

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

Understanding the Digital Age

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

Actor constellations in the digital transformation

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

Arenas of digital change

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

Drafts for the future and visions on digitalization and sustainability

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

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

Synthesis

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

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

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

Global governance

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

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

Recommendations for action

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

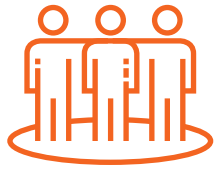
Sustaining the natural life-support systems

At present, digitalization is perpetuating existing trends towards rising emissions, increasing resource consumption, soil degradation and the destruction of ecosystems, and

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

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

Poverty reduction and inclusive development



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

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

Work in the future and reducing inequality

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

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

Future-proofing education

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

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

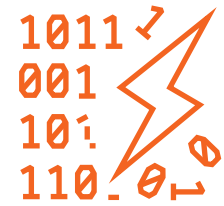
tive approach to trends and challenges. Anticipation and 'futures literacy' should be specifically promoted as new research and education subjects and consolidated in existing bodies; or else suitable future bodies should be created for the purpose.

Big Data and privacy

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

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

Fragility and autonomy of technical systems



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

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

Economic and political power shifts

Digital technologies are shifting power and influence between states, companies and citizens. As a result of strong network effects and economies of scale, digitalization today is largely being shaped by a few,

mostly private-sector stakeholders. Individual countries, too, are already making intensive use of digital technology to increase their state power. Digitalization will exacerbate existing social inequalities unless all people are equally given the opportunity to share in its potential. The WBGU recommends:

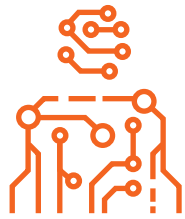
- *Create public-service ICT and digital commons:* All people should have non-discriminatory and barrier-free access to ICT infrastructures, to reliable and high quality data, information, services, knowledge and digital commons as a public service. Net neutrality and a reduction in discrimination should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

Global governance for a sustainable Digital Age

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

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

New normative questions – the future of *Homo sapiens*



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

- *Anchor research ethics, data protection and a shutdown option within brain-computer interfaces and*

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

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

Research recommendations

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

Ideas for the further development of basic research

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

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

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

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

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

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

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

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

High-Tech Strategy.

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

Stimuli for sustainable digitalization in industrial research

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

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

Recommendations on the content of research on sustainable digital transformation

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

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

on the impact of AI on the digitalized sustainability society should be significantly increased.

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

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

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- elaborates recommendations for action, and
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