DIGITAL RESET

« Redirecting Technologies for the Deep Sustainability Transformation

D4S Digitalization for Sustainability
Science in Dialogue

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D4S Digitalization for Sustainability Science in Dialogue

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Content

For the hurried reader

Governments around the world, as well as the European Union and United Nations organisations, are currently putting forward new initiatives to govern digital technologies and media infrastructures. However, most of these policy initiatives disregard the broader implications of digitalisation for environmental sustainability and social justice.

This report argues that governing the megatrend of digitalisation must step up to today's societal challenges. Runaway climate change, biodiversity loss, increasing social polarisation and an erosion of democracy require swift and decisive action. The state of scientific knowledge demonstrates that digitalisation, in its current and mainstream form, does not deliver solutions and that incremental changes are insufficient to remedy this situation. What is needed, therefore, is a Digital Reset: a fundamental redirection of the purpose of digital technologies towards a deep sustainability transformation. To this end, governance should follow several principles: Technologies should be built according to **regenerative designs** and pursue **system innovations** that advance **circularity** and **sufficiency**, improve economic **resilience**, and foster digital **sovereignty** and social **equity**.

The report details how the principles can guide the use of digital technologies for deep sustainability transformations in the following sectors:

- In **agriculture**, digital technologies can support a transformation towards locally adapted and ecological farming practices rather than optimising high-impact industrial monocultures.
- In **mobility**, governance should responsibly open up data and code and advance those applications and platforms that foster low-carbon multimodal mobility rather than high-tech automobile transportation.

- In **industry**, digital technologies can foster resilient and circular production patterns rather than prolong growth-dependent linear economies.
- In the **energy** sector, policymaking should improve the use of digitalisation to support distributed systems based on 100% renewable energy carriers.
- In the **building** sector, fostering a new data culture can decrease demand for new construction, reduce energy consumption in the operation of buildings and facilitate circularity in design and refurbishment.
- Regarding the general **consumption** of goods and services, policies should mitigate the potential of new digital marketing to spur overconsumption, foster new technologies for sufficiency-oriented consumption habits and move towards greener products and services.

Three requirements must be met for digitalisation to work for sustainability:

- The social and environmental impacts of producing and operating **digital devices, infrastructures and data centres** must be reduced. To make a difference in the short term, this report presents a combined strategy for digital sufficiency, repairability, circularity, and efficiency.
- The growth-oriented **business models of Big Tech companies** must be controlled and eventually replaced by business models that are oriented towards the common good. This report points out three policy pathways that can initiate this transition.
- The governance of **data and artificial intelligence** needs to actively pursue an information-based circular economy. This report shows which new institutions are required, and which policies can put data and AI in the service of sustainability.

A successful redirection of digitalisation requires decisive policy action and a clear vision of the role of digital technologies for the realisation of decent lives for all people within planetary boundaries.

About D4S

"Digitalization for Sustainability – Science in Dialogue" (D4S) is a research network of European expert researchers as well as practitioners representing a variety of scientific disciplines and schools of thought. The research conducted within D4S is dedicated to developing a progressive vision for a digitalisation that fosters deep sustainability transformations.

The D4S project is coordinated by Prof. Dr. Tilman Santarius and his team (Patricia Jankowski, Johanna Pohl) at the Einstein Center Digital Future and the Technical University of Berlin and is funded by the Robert Bosch Foundation.

More information:

https://digitalization-for-sustainability.com/

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D4S Digitalization for Sustainability
Science in Dialogue

Preface

Many governments around the world are currently developing new legislations to govern aspects of digitalisation. At the same time, the world is facing multiple sustainability challenges – with the environmental challenges, such as climate change, biodiversity loss, pollution and waste – among the critical ones. Our unsustainable resource use lies at the heart of these challenges: with global extraction and processing of material resources causing 90% of biodiversity loss, half of greenhouse gas emissions, and a third of health-related pollution impacts.

Meanwhile, current efforts to tackle sustainability challenges do not focus on root causes. To meaningfully do this, they need to overcome several blind spots, including lack of a systems approach, lack of a resource perspective, and lack of focus on demand-side solutions leading to actual reductions in resource use.

There is still not enough overlap of the two policy arenas of sustainability and digitalisation: actual policymaking does not systematically address the question of what the rapid development of digital technologies and applications mean for a sustainable global future. For instance, the European Union has set itself a Green Deal while at the same time it has tabled landmark legislations that address digital markets, digital services, data governance, or artificial intelligence. While all important and needed, none of them are systematically integrating the digitalisation and sustainability areas.

Research on digitalisation and its manifold implications for social justice and environmental integrity has been gaining momentum in recent years. But it is still unclear: What can digitalisation contribute to the urgently required sustainable transformation, enabling sustainability action to overcome its blind spots and focus on root causes? And what are core policies that ensure a sustainable digitalisation?

The European research network "Digitalization for Sustainability – Science in Dialogue" (D4S) has addressed these questions in an intensive two-year dialogue process. This report synthesises this endeavour and presents a truly comprehensive investigation of the relation between digitalisation and sustainability. By integrating digitalisation with deep transformations of economic sectors, the report binds digital potential to environmental necessities. And it develops design principles, specific policies, and suggests new institutions to shape digitalisation towards deep sustainability transformations.

The report is not only a must read for policymakers from all spheres. It is also a treasure for science, civil society, business, and the interested public to profoundly learn about prospects and risks of digital technologies for a future fit society. Whoever gets it in hand, I am sure will experience a deeply enlightening, and a highly delightful reading.

Janez Potočnik
Co-Chair of the International Resource Panel, United Nations Environment Programme
Former European Commissioner for Environment, and for Science and Research

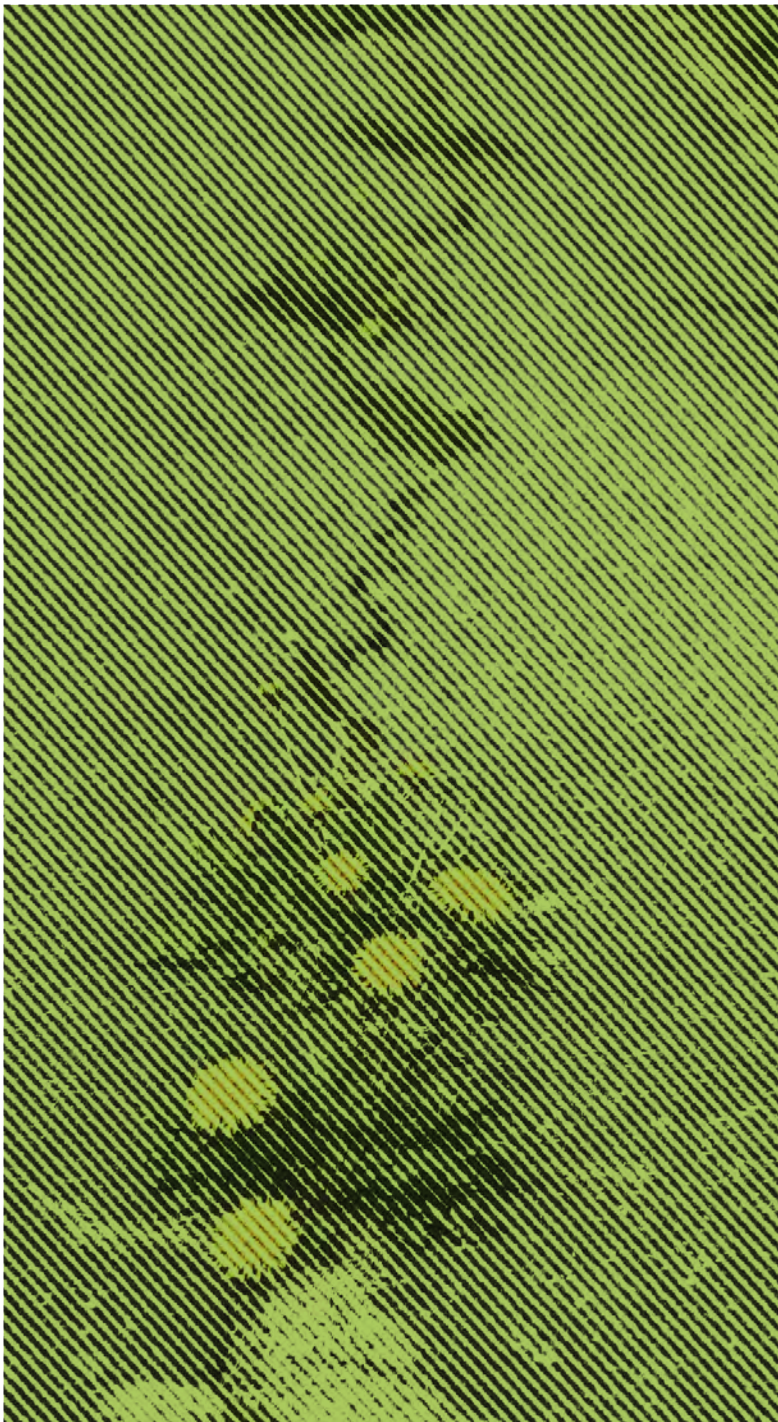
Introduction

When future historians ponder the years around 2020, they might consider this time as a remarkable period of seismic cataclysm. In fact, it appears as if time is out of joint. The world has experienced a centennial pandemic, with unprecedented political reactions that certainly saved many lives but that also posed new social challenges. The global thermometer displays a sequence of hottest years on record, leading to fatal droughts, e.g., in Ethiopia, Somalia and Kenya; raging forest fires devastate vast swathes of land in Spain, France, Korea, and Mexico; and storms, floods, heat waves, and historic water scarcities afflict many other countries around the globe. And as if that were not enough, the Russian war in Ukraine has shattered political order. This illegitimate ground offensive has already claimed tens of thousands of lives in its first six months and has spawned a new bloc confrontation between authoritarian and democratic states.

Unsurprisingly, the economy is severely affected. COVID-19-related lockdowns of factories, climate-related shortages in supply chains, and high inflation rates due to Russia's aggression are driving firms to the brink of bankruptcy, workers into unemployment, and lower-income citizens towards poverty. Most sadly, the global number of people living below the extreme poverty line is estimated to rise by millions in 2022, reversing the downward trend of past years. With this list of multiple crises, one is tempted to shake oneself like after a nightmare: Was that it with the socio-economic disruptions? Probably not. It seems that more challenges are yet to come.

Dire challenges demand swift and coherent answers. If the saying 'the turn of an era' is true, a simple continuation of business as usual is not an option. New geopolitical tensions require strong solidarity that is in stark contrast to rising inequalities and social polarisation. Runaway climate change and biodiversity loss require action that goes far beyond optimisation of the status quo. If society wants to tackle the multiple social and environmental crises of our time, it needs to undergo large-scale, deep transformation: Politics has to become more inclusive and transparent if democracy is to be the answer to populism and authoritarianism. Businesses must serve the common good if the polarisation of financial wealth is to be reversed. Production and consumption patterns need to profoundly change if carbon-neutrality is to be achieved and planetary boundaries are to be respected.

Hence, the agenda for a deep and sustainable transformation is: Take the most stringent action to avoid the transgression of planetary boundaries that endanger the very basis of livelihoods on planet Earth. Mitigate the calamitous rise in inequalities and the divergences in capabilities to sustain social cohesion and democracy. And improve participation and inclusion in political decision-making to redress the power asymmetries that have been causing the clashes of classes and cultures in recent years. If not now, when is the time for deep change?



« Digitalisation in a fragile world

Occurring much more subtly and softly, yet another megatrend is being witnessed by the world: the increased digitalisation of society, economy, and private life. Like climate change and rising equalities, digitalisation is also not a new phenomenon. But the COVID-19 pandemic nudged it along even further: Social distancing is amplifying media use and digital interconnectedness in daily life. IT companies have reported record profits and become the unquestionable spearhead of the global economy. And public services such as education and public administration increasingly rely on digital infrastructures. Was that it with the technological drive? Probably not. Again, it seems that more digitalisation is yet to come.

For governments worldwide have designated digitalisation to be a main driver behind economic growth and improved competitiveness. The Industrial Internet of Things, new business cases based on 'Artificial Intelligence', and a systematic improvement of digital competencies are supported by large funding grants to ensure digitalisation provides high value for the economy. But how does the digital economy relate to the current social and environmental challenges? Will a digitalisation that is largely driven by expansionist business models deliver answers to the multiple crises of our time?

This report investigates how digitalisation can support the quest for a deep and sustainable transformation of society. Yet a key finding of this report is: Digitalisation, in its current and mainstream form, is instrumental in aggravating many of the crises. For example, it furthers the polarisation of income and financial wealth – as digitalisation is widening the gap between a growing share of total income stemming from capital, and a shrinking share stemming from salaries. Likewise, digitalisation brings about additional burdens – as the environmental footprint of digital devices and new digital consumption is substantial and the efficiency improvement of applying digital technologies is less than hoped for. All in all, current digitalisation is optimising the unsustainable status quo rather than transforming it.

This does not have to be the case. Indeed, this report will spell out how digital technologies can promote sustainable lifestyles and facilitate a resilient economy that works for the common good. More importantly, the report will identify the conditions, including comprehensive political governance, that need to be in place in order to ensure that digitalisation delivers to ecology and justice. The digital and sustainability transformations are purported by policymakers in the European Union to be twin transitions. But the two are not equal twins, as the former is a means and the latter is an end. The premise is, therefore: Only if digitalisation is subordinated to, and becomes part of, a deep transformation can it contribute to sustainable development in a meaningful manner. Accordingly, this report calls for a Digital Reset: To fundamentally reevaluate digital technologies and redirect them for the urgently required sustainability transformation.

« A new perspective for the European Union

This report is based on a two-year scientific dialogue between 15 international experts *(https://digitalization-for-sustainability.com/)* that took place at the timely moment when many governments, as well as supranational bodies, initiated substantial new legislation to govern various aspects of digitalisation. For instance, the United Nations Secretary-General laid out a Roadmap for Digital Cooperation in 2020. The World Trade Organisation is currently working on an Agreement on E-Commerce. The European Union launched several important regulatory initiatives, including the Digital Services Act Package, the Data Governance Act, and the Artificial Intelligence Act. Other nation-states, such as China, the United States, Egypt, and South Africa, have developed their own national approaches to digital regulation. Yet it is problematic: The discussions and policies to govern digitalisation, are seldomly connected to policies governing sustainable development.

It appears as if digital policymaking and sustainability policymaking take place on different planets. For instance, the current European Union's two major policy packages are the 'European Green Deal' and 'Fit for the Digital Age'. But the vast majority of regulatory initiatives coming from either package do not address the opportunities and risks of digital technologies for sustainability. Even more problematic, the EU intends to govern digitalisation not only by protecting consumer rights but by pushing European companies' competitiveness in the global market. However, if economic growth is the overriding goal of digital governance, outcomes will likely run counter to sustainability. High hopes that digital-borne efficiency improvements will cut absolute energy levels and emissions or resource demands will not materialise if industry clings to linear production models and citizens maintain unsustainable consumption habits. The latter will result in rebound effects that eat up savings potential. Quick wins for the economy and environment are no measure for the challenges squarely facing us. So again, a Digital Reset is needed: Digitalisation must be governed with the aim of eliminating the root causes of unsustainable production and consumption patterns, not just alleviating their symptoms.

This report provides a blueprint for the European Union on how to reconceptualise digitalisation so that it first and foremost contributes to a resilient economy that achieves carbon neutrality, protects biodiversity and reduces resource consumption while supporting equity and fully respecting citizens' rights and privacy. This requires digitalisation to become an integral part of the European Green Deal. But while current Green Deal policies herald an economic reorientation for the European Union, they merely form the beginning of a much deeper transformation yet to come. Digitalisation should now be governed in a way that promotes system innovations and new practices to make Europe a laboratory for a society that is fit for the future.

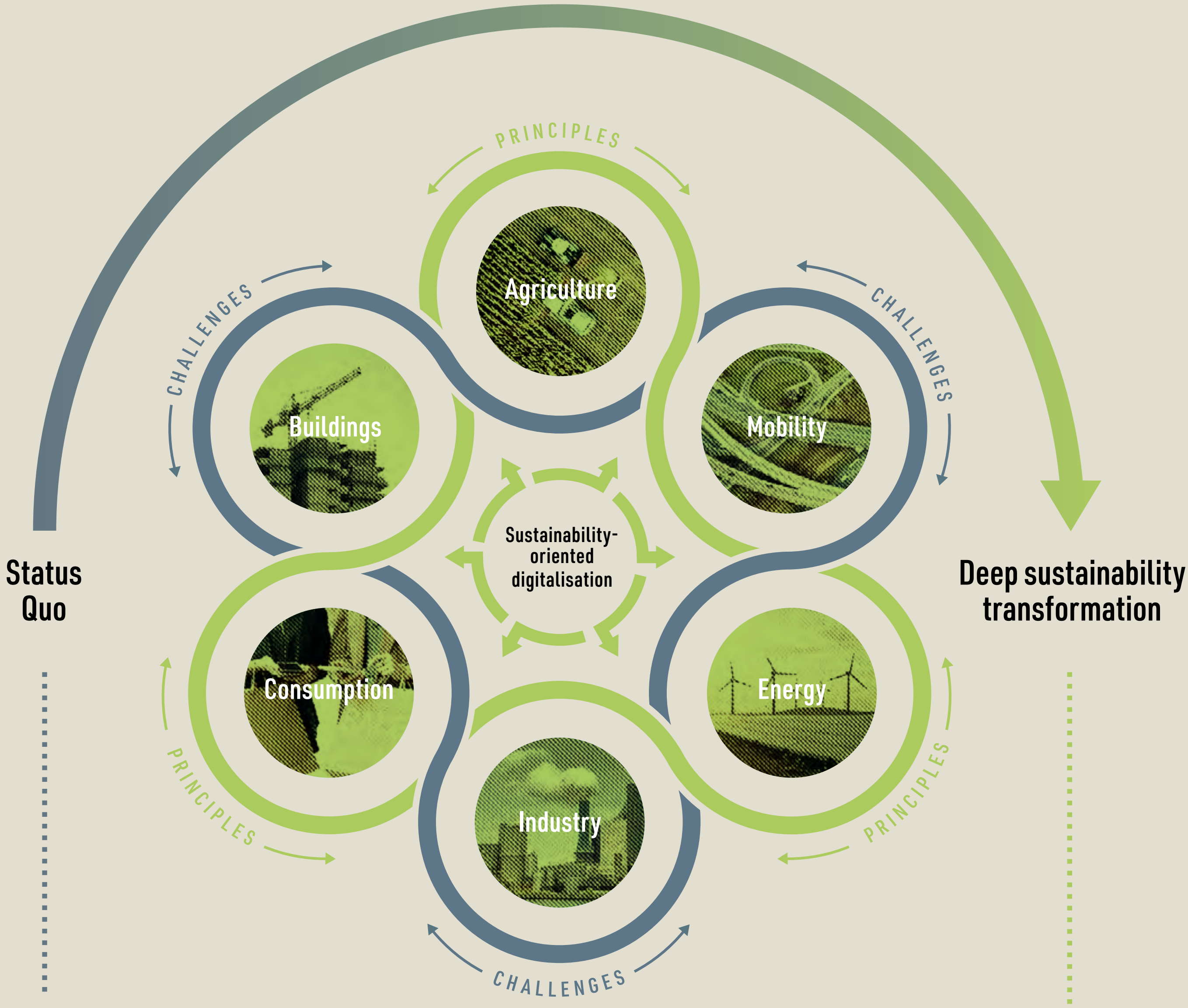
To ensure digitalisation delivers for a deep sustainability transformation, it needs to be shaped according to a set of new principles. These principles are outlined at the end of Part 1, based on a systematic analysis of why digitalisation is currently failing to avail of the chances of such a transformation. Following the new principles, Part 2 spells out how sustainability policymaking in key sectors such as agriculture, mobility, industry and others can systematically address opportunities and risks of digital technologies for deep transformations. Part 3 lays out how digital policymaking, from standard settings for information and communications technology (ICT) hardware and infrastructures to governing digital business models or Artificial Intelligence, can pursue sustainability goals from the ground up. Finally, the report concludes by providing a set of overarching recommendations that are needed now to initiate a Digital Reset.

Figure 01 Digital Reset for the deep sustainability transformation

Figure 01

Digital Reset for the deep sustainability transformation

All economic sectors will undergo a deep transformation. Digital technologies must be redirected along seven principles to overcome the challenges of the status quo and initiate shifts towards sustainability.



Challenges

Sustainability challenges

- Multiple crises
- Overconsumption
- Linear economy
- Growth-orientation
- Environmental inequalities

Digitalisation challenges

- Monopolies
- Power asymetries
- Appropriation of commons
- Polarisation
- Surveillance

Principles

- Regenerative design
- System innovations
- Sufficiency
- Circularity
- Sovereignty
- Equity
- Resilience

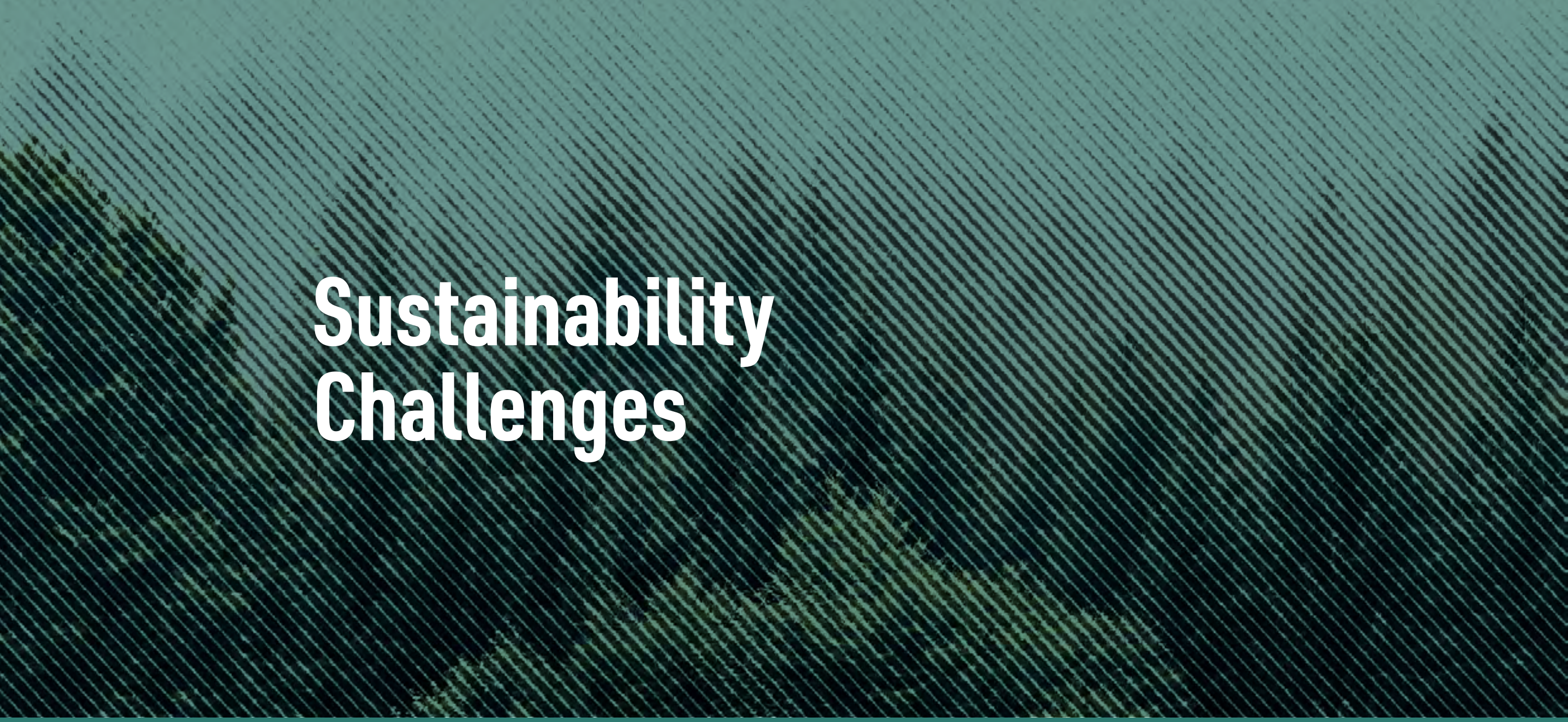
1

Why Digitalisation Needs To Be Redirected

Digitalisation has been transforming society for a long time. But can digital technologies contribute to the urgently needed deep sustainability transformation? Addressing this question requires recalling the major challenges and lock-ins a sustainability transformation must overcome and, equally importantly, considering the nature of digitalisation as a process of societal change. Digital communication and media technologies have not only transformed many aspects of life in a matter of a few decades but also generated new challenges. For example, the world has seen a rise in unprecedented economic monopolies, new highly invasive forms of surveillance and a buildup of critical power asymmetries in society at large. Part 1 of this report starts with two chapters that briefly describe such key sustainability and digitalisation challenges to paint the panorama in which a deep transformation is taking place.

The next question is: Have digital technologies so far contributed to sustainability, and are these technologies likely to do so in the future?[1,2] High hopes exist that digital-borne efficiency improvements could decarbonise industry, that substituting physical goods with digital services could dematerialise the economy, or that physical transportation could be replaced by remote communication. However, as our analyses show, such potential has not been realised on a large scale.[3,4] While these positive sustainability contributions remain in niches, the direct footprint of manufacturing and operating digital devices is growing at unanticipated rates. Moreover, dominant market actors have appropriated many innovations to maintain path dependencies of unsustainable modes of production and consumption. Our analysis in the third chapter of Part 1 shows that digitalisation is a double-edged sword regarding social and environmental sustainability. Positive contributions do not come easily.

To make digital technologies work for a deep sustainability transformation requires strong, coherent and cross-sectoral policymaking on all levels of governance.[5] But what is the new logic a redirection of digital technologies should follow? Part 1 concludes by presenting principles that provide orientation for policymakers, business representatives, civil society and citizens to shape digitalisation for the common good.



Sustainability Challenges

1

Multiple crises

The beginning of the third millennium has been marked by multiple interlinking crises occurring simultaneously. To mention but a few, in most recent years, the world has experienced the COVID-19 pandemic; lockdown-related economic instability and social inequality; increased geopolitical tension due to the Russian war in Ukraine; war-related disruption of global food, energy, and material supply chains. At the same time, local and regional environmental crises induced by global warming, loss of biodiversity and ecosystems, soil degradation, water scarcity and pollution have been occurring with unprecedented frequency. And subsequent extreme weather events, loss of harvest, widespread forest fires, flash floods or droughts have the potential to destabilise society.

The scientific evidence is unequivocal: Humanity will face even more severe environmental and social crises in the coming years and decades. Six of nine planetary boundaries have already been crossed; others will likely be transgressed in the foreseeable future.[6–8] Also closely related to climate change, biodiversity loss poses an equally serious threat, putting at risk the availability of food and materials for millions.[9] Overconsumption, the linear economy and growth orientation are all root causes of transgressing the planetary boundaries. At the same time, the world faces several social crises. Income inequality is on the rise in OECD countries[10] as well as globally.[11] In the EU, more than 20% of the population is at risk of poverty or social exclusion.[12] And while until recently, extreme poverty has fallen substantially worldwide, relative poverty has not, with 2.1 billion people still living without adequate access to essential services and decent living standards.[13]

For a deep sustainability transformation, governance needs to provide solutions that simultaneously address these multiple socio-economic crises, inequalities and long-term environmental and social risks. Drawing up and implementing a coherent and long-lasting agenda for this task is the challenge of this very decade.

Overconsumption

The main driver of the overuse of natural resources and sinks – such as the atmosphere and the oceans – is current modes of production and living. Specifically, the exponential levels of consumption of goods and services by the 'transnational consumer class' in both the global North and global South are directly attributable to the transgression of planetary boundaries and the proliferation of social and environmental inequality.[14] Such increased consumption is an integral part of the growth orientation in a linear economy. In addition, this behaviour is part and parcel of the 'consumer culture' that has developed over the past century in many countries worldwide.[15,16] A central characteristic of this consumer culture is the desire to augment social distinction and status; another is the thirst for ever increasing convenience, with ever new technologies promising to save time and alleviate effort. Driven by accelerating product-innovation cycles, advertising and product obsolescence, this results in high material living standards and a vast throughput of energy and resources.

To remain within planetary boundaries and fairly and equitably satisfy the needs of a growing world population requires consumption to be reorganised based on principles such as regenerative design, circularity, sufficiency and equity.

Growth orientation

The linear nature of economies is closely related to the exponential growth of the world economy. Human activity and with it humanity's impact on the Earth's ecosystems experienced a great acceleration in the 1960s.[17] The level of global economic activity measured by gross domestic product has grown exponentially in the past decades, and with it the increased use of fossil fuels, natural resources, greenhouse gas emissions and various other environmental impacts. This has already led to the transgression of six out of nine planetary boundaries.[6–8]

Over time, various economic and social institutions in European economies providing, for example, social welfare, unemployment and other state services have been designed to depend on continuous economic growth; they function well only if the economy keeps growing. Similarly, the metabolism of equity companies and the overall financial system is deeply entrenched in a steadily growing economy. Such dependencies impede the implementation of sustainability transformations, particularly during a period of stagnation or reduction of production or consumption. An economy that respects planetary boundaries must overcome this growth dependency and instead focus on satisfying the needs of all people on the planet without violating the boundaries of the safe environmental operating space.[18] If governed properly and supported by system innovations, digitalisation can become a key lever to achieve growth independence.

Environmental inequalities

Environmental sustainability challenges are inextricably linked with economic and social inequalities. Vulnerable societal groups tend to be most affected by environmental degradation. They often live in the most severely affected and polluted areas. For instance, low-income communities are often most affected by a rise in extreme weather events due to climate change.[19] Vulnerable groups also have less choice, mobility and flexibility regarding where they live, work and how they consume services. This leaves them ill-equipped to adapt to environmental changes.[20]

Inequalities between social groups are complex, as various dimensions of inequality and discrimination exist. These are intersectional and run along the axes of income, class, education, race, gender, age, disability etc., causing some citizens to be disadvantaged in more ways than one. Moreover, vulnerable groups face multifaceted inequalities, such as insufficient access to housing, public services, health care, healthy food, or digital infrastructures and services. Reducing such inequalities is at the core of a deep transformation. A more equal distribution of resources and opportunities is a prerequisite to facilitating the societal and economic changes needed to achieve environmental sustainability. If governed properly, digitalisation can contribute to improving economic resilience, which in turn can greatly enhance equity in opportunities globally. But this will only happen when policies that actively direct digitalisation towards this purpose are in place.

Linear economy

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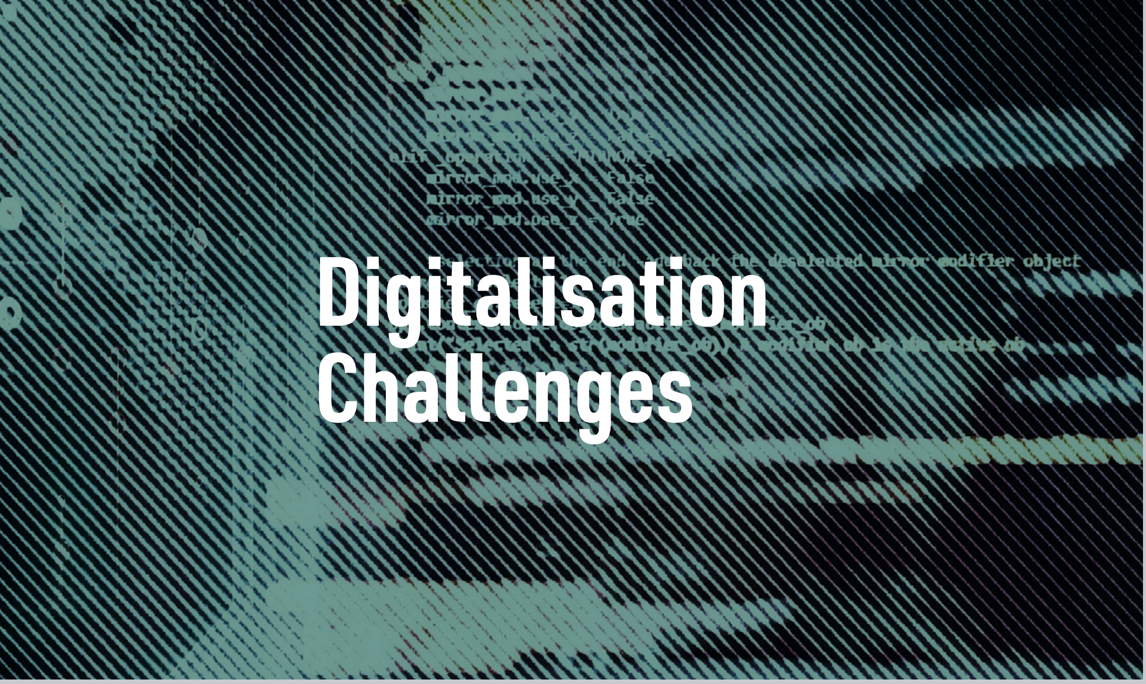
Current production systems are characterised by paradigms stemming back to the industrial revolution. In these linear systems, raw materials are extracted, transformed into consumer products, and then discarded as waste. The linear production system is also rooted in colonial systems and neo-colonial trade relations: To this day, the industrial global North continues to enjoy an abundance of materials and fossil energy carriers at the expense of the global South, where raw materials are exploited at low cost, under problematic labour and safety conditions. It is everything but a level playing field. The advantaged position in the global North incentivises organisations to exploit energy and materials as a substitute for labour. But the North's insatiable demand for resources comes at a high cost, and the resulting carbon emissions, resource depletion, and environmental degradation further increase the environmental debt owed by the global North to the global South.

Linear production depletes natural resources and has a detrimental impact on ecosystems and local as well as global communities. Such systems from the last century are ill-equipped to equitably serve the needs of the Earth's predicted ten billion citizens by 2050. Ergo: Continuing to bet on the linear economy and kick the can down the road is neither tenable nor defensible. This old economy must be overhauled and turned into an information-based circular economy comprising connected systems designed to reduce the impact on scarce resources, protect fragile ecosystems and decrease exploitative global relations. Key digital innovation in the circular economy will facilitate a shift away from merely accelerating the linear economy towards creating a new circular economic system. This transformation towards circularity must, at the same time, support sovereignty in choices as well as equity in opportunities.



Digitalisation Challenges

Monopolies

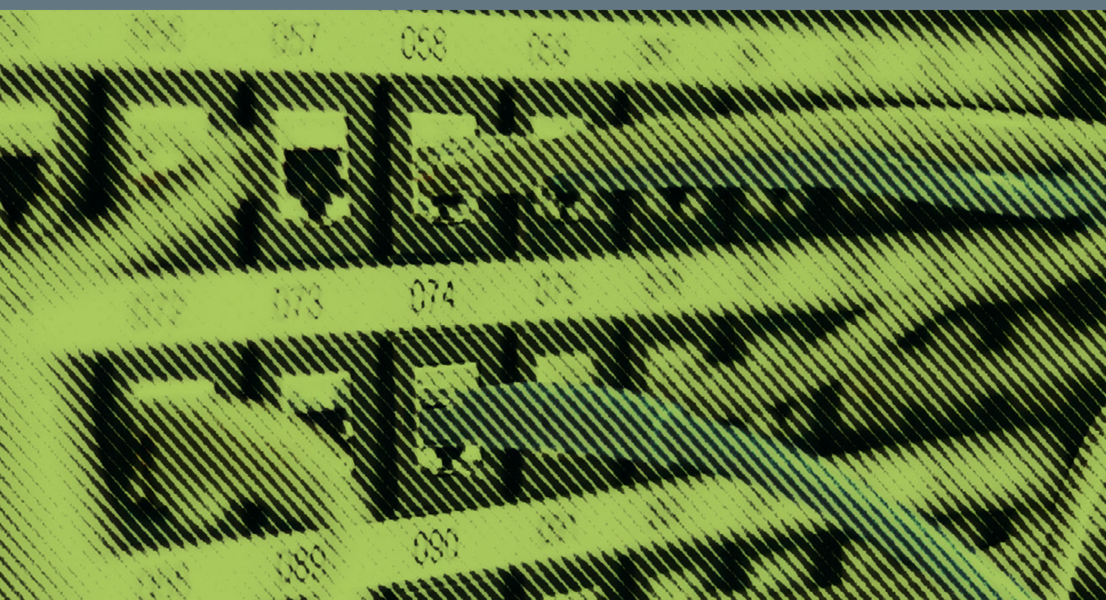
Current forms of digitalisation bring about concentration of power in the digital economy as well as in other sectors. From hardware to software production, from social media to cloud computing – the digital economy is in the hands of very few global companies. Markets of the digital economy are often 'superstar markets': Strong network effects and the tendency towards 'natural monopolies' can be witnessed in diverse areas such as microchip production, operating systems, business application software, internet search, social media, online advertising, cloud computing, digital payments, video streaming and online shopping to name but a few. Such concentration of economic power allows dominant companies to be powerful gatekeepers and prevent competitors from entering the market. Moreover, they dominate the policy agenda through lobbying with a revolving door between their employees and government staff and championing a trend of self-regulation.

Market monopolisation also stands in the way of innovation. Dominant tech companies buy up start-ups. With privileged access to big data, they are best situated to apply Artificial Intelligence-based services that are likely to rule the markets of tomorrow. The concentration of power in digital markets moves economic injustice from a division of labour to a division of learning: between those economic actors that are able to learn and make decisions based on global data flows and those that are (often unknowingly) subject to data extraction. As a consequence, the superstar companies are able to maintain and continuously expand their enormous profits. Strategies for a deep sustainability transformation will follow principles of equity and sovereignty in order to retrench and avoid market monopolisation for the economy of the 21st century.

Power asymmetries

Next to the concentration resulting from network effects, a second type of power is emerging. Information asymmetries are known in many markets and are a typical form of market failure, calling for governmental policies. However, never before in history have single private or public institutions had such detailed and real-time data about political opinions, consumption desires, movements, behaviours, physical attributes, psychosocial profiles, political opinions, consumption habits and social trends. Just a smattering of tech companies, such as Acxiom, Alibaba, Alphabet (Google), Amazon, Apple, ByteDance, Meta (Facebook), Microsoft, Oracle, Tencent and others, possess information not only about billions of people worldwide and can profile and target them as individual consumers and voters, but also possess detailed information about other companies, civil society organisations, political parties, infrastructures, and physical environments such as agriculture. A similar threat arises when states assemble the corresponding knowledge and use it to control their citizens.

This concentration of data has become a matter of political power. Whoever has access to data on profiles, trends, and designs, and whoever controls the technologies that monitor the activities of billions of individual citizens, is able to influence opinions and even shape behaviour. If allowed to continue unfettered, the increasing power of those who accumulate information will further undermine the sovereignty of citizens and reduce the ability of democratic politics to govern digitalisation for the common good. As power asymmetries have already reached highly problematic levels, big-picture thinking is required, and existing structures must be comprehensively overhauled. By following principles of participation, regeneration, (data) sufficiency, and sovereignty, this change has the potential to establish more equitable market structures and power relations.



Appropriation of commons

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Several digital services that are public goods are provided and governed by private companies. These include the two generic search engines (Google, Bing), the two mobile app stores (Google Play Store, AppStore), as well as a variety of platforms (e.g., social media, shopping, payment, video conferencing, industrial product data, etc.) and ICT infrastructure (e.g., cloud services, authentication services). All of these platforms have a large global user base and provide services that are of key importance in economic and social life today. During the COVID-19 pandemic, the dependencies of citizens, other companies, and also governments on these platforms further increased. At the same time, their rise boosted the displacement of publicly owned and governed (traditional) infrastructures. The private companies operating them intend to earn revenues by providing commercial goods and services rather than providing social welfare. This shift of public infrastructures and their services to private hands reconfigures the welfare state as one that is increasingly directed by the computational optimisation done by a handful of market players rather than by social aims and legitimisation through democratic processes.

Several digital companies are now no longer market competitors but have become the market itself. As digitalisation has proliferated without almost any regulation, it is the companies that set the rules ('code is law') of their proprietary markets.[21] Companies usually require customers to concede far-reaching rights over their data and restrict access of any third-party competitors. This generates unprecedented new dependencies as other industries begin to follow suit. For instance, in agriculture, the concentration of field and farm data in the hands of a few companies turns millions of farmers into the farming subject of those firms, and creates lock-ins for established farming practices and contracts. Strategies for digital sovereignty and a regenerativedesign of digital technologies are required to redeem politics over profit motives.

Surveillance

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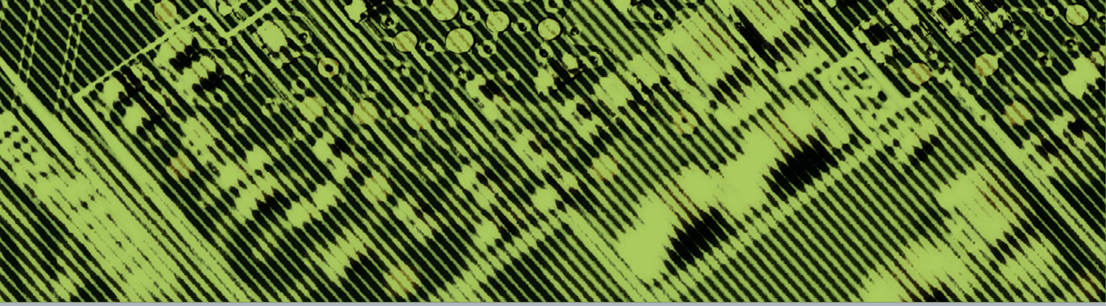
Widespread datafication of a growing part of personal and social life is not solely driven by private companies but also by state institutions to ensure security and public order - or to stabilise authoritarian rule. While capitalist surveillance[26] has severe implications for consumers, state surveillance has even more significant implications for citizenship and procedural justice. Surveillance runs the risk of proliferating social sorting and scoring practices – for example, crime and predictive policing in low-income communities or among people of colour. Moreover, the ability to monitor, record and store digital transactions on a massive scale creates an atmosphere that limits the possibilities for dissent, social and environmental protest, and the freedom to experiment with new sustainable living and working practices.

Extended data collection and surveillance of urban spaces – from mobile phone companies to digitalised public transportation facilities – can be utilised to control political dissent and protest.[27] This may impede free speech, leading to self-censorship, or active repression. Surveillance capacities have also massively expanded into rural spaces with the introduction of 'big data' in agriculture, where digital service platforms currently remove decision-making and autonomy from farmers.[28] Beyond the implementation of privacy and data protection regulation, which enhances digital sovereignty, strategies for digital sufficiency can help ensure the least necessary amounts of data are stored and analysed in the first place.



Polarisation

The age of digitalisation is accompanied by high and often increasing levels of economic and social inequalities domestically and internationally. Income inequalities have risen in almost all OECD countries over the past decades,[10] and the increasing application of digital technologies has contributed to this development. Digitalisation polarises wage levels both within as well as between companies.[22,23] Rationalisation of jobs is expected to affect disproportionately strong middle- and low-paying jobs.[24] New jobs created by digitalisation tend to necessitate either very high education levels combined with legal permission to work, or they are located in the very low-skilled service sector.[25] In addition, digitalisation promotes a reduction in the share of wages in gross domestic product vis-a-vis the share of capital income. Hence, wage inequality and income inequality increase. Moreover, the digital economy is characterised by a high level of precarious work: Stackers in e-commerce warehouses, 'juicers' from e-scooter platforms, drivers from ride-sharing services, as well as lower-skilled gig workers often work under precarious conditions with poor pay.

Polarisation also occurs along other lines of social segregation, such as gender, race and class. Globally, the digital economy is characterised by unequal geographies: Headquarters of key corporate actors are mainly in the US, China and, to a lesser degree, Europe. Seen from the headquarters, the world is divided into promising markets of countries with sizeable domestic consumer bases and growing consumer classes. Rural peripheries, smaller countries, and less affluent consumers are frequently left behind in the commercial logic. With one exceptional role for the low-income countries: They may serve as reservoirs for cheap gig work to be outsourced, for cheap raw materials for ICT hardware to be mined, and for e-waste to be exported to their territories. To address polarisation, technology development must be reoriented along principles of equity. In addition, new technologies geared towards system innovation open up the possibility of reducing polarisation and creating greater equity of opportunities.

Taking Stock of Digitalisation for Sustainability

Digitalisation is associated with high hopes to achieve the changes needed for environmental sustainability. As stated by the European Commission, "Digital technologies could play a key role in achieving climate neutrality, reducing pollution, and restoring biodiversity".[5] At the same time, it is widely agreed that digitalisation is a central strategy for economic growth. Accordingly, the European Commission states, "The digitalisation of European businesses is essential for the future competitiveness and growth of the economy".[29] But as argued above, digitalisation generates several social and environmental challenges. The question therefore is: To what extent are current forms of digitalisation capable of solving sustainability challenges? And how can digital technologies be governed to help solve sustainability challenges while at the same time avoiding new problems?

56%

The share of people using video conferences grew by 56% in the wake of the COVID-19 pandemic.[33]

The hopes

There are grounds for optimism that digitalisation's potential can be harnessed to reduce energy and resource demands in various sectors and fields of applications and prevent further violation of the planetary boundaries.[18] And indeed, the material and energy requirements to produce one unit of digital service have been decreasing dramatically over decades. Also, ample scenarios show the potential of digital technologies to decarbonise and dematerialise the economy, for example, in smart factories.[30–32] Other case studies show the potential of digital technologies to substitute physical goods with digital services. For instance, video conferencing and working from home during the COVID-19 pandemic were important prerequisites for reconciling reduced transport while keeping up with high personal productivity. Consequent substitution of physical goods and travel by digital alternatives can be a powerful tool to decarbonise and dematerialise production and consumption patterns. In the future, technological progress and economies of scale may make substitutes such as holographic telepresence even more attractive and affordable. Hence, the potential to substitute physical products as well as travel with virtual alternatives is likely to rise.

The realities

In the past, the total material and energy required to produce and operate digital technologies exceeded expectations due to the immense growth in the number and intensive use of devices and applications. Moreover, the two central hopes – efficiency improvements and substitution potential – have not been realised on a large scale. Digitalisation in manufacturing generates only marginal efficiency improvements,[33,34] precision farming in agriculture reduces pesticide use only slightly in most cases,[35] and whether online shopping is more sustainable than shopping in a store depends on specific circumstances.[36] In addition, several countervailing effects also pose challenges to realising substantial environmental improvements in the future. The potential to improve energy and resource efficiencies is accompanied by various unintended side effects. Efficiency improvements are associated with new possibilities to apply digital technologies – leading to an even stronger increase in the number of devices and their usage. Moreover, many digital technologies save time and increase convenience; but the more attractive, the higher the demand – which in turn boosts energy and resource use. A case in point is that consumers can engage in one-click shopping at any time, and from anywhere, which can be directly correlated to rising consumption levels.[37] Or a driverless car that drives more energy-efficiently per kilometre may – in effect – increase traffic and fuel consumption overall.[38] Likewise, on the production side: Digitalisation increases labour productivity, which contributes to an expansion of production and hence, causes additional demand for energy and resources, despite increasing energy efficiency.[39] To summarise, efficiency improvements cause rebound effects, increasing the overall volume of consumption and countervailing the beneficial environmental effects.[40]

0.007%

Digitalisation in firms increases energy efficiency by only 0.007% per 1% increase in software capital.[33]

Concerning the substitution potential, consequent replacement of physical goods and travel by digital alternatives appears not to be the rule but rather the exception. Consumption of digital services often complements pre-existing consumption practices, as is the case with video-streaming compared to conventional TV watching.[41] Besides, digital devices and services are far from being immaterial. The increasing number of applied devices, intensified use patterns, and new digital consumption desires are accompanied by substantial energy consumption, resource use, and emissions from the ICT sector itself.[42]

As has been shown, digital communication technologies and media infrastructures have so far not initiated a circular economy, nor have they contributed to solving any of the pressing environmental issues of our time. Hence, digitalisation is a double-edged sword with regard to environmental sustainability. On the one side, digital technologies initiate higher efficiency, and digital services substitute physical goods. But on the other side, the growth in the number of digital devices and services spurs energy and resource consumption, and their application leads via various rebound effects to additional consumption in other sectors.

The obstacles

Some studies highlight the potential of digital technologies to increase their sustainability contributions in future years. For instance, there are promising examples of how Artificial Intelligence could play a role in climate change mitigation and adaptation, for instance, by better predicting energy demand patterns and flattening energy peaks in urban spaces.[43] While such potential ought to be explored, the capacity of digital technology approaches alone to prevent further transgressions of planetary boundaries should not be overestimated.

Similarly, the socio-economic potential of digitalisation is repeatedly stressed. Digital technologies have the potential to make economies more resilient, support equity and strengthen participation. But as has been demonstrated above, current forms of digitalisation exacerbate challenges such as monopolisation, polarisation and surveillance.

The two hopes of digital technologies – efficiency improvements and substitution potential – have not delivered for environmental sustainability.

However, digital technologies do not automatically lead to environmental and societal improvements. These largely depend on the circumstances under which the technologies are implemented. Such circumstances need to be understood and shaped to fully exploit digitalisation's potential. Innovations always take root in political, economic and regulatory systems.[44] Technology adoption and use take place in pre-existing power structures and happen unevenly across the world.[45] Dominant market actors, embedded and successfully operating within the existing economic framework, often appropriate innovations to sustain path dependencies and perpetuate locked-in modes of production and consumption.[46] For example, as the car industry faces strong political interventions as well as loss of image due to its climate impact, new visions of self-driving vehicles and luxury driver-assistance systems are used to maintain attractiveness and market power. Obviously, such path dependencies prolong existing risks from the unsustainable status quo, as they optimise current production processes, bind customers to established markets, and uphold habitual consumption practices as there is no incentive to do otherwise.

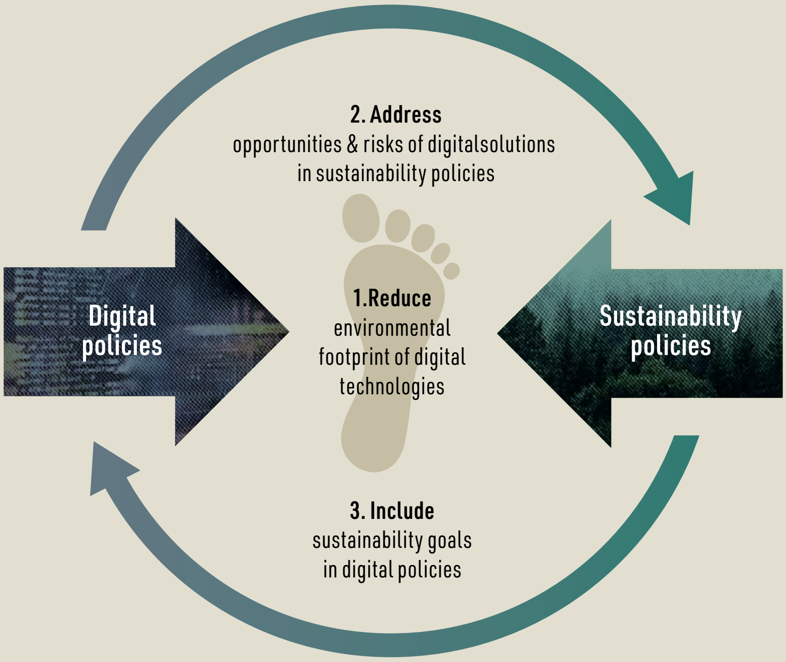
264 billion US dollars
Tech companies spent 264 billion US dollars on buying up rivals in 2021.[47]

As long as new digital technologies and practices are introduced without being integrated into a mindful preconceived programme of replacement or reduction of harmful practices, sustainability aims will likely not be met, or if (in the unlikely event that) they happen to be met, will only appear as an arbitrary collateral outcome but not as a systematic and planned sustainability programme.

Figure 02

Three policy strategies for a sustainable digitalisation

To ensure that different policy fields are coherent, digital policies need to become sustainability-oriented, and sustainability policies need to address the opportunities and risks of digital technologies.



‹ The actions needed

To sum up: Yes, digital technologies bear the potential to spur the societal and technical innovations necessary for deep sustainability transformations. But it does not suffice to wait for this potential to materialise out of thin air. Green digital innovations remain in niches, while the prevailing market forces of digitalisation maintain linear economies that service economic growth and increasing overconsumption.

To change this, governance needs to be tied to a broad vision of the role digital technologies play in facilitating that people in all places attain a decent standard of living within planetary boundaries. What purposes do different nations, social groups, and individuals want digitalisation to serve? How can digital technologies be harnessed to help transform the existing economic model towards greater social and environmental sustainability? What guiding principles must policymakers, companies, and individuals follow to ensure that governing digitalisation allows it to become a meaningful contributing factor to overcoming the great challenges of the 21st century? Developing a sustainable vision of digitalisation needs to engage citizens and civil society but also the private sector – in all its diversity (company sizes and business models) – to be key partners at the table, rather than allowing big technology firms to be the dominant framing power and wardens of the future. As a starting point to developing mindful and purpose-focused collective digital futures, citizens themselves must be invited to consider their own visions of a life they have reason to value, within planetary boundaries.[48]

Against this backdrop, the governance of digitalisation must pursue three integrated aims: First, the environmental footprint stemming from production and use of digital technologies and infrastructures must be minimised. Second, the environmental opportunities and risks of digital technologies must be incorporated into sustainability policies throughout economic sectors. And third, the governance of digital technologies must inherently account for sustainability goals. In the following chapter, this report develops guiding principles for how governance needs to shape digital technologies that support these three aims.

Figure 02 Three policy strategies for a sustainable digitalisation

Principles for a Digital Reset

A deep sustainability transformation requires fundamental changes in digital governance and the organisation of economic sectors. Old logics and leitmotifs that drive digitalisation to pertain to the fossil age and to neo-colonial globalisation need to be discarded. New principles that guide forms of digitalisation subordinated to the goals of a deep sustainability transformation have to be established and need to become mainstream. Such principles can act as guiding stars for policymakers, business leaders, civil society, and citizens because they prescribe the direction for concrete transformative action.

The following chapter defines seven principles that should serve as the starting point for a Digital Reset. These principles advise how to shape digitalisation in a way that helps surmount the general sustainability challenges mentioned above while redressing the particular challenges that the process of digitalisation has generated so far.

‹ Regenerative design

The design of digital technologies (hardware and software) should be determined by democratic and participatory processes and help regenerate natural ecosystems and promote social cohesion.

The design of digital technologies shapes not only economic processes but also has environmental and social implications. For instance, data-driven technologies are increasingly integrated into environmental and climate-related responses, from geo-engineering to ecological conservation to disaster management. At the same time, design features prefigure which population groups will use the technology and be able to take advantage of the information (data) generated. Yet to date, most technology design is associated with power accumulation, a polarisation of opportunity and environmental inequalities. A major reason for this is that the design of key ICT devices such as smartphones and sensors, key apps such as social media messengers and shopping apps etc., as well as digital infrastructures, are left almost entirely in the hands of a handful of corporations.

To regenerate natural ecosystems and promote social cohesion, the process of designing technologies must become more democratic, co-creative and sustainable. At the heart of regenerative design is creative problem-solving rather than profit maximisation. By taking a wide-angle perspective, regenerative design transcends from a consumption-centred focus to a planet-encompassing focus - with humans as an integral part. Ultimately, this evolution from designing objects to designing material flows and systems serves the common good.

To achieve a balance between innovation and creativity in industry on the one hand and securing freedom of choice and societal legitimation of digital infrastructures on the other, the design process should be as open, participatory, and transparent as possible. Regenerative design helps to integrate diverse views, needs and issues – not just those of predominantly highly-educated, middle-class males in urban centres. Co-design principles with active participation from all users are essential. Therefore, design specifications must include mandatory accessibility requirements for special-needs users. If designers, technologists, communities, and industries around the world are able to support and champion independent spaces for critical reflection across disciplines, as well as support design-led environments that foster open learning and iteration, a regenerative digital design movement may emerge. This movement can play a significant role in enabling the deep transformations that our societies need to stay within the thresholds of critical Earth-system processes.

System innovations

Digital technologies should be used for system innovations that alter the basic operational patterns of sectors and arenas rather than merely for incremental optimisations that maintain the status quo.

In order to overcome the sustainability and digitalisation challenges caused by linear production systems, growth dependencies, polarisation, and monopolies, economic sectors must go beyond (mere) incremental change and embrace systemic transformation. This is challenging, as each sector entails several lock-ins and is deeply entrenched in the existing economic and societal structures. However, digital technologies can potentially be used for system innovations that bring about systemic change and overcome such lock-ins. For instance, instead of optimising agricultural production by use of precision farming, digital technologies need to become part of transforming large-scale and input-intensive farming systems into locally embedded ones that are adjusted to diverse cultural, geographical and climatic conditions. Likewise, a profound transformation is needed in mobility: Instead of initiating driverless cars, digital innovations need to be geared towards designing more public and shared transport, thereby reducing the number of kilometres driven per person. And instead of making linear production systems more efficient, data and information can be put to better use, designing and pioneering ground-breaking circular production systems.

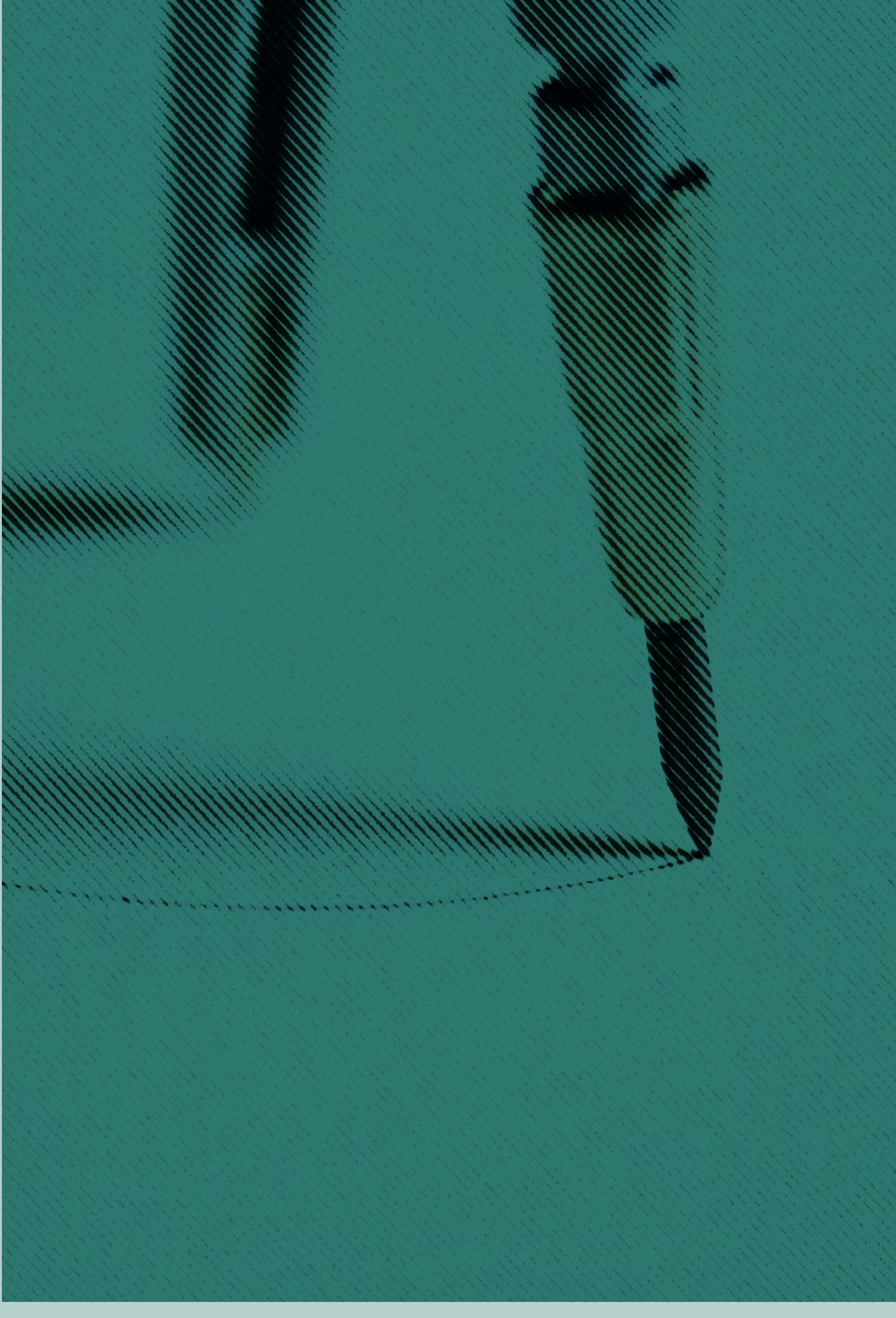
Digital system innovations require the development and implementation of different types of technologies. These technologies must go hand in hand with social innovations and the institutional and behavioural changes that make them happen. Together, technological and social innovations can bring about the systemic transformation needed to overcome overconsumption, the linear economy and growth orientation.

Sufficiency

The prevailing strategy of using digital technologies to improve efficiency must be guided by an overarching strategy for sufficiency – aiming to seek enough rather than more.

The level of overconsumption and growth orientation hardwired in current economic systems must be replaced by both efficiency and sufficiency strategies towards sustainable production and consumption. This applies both to the ICT sector as well as the broader economy. Despite increasing resource efficiencies in the ICT sector, its overall environmental impact is currently increasing. This is due to the sector's strong growth in terms of hardware production, rise of digital use cases, data volumes, and unsustainable ICT use patterns.

Making digitalisation work for sufficiency comprises four dimensions.[49] First, as a general rule of thumb for individual users, companies and public authorities, digital technologies and infrastructures should be used frugally, along the lines of 'As much digitalisation as necessary, but as little as possible'. Second, ICT design needs to make devices durable, repairable and built to last. To achieve this, it is essential to promote the idea of quality over quantity in digital products and ensure interoperability, repairability and open modification. The digital sufficiency criteria that hold for hardware also need to be developed for software products to organise data transfer and use processing and storage capacities more frugally. Third, digital technologies should be designed to support sufficiency-oriented behaviour in all areas of life. Fourth, in the broader economy, digital sufficiency means implementing markets and business models that support sufficiency for individuals and devices as well as shifting away from growth orientation. This helps to contain rebound effects from digital efficiency improvements and to keep resource and energy demand within planetary boundaries. Seen from a larger perspective, a comprehensive strategy for digital sufficiency is a key lever to facilitate the transition to growth-independent and resilient economies.



Circularity

Digitalisation should be geared towards achieving circular production patterns, both in the ICT sector as well as in other sectors.

A future economy will become sustainable only by restructuring the linear economy to a circular economy. The first step towards circularity is to make the production of digital devices and infrastructure, i.e., the ICT sector, more circular. Most notably, non-renewable resources must be kept in permanent use, and entropy must be minimised. This includes the reduction of material complexity in hardware, the design of devices and infrastructures that ensure repairability, longevity and recyclability (e.g., through modularisation, use of standardised components, publication of construction plans and code based on open-source hardware and software). In addition, users and small-scale businesses must be granted a 'right to repair', and appropriate access to recycling infrastructure after the devices' end of life.[50]

Beyond the ICT sector, digitalisation is best suited to support and enable the circular economy in other sectors that are responsible for substantial material consumption. ICT can contribute to collecting and providing relevant information on resources, components, construction, and supply chains and, thus provide the information needed to design for and realise circularity. It can be used to manage material flows, increase recyclability and reduce waste. ICTs can also be instrumental in creating alternative platforms and establishing new cultures of consumption that keep goods in circulation longer, such as in the fast fashion industry. Moreover, they can enable the measurement, automation and optimisation of systems of production, consumption and waste, such as food, plastic and even localised urban infrastructures, if these systems of material flows are redesigned with circularity in mind. However, because there are physical limits to circularity, the economy will only be able to stay within planetary boundaries by combining the principle of circularity with the principle of sufficiency.


BIG DATA IS

Sovereignty

The use of data should be geared towards enlarging citizens' freedom of choice and reducing dependencies.

Individual, as well as corporate end users today, have very limited control over the data they generate. A few decades ago, data was only generated by an explicit user action, such as pressing an enter key. Today, most data is generated and transmitted by devices without the user's awareness and stored by monopolistic companies or states. As consumers, people are subject to manipulative forms of personalised advertising, including so-called 'dark patterns' which encourage them to behave in a way that is neither intended by them nor in their interest. This may expose citizens to challenges of surveillance and coercion and cause them to be subject to political influence and misinformation, for example, on climate change and other sustainability issues.

Making digitalisation work to improve – rather than impede – citizen sovereignty involves broadening users' freedom of choice to use digital media and services competently and responsibly. This involves both rights and duties in the state regulatory framework, including those established to make consumption practices more sustainable. On the one hand, this requires strong legislation that reduces the amount of ambient and non-essential data collected, demands maximum transparency of what companies collect and how they use data, and sets design criteria for applications to become client-based and commons-oriented, particularly those including machine learning and other types of 'artificial intelligence'. Ways of providing this transparency that do not place the burden of responsibility on the user must be designed and legally implemented. On the other hand, users must gain improved abilities and skills to better reflect and decide on access and rights of third parties to use their personal data.

Besides its focus on users, making digitalisation work for sovereignty also aims at ensuring fair competition between companies, including increasingly practical measures such as portability and the right to remove. This is particularly relevant with a view to the digital economic infrastructures provided and operated by very few global platform companies within 'proprietary markets'. These proprietary platforms gather large amounts of data that lead to wealth, knowledge, and power accumulation in other parts of the world. Hence, digital sovereignty also aims to reduce the dependency of companies, communities, and countries on platforms operated from other territorial jurisdictions in order to ensure democratic control and achieve greater economic resilience.

Resilience

Use digital technologies to foster economic decentralisation and establish distributed economies to improve economic and societal resilience to crises.

This is an age when economic crises may occur with rising frequency and severity. Both the sustainability as well as the digitalisation challenges outlined above pose serious obstacles to ensuring stable economies. Particularly urgent are the current Russian war in Ukraine, increasing environmental inequalities, and the polarisation of wealth and economic opportunities. As digital economy start-ups emerged, some entered established markets and reshuffled existing power relations. Yet as they have grown, they too, have become dominant players and a part of the linear economy. Large platforms are now prime examples of growth orientation while bringing about additional power accumulation and surveillance problems.

The growing centralisation in the digital economy, with the increasing dependence of public and private services on oligopolistic companies and infrastructures, diminishes economic resilience. However, with the appropriate framework conditions in place, digitalisation could also be a powerful lever to decentralise economic power and create 'distributed economies'.[51] Distributed economies interconnect regional and local production systems, which operate independently. This can greatly enhance resilience to economic, environmental and geopolitical crises and also support sovereignty and circularity. At the same time, such a transformation would redistribute economic (market) power, which increases fairness in competition and provides better access to knowledge and resources for all economic actors. Moreover, resilience to the increasing cyber threats that accompany 'digital monocultures' is needed. As traditional cybersecurity measures often work against sovereignty and sufficiency, the principle of resilience also entails finding new and less resource-intensive ways of implementing cybersecurity.

To achieve decentralisation and distributed economies, oligopolies must be prevented. This would also reduce the societal threat of individual companies and institutions surveilling and potentially manipulating large parts of the world's population. Moreover, data must also be made available to small businesses, public actors and civil society organisations in sectors such as agriculture, mobility, consumption, and others. In addition, software and hardware developers should innovate digital technologies for small-scale and local production. At the same time, economic framework conditions must be developed to incentivise the use of digital technologies for decentralised business models.


JUST TRANSITION NOW

Equity

Digitalisation should be designed to improve social and environmental equity.

Digitalisation as well as a deep sustainability transformation may alter existing configurations of opportunity, privilege, and income in different societal groups concerning income, class, education, race, gender, and disability. Inequalities along these lines exist both between countries and within societies. So far, digitalisation has exacerbated the polarisation of opportunity and environmental inequalities. Income inequalities are rising. In terms of environmental equity, digital overconsumption in the global North fuels emissions, the mining of conflict minerals and e-waste problems in the global South. In addition, digital divides along various intersectional axes trace existing lines of inequality between countries and within societies.

In a deep sustainability transformation, economic, political, and societal opportunities need to be distributed equitably to be scalable to ten billion people in the 21st century. First, the digital world, including political participation, public services and information access, needs to be accessible to and affordable for everybody. Second, economic and social opportunities in a digitalised economy must be equitable. This includes providing access to education to everybody to obtain the skills needed in the digitalised society, as well as distributing capital-based income more equitably among the population. It also entails equitable opportunities regarding various lines of discrimination, including class, race and gender. Third, digitalisation and the sustainability transformation within Europe, must aim to facilitate exchange with and opportunities for people in other parts of the world.

To redress the polarisation of wealth and power asymmetries, digital gig workers need to be supported in their struggle for better working conditions, by legislation and by supporting their legal right to unionise. The gender gap in science, technology, engineering and maths education and in participation in the IT workforce must be addressed. This will require engagement with discriminatory social norms and discourse. Procedural fairness and racial and gender justice considerations must be considered before using algorithms to make decisions about people, thereby guarding against systemic bias.


2

How Digitalisation Can Support Deep Sectoral Transformations

Humanity is at a watershed moment. How societies respond to the multiple sustainability and digitalisation challenges at hand will shape this century and the next. Tackling these challenges head-on requires a deep transformation. Such a transformation occurred once before – in the 19th and 20th centuries when many European economies transitioned from agrarian to industrial societies. This change process affected all sectors and is often referred to as the "Great Transformation".[52] In order to avert the urgent social and environmental crises of our time, a transformation of similar scale is now necessary.[53] Such a transformation will encompass simultaneous transformations of all economic sectors in parallel. Agriculture, mobility, industry, energy, housing and consumption of goods and services all must undergo profound changes.

In Part 2, this report develops a concrete vision of the role digital technologies can play in the endeavour to set in motion deep sectoral transformations. For instance, industrial monoculture farming, which is currently threatening farmers' livelihoods and biodiversity, must implement system innovations towards agroecological farming practices in order to become circular and redress global inequalities. What is more, the design of digital technologies needs to be developed and shaped by democratic and participatory processes – with farmers and consumers getting a greater say in tech development.

> * How societies respond to the multiple sustainability and digitalisation challenges will shape this century and the next.

In the following, such visions are developed sector by sector, highlighting particular challenges, actors and principles for each. Moreover, detailed policies, new institutions and alternative practices are presented that can enable government representatives, business leaders and consumers to contribute their part. Naturally, transformations in each sector will proceed differently. Still, coherence is key: Only if the opportunities and risks of digital technologies are systematically addressed along the same principles will the various sectoral transformations contribute to the larger goals.

« Diverse and Embedded Agriculture

Transformation of the agricultural sector is crucial to tackle climate change, stop biodiversity loss and soil degradation, and ensure functioning ecosystems. The Russian war in Ukraine and the subsequent shortage of fertilisers, grain and other crops on the world market has again highlighted the environmental and social importance of agricultural production. Farming is crucial because it provides the very basis of livelihood for more than two billion people on Earth who directly depend on this type of work, plus approximately another billion people who work in sectors linked to food and agriculture. Agriculture is particularly pivotal in reducing the hunger and poverty of the world's poorest people. These billions of individuals, their families, and the functioning of fragile ecosystems of farming communities worldwide must be at the heart of a deep sustainability transformation of agriculture. Hence, ensuring that farmers and farm workers achieve a democratic say in the governance of that process is not only a matter of procedural justice but of basic human rights.

69%

In the EU, 69% of all farms are small or very small (production value of less than 8,000 EUR/year).[54]

‹ A purpose for digitalisation in agriculture

Digitalisation can support such a transformation process. However, evaluating which kind of agriculture and land use system is socially and environmentally most sustainable is key to determining the technologies that are best suited to precipitate the transformation pathway. Currently, a relatively small number of transnational corporations in the agricultural system, such as Bayer (incl. Monsanto), Chem China (incl. Syngenta) and Corteva (incl. DuPont & Dow), are forging ahead with their vision of the future of industrialised farming systems. They have set in motion a comprehensive change process, which is indeed much about the digitalisation of farming and food systems. However, strong criticism has been voiced from the scientific community, civil society and farmer organisations, most notably in the global South.[28,56] The criticism concerns whether the digital farming solutions marketed by these corporations will deliver not only on shareholder value but on social inclusion of farmers and the regeneration of soils, biodiversity and ecosystems.

700 million US dollars

Venture capital interest in new agricultural technologies grew more than 100% in 2017 compared to 2016, exceeding 700 million US dollars annually.[55]

Current proposals for 'smart farming', 'precision farming' or 'agriculture 4.0' are based almost exclusively on bringing about environmental improvements through digital optimisation of the existing agro-food systems.[57] These approaches do not aim at a deep transformation, nor do they follow a farmers-first approach.[58,59] A deep transformation approach would start with remediating the causes of environmental destruction and precarisation of

farmers rather than simply mitigating their symptoms.[61–63] This deep transformation is often related to concepts of Agroecology, which contain the contextualised application of ecological principles to agriculture and build on the identification and use of best locally adapted practices in food production.[64–66] The Food and Agriculture Organisation has developed a broad participatory process with many farming, scientific and civil society actors, which has established '10 elements of agroecology'.[67] Digitalisation must be integrated into such approaches in order to transform agriculture to the extent needed.

1.75%

Yield increases by only 1.75% due to applying the Internet of Things in farming.[60]

Social implications of industrial agriculture

The 20th century witnessed the horizontal consolidation of specific agricultural input sectors (e.g., seeds, pesticides, fertilisers) as well as strong market concentrations among the buyers and sellers of agricultural commodities. The first decades of the 21st century, however, saw the vertical convergence of these various agricultural sectors into agricultural 'technology platforms'.[56] This vertical integration became possible with the exponentially growing computing, geospatial and networking capacities and the increasing availability of various data sets. These gave rise to complex platforms, driven largely by algorithms and big data analyses that interconnect available farm inputs with cultivation methods, harvested outputs with marketing, and distribution channels with logistics and transport.

Figure 03 Global market concentration in agriculture[68]

This model is scalable and can be established at global and national levels. At the global level, Bayer is currently the top performer of such a business model. Bayer strategically acquired Monsanto and prime assets in the digital sector like the Climate Corporation and other IT companies. The newly formed mega-corporation set out to digitally integrate all its products and services and created 'Fieldview', a platform operating at the global level. However, other global actors like John Deere are also attempting to enter this lucrative market. Platform providers offer digital services for autonomous or remote-controlled precision cultivation techniques tailored to large-scale and capital-intensive farmers. It is not by coincidence that the platforms also serve the companies to increase sales of their own chemicals (e.g., pesticides, synthetic fertilisers) and biotech seeds.

Such digitalisation of industrial agriculture can impact the agency of farmers and farm labour in the field. New technologies are presented as augmenting decision-making, which may be true to some extent. But the data from all farms are gathered and analysed centrally, creating value as patterns and unique insight across millions of farms and billions of hectares of land are revealed. The farmer's 'knowledge' is reduced to its function as a data provider that serves as a resource for extraction by mining algorithms. In fact, in these centralised industrial models, the farmer's data becomes the new commodity for value-addition business models. On top of that, rigid lock-ins into high input and emission systems and capital-intensive farming systems are created.

385 million EUR

Bayer's Crop Science division plans investments of 385 million EUR in digital methods and novel technologies by 2026.[69]

These digital approaches and business models are ill-suited to making agriculture sustainable. At best, they increase environmental efficiencies, e.g., reduce energy or water consumption per field and yield.[70] But increased precision in irrigation, for example, often creates incentives to grow more water-intensive crops or to expand the cultivated area and thus leads to increased water consumption – a rebound effect.[71] More importantly, the increase in efficiency does not automatically initiate a shift towards production methods that are adapted to local conditions, foster social coherence within the farming communities, and address the multiple environmental and social challenges agriculture faces. Instead, farmers become increasingly dependent on service packages offered by the farm information platforms.

Digitalisation for agro-ecological farming systems

In order to transform industrial farming systems along agroecological principles, digital technologies need to support farming practices that are independent of specific inputs like synthetic pesticides and fertilisers as well as from the obligatory use of heavy, cost-intensive and proprietary machinery. Digital technologies must be designed to replace monocultures and encourage the use of locally adapted seed varieties, including those saved and developed by farmers. If public, private and civil society funding institutions realise that the potential of implementing digital technologies for dealing with the complexity and diversity of agroecological farming systems is severely under-researched, the purpose, as well as the content of funding schemes, can be adjusted accordingly. The development and use of field robots, sensors, farm management information systems, decision support systems, geospatial capabilities, and other technologies can and must be geared towards supporting diverse polycultures, the use of organic fertilisers, cover cropping, and no-till practices. This will be possible if the potential is recognised not only by policymakers but also by other key actors – first and foremost by farmers and their communities whose

Figure 03

Global market concentration in agriculture

Agricultural markets are highly concentrated for seeds, agrochemicals, synthetic fertiliser and farm equipment.[68]

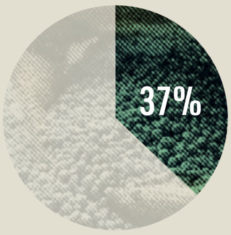
Market power of the top 5 companies:

Seed Sales

- 22 % **Bayer Crop Science** (includes Monsanto, Germany)
- 19 % **Corteva Agriscience** (USA)
- 7 % **ChemChina / Syngenta** (China)
- 4 % **Vilmorin & Cie / Limagrain** (France)
- 3 % **KWSi** (Germany)

Agrochemical Sales

- 24 % **ChemChina/Syngenta** (China)
- 18 % **Bayer Crop Science** (Germany)
- 12 % **BASF** (Germany)
- 11 % **Corteva Agriscience** (USA)
- 7 % **FMC Corporation** (USA)



Synthetic Fertiliser Sales

- 11 % **Nutrien Ltd.** (Canada)
- 9 % **Yara** (Norway)
- 9 % **The Mosaic Company** (USA) (incl. Mosaic Fertilizantes sales, Brazil)
- 4 % **CF Industries Holdings, Inc.** (USA)
- 4 % **Israel Chemicals Ltd.** (Israel)

Farm Equipment Sales

- 18 % **Deere & Co.** (USA)
- 11 % **Kubota** (Japan)
- 9 % **CNH Industrial** (UK/Netherlands)
- 7 % **AGCO** (USA)
- 4 % **CLAAS** (Germany)

engagement in co-creating these tools is fundamental to their success. There is a growing field of independent start-ups, designers, developers and engineers from different disciplines (including software and hardware developers in the IT and machine engineering sectors) who are willing to contribute to ecological innovation in this sector. However, targeted funding opportunities must become available for these sectors to co-develop digital tools that address the needs of ecological farmers and support farmers who are willing to convert their conventional farms to agroecological farms. A diverse, accessible and independent digital agriculture sector that is in the service of regenerative principles is a crucial building block in the successful transformation of our food systems.

Designing digital technologies for agriculture must be open, transparent and include farmers and their communities in a co-creative process.

Digital technologies should be designed for locally adapted and independent farming practices, not to consolidate market power in agriculture.

Therefore, it is critical to have technology and innovation policies that promote a digitalisation strategy in agriculture towards achieving agro-ecological system change, including its social, cultural and economic dimensions. This could entail regulating digital platforms in agriculture[72] and providing public data infrastructures that require, for example, compliance with environmental goals such as circular economy principles. Projects pursued by GeoBox or the EU's Agri-food data portal are on the right track. However, without a comprehensive digitalisation strategy, none of these projects are targeted towards a deep and sustainable transformation of agro-food systems but rather follow the paradigm of optimisation and improved efficiency within the framework of the existing destructive forms of agriculture.[73] While some scholars have pointed out the lack of regulation in the field of digital agriculture and highlighted the current laissez-faire attitude, the concerns raised focus almost exclusively on data ownership and privacy issues, the competitiveness of the ICT sector, unequal access and social, and economic inequalities.[74,75]

Digital technologies can only unfold their potential to contribute to sustainability goals as a part of an overall transformation agenda of the agricultural sector. Digital platforms should be required to provide evidence on how they support biodiversity and soil fertility, reduce greenhouse gas emissions to reverse climate change and connect to circular economy goals such as recycling of materials. Funding schemes in science and research, including public and private investments, should establish criteria to analyse and address the risks and opportunities of digital technologies for sustainability goals. "Food first" has long been a proposed guiding principle for innovation and progress supported by farmers, scientists, and civil society organisations.[76] Only if a combination of regulation, incentives, and consumer behaviour encourages, enables and rewards more sustainable and diverse production methods can scientists, engineers and farmers co-develop and use digital potential to support an agroecological transformation.

Digital platforms must provide evidence on how they support biodiversity and soil fertility and reduce greenhouse gas emissions.

« Multi-Modal and Equitable Mobility

Current transport systems are profoundly unsustainable, and deep transformations are urgently required. The ongoing energy crisis in Europe, resulting from the Russian war in Ukraine, has again highlighted the importance of such transformations. These should be guided by three overarching goals: (1) transport must achieve net-zero greenhouse gas emissions and zero air pollution (at tailpipe) as soon as possible; (2) transport must become resource-light, including space (e.g., in cities) and scarce materials used (e.g., in batteries); and (3) passenger transport must be inclusive, affordable, safe and comfortable for everybody irrespective of their social background and location. Achieving these goals will require shifts towards electric propulsion and, for trucks and other large and heavy vehicles, to hydrogen-powered propulsion. In addition, a modal shift away from privately owned vehicles as well as vans and trucks will be required, and levels of mobility – distances travelled and the number of trips – will have to be reduced.

‹ Mobility digitalisation at the crossroads

Digital technologies nowadays mediate almost all transport movements – in Europe and many parts of the world. The range of digital technologies in contemporary transport is vast, but they are all implicated in the two fundamental processes of datafication and algorithmization. Neither process is recent; both go back many decades. However, the amount and diversity of data generated and used because of the proliferation of sensors in mobile technologies (e.g., cars, e-scooters, smartcards, mobile phones) and infrastructures (from street furniture to satellites) have grown steadily. The learning capabilities and interdependence of algorithms have improved, and the speeds with and physical distances over which data circulate and interact with interdependent algorithmic configurations are ever accelerating. Most datafication and algorithmization are invisible to transport system users, but effects can be observed in the emergence of multiple functions and capabilities at different levels and for different actors.

The transport-related functions and capabilities enabled by digital technologies can enhance transport sustainability, but this outcome is far from given.[77] Clear regulation and proactive governance are required to ensure that digitalisation does not exacerbate transport's profound unsustainability. For instance, digitalisation can reinforce the lock-in of private car ownership and use, as well as the growth of private aircraft use and ownership by economic elites. It can also intensify inequalities in mobility. This may occur, for instance, when integrated Mobility-as-a-Service (MaaS) systems become primarily geared towards, and used by, younger middle-class individuals in cities (who usually already have a wide range of mobility options available to them) and exclude other population segments to a greater or lesser extent. Moreover, digitalisation can further erode

39%

Autonomous vehicles as part of free-floating carsharing may result in a 39% increase in vehicle kilometres travelled.[79]

transport workers' rights, earnings and wellbeing – as is common practice on most platforms for ride-hailing and last-mile delivery.

Further digitalisation in the transport sector can go in different directions. It can optimise and thereby reinforce existing transport systems, including their unsustainable impacts. It could, however, also help to transform those systems into substantially different and – from environmental and social sustainability perspectives – more desirable transport configurations.[78] Unfortunately, current trajectories tend to point towards optimisation rather than transformation. Consider the automation of driving: if and when (almost) fully autonomous vehicles (automation level 4/5) become commercially available, this is likely to increase car traffic due to higher convenience, rather than reducing traffic or shifting it into public transport - which is necessary to reduce greenhouse gas emissions to the extent needed.

✱ Opening up data, code and algorithms responsibly fosters multi-modal mobility in order to shift away from automobile transportation and reduce the distances travelled.

Also, the price premium will ensure autonomous cars are only affordable to higher-income groups and large, high-end-of-market freight operators. As things stand, vehicle manufacturers (including those producing electric vehicles) are also likely to focus on selling or leasing autonomous vehicles to individuals or organisations, further pushing for individualised car usage.

A different concept focuses on the role of robotaxis. In this future, ride-hailing companies succeed in producing safe and reliable shared autonomous vehicles ('robotaxis') at scale before autonomous cars succeed in the individual car consumer market. Imperative for robotaxis to be first would be regulatory approval. Currently, this looks unlikely, and even if robotaxi producers succeeded, the loss of livelihoods they would create among their own precarious 'self-employed' workers and across the broader taxi and public transport sector would constitute a cause for concern. Besides, there is a genuine risk that robotaxis will generate such stark, direct rebound effects – i.e., extra movements and distance travelled – that congestion problems will worsen, particularly in cities.[80] For robotaxis to make sense for a sustainability transformation in mobility, they need to become part of a broader strategy.

36%

As part of public ridesharing, autonomous vehicles combined with public rail transport can result in a 36% decrease in vehicle kilometres travelled.[79]

Multi-modality and open data for mobility justice

Harnessing the contributions that digitalisation can make to truly sustainable futures requires strong and proactive governance at the EU, national and local levels.[77,80] As in agriculture, digitalisation in mobility can only unfold its potential as part of a more generally initiated deep transformation, including several policy areas, from price incentives to regulations, a shift of state subsidies from cars and aircraft to public transport, to cultural changes of habits. These policies would lay the foundation for true system innovations in the mobility sectors. To further foster such a transformation, governance should be reconfigured around the three interdependent dimensions (1) multi-modality, (2) opening up data, code and algorithms responsibly and (3) strengthening mobility justice.

Figure 04 Three pathways for the mobility transformation

First, digitalisation needs to be used for multi-modality as well as sufficiency – i.e., the reduction in kilometres travelled and freight transported – in the mobility sector. Multi-modality would entail real-time and 'inter-system' coordination, including integrated information provision, booking and payment across institutionalised systems, and automation of driver and other tasks, insofar as sensible and appropriate. This will require proactive action by local and regional governments with adequate regulatory powers, particularly when services are procured and contracts negotiated with public, private or community sector operators. Multi-modality means above all that walking, cycling, 'micro-mobility' (i.e., shared e-scooters and [e-]bikes) and public transport are strengthened. The role of robotaxis in multi-modal futures should be limited to 'gap-filling' and at a low rung in the hierarchy of desirable forms of mobility, albeit above personal vehicle ownership.[80] The key function of robotaxis should be to fulfil mobility needs for which no alternative is available, which is likely to be more important in rural than in urban areas. Since licensing, procurement, contract negotiation, and enforcement of agreements and regulations will be critical to avoiding that robotaxis displace other forms of transport, it is vital that local and regional governments are better equipped with funding, regulatory power and technical expertise to coordinate different services and multi-modality and intervene when necessary.

Multi-modality platforms can facilitate more walking, cycling, 'micro-mobility' (i.e., shared e-bikes) and public transport.

Second, data, code and algorithms need to be opened up responsibly. User sovereignty and open source should be the default principles for digitalisation in the transport sector. These principles will increase transparency, data sovereignty among transport workers and users, and opportunities for citizens and communities to enrich data (as with OpenStreetMap and the BBBike.org initiative). At the same time, they can enable under-resourced public authorities to develop better, evidence-based policies.[77,80] The Data Commons arrangement discussed in the chapter "Data Governance for Transformation" in Part 3 could ensure that data and algorithms become open source. However, sharing of transport-related data, code and algorithms must be secure and in line with the EU General Data Protection Regulation. Extra protection and anonymity will be required if users are expected to share their use of multiple transport services or have their mobile phones tracked continuously. Investment is urgently required for responsible sharing at scale, e.g., investment in the development of low-energy blockchain technologies.[81]

Figure 04

Three pathways for the mobility transformation

To ensure affordable and accessible mobility for all, multi-modal transportation can be facilitated by opening up data, code and algorithms.

Opening up data, code and algorithms responsibly

Strengthening mobility justice

Multi-modality

Third, strengthening mobility justice comprises two sets of activities. The first centres on overcoming digital mobility divides. For instance, the freight industry is characterised by a highly uneven distribution of digital mobility capability, with a relatively small number of large and well-resourced firms and many small companies, including owner-operators. The latter will struggle to transition to vehicles with advanced driver assistance systems and/or smart charging, whereas this could make their operation significantly more environmentally and financially sustainable. Hence, there is a need for subsidies, loans and training schemes with very low entry barriers that specifically target small freight and logistics firms. Providing open-source, secure and easy-to-use digital tools for calculating the total cost of ownership of vehicle purchase and use as well as low-cost telematic equipment is one way in which small freight and logistics companies can further enhance digital capabilities among small firms.

The second set of activities to strengthen mobility justice entails 'commoning' mobility platforms.[82,83] Platforms for ride-hailing, food delivery, bike-share, MaaS, etc. do not have to be hyper-capitalistic, vying for monopoly status, disrupting regulation or disempowering users and workers. They can also cultivate the 'commons', i.e., all goods and entities that are reproduced and shared – 'commoned' – by collectives of humans (e.g., language, wellbeing) or living organisms (e.g., clean air).[84] Digital platforms for mobility can offer decent wages, respect worker rights and concentrate on fulfilling otherwise unaddressed mobility needs, particularly among vulnerable social groups and organisations. They can also decentralise governance and decision-making to local communities, such as the Eva ride-hailing and delivery platform in Canada has done. If configured and governed appropriately, mobility platforms can advance environmental and social sustainability. Open-source data and algorithms, as well as blockchain technology, can enable mobility platforms to function in this way, but customers will have to demonstrate solidarity with transport workers and may have to pay for services according to ability. Local and national governments may have to protect commoning mobility platforms from cut-throat competition by hyper-capitalist counterparts that are primarily interested in enhancing profit, increasing market share and achieving monopoly provider status.

The role of robotaxis in multi-modal futures should be limited to 'gap-filling'.

Circular Industry Beyond Growth

Most industrial processes can be served by renewable energy. However, decarbonising industry's energy consumption will lead to a particularly strong increase in electricity demand. Therefore, wherever possible, decarbonisation must concur with a reduction in energy consumption. At the same time, most industries face strong competition due to economic globalisation and depend on capital markets. This puts pressure on companies to expand output, introduce new processes to reduce costs or relocate abroad. Furthermore, recently the COVID-19 crisis and the Russian war in Ukraine have called into question the reliability of global supply chains. Hence, manufacturing has to solve multiple issues simultaneously: Dealing with global competition, reorienting in times of global economic insecurities and radically reducing its greenhouse gas emissions. Therefore, a strategy of system innovations is needed that fosters resilience and adds circularity and sufficiency to existing efficiency strategies.

16%

Investments in ICT hardware increase labour productivity by 16% in the service sector.[85]

A zero-sum game with new challenges

The digitalisation of manufacturing has been an ongoing process for many decades. Recently, however, high hopes have been placed on new digital technologies to improve competitiveness and reduce environmental footprints. For example, Germany's 'Industry 4.0' agenda, as well as similar strategies in the US ('Industrial Internet') or China ('Made in China 2025'), aim to improve – among other things - resource efficiency and enable a stronger localisation of production. On top of that, digitalisation is associated with a shift away from producing and selling products towards systems of product-as-a-service. When firms sell services, they could have environmentally beneficial incentives to make products more durable and less energy-consuming.

However, digital technologies have not led to a strong surge in energy and resource efficiency in the industrial sector thus far. Introducing ICT in industrial processes reduces energy consumption only slightly per unit of production.[34] When considering the energy consumption of the entire value chain, this effect even becomes negligible. For one, more energy-intensive processes are outsourced to non-European countries due to digitalisation.[33] And second, industrial energy and resource efficiency improvements are particularly prone to rebound effects, which lead to an expansion of economic output rather than a reduction of emissions and material inputs. Thus, instead of relying on digital efficiency improvements alone, pursuing a combination of circularity and sufficiency in manufacturing is necessary.

✱ To move towards a resilient economy, digital efficiency improvements must be combined with strategies for circularity and sufficiency in manufacturing.

For big industries such as car manufacturing, a recent trend offers opportunities in this regard. Leading companies are currently trying to gain transparency in their production and distribution networks by integrating them into new types of cloud platforms. This development applies to 'closed' value chains of single companies. But there is also a trend among several large manufacturers to collaborate, as in the project Catena-X, run by several leading German car manufacturers and the federal government of Germany. While there is a risk of further strengthening the iron grip of car manufacturers on their suppliers, cloud platforms also create opportunities for sufficiency and circularity improvements. Large data sets are being created that offer new possibilities to capture efficiency increases via data analysis, thereby opening up the potential to reduce over-capacities or unnecessary redundancies over the entire production chain. Integrated cloud platforms in manufacturing could also be used in combination with the digital product passport (see below) to enable reusing materials and repairing products, thus strengthening a circular economy agenda from within the industrial sector.

0.235%

A 1% increase in firms' ICT capital reduces energy demand by only 0.235%.[34]

An information-based circular industry

The circular economy has emerged as a new paradigm in redesigning production and consumption systems. The Circular Economy Action Plan adopted by the European Commission in 2020 is a central element of the European Green Deal. However, circularity in industry is still at an early stage. A crucial obstacle to organising circularity is the missing information on products and production processes along the value chain.[87] Digital technologies can greatly help to deliver the information needed. They can monitor costs and compliance with environmental standards and facilitate a systematic provision of information about potential product reuse, recovery, repair and recycling. For instance, technologies can provide life cycle inventory data of products and services and monitor ecological costs in the economy. Longer product life can be promoted by providing repair and maintenance information as well as compositional data. Reliable data flows on byproducts, and recyclable waste can help reduce demand and close material flows. In addition, platforms and data-based connection of providers can facilitate matching supply and demand to enhance the shared use of infrastructure services. At the same time, improved data can help policymakers regulate production patterns according to their environmental impact and their necessary contribution to emission savings. Overall, decision-making can be improved by analysing Big 'environmental' Data. This can be facilitated by the obligation to make environmental and social sustainability data available on industrial cloud platforms and by the initiation of an EU oversight body defining common standards and imposing mandatory access to this data.

Figure 05 Data governance for the circular economy[88]

A major political instrument currently being developed is the digital product passport. This legislation will be introduced as part of the European Commission's Circular Economy Action Plan and will require companies to create passports for certain products. The digital product passport summarises information about the components, materials and chemical substances, but also about repairability, spare parts or professional disposal of a product. The data comes from all phases of the product life cycle and can be used in all these phases for different purposes (design, manufacture, use, disposal). However, the practical implementation still poses some challenges for companies, for example, the precise recording and allocation of CO_2 emissions generated in production. In order to work, the digital passport needs to connect different EU initiatives and other similar initiatives and collect the appropriate data for specific actors and purposes.[89] But the passport should also be designed to facilitate a circular economy beyond the business in the supply chain. It should become an important source of reliable consumer information and sustainable consumer decisions in both stationary and online retail. And, it needs to be used for more stringent sustainable public procurement and strong eco-social labelling.

5–10%

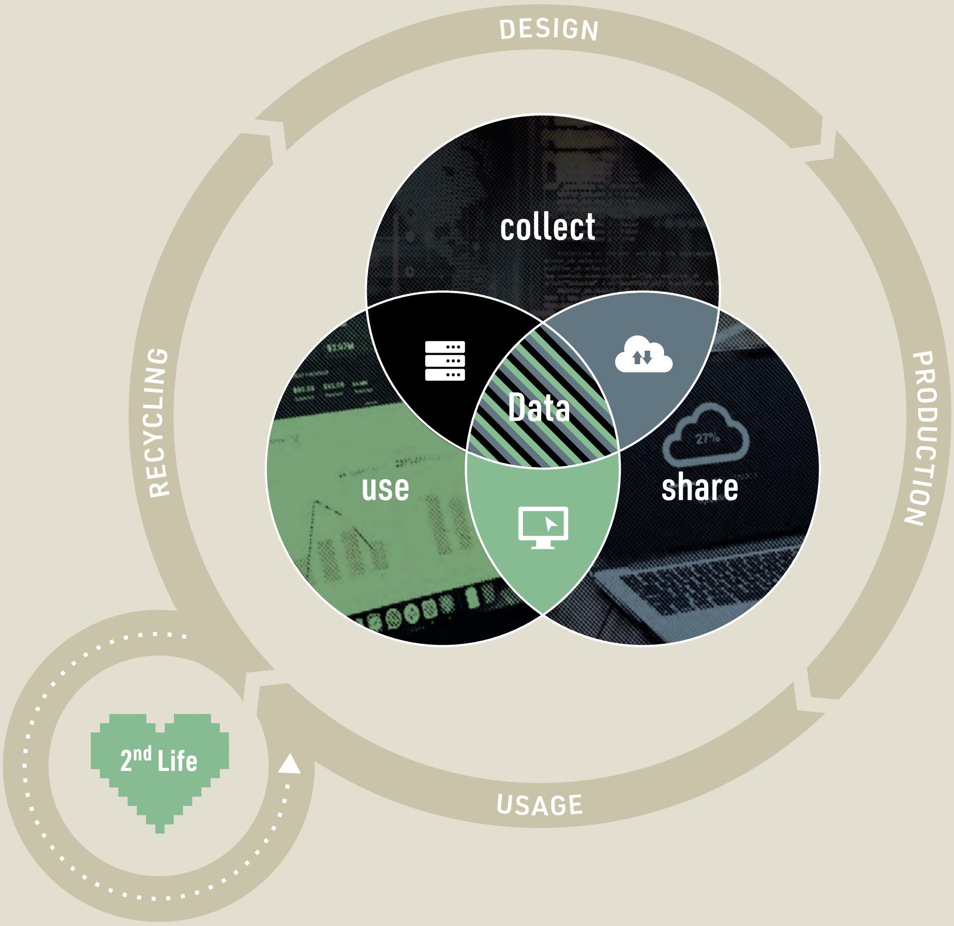
Circular business models account for only a small fraction of output, usually no more than 5-10%.[86]

Digital technologies can also support monitoring, thereby ensuring that companies fulfil their legal obligations concerning labour and environmental conditions along the value chain. This is currently under discussion in the Corporate Sustainability Due Diligence Directive. But to make it a true driver for a

Figure 05

Data governance for the circular economy

At every stage of a product's lifecycle, data collection, data sharing, and data usage can help to enable a circular economy.[88]



Design

- Producers create digital 3D models of spare parts
- Producers share 3D models via trusted parties
- Users can buy 3D model data

Production

- Producers create life cycle inventory (LCI) data for products
- Producers share LCI via Application Programming Interface (API) with sellers, buyers, regulators
- LCI data for life cycle assessment and labelling of products; producers and consumers can adjust their purchases according to the ecological impact of products; regulators can monitor progress of industry transitions

Usage

- Smart products send status data of condition, availability, energy consumption
- Sharing of status data via API
- Producers and users monitor energy consumption, product quality, allow for maintenance; sharing platforms integrate products-as-a-service to increase product accessibility

2nd Life

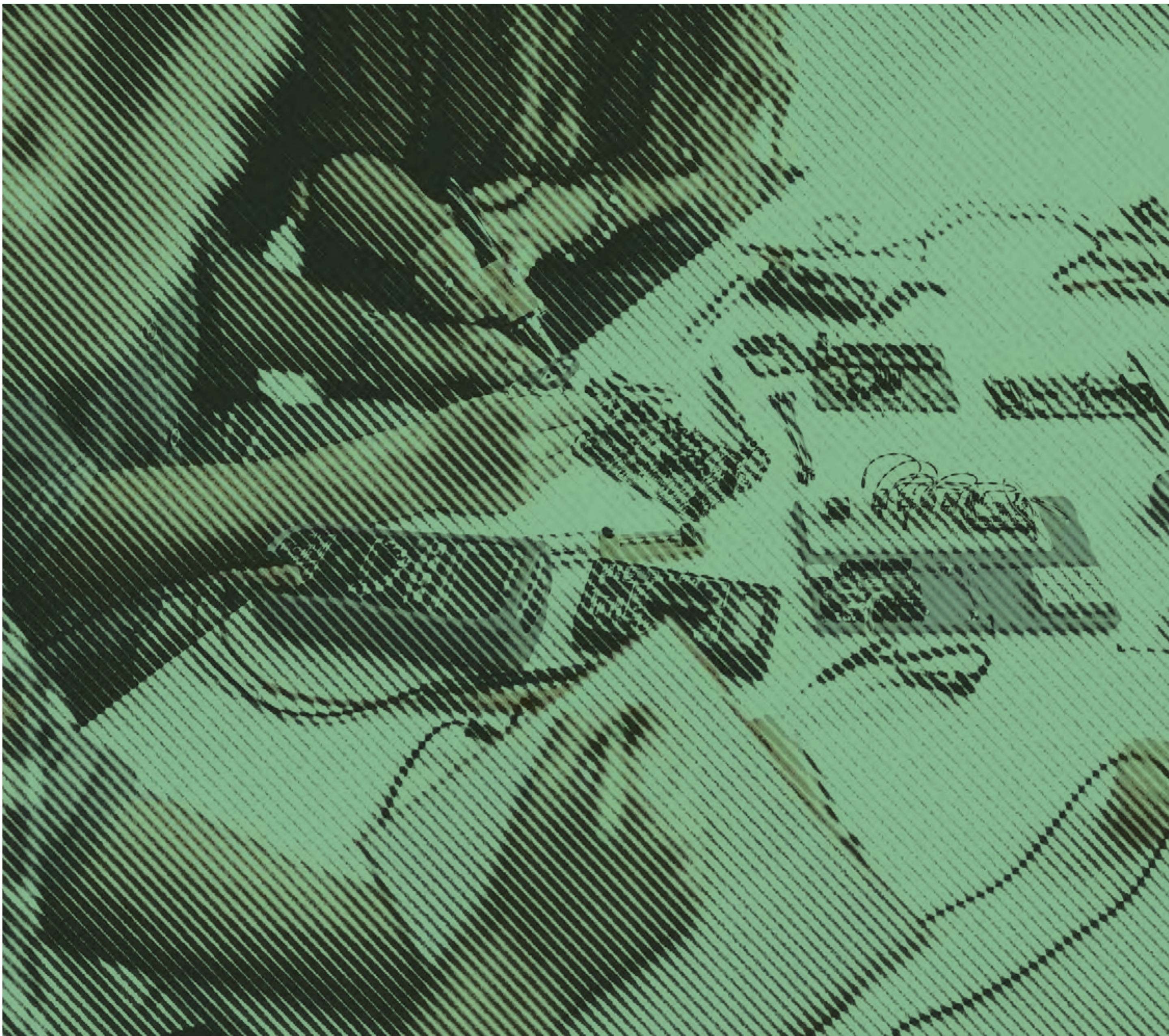
- Producers create repair and maintenance information (RMI)
- Producers share RMI data via API
- Repairers use RMI to faciliate product recovery and prolonged lifetime

Recycling

- Producers create bill of material (BOM) data to declare recyclable materials and components
- Producers share BOM data via API with recyclers and platform intermediaries
- Recyclers use BOM data to disassemble products and facilitate resource recovery

sustainable transformation, this directive needs to avail of current digital possibilities to incorporate the entire supply chain and to include a comprehensive set of social and environmental indicators. Such legislation also needs to be designed along the principle of regenerative design and made applicable not only to large companies in the EU but also to medium-sized companies in the EU – also those with headquarters abroad.

However, while data availability is necessary to facilitate a circular economy, this alone will not suffice. Next to the ability to repair, reuse, recycle etc., economic actors also need to be offered strong incentives to use such practices. Also, a culture of circular practices needs to be established. While the latter is difficult to implement by policymakers, the former can be put into place by the right policies, such as taxation that makes newly exploited materials considerably more expensive, sector-specific or process-specific mandatory reuse and recycling quotas, and best-practice guidelines.



Digitalisation for sufficiency in industry

Even with full use of digital technologies to facilitate circularity in industrial production, reaching necessary reduction targets of greenhouse gas emissions and resource consumption will be challenging to achieve.[90] The transformation towards a climate-neutral industry will be accompanied by a massive increase in energy demand, and industrial production will need to become more sufficient. The sufficiency-strategy partly overlaps with circularity: repairing and reusing physical products are part of sufficiency-oriented lifestyles and business models. Digital technologies can greatly help set up appropriate business models. But sufficiency also suggests limits to the expansion of industrial production. Again, the right policies would go a long way here: Capping the use of natural resources and emissions, e.g., by flexible quotas or trading schemes, would provide the framework conditions to allow business models focussing on repairing, reusing and recycling to flourish. In addition, national and EU funding schemes for new circular and sufficient business models would advance such business models – from early stage funding to long-term funding schemes where profitability is not feasible.

Reforming education and training programs, and providing financial support for people who become unemployed can facilitate a just transformation of industry.

It is often feared that making industry circular and sufficiency-oriented would go along with the loss of many jobs and endanger the livelihood of those communities that particularly depend on fossil and resource-intensive sectors. However, the transition towards circularity and sufficiency will also bring about many new firms and additional jobs.[92] When repairing, recycling or the organisation of reusing becomes financially attractive, new business models will mushroom.[91,93] These business models will partly appear in the digital economy – e.g., repairing and recycling end-user devices. Digital services will further greatly help to establish such new business models by making it easier to reach customers, collect the products to be repaired, facilitate recycling and obtain knowledge about product features.

It is a crucial role of politics to ensure that the new jobs are well-paid with good working conditions. As it is still unclear whether the new business models will offset the reduction of their predecessors in terms of revenues and employment, the industrial sector must be made resilient to a possible reduction. The transformation needs to be accompanied by reforms in education, training programs and on-the-job qualifications, which are adapted to regional situations. Here, online-learning environments can facilitate the know-how, despite a shortage of experienced trainers in the field. Overall, the transition in industry and beyond needs to follow the principle of equity and resilience. Politics must not only initiate but also socially organise the transformation, including the provision of adequate support for people who lose their jobs or need to retrain.

Capping the use of natural resources and emissions can provide the framework for business models focussing on repairing, reusing and recycling to flourish.

« Distributed and Flexible Energy Systems

Emissions from the energy sector need to be curbed drastically and without delay. This entails replacing carbon-based with renewable energy carriers, improving energy efficiency, and reducing energy consumption by implementing strategies of sufficiency. Next to the climate crisis, the Russian war in Ukraine has recently created an urgency in mastering the transformation of the energy system. This transformation also must follow the principles of regenerative design and equity, as issues of participation and distribution are crucial. At the beginning of the energy transformation, the main endeavour was to establish renewables as technically and economically viable options. As a result of these efforts, in the last decade, the production of renewable energy has gained considerable momentum.

22%

The share of renewable energies in the EU was 22% in 2020. It more than doubled compared to 2004 (9.6%).[94]

In addition to greatly accelerating the share of renewables in the system, the current phase of the energy transformation involves several qualitative changes. And this phase coincides to a large extent with increased digitalisation. As energy production is increasingly moving from centralised power plants to smaller and more decentralised sites, supply becomes more distributed throughout the electricity grid and, therefore, closer to where people live. Often, consumers even turn into 'prosumers', both consuming and producing electricity. A particular challenge of such new systems is that energy sources become more 'intermittent' or variable, meaning that energy produced from wind or sun varies according to changes in weather, season, and the time of day. Naturally, such fluctuations mean that electricity cannot be generated consistently to meet energy demand. Therefore, demand must be more strongly aligned with the supply of electricity, and the logic of the new system must be changed to become more flexible.

‹ Automate, integrate, coordinate

Three key levers can be used to make the energy system more flexible. First, demand can be adjusted to become more flexible, in particular by automation. When electricity production is high, large industrial manufacturers and businesses can step up their production, bring forward activities that do not need to be performed at a specific time or postpone consumption when electricity consumption peaks and availability is scarce. For example, cold storage can be chilled to a few degrees below its usual temperature when electricity is abundant and energy-intensive industries (such as large steel manufacturers) or high-consuming data centres can adjust their activities according to energy availability and electricity grid constraints. Domestic users can also adjust their electricity use to compensate for fluctuations in supply. For instance, energy-demanding activities such as heating homes, washing clothes, dishwashing or heating water can be done at times when supply abounds. In practice, achieving more flexibility through behavioural change has been hard to achieve (especially in the domestic sector).

This is also where digitalisation can play a crucial role. The information signals and coordination tasks required to adjust demand to supply can be provided by algorithms and digital technologies that, on the household level, are often manifested through smart metres and home automation systems made possible by the Internet of Things and automated demand side management solutions. Such technologies may also facilitate the coupling of electricity and heating systems by automating heat pumps, boilers, and other domestic appliances. On a national and regional scale, virtual power plants are increasingly employed to balance European electricity grids, providing services to the public grid owners and especially transmission grid operators by pooling or aggregating flexible resources and loads.

8–10%

ICT makes up 8–10% of worldwide electricity consumption.[40]

✱ Using technologies that automate, integrate, and coordinate supply and demand is a cornerstone for a fully renewable energy system.

Second, the integration and management of energy systems are growing in importance. As electricity supply becomes more and more variable, there will be an increased need to store energy when supply is high and use the storage as back-up when supply is low. Thus, distributed and renewable energy systems reinforce the need for batteries and other forms of storage. Integrating storage solutions into the energy system also needs digital technologies and algorithms to coordinate effectively with the overall system.[95]

Third, a successful transition of the energy system requires the coordination of different systems and sectors.[95] As energy demand of other sectors such as mobility, industry, heating or cooling, and even agriculture electrifies, this puts additional pressure on the electricity supply. Digitalisation is central to the coupling of sectors as distributed and sector-coupled energy systems require dynamic load management to manage overall grid load vis-a-vis uncountable sources of demand throughout several sectors. For example, digital management systems enable charging batteries for electric cars, cruise ships or ferries when electricity is available and at times and speed that is best for the overall electricity system.

Digitalisation is crucial to the decarbonisation of the energy sector. Digital technology platforms allow users to produce, consume, store and trade energy services with multiple parties, potentially constructing new forms of value for users, communities and businesses. Digitalisation is a cornerstone for transforming the energy system towards fully renewable and much more decentralised sources using software and digital technologies that may automate, integrate, and coordinate supply and demand across systems and sectors. However, the energy transformation is not solely a technical but also a social issue with important implications.

Shifting power relations

On the positive side, digitalisation may facilitate the self-production of energy ('prosuming') as well as 'citizen energy' communities. This allows for a more participatory and regenerative design of the components of the system and in the end, makes it more democratic.[96] On the negative side, analytical and practical complexity grows, reshuffling power relations and actor roles and including new business and organisational models, which will have uncertain social implications. When decision-making is increasingly automated, taking place in systems that are exceedingly complex and that penetrate everyday decisions such as home energy use,[97] the need to understand the effects of such systems and how they relate to issues of justice, public acceptance, legitimisation, and trust becomes even more important.

Therefore, reconfiguring the energy system requires following the principle of equity. For example, the ability to shift energy use in time and space is a highly unevenly distributed capacity among different groups in society.[98,99] This inequity also means that demand-side flexibility and automated demand-side management may deepen existing (energy) injustices in ways that privilege the already privileged.[100] Therefore, the digitalisation of energy systems needs not only to be governed more carefully but also to be developed by more inclusive means and in the most transparent way.

45%

The EU aims to increase the share of renewable energy to 45% by 2035.[101]

The reconfiguration of energy systems should not obscure changing power relations and economic implications for citizens without overt and open public debate. For instance, along with the creation of demand-side flexibility solutions and markets, new actors enter the market. As they take up roles as flexibility aggregators, they may become powerful actors that strive to profit from and steer (reward or penalise) the energy consumption behaviour of ordinary citizens and households. At the same time, the distribution of benefits and burdens is still rather unclear – as is the question of how households that provide value in these markets should be compensated or remunerated.

Digital energy justice

To sum up, digital technologies allow for complex supply-demand management and enable new forms of coordination, monitoring, and feedback systems that are necessary to realise the transformation towards fully renewable, distributed, and more decentralised energy systems. But a deep transformation of the energy system would also need to ensure that most citizens and non-profit actors can benefit from the new opportunities instead of aggravating social inequalities. This requires additional social innovations as well as policy interventions.[102] Most notably, a deep energy transformation needs technology and innovation policy that can perform 'anticipatory governance', i.e., governance that establishes institutions that follow developments more carefully over time instead of moving governance 'upstream' in the innovation process. This includes new institutions that advise policymakers on digital energy matters in other areas, such as the Danish Board of Technology or the Dutch Advisory Council for Science, Technology and Innovation. This policy lack has also been identified by Science Advice for Policy by European Academies, advocating for the need to put in place an independent monitoring system for the European transformation process that collects evidence and shares information in a transparent fashion.[95] While developments of key infrastructures or energy-related ICT applications should be stimulated, progress in rapidly diffusing innovations should be continually scrutinised so that they neither compromise equity in opportunities nor the digital sovereignty amongst various groups of the population. Thus, politics should pay more attention to developing indicators and metrics that capture and monitor the uneven implications of different (digital) energy solutions, energy system innovations (such as flexibility markets) and policies to not deepen existing inequalities. An energy justice citizen observatory would be a starting point.

Establishing an 'Advisory Council for Science, Technology and Innovation' as an independent monitoring system can support a just energy transition.

Finally, politics for digital energy justice should include reflexivity and policy learning to account for uncertainties during transformation processes.[103] More inclusive citizen participation and broad stakeholder involvement are needed to secure societal support and equity. To foster such democratisation, the use of deliberative fora, such as round tables, "climate citizen councils", citizen assemblies and co-creation methods should be used in research, innovation and policy development.

Reduced Construction by Smart Buildings

A deep transformation of the building sector needs to pursue a variety of goals, such as carbon neutrality, less material consumption and reduced ground sealing. But a future-fit building sector also needs to pursue social goals such as affordable and appealing housing for people irrespective of their social, geographic and financial background. And the transformation must provide answers to current challenges, such as price increases and supply issues for construction materials, following the Russian war in Ukraine. To this end, the transformation of the sector will follow the principles of equity, sufficiency and circularity.[105] Regarding equity, housing must remain affordable even after widespread retrofitting has been carried out and insulation and new heating systems have been installed. Regarding sufficiency, floor area per person in European countries needs to be reduced to decrease energy and material demand and to ease price pressure on rental markets. Finally, regarding circularity, materials used in construction need to become renewable – such as timber or hemp – and be reusable when buildings are demolished.

31%
The building sector is responsible for 31% of the worldwide total material flow.[104]

Figure 06 Drivers of carbon emissions in the building sector[106]

Smart design for construction and operation

The design phase paves the ground for many sustainability strategies. For example, the right design facilitates less resource-intensive construction, more energy-efficient operation, more recycling of demolished houses and even a reduction in floor area.

Digital applications provide a promising lever to include environmental aspects in the design phase. Simulation software and 3-D designs such as 'building energy models' can help optimise the use of materials in construction. Such tools also enable comparing fundamentally different designs regarding environmental aspects early on.[107] Digital software can also improve construction logistics to avoid waste and even recycle waste into new production materials. For example, the start-up Betolar uses artificial intelligence to analyse industrial waste and develop recipes to turn it into alternative materials to cement. Other software applications can help reduce energy consumption in the construction phase by improved monitoring.

Digital applications can also be used to improve energy efficiency in the use phase of the building by calculating life cycle effects of the design choices. For example, in 'building information models' structures are first built virtually before being built in reality. This can support the principle of regenerative design by enabling all stakeholders in a building project to participate in the design process. Digital twins take this even further by striving for a dynamic model of the building, thus creating even more opportunities for efficient operation.

So-called smart building solutions include tools to support operating and managing the building using sensors, actuators and data processing, often in an automated way. Employing such tools can reduce the energy demand for heating as well as other energy-intensive operating services. Smart building solutions can support a more efficient operation of buildings directly through optimised heating and cooling or by providing more and more easily accessible information on energy-related user behaviour options, thus supporting energy savings.

Moreover, in a deep transformation of the building sector, refurbishment will be ever more important as total building space should no longer increase, and construction is very resource intensive. Refurbishments need to embrace 'deep renovation', i.e., thorough insulation of buildings and shifts to renewable energy in heating and cooling. A major problem for renovation on a large scale in Europe is limited resources in materials and personnel. Digitalisation can be used to increase productivity through digital planning and monitoring. Sufficiency is a second strategy – the existing material and personnel resources must be used for refurbishment instead of constructing new buildings. The sufficiency strategies described in the next section also help to achieve refurbishment goals.

Despite the increasing role of refurbishment, buildings must be demolished at some point. Therefore, as large a component of the existing building stock as possible must be recycled and reused in a circular manner, and new buildings must be designed to later be as recyclable as possible. A key strategy for achieving this, for both existing and new buildings, can be using digital building log books. However, such log books must be designed according to the principle of sufficiency; otherwise, the effort required to produce the enormous amounts of data necessary for such records may outweigh potential gains. Therefore, log books should contain only the information needed to reuse and recycle buildings in the building stock.

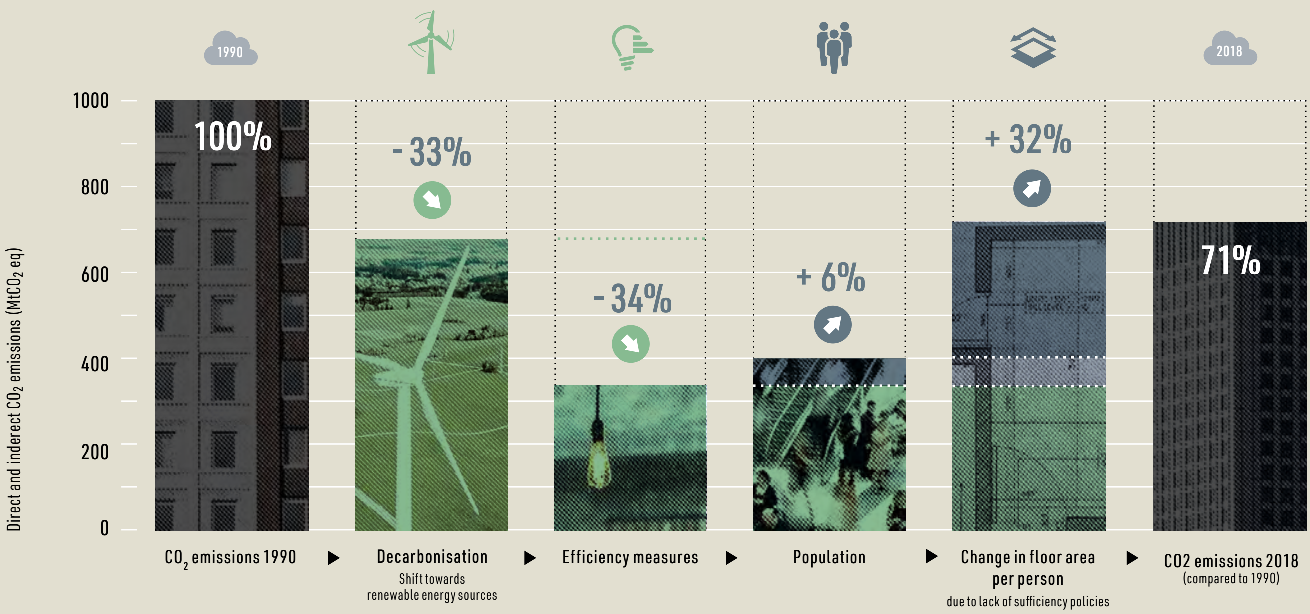
0.4–1.2%

75% of the building stock in the EU is not energy efficient, and only 0.4–1.2% of this stock is renovated annually.[2]

Drivers of carbon emissions in the building sector

Figure 06

From 1990-2018, carbon emissions from the building sector in Europe declined by almost 30%. Yet an increase in square metres per person prevented a more substantial reduction in emissions.[106]



A sufficient building stock

Next to circularity and efficiency, opportunities to limit the total building stock need to be realised.[108] Digitalisation can support sufficiency by reducing demand for construction. For office buildings, the opportunity to use flexible seating combined with space-independent work is transforming the office real-estate sector, potentially leading to less demand for space. Moreover, digitalisation of customer relations is already reducing floor area formerly necessary for customer interaction – the reduction of bank and post offices might be the most prominent example. And online shopping is another example, with the potential to reduce space in stores.

* A new data culture in the building sector can reduce demand for new construction and facilitate circularity in the design, operation and renovation of buildings.

In the housing sector, an important issue is overcrowding and under-consumption. Digital technologies can support a more intense use of housing, e.g. through matching services so that renters get access to flats of a size they really need. While such matching could contribute to greater equity, a matching service such as AirBnB does not seem to have led to increased space efficiency or lower rents. This throws up an important question regarding ownership of the platforms. Extractive business cases should be governed much more stringently, while communities can establish regional and cooperative matching platforms.

30%
The global residential building stock grew by 30% between 2005 and 2019.[105]

Data for repurposing buildings

A shift towards circularity and sufficiency demands a new data culture for the building sector. Integrated building design demands high amounts of very specific data on the total environmental impact of various construction decisions as well as on refurbishment, rebuilding and operation. This is a challenging task as data could either be locked in, accessible only to specialised companies or be too open, disclosing private or business-critical information. Digital building log books might fail in assembling appropriate data since generating forward-looking life-cycle information is highly complex. Policies need to support the collection of appropriate data, for example, by standardised digital building logbooks while guaranteeing privacy and data sovereignty.

Within the EU, there are ongoing policy developments related to the energy use of buildings, such as the Energy Performance of Buildings directive.[109] This will make investing in further automation of building design and operations more cost-effective. However, such policies need much more commitment, particularly regarding incentives and subsidies to insulate buildings and decarbonise their energy supply. At the same time, the related investment costs must not be borne primarily by tenants. Instead, the opportunity to reduce energy costs should be used to reduce energy poverty, and the opportunity to reduce pressure in the housing market by reducing square metres per person should be used to help to avoid the unaffordability of appropriate apartments.

Policies can also support a reduction in floor area. There is already a drive towards reduced space use in the business sector. This stems from new ways of working (and conducting business), including space sharing and the resulting reduction in the need to build new commercial properties. However, a considerable barrier to office-sharing is the lack of trust in data security, as well as in who has access to the premises.[111] Policymakers, therefore, need to push data security and security systems that can help overcome these obstacles. An even more ambitious step for policymakers is to counteract 'space waste', i.e., underused commercial space, by introducing economic incentives for a more intensive use of existing office space. This would make inefficient use of spaces too expensive to maintain. It would also spur the development of applications that facilitate office sharing and push innovations for adjusting organisations' space supply to their demand, such as OfficeSwapp.

75%

The floor area of buildings globally is expected to increase 75% between 2020 and 2050.[110]

In addition, policies need to support rebuilding one-family housing to multi-family housing, e.g., in terms of tax deductions for letting out a part of the home. Finally, economic instruments that reward living in fewer square metres per person need to be developed. These measures would be easier to implement in a well-functioning market for subletting. Digital solutions here are vital in creating the market through services for matching property owners with tenants and developing those services with safety-enhancing services such as integrated legal agreements and id-control.

Policymakers should counteract 'space waste' by fostering platforms for office sharing and introducing economic incentives for a more intensive use of existing building space.

All in all, well-developed services for sharing spaces facilitate the implementation of policy measures for more sharing. And the stronger policy measures for sharing there are, the better sharing services will be developed.

« Shifting and Avoiding Consumption

A deep and sustainable transformation of society will only become a reality if consumption patterns change accordingly. The main pathways to change are more efficient and sufficient lifestyles as well as circular modes of co-production, consumption, and disposal. In practice, this means avoiding overconsumption in the global North, shifting to more socially and environmentally sustainable products and services and improving the efficiency of using resources and sinks to fulfil real, reflected consumption needs. Efficiency – making more out of materials and energy and wasting less – is needed for sustainability. Yet rebound effects (i.e., consuming more of the more eco-efficient product) can level out these gains. Therefore, to achieve a level of sustainable consumption, products must not only be produced in a circular manner but also be imbued with the principles of sufficiency and equity.

‹ Digital consumer risks

Digital technologies have substantial risks for sustainable consumption and consumer welfare. For one, digital products, services and networks – from e-commerce to streaming videos to online gaming to Bitcoin mining – substantially contribute to the increase in energy and material use in the digital world, both directly and indirectly. And, a realm of new digital consumption options further increases energy and material demand. In addition, digitalisation can inflict social harm, putting access, equity, fairness, social cohesion, and social peace at risk. This is because digitally sophisticated consumers can tweak the technology and profit from its potential. In contrast, digitally less sophisticated consumers – particularly the systemically vulnerable consumers such as the poor, the illiterate, those with limited access, and those with few digital skills – are easy victims of exploitation and misinformation online.

Another risk arises from digital marketing strategies such as personalised advertising. Every type of advertising aims to encourage the purchase of certain products. Worldwide media advertising spending is on a continuous rise, despite the COVID-19-related economic recessions. Since advertising revenue is often part of the central financing model of tech companies, with Alphabet (Google) and Meta (Facebook) gaining the largest share by far, big tech has a particular interest in making advertisements as effective as possible to further increase consumption. Accordingly, research has shown increased effectiveness of online advertising when personalization, such as retargeting or individual pricing techniques, is used.

46%
of EU citizens do not possess basic digital skills in online communication, digital content creation or digital safety.[112]

Unfair discrimination through algorithms and the widespread use of dark patterns threaten consumer privacy, undermine digital sovereignty, and promote overconsumption in online shopping. Dark patterns are stealthy website or app designs, or put simply, tricks used to manipulate a user to act (such as buying

insurance, making a booking, or compromising personal data) in a way that is against their interest. Consumers in the digital world are also particularly prone to personalised price and quality discrimination, made possible by real-time individual data profiles using purchase history, situational needs, or traits such as race, gender, or postcode. Finally, ubiquitous and targeted digital advertising (in stores, on streets, on websites and apps) and easy money available from dubious consumer credit schemes ("Get now, pay later") make consumers prone to overspend and lose financial control. Overall, much of the digitalisation of consumption environments perpetuates overconsumption in a linear ('throw-away') economy.

700 billion US dollars are spent on media advertising worldwide. Spending rises on average 5% per year.[113]

‹

Avoid, shift and improve consumption

However, digitalisation has considerable potential to promote more sustainable consumption, for instance, by providing more useful and accessible information on sustainable product and service choices or enabling access to bespoke, high-quality products that outlast fashion and fads. Digitalisation also facilitates possibilities to avoid consumption by sharing, swapping or renting.

Independent, trustworthy, consumer-friendly recommendation systems cut through information noise and label mazes and provide valid information signals for end consumers, decreasing search costs and increasing trust. Green consumption assistants can pre-screen the market and curate a bespoke sustainable range of choices based on a scientific and transparent rating approach, ideally with interactive consumer advice and up-to-date product tests. Apps can suggest more sustainable travel modes, such as trains instead of flights, based

on real-time data, flagging the 'true price' such as CO_2 emissions or ecological footprint. Or apps can even suggest an alternative way to fulfil the need, such as participating remotely in an event instead of travelling.

Sharing, swapping and renting apps dramatically reduce the transaction costs needed for communal and shared use of consumer goods (such as cars, seldom used appliances, fashion).[115] The same holds for online second-hand consumer goods markets where 'pre-loved' items are sold. Improved digital technologies such as 3-D printing of spare parts or self-repairing materials can help keep the product in the use phase longer, reducing premature discarding and technological obsolescence.

100%

The online second-hand market for fashion and family items in Europe grew by 100% in 2020 and is projected to continue to grow by 35% by 2025.[114]

Personalisation of products and services can also help to reduce harmful consumption. Personalised items have a higher value for consumers and tend to be less easily replaced than generic products. Personalised interactive web-based services and apps advise consumers, e.g., on how to reduce avoidable food waste by suggesting recipes and giving tips for storing based on individual diets and food preferences. Smart labels can signal safe consumption beyond the use date. Smart technologies and digitalisation can make circular economy approaches – reuse, recycle, upgrade, upcycle – much more cost-efficient and attractive for post-consumption uses of products and materials.

However, behaviour plays a significant role. For instance, a large percentage of the emissions caused through frictionless online shopping is due to products consumers order mindlessly and then send back to the retailer – which amounts to lots of surplus packaging, freight miles, and frequently the destruction of the returned products. Market conditions like free returns and the 'fast everything' system encourage this behaviour. It is important to keep in mind that people do not consume in a social vacuum, even not when sitting alone in front of a screen. Practically all decisions are socially and culturally embedded and take place in a choice setting that a 'choice architect' has created, usually with a commercial goal. Therefore, a different choice architecture needs to be put in place to help avoid, shift, and improve consumption in the digital world.

A digital toolbox for sustainable consumption

An effective policy mix for sustainable digital consumption must ensure that digital consumption does not exceed ecological and social limits. Therefore, the framework conditions of digitalisation must be addressed, and suitable instruments found to stop or reverse unsustainable developments. Positive examples of sustainability-promoting digital applications are important to define the future standard of sustainability-oriented digitalisation. Furthermore, synergies with consumer policy and specific aspects of digital policy such as personal rights, democracy, or human rights should be leveraged when designing political measures for sustainable consumption.

Because green default options can successfully promote sustainable consumption, EU consumer law that limits the use of such defaults should be reviewed.

Supported by gamification and visualised 'stories', consumer education can help develop skills to become digitally sovereign consumers at any age; this includes knowing how to detect dark patterns, greenwashing and misinformation and which information sources (not) to trust. For instance, the German State of Hessia is currently introducing the school subject "Digital World" into school curricula, which goes beyond informatics and coding. Also, against the backdrop of the escalating energy price crisis in the wake of the Russian war in Ukraine, companies and the media can employ their intricate communication expertise and knowledge of their customers 'for good': making information and advice on "how to consume more sustainably" more accessible and targeted to specific psychographic groups of consumers.

✱ Governed with purpose, digitalisation can promote sustainable consumption by providing information on green products and enabling reuse and sharing.

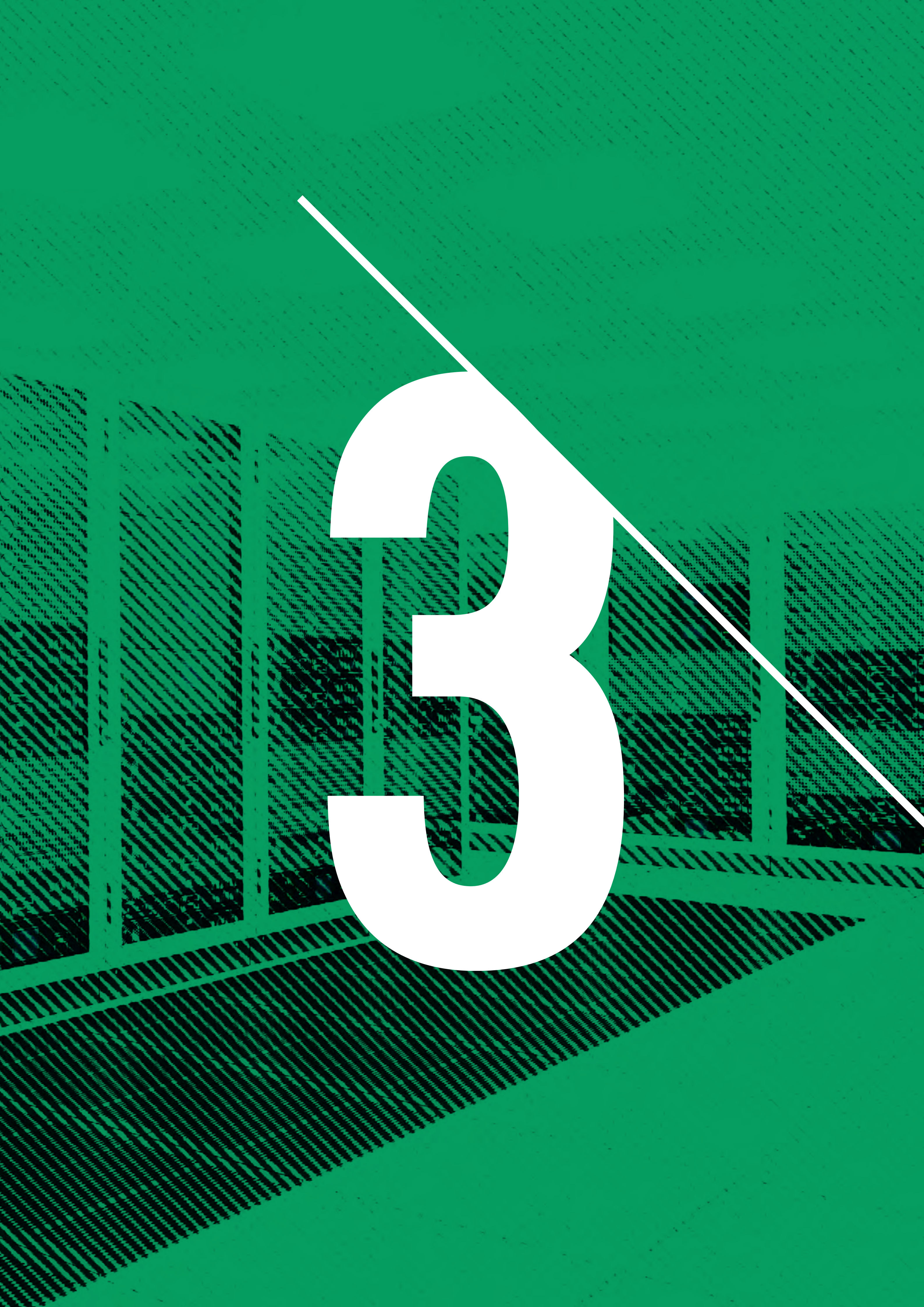
Education and information are important for knowledge and intentions but have clear limits when it comes to behaviour change. Soft regulation works with so-called 'nudges', such as behaviourally informed stimuli (e.g., warning labels, primes, self-nudges such as pledges) and small changes in the consumption environment that guide (not force) consumers to more sustainable purchases or behaviours. For instance, defaulting online food shoppers into greener options for delivery and packaging can be quite successful since defaults usually 'stick', and consumers tend not to opt out unless they strongly prefer to do so. Any online customer journey is deliberately designed, and offers can be curated so that more sustainable options (e.g., a meat-free dinner) are easy and attractive choices.[116] Hence, platform companies could choose to deliberately use such defaults and other behavioural tools to gently steer consumer choice into a more sustainable direction. Current EU consumer law limits the use of defaults to protect consumers from unwanted purchases, for instance, by limiting the number of pre-checked boxes in online commerce, such as flight booking extras. However, it is worth carefully reviewing current consumer regulations in light of the immense and fast advancement needed to achieve green consumption. It goes without saying that any behavioural and legal tools are strictly bound to the rules of good governance.[116]

Digital corporations must prove that user guidance and recommendation systems are not tailored to favour only the platform's interests but are oriented towards consumer interests.

Voluntary self-regulation alone hardly works. However, it can supplement hard regulation by connecting influential tech companies with the stakeholders. For instance, installing

digital consumption oversight boards in large companies (parallel to Social Media Councils tasked with disinformation and hate speech) can be a helpful governance innovation overseeing the fast pace of digital innovation and putting official measures in place to put a stop to digital misconduct.

Governmental regulation can help change the availability, accessibility and affordability of sustainable consumption choices. For instance, extended product warranties and a right to repair can potentially keep products in the use phase for longer. Regulation making circular approaches easier and removing hassle with rules about reuse, recycling, and resale can stimulate online second-hand markets for all kinds of products. Platform business models geared towards the common good and sustainability are being strengthened by providing user-oriented long-term funding instruments. Rules for online advertising limit the manipulation potential of personalised profiling for commercial uses; regulation forbidding harmful dark patterns and wrong green claims is underway within the EU. Obviously, there is a fundamental conflict between consumer privacy interests and opportunities to market and target greener offers, for instance, when companies use big data psychographic segmentation techniques. Consumer and competition authorities must cooperate to avoid sacrificing privacy even for green reasons. Reversing the burden of the proof could also help to put consumers' interest at the core of algorithmic decision-making. Digital corporations with market power would have to prove that user guidance and recommendation systems are not manipulative in favour of the platform's interests but are oriented towards consumer interests. Further, macroeconomic environmental policies such as higher prices for greenhouse gas emissions and natural resources would make more sustainable products comparatively cheaper than traditional products. Such policies would also make repairing and reusing financially more attractive than buying new products.


3

How Digitalisation Can Become Sustainability-Oriented

Like groundbreaking technology innovations of past centuries, such as the railway or electricity, so too is the innovation of the programmable computer profoundly recasting the organisation of society. From the ubiquity of the internet through the rise of platforms to the creation of cyber-physical systems, from big data analysis through artificial intelligence to smart cities, all of these digital technologies feed into a process of societal change with far-reaching implications for many areas of life and the economy. Yet still unresolved is: How can these technologies meaningfully contribute to the deep sustainability transformation needed?

The first point on the agenda is to make end-user devices less energy-intensive and toxic. This is the debate about 'Green IT'. It has lost nothing of its relevance today: Making digitalisation sustainable, first and foremost, requires reducing the social and environmental impacts of end-user devices, data centres and network components and making their production as circular and equitable as possible. The first chapter of Part 3 is devoted to this challenge.

3

Of course, digitalisation is much more than devices. It is the restructuring of social life domains around and with digital communication and media infrastructures. Such far-reaching transformations immediately draw attention to the question of who drives such technologies and with what intention. As outlined in Part 1, an alarming process of monopolisation has created a status quo in which a very small number of very powerful companies, so-called 'Big Tech', are now controlling a large share of digital service supply and global data flow. The second chapter of Part 3 addresses sustainability challenges associated with the digital business models of these companies. And it suggests policy measures that help reconcile the digital economy with democracy, environmental protection and greater economic resilience.

Making digitalisation sustainable, first and foremost, requires reducing the social and environmental impacts of end-user devices, data centres and network operations.

Moreover, the quest for sustainability-oriented digitalisation requires prioritising issues of data governance and Artificial Intelligence (AI). Policymakers from city-level to the European Commission have now fully comprehended the relevance of (big) data analysis and AI-based applications for the common good. Still, politics has a serious blind spot on the environmental side. Two chapters in Part 3 conceptualise how governance of data and artificial intelligence work for a circular economy, sustainable consumption and climate protection. For only if hardware production, the business cases of the digital economy, and the mainstay of information-based services deliberately serve sustainability goals will digitalisation truly support the transformative efforts pursued throughout the remaining sectors of the economy.

« Sufficiency in Infrastructures and Devices

Production and operation of digital technologies cause substantial energy and resource demand and related environmental impacts. Total electricity demand of production and use of all Information and Communications Technologies (ICT) accounts for approximately 8% to 10% of worldwide electricity consumption and is projected to at least stay at this level or rise further.[40] In terms of greenhouse gases, the production and use of ICT account for 2% to 4% of global emissions, which is roughly the amount emitted by an industrial country like Japan.[42]

Figure 07 Global electricity consumption of the ICT sector[117]

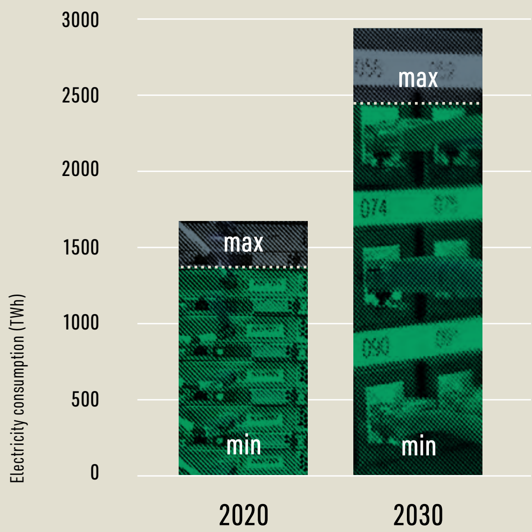
Regarding natural resources, the ICT sector makes up a comparatively low share of global demand. But for certain materials, such as Indium, it accounts for a significant share. Crucial resources, such as Tantalum and Terbium, have already reached scarcity today, while production levels of other key minerals will become insufficient in the short-term, even in best-case sustainability scenarios.[118] Meanwhile, new geopolitical tensions make the dependence on resources an issue for economic resilience, not only in Europe.

A particularly serious problem is that the extraction of many resources still follows neo-colonial practices, with the trade in certain metals causing local and regional conflicts or even wars. Mining operations, as well as production in hardware facilities, often take place under human rights abuses, unsafe working conditions, insufficient environmental standards, and sometimes even involve child labour. These problems also occur in many cases of semi-legal recycling in countries of the global South.[120] At the same time, the recycling potential for e-waste is currently largely untapped, making the ICT sector a classic case of a linear economy. Most scrapped devices end up in residual waste, which is later incinerated or exported illegally to the global South.[121] Even from those parts that are collected and enter decent recycling processes, only a small subset of the metals contained can be recovered economically.

Figure 07

Global electricity consumption of the ICT sector

The electricity consumption needed to operate all digital devices and infrastructure is expected to rise by up to 80% between 2020 and 2030.[117]



Expansion versus efficiency

The energy demand of the ICT sector depends on two factors: how energy-intensive the production, operation and end-of-life treatment of ICT is, and how many units of digital devices and services[122] are produced and consumed. Current trends regarding these two factors run counter to each other: Efficiency improvements initially ease energy and resource demand, but expansion in number of devices and use intensities eat up the savings potential. This holds true for all three subsectors: end-user devices, communications networks and data centres.

Regarding end-user devices, annual energy efficiency improvements range from 0% to 10%,[123] but the number of networked end-user devices increases into the billions as the number of devices per capita continuously increases. In addition, devices have ever shorter life cycles. Apart from dedicated ICT devices, more and more digital components are embedded in all sorts of objects for the Internet of Things.[124,125] Even if the energy efficiency of operation increases, the production of all the electronic components is still energy-intensive and often takes place at locations with a high proportion of coal in the electricity mix.[126]

Regarding communication networks, on average, both fixed and mobile data transmission technologies become 20% to 25% more energy efficient per year.[124] Yet strong increases in global Internet traffic, a shift from fixed to mobile access network use (the latter is more energy-intensive than the former), and the establishment of new data-intensive mobile services massively counteract the efficiency gains in communication networks.[123]

Regarding data centres, annual energy efficiency improvements range from 10% to 15%.[124] Again, increasing energy efficiency of digital equipment and power usage effectiveness in data centres is countervailed by rapidly increasing demand for processing, storing and transmitting data. Moreover, there is a trend towards larger data centres with increasing capacity deployed in multi-tenant cloud infrastructures. These effects on data centre power consumption are currently the subject of controversy. Although there is legitimate hope for further efficiency improvements in data centres,[127,128] a drop in data centre total energy consumption does not seem likely given expected further growth in data traffic, and given the impact of temperature increase due to climate change and the upcoming edge computing.

2030

Global demand for copper, lithium, and cobalt will exceed projected production and processing capacities by 2030.[119]

100%

Global generation of e-waste is estimated to rise by 100% compared to 2014 and amount to 74 megatons by 2030.[121]

New technologies, more service affluence

Besides these growth trends in efficiencies and the number of devices, the volume of digital services consumed also increases – the co-called ‘digital service affluence’. Digital service affluence is growing particularly fast, with growth rates exceeding 45%.[129] Services such as video streaming, cloud gaming, social networks and business intelligence are among the main drivers of network traffic.

Emerging technologies such as cryptocurrencies, the Internet of Things, Artificial Intelligence-based systems and Virtual Realities are particularly relevant. The International Energy Agency estimates that energy demand of cryptocurrency mining may have comprised approximately 0.5% of global electricity demand in 2020.[130] The burgeoning Internet of Things, which connects objects that exchange data mainly without explicit user action, has significant implications for energy demand – in particular for devices that transmit videos or track vast amounts of data, such as sensor data in self-driving vehicles. By 2023, half of all connected devices worldwide may be attributed to the Internet of Things.[128] And if the ‘Metaverse’ and similar innovations based on immersive technologies for Augmented and Virtual Reality become widely applied, this will have significant consequences for resource and energy demands.

66%

of global monthly mobile data volume accounts for video apps.[122]

5.1 billion

The number of Internet users is projected to rise globally to 5.1 billion by 2025, compared to 1.9 billion in 2010.[132]

The effect of increasing digital service affluence has, so far, not been to get more people online and diminish the digital divide. Digital affluence increases the fastest in those parts of the world where they are already highest, namely in North America, South Korea, Japan and Western Europe.[123] Hence, inequalities between the global North and South are actually widening.

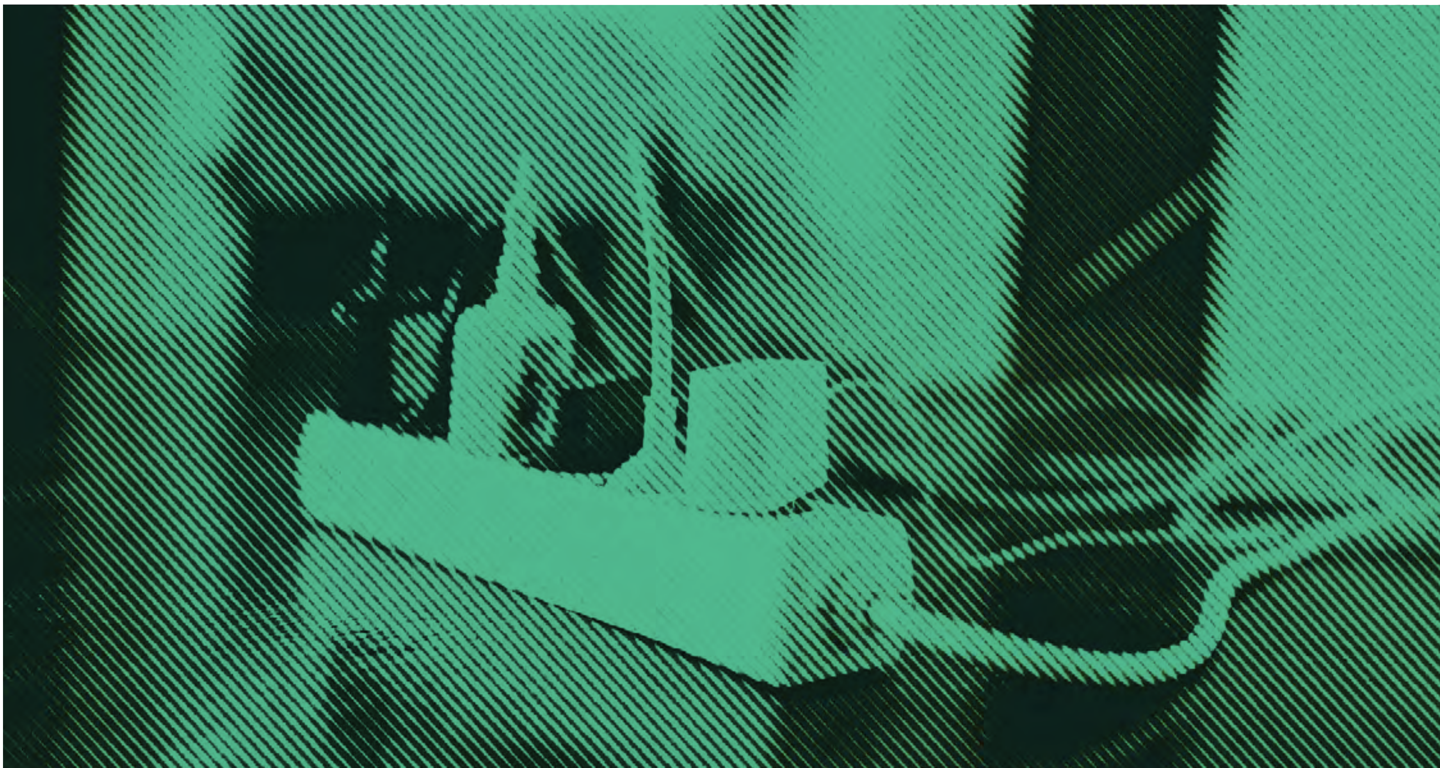
Taken together, savings potential by way of efficiency improvements of digital technologies are eaten up by a variety of expansive trends. Although reliable long-term scenarios are not available and forecasts of how digitalisation may evolve in the future are rather uncertain, evidence from long-running studies on other general-purpose technologies provides valuable insights. These studies suggest that during the take-off and expansive phase of general purpose technologies, efficiency improvements do not lead to absolute savings in energy and resource demand.[131] Compounded by the fact that Artificial Intelligence, the Internet of Things, and Augmented or Virtual Reality are still in their infancy and that an estimated three billion people on Earth are not yet online, it is unlikely that the ICT sector will contribute to substantial absolute reductions in emissions and energy and resource demand, all of which is urgently needed for a deep sustainability transformation.

Policy measures for ICT within limits

Further improvements in energy efficiencies of devices, communication networks, data centres, and service provision are important but will not suffice. Governing the ICT sector must also include policies and measures that serve circularity and sufficiency. Strategies for consistency aim at eliminating toxic materials in ICT production processes, ideally achieving production cycles with fully renewable or recycled materials powered by renewable energy. Strategies for digital sufficiency[49] aim at designing devices that last for a long time and ensuring that their complexity and resource use do not surpass the purpose they are designed for ('not cracking a nut with a sledge-hammer'). Comparing the effectiveness of efficiency, circularity and sufficiency strategies, the highest contributions to reducing energy demand and resources in the short and medium-term come from strategies for digital sufficiency.

Hardware companies should be required to design devices in a modular fashion, use standardised electronic components where possible, and ensure repair and update capability of hardware and software.

Regarding devices, first, the demand for new devices should be reduced by enabling longer lifetimes. Hardware companies should be required to design devices in a modular fashion, use standardised electronic components where possible, and ensure repair and update capability of hardware and software. At the same time, a 'right to repair' should be established to help repair businesses or peer-to-peer 'repair cafés' to flourish. With the revision of the Ecodesign Directive and the Digital Product Passport, the European Union is already preparing great steps towards improving durability, repairability and upgradability. Other legislation should require the standardisation of electronic equipment. Here, by mandating USB-C as the single charger solution for all devices, the amended Radio Equipment Directive sets a good example. Policies should further encourage reuse and recycling of devices, for example, by setting minimum standards for rates in recovering metals. However, an overall strategy for a functioning recycling system is urgently called for; one that fully utilises its potential through the



efficient collection (e.g., a deposit system for equipment or low-threshold return in shops) and further development of recycling technologies.

Meanwhile, hardware companies should refrain from marketing faster life cycles of end-user devices, e.g., bundled contracts that include a new smartphone after a certain period. Instead, they need to change their business models from selling to letting (device-as-a-service), allowing devices that do not meet user requirements to be returned and redistributed to other users after refurbishment.

Policies should encourage reuse and recycling of devices, for example, by setting minimum standards for rates in recovering metals.

Regarding communications networks, clear guidance is essential to avoid too many systems in parallel. For instance, the introduction of 5G mobile networks has been politically supported without a clear purpose or mandated conditions – simply by following the faster-is-better paradigm. Future decision-making must ensure resource-intensive digital infrastructures do not become obsolete prematurely and prescribe joint use of base stations by different network operators. Perhaps the most important but also the most challenging aspect is to prevent network efficiency improvements from being countervailed by rebound effects due to ever more interconnected devices in the Internet of Things.

* Perhaps the most important challenge is to prevent efficiency improvements from being countervailed by rebound effects due to ever more interconnected and digital services.

Regarding data centres, political efforts currently aim to establish inventories of energy demand levels and efficiencies. Yet more ambitious steps are urgently needed, such as mainstreaming the German 'Blue Angel' label for energy-efficient data centre operation. Moreover, this label could be extended to include criteria that assess environmentally sound planning, operation and disposal of data centres, such as the utilisation of waste heat. Implementing such a label should be mandatory for new data centres, which should also be prescribed to run on 100% renewable electricity. Again, most important is to prevent that all these efforts are countervailed by ever exploding amounts of data. And at the same time, data centre providers must take responsibility to help increase the pressure for renewable energy.

Therefore, governance is needed to address energy and resource demand stemming from growing digital services. Developers should follow Sustainable Software Design Principles to minimise electricity and resource consumption, as presented with the German 'Blue Angel' label for software. For the Internet of Things, energy-saving functions for network, memory and computing should be required whenever devices are in 'no use' or 'low use' states. But the most effective lever to reduce digital service affluence is to change the business models that so far invent ever new ways to drive demand. This is the topic of the next chapter..

« Business Models with Purpose

A growing part of the world economy is becoming digitalised but is in effect, driven by only a handful of platforms, so-called 'Big Tech'. Big Tech companies include Alphabet (Google), Amazon, Apple, Meta (Facebook) and Microsoft, as well as, foremost in Asia, Alibaba, Baidu, Tencent, and Xiaomi. Netflix, Twitter, Bytedance (TikTok) and a few other platforms could join the Big Tech club in the near future. The business models of these companies are, first and foremost, catering to capital interests. They have made many aspects of life and work easier, more convenient, and more productive. But the rise of these companies came at the expense of historically unprecedented power asymmetries, data silos, an erosion of digital sovereignty and creeping privatisation of public goods and infrastructures (see Part 1).

✱ The business models of Big Tech companies must profoundly change to overcome their growth fixation and foster the common good.

In light of the pressing social and environmental challenges of our time, it is not enough to say the social responsibility of Big Tech is to make profit. Instead, business models must profoundly change to foster the common good and overcome the existing growth fixation of the fossil and linear economy. And the sheer power of Big Tech companies must be subordinated to democratic legitimation and rules of fair competition in the market.

Hypergrowth drives energy demand

The Big Tech companies are driving much of today's digitalisation, and they capture the bulk of the economic value in digital markets and yield high growth rates at a steady pace.[133] While thousands of other digital companies have, on average, experienced modest growth in their revenue (1% to 5% per year) in the past ten years, the few Big Tech companies have approximately doubled their revenue every three years during that period.[134] Does this increased wealth and responsibility pay off for the environment as well?

Surprisingly, the energy consumption of the digital economy increases at a similar pace to the revenue it generates.[124,134] Contrary to most other sectors, the energy intensity of the digital sector (measured as energy input per revenue) has not declined in the past ten years.[135] This is in stark contrast to the fact that the global energy intensity must be reduced by 35% between 2020 and 2030 in order to achieve net zero emissions by 2050 – the amount required to limit global warming at 1,5°C.[136]

7%

Energy consumption and revenues of the digital economy rise 7% per year.[124,134]

In response to rising greenhouse gas emissions of the ICT sector, many IT companies have made public climate pledges stating their goals to reduce emissions and become carbon net-zero. However, an evaluation of publicly available climate pledges by IT companies shows that the sector will not be able to play its part in preventing dangerous global warming beyond 1.5°C if all digital companies follow the inadequate climate targets of most of the Big Tech firms.

Figure 08 The (un)sustainability of Big Tech companies[138]

The energy intensity of digital business models depends on two factors: how energy-efficient the provision of one unit of digital service is and how many of those service units are provided and consumed – the so-called 'digital service affluence'. While Big Tech firms contribute to improving the energy efficiency of their algorithms and data centres to keep costs at bay, the main reason for the rise in 'digital service affluence' and related energy consumption on the side of users and in the entire economy is the dominant business model of Big Tech companies.

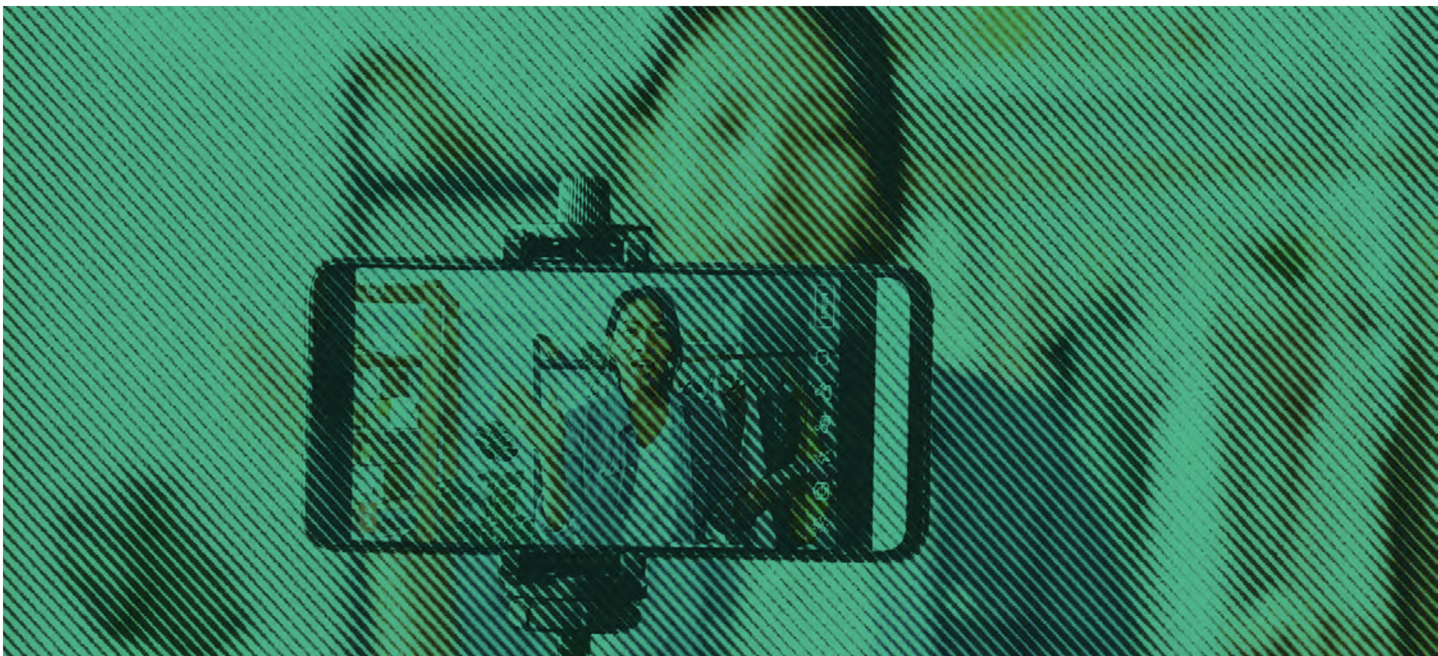


Figure 08

The (un)sustainability of Big Tech companies

If all digital companies follow the insufficient climate ambition of these influential IT companies, the sector will not play its part in preventing dangerous global warming beyond 1.5 °C.

Company	Rating	Climate Pledge (What's there: + / What's missing: −)
Alphabet	C	+ Achieve net zero emissions and use 100% carbon-free energy by 2030. − No concrete targets to reduce indirect emissions outside the organisation's energy consumption.
Meta	C	+ Reach net zero by 2030 by reducing its emissions and supporting carbon removal projects. − No concrete targets to reduce indirect emissions outside the organisation's energy consumption.
amazon	D	+ Reach net zero by 2040 and use 100% renewable energy for operations by 2025. − No credible and publicly available plan to reduce its emissions.
NETFLIX	C	+ Reach net zero by 2022, reduce internal and energy emissions by 45% by 2030, and encourage suppliers to set reduction targets by 2025. − No concrete targets to reduce indirect emissions.
ebay	C	+ Reduce direct emissions by 90% and indirect emissions by 20% by 2030. − No net zero pledge.
Microsoft	B	+ Become carbon negative by 2030, by investing in carbon removal projects and reducing overall emissions by over 50%. − Indirect emissions other than the organisation's energy consumption still increased in 2021.
Spotify	C	+ Reach net zero by 2030, by reducing overall emissions and offsetting the rest. − No concrete and transparent reduction targets for all indirect emissions.
twitter	D	+ Significantly reduce emissions by 2030 and power data centres with 100% carbon-neutral energy by 2022 − No net zero pledge and no concrete reduction targets.
Etsy	C	+ Reach net zero, reduce direct and energy emissions by 50%, and further indirect emissions by 13.5% by 2030. − Pledge to reduce indirect emissions other than the organisation's energy consumption is too low.
Pinterest	F	− No publicly available climate pledge.

A = Leading **B** = Good **C** = Modest **D** = Weak **F** = Failing

The rating of companies' Climate Pledges was developed and conducted as part of the Green Consumption Assistant project,[137] a joined collaboration project between the Technische Universität Berlin, the Berliner Hochschule für Technik, and the green search engine Ecosia. **Methodology:** Rating based on publicly available information (e.g. companies' sustainability reports). Best possible rating 'A' indicates that companies pledged to reduce their overall emissions by at least 50% by 2030, reach net zero emissions by 2030, and credibly prove that they are on track; grade 'F' indicates that no publicly available climate pledge and no evidence of credible climate action was found.[138]

Big tech drives digital affluence

Big Tech business models are often Multi-Sided Platforms. Such platforms "create value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers".[139] They attract users on one side of the market by offering services at an apparent zero cost. However, they derive most of their revenue from online advertising.[140] The goal of a platform is to maximise the number of users and their engagement. This will allow an increase in the number of transactions made by the users and the capture of more data. In turn, this data can be monetised by providing targeted advertising services or selling user-related or market-related information to third parties – which promotes further overconsumption.

Consequently, the core business of Multi-Sided Platforms is to constantly develop techniques that stimulate user engagement and increase digital service affluence.[141] Autoplay, constant scrolling, embedded videos, ads, pop-ups, thumbnails, removal of start and end credits in series episodes, automatic preview of videos before they start, automatic refresh of the news feed when the user is about to leave, and many other such techniques have invaded everyday experience in the internet. By way of these strategies, Big Tech firms effectively turn 'users' into assets through the performative measurement, governance, and valuation of user metrics (e.g., user numbers, engagement type and duration etc.) – rather than extending ownership and rights over personal data as envisioned by the principle of digital sovereignty.[142] In the case of Alphabet (Google) and Meta (Facebook), this resulted in tremendous growth rates between 2015 and 2020 in both their revenues and their energy demands – despite massive energy efficiency gains in their hyper-scale data centres.[143–146]

5–14 megatons

The yearly carbon footprint of advertising and tracking services in smartphone apps in Europe is estimated at 5–14 megatons CO_2 eq. per year.[140]

61%

of all video ads in the Chrome browser play without user initiation.[148]

Figure 09 Energy consumption of Alphabet and Meta[143–146]

Business models for the common good

If digitalisation's environmental footprint is to be reduced and digital technologies are to become a driver rather than an obstacle to sustainability, the dominant business models must fundamentally change. This is a challenging task, as the biggest companies in the world rely on such business models. To transform them, three strategies need to be integrated:

First, the unprecedented societal power of Big Tech – from their market dominance to their data supremacy – needs to be controlled and subordinated to democratic control. This will send a strong signal to venture capital firms and shareholders that such business models are no longer the standard to follow. Several initiatives in the European Union are already underway to reduce Big Tech's power: The Digital Markets Act, the Digital Services Act, the Data Governance Act and the Data Act. In the United States, the proposed Platform Competition and Opportunity Act aims to achieve similar objectives. Particularly, these regulations allow governments to review mergers and avoid so-called 'killer

Competition and monopoly law must redress data monopolies as well as the cross-market power of platforms.

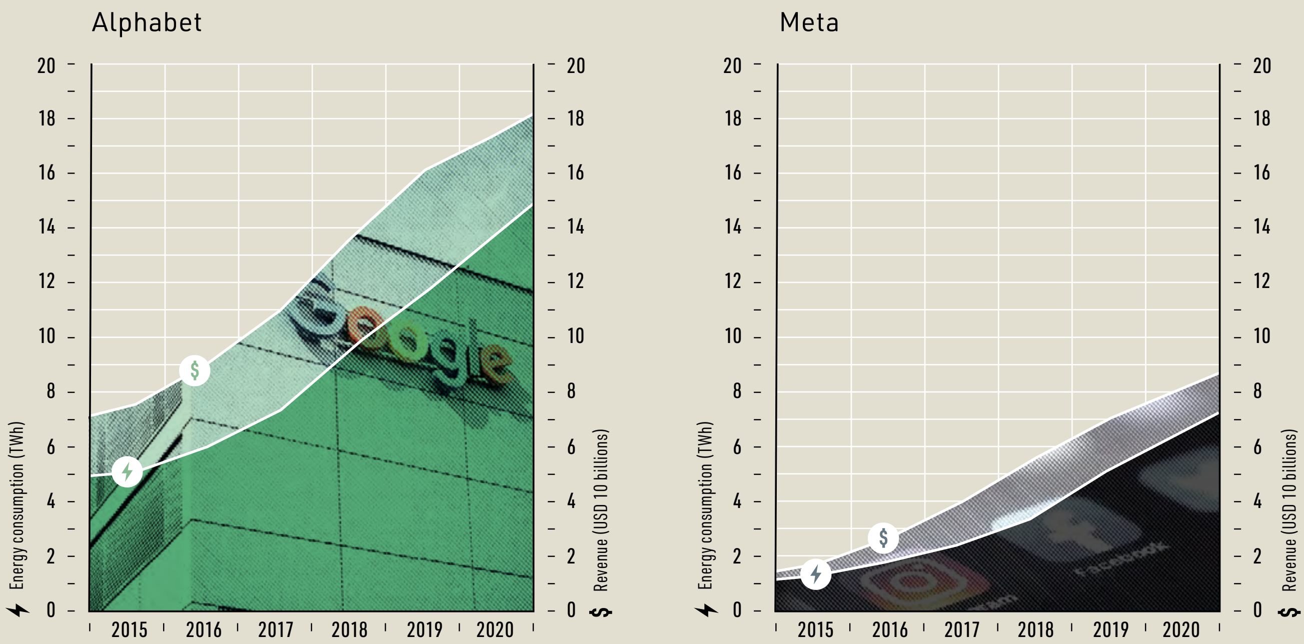
acquisitions' that mainly serve to eliminate competitors. Further rules promote interoperability between platforms and open up access to data generated from use of the platforms. However, competition and monopoly law must include additional tools that can effectively redress data monopolies as well as cross-market power of platforms because Big Tech platforms often serve as gatekeepers for market access of third companies and control distribution channels. Irrespective of whether some may consider it a measure of last resort while others believe it is already overdue, antitrust authorities should be equipped with an explicit break-up instrument for such cases, as recently proposed by the German Federal Ministry for Economic Affairs and Climate Action.[147]

Second, the exploitative and extractivist business model of Big Tech companies must be ended. This requires measures in different policy fields, including fiscal policy, competition, digital sector regulation, and corporate sustainability reporting standards. Measures should be enforced to ensure that Big Tech companies pay adequate taxes regularly (building on the OECD global minimum corporate tax agreement) and to internalise financial costs that today are 'externalities' for Big Tech companies, such as network costs. Moreover, the acquisition of personal data 'by default' should be banned, and abusive use of personal data that undermines digital sovereignty should be curtailed (see next chapter).

Figure 09

Energy consumption of Alphabet and Meta

The energy intensity of Alphabet (Google) and Meta (Facebook) increases at a similar pace to the revenue they generate.[143-146]



Finally, a bundle of measures must ensure digital business models deliberately contribute to environmental goals. For example, most platform markets lack 'production standards' – there are neither energy standards for video streaming or social media platforms, nor are services on rental or sharing platforms bound to contribute to low-energy housing or carbon-free modes of transportation. Since even comparatively strong platform legislation such as the EU's Digital Services Package does not fill this void, future legislation that includes environmental and social standards for service provision in platform markets is needed. In the meantime, mandatory reporting of so-called 'scope 3' emissions, which would cover greenhouse gas emissions stemming from the application of digital services throughout society, should be enforced. This will trigger Big Tech companies to pursue more ambitious climate pledges and take on true responsibility to avoid dangerous interference with the climate system.

Non-profit platforms and cooperatively owned businesses should be developed and supported by public finances.

And third, the creation of alternative platforms with sustainable business models should be supported. Sustainable business models pursue the common good rather than profit-maximisation via commercials and unsolicited data extraction. Such models are more likely to be implemented by civil society or public companies than profit-driven platforms. Therefore, public support for non-profit platforms, such as Wikipedia, is a helpful strategy, particularly in cases of natural monopolies. Another possible option is to develop and financially support platform cooperatives.[149] These are cooperatively owned businesses that use a digital infrastructure to facilitate the sale of goods and services. They can be multi-stakeholder, which fits well with Multi-Sided Markets. Contrary to Big Tech business models, they rely on the voluntary and explicit provision of specific data by consumers to vendors rather than on the extraction of personal data based on hidden algorithms and attention-capturing ploys. Such platform cooperatives can result from the digitalisation of existing conventional cooperatives – according to the International Organisation of Industrial and Service Cooperatives, 220,000 cooperatives exist in Europe. Alternatively, new cooperative start-ups can be supported, such as Fairbnb (a platform for short-term holiday rentals in Italy) or Les Coursiers Nancéiens (providing ethical, solidary, ecological and local delivery services by bikes in Nancy, France).

Data Governance for Transformation

Availability and use of relevant and reliable information are vital to improving the governance of countries, cities, and companies to achieve sustainability goals. Even at the individual level, the availability of relevant information can help promote sustainable lifestyles, for instance, by providing information on a product's production standards or the savings potential of alternative consumption practices. In countries, cities and firms, up-to-date or even real-time data facilitates planning and management and enables robust monitoring and assessment of impacts, which is urgently needed for deep sustainability transformations in all sectors and at all levels. Yet until today, data governance has not been systematically conceptualised to serve sustainability goals.

Putting data governance in service of environmental and social sustainability requires a reconceptualisation of currently dominant practices in the collection, management, and analysis of data. To shift from growth orientation to a resilient economy and society, sustainability-oriented data governance must back away from the approach that aims to maximise commercial value and extract the most economic benefit from data towards an approach that focuses on nurturing the common good and emphasises the role of accountability, representation and rights of citizens and communities. For whenever data is not governed for the purpose of the common good, a market comes into being in which data is extracted and traded to the benefit of those able to gather and process it. A sustainability-oriented data governance will render data that is considered a public good resilient to capture by Big Tech. Moreover, with a particular view to redressing surveillance and fostering digital sovereignty, sustainability-oriented data governance shifts the focus from collecting and using personalised data towards collecting and using anonymous data. Moreover, it will shift from centralised to decentralised storage and processing of data, particularly when it comes to opening up databases for public use.

2.98 trillion US dollars

The value of global data is estimated at 2.98 trillion US dollars.[150]

Data as a public good

Sustainability-oriented data governance must pursue a three-fold strategy: First, it should restrict and regulate the use of data for purposes that aggravate social and environmental risks, prolong path dependencies and countervail necessary deep transformations. For instance, governance needs to address 'data markets' such as online advertising markets run by Alphabet (Google) and Meta (Facebook), which aggravate overconsumption.[151–153] Abusive use of personal data that undermines digital sovereignty should be curtailed much more forcefully. The European Union's 'General Data Protection Regulation' (GDPR) posed an historic first step – but unfortunately, it has changed little concerning the practices and privileges of surveillance capitalism. Big Tech companies and online advertisers de facto disregard the very ideas behind GDPR principles, such as Data Minimisation and Prohibition of Coupling. Once user consent to the Terms of References is given, digital companies can collect as much personal data as possible without an actual necessity for the functionality of the services they offer to users. However, as services such as social media, internet search, navigation and others today equal basic public infrastructures, consenting to their Terms of References is pretty much as voluntary as compliance with national traffic regulations; the alternative is to stay home. The EU's GDPR must be developed further in order to contain these enforcement deficits.

92%

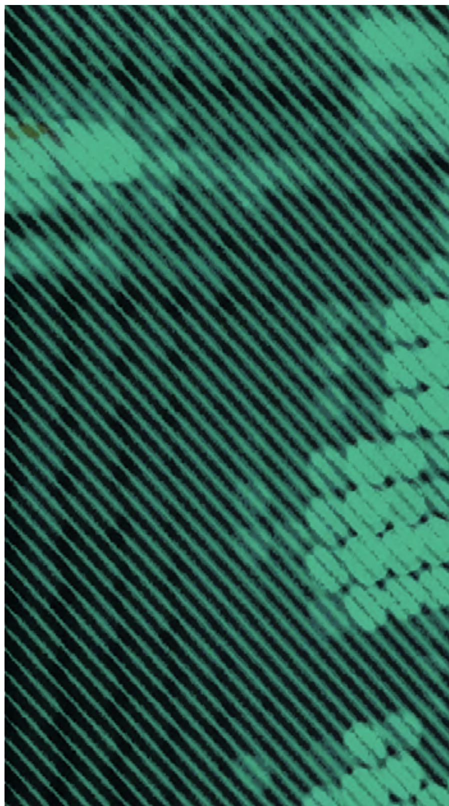
Google's search engine has a market share in Europe of 92% in 2022.[151]

Moreover, as part of the risk-reducing strategy, data governance must be aligned with approaches for environmental data justice. A participatory and open collection of data on issues related to racism and environmental inequalities can help improve environmental justice. Policies should set standards for documenting all forms of environmental harm, including corporate and government practices of manipulating and withholding data.[154]

* Policymaking has now comprehended the relevance of (big) data analysis and AI-based applications for the common good. But it still has a blind spot on the environmental side.

A second strategy is to open up data monopolies. It is neither in the common interest nor legitimate for fair market competition that platforms are walled-off as if they were proprietary markets. Asymmetric accumulation of data – and hence, of societal power – is likely to aggravate in the coming years. Today's monopoly regulation is not suited to counteracting this development, as large concentrations of data in the hands of few actors are not yet a criterion in antitrust and competition laws. In fact, data oligopolies are legal under current competition law, and antitrust laws only take effect when companies abuse their market power to deprive competitors, exploit market partners or raise unjustifiably high consumer prices. Antitrust law worldwide must be reformed accordingly, with data asymmetries becoming a key criterion.

Third, sustainability-oriented data governance should improve data collection, availability, analysis, and use for purposes that advance deep sustainability transformations. This includes a variety of approaches, including top-down regulation by governments, the establishment of new public or civil society institutions, incentivisation of self-regulation and data-management by certain actors, most notably private companies, as well as the establishment of ethics committees, oversight boards, or initiatives such as codes of conduct for data handling. Regarding environmental sustainability and justice, it appears that the founding of new institutions is particularly important. Several options are currently under discussion:[155] (1) The establishment of Public Data Trusts, which pool data

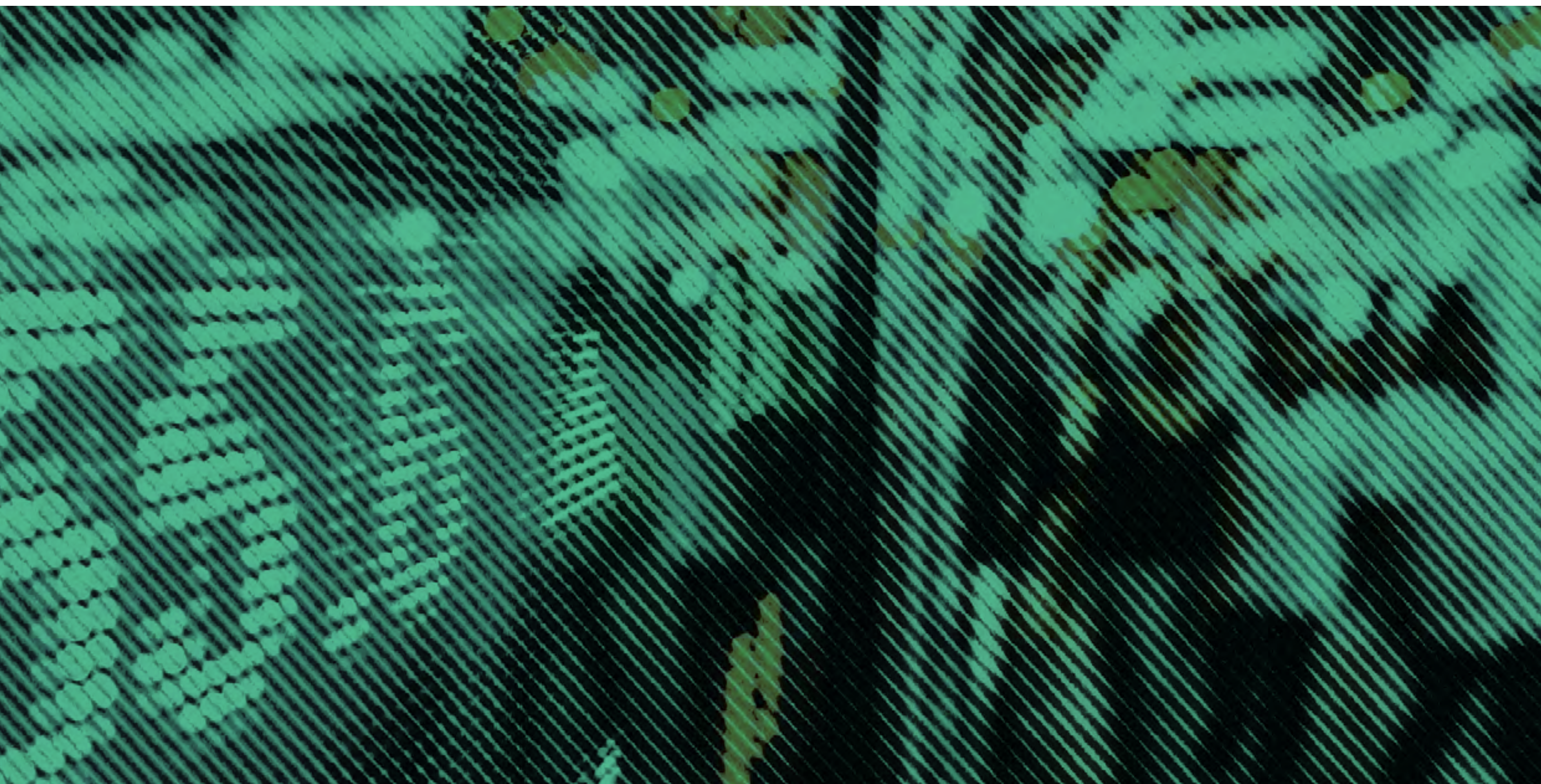


collected by private companies with data collected by public authorities, mainly with the aim to ensure access and improve decision-making for law-makers at all levels; (2) The establishment of Data Cooperatives or Data Collaboratives, which also pool data from different sources (private, civil society, public) but govern it through an independent third party, such as an industry association or a civil society foundation; (3) The setting of appropriate framework conditions for 'Data Commoning', which treats data as a pool resource and aims at keeping data as an openly accessible public good – or wherever necessary, discloses proprietarily managed ('owned') data to become publicly available. The institutional structure that is most appropriate may vary for each sector.

86%

Facebook's social media market share is 86%, and Microsoft's market share in desktop operating systems is 78%.[152,153]

Policymakers should forge ahead and launch pilot projects to gain experience and draw lessons-learned. For instance, setting up a Public Data Trust could be considered for the energy sector to share data from electricity providers, network operators, and governmental bodies, while establishing Data Collaboratives amongst firms should be considered for data governance of the Industrial Internet of Things. A prime example for Data Commons could be the transport sector: To foster the transformation towards low-carbon mobility and mobility justice, governments could establish a common pool resource structure that requires public actors (such as community transportation associations) as well as private actors (such as Google Maps, Uber, commercial sharing platforms, national railway or bus companies etc.) to disclose and share their data. Access to use these public data resources could be granted to third companies developing new transportation services, civil society organisations and even the general public. Data usage could be free of charge if clear sustainability goals are pursued in not-for-profit cases. In for-profit business cases, data use should be based on binding regulation for access and benefit sharing.



European data governance for the circular economy

The forthcoming European data regulations, in particular the Data Governance Act and the Data Act, address the algorithmic design of data flows and provide standards for effective data portability, mandatory interoperability against abusive market exclusions, a right for users to access data generated by themselves, and an obligation for digital platforms (e.g., social media, shopping platforms etc.) to provide information on how their algorithms function regarding analysis of user data as well as curation of information in services. However, this new European data legislation pays surprisingly little attention to achieving social goals, such as anti-discrimination and equity, or environmental goals, such as reducing CO_2 emissions, encouraging the reuse of materials, or minimising waste. This neglect is puzzling: Data-based companies such as Alphabet (Google) or Amazon are among the most powerful in the world, but their responsibility for climate and the environment plays little role in the current regulation debates. The EU Data Strategy announces an EU Green Deal Data Space to create a common framework for sharing environmental data. But the much broader question of which data should be shared to enable a sustainability transformation towards a zero-carbon and circular economy remains by and large untouched.

Establish new institutions for sustainability-oriented data governance, such as Public Data Trusts, Data Cooperatives, or Data Collaboratives.

Circular Economy scholars have stressed that a deficit of information is one of the main impediments to establishing circular value chains.[87,156–158] In the European Union, key data governance legislation such as the European Data Strategy and the Rolling Plan for ICT Standardisation claim to support the transition towards greater circularity. On the side of EU Green Deal policies, the Circular Economy Action Plan and the Sustainable Product Initiative aim to establish a Digital Product Passport, which shall combine information on all phases of a product's life cycle, such as "product's origin, composition, repair and dismantling possibilities, and end of life handling".[159] However, data governance policies and circular economy policies are still not systematically integrated.

A viable strategy to make data governance a driver for the transformation towards circular economic structures is to combine the five phases of the product life cycle – design, production, use, repair, and recycling – with the four steps of the data value chain – data collection, data sharing, data usage, and data standardisation. The matrix that emerges, which can be called a 'Circular-Data-Action Matrix',88 can help prolong the lifetime of durable products, increase the use of each product, close material flows in production, and hence, reduce the overall amount of resources, energy and emissions during the entire product cycle.

Systematic data sharing along the product life cycle should become mandatory for suppliers, producers and operators.

Systematic data sharing along the product life cycle should become mandatory for suppliers, producers and operators. The more stakeholders have access to and can use this information; the more products can be reused, remanufactured, repaired and recycled. In addition, the most environmentally friendly products can be consciously purchased and put to shared use. Therefore, data governance that requires collecting and providing product data in a standardised format can substantially contribute to the principle of circularity.

An even bolder action by European policy-makers would be to establish a 'Sustainable Digital Audit'. This would be an institution tasked with investigating if and how data and digital technologies can be used to support social and environmental goals within all sectors. The Sustainable Digital Audit would have the mandate to suggest new policy actions and new research areas in cases where it is identified that digitalisation is not used to its full potential or where it works against societal goals.

Artificial Intelligence within Limits

The application of 'Artificial Intelligence' (AI), such as machine-learning in automated decision-making systems, is becoming increasingly widespread in many societal and economic spheres. While the comprehensive reproduction of human intelligence, usually referred to as 'strong AI', is still far from a real-world application, 'weak AI' such as deep-learning is now already informing uncountable applications.

Several challenges accompany the application of AI. One of them is its inherent lack of transparency. AI uses data and algorithms to make recommendations, but in many cases, not even AI researchers fully understand how decisions come about. This lack of transparency poses a serious threat to consumer sovereignty and even to democracy. Additional challenges are trustworthiness, autonomy and data protection. For these ethical and technical issues, a set of guidelines and rules have now been developed to avoid non-transparent decision-making processes, discrimination or increasing inequalities that can occur through AI-based applications.[161,162] Moreover, the European Union has published a proposal for an Artificial Intelligence Act. However, considerations of the environmental implications of AI are still in their infancy, and the current draft of the European AI Act does not list any environmental mandates on AI providers or deployers.

21%
The value of the artificial intelligence market is projected to grow by 21% from 2022 to 2030.[160]

Two key questions arise at the interface between AI and sustainability: How can AI be employed in ways that positively contribute to socially and ecologically desirable developments, such as climate protection? This is the quest of 'AI for sustainability'. And, how can direct negative social and environmental impacts of the operation of AI-based systems be minimised? This is the quest of 'sustainable AI'.

AI for sustainability

Regarding 'AI for sustainability', implications depend on the kind of AI systems but even more so on the purposes and goals that are pursued with their application.[163] AI can be used in literally any field of action – including those of high relevance for deep sustainability transformations. For example, AI can be applied to improve coordination of smart grids, increase efficiencies in transport management and infrastructures, optimise precision in earth observations, inform new weather warning and forecasting systems, enhance waste and resource management in a circular economy, or help consumers find the most sustainable products.[164,165]

36%
of use cases for artificial intelligence in the consumer goods and retail industry are in the personalisation of products and services.[166]

Eventually, the specific interests of the actors who drive the creation of AI applications and markets will determine whether and to what extent these actually support deep sustainability transformations – or run counter to them. Current circumstances are not promising: Much research and AI development are tailored to marketing interests, such as personalising services, forecasting cus-

tomers' purchasing interests or optimising online advertising. These applications intend to increase existing overconsumption. Just as there are numerous fields of AI applications that support sustainability, there are equally numerous fields of application that prolong the lock-in of fossil-based and resource-intensive production and consumption patterns. For instance, AI is used to optimise the exploration and extraction of oil and gas and make fossil fuels more competitive.[167]

Equally challenging is the exacerbation of monopolisation and power asymmetries. Large tech companies are in a prime position to make use of big data for AI to enhance their competitive advantages – and, in turn, acquire start-ups and competitors to gain access to further data sources that again improve their options for AI development.[168,169] A reform of antitrust and competition law to avoid data monopolies is even more urgently needed as AI gains importance (see the previous chapter).

32,000

Alphabet, Meta, Amazon, Apple, and Microsoft have launched 32,000 venture capital deals and have bought 400 tech start-ups since 2010.[170]

* AI-based applications must generate substantial energy and emission reductions in their use phase to ensure that energy demand in their training phase is balanced out.

Public funding should deliberately support the development of AI-for-sustainability research and development. Even public research and development funding of AI in other topic areas, such as medical or marketing-related research, must be bound to include a clear reference to sustainability goals. In particular, small enterprises, start-ups and civil society projects that are committed to sustainability goals must be supported in improving their AI literacy and stacking up their technological capacities to develop true AI-for-sustainability solutions. This can be facilitated by establishing learning hubs and actor networks, incubators or labs that provide spaces for knowledge sharing and exchange of experiences. For instance, the German government launched a Digital Innovation Hub for Climate as well as a civil society Platform for Socio-Ecological Innovations.[171] Such networking endeavours can serve as learning grounds to be adapted by other countries.

Public funding should deliberately support the development of AI-for-sustainability research and development.

Sustainable AI

The discussion about AI opportunities and risks has only recently begun to consider how much energy and resources AI itself consumes for computing. Similar to the implications of digital infrastructures and technologies in general, the implications of AI depend on (1) computing-related impacts, (2) the impacts of AI-based applications in their use phase and (3) broader economic and societal changes that AI may induce.[43] Energy demand for model development, model tuning, model training and model use drastically vary between different AI systems.[172] In general, AI development and training are expected to become more complex and comprehensive in future years, which may demand more energy and natural resources.[172] Whether efficiency improvements in the models will outpace increasing complexity to prevent additional energy consumption remains an open question. Each single application in the use phase of an AI application usually accounts for the least energy-intensive process in the AI life cycle but can add up in orders of magnitudes – as the example of Google's machine translation system shows, which is assumed to process several hundreds of billions of words per day.

Figure 10 Energy consumption of Artificial Intelligence[175]

Ensuring that AI generates net benefits requires assessing whether the energy consumed in the training and use phases justifies the intended effects. Therefore, the development of AI-based applications must be bound to effect substantial energy and emission reductions in the use phase to ensure that demand in the training phase is balanced out. In addition, AI developers should be obliged to report on the energy demand and carbon emissions of the AI models used. Software tools, metrics for reporting model accuracy, and benchmarks to measure the energy and carbon intensity of AI are already available.[43,176] Creating greater transparency on environmental implications would also incentivise cloud providers to offer more climate-friendly services.

AI developers should be obliged to report on energy demand and carbon emissions during model development, model tuning, model training and model use of AI systems.

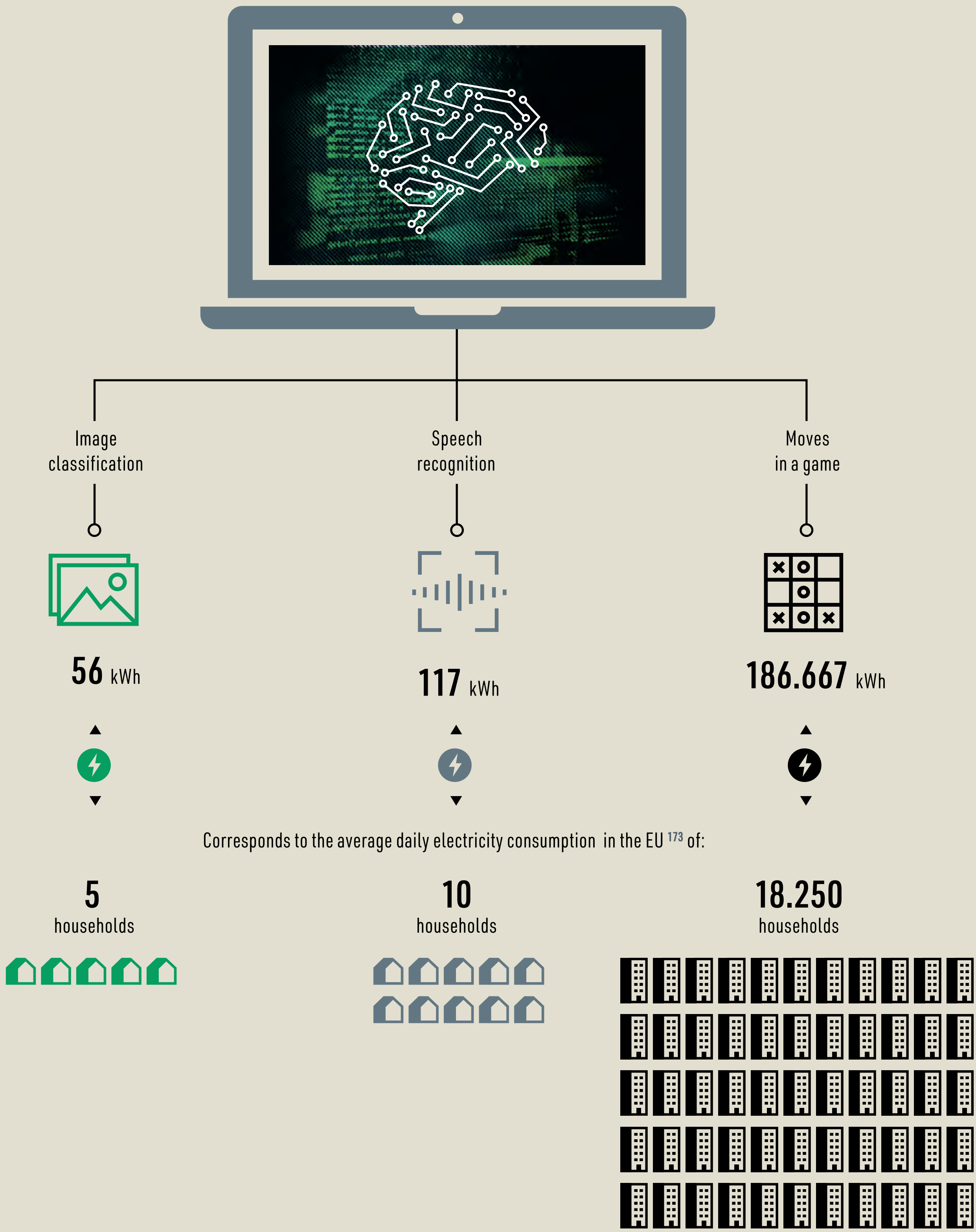
Moreover, policymakers should consider price incentives such as CO_2 or electricity taxes, which would make developing less complex or 'tiny' AI models[177] more attractive and incentivise software developers and their clients to balance energy costs with performance benefits. This is all the more important as efficiency improvements in computing power, and ICT infrastructures are expected to be large, but at the same time, the amount of computation needed for AI training phases and applications is also expected to increase rapidly. As a result, it is uncertain to what extent efficiency improvements can realise absolute reductions in energy demand and emissions – or whether these will be outpaced by the growing sum of applications and use cases. Finally, note that today's decisions for an increasingly AI-powered infrastructure are relevant not only because of the carbon emissions these will generate but also due to constraints and emerging new lock-ins that will prevent future generations from changing course if that infrastructure proves to be unsustainable.[178]

Figure 10

Energy consumption of Artificial Intelligence

The training of increasingly complex, multi-layered deep-learning systems needs vast amounts of computing power and energy.[175]

Amount of energy consumption of different training models

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Ten Lodestars for a Digital Reset

This report has analysed the role played by digital technologies in the past. And it has revealed how digitalisation can become a force for transformation if its potential is governed by an active digital policy. The scientific evidence reported in Part 1 makes one thing crystal clear: So far, digital technologies have not sparked the change necessary for a deep sustainability transformation. In Part 2, this report has taken a deep dive into six sectors and analysed the role of digital technologies for the sustainable change necessary for tomorrow's world. It has explained how good digital governance can initiate a Digital Reset in each sector so that technologies become redirected towards social and environmental goals. Part 3 of the report has underpinned how applications, business models and governance of data and artificial intelligence can change if technologies align with ecology and justice.

The changes needed are complex and challenging, as are the policies required. The sooner the course is reset, the higher the likelihood of a successful redirection.

Ten recommendations below summarise the insights gained from the intensive two-year research project with the international expert panel that prepared this report. These recommendations may serve as lodestars for decision-makers and citizens who want to embark on the journey towards a deep sustainability transformation.

#01 A **clear vision for digital technologies** is indispensable to address social and environmental challenges successfully.

The EU is on the verge of initiating a sustainability transformation. But as ambitious as the 'European Green Deal' and its many legislations are, they do not suffice. For one, because time is running out. And also, because the EU's other overarching policy package, 'Fit for the Digital Age', does not serve the same goals. Major technological advances are not geared towards solving the pressing social and environmental challenges of our time. Why is artificial intelligence used to trick consumers into staying longer on social media rather than solving climate change? Machine learning, the Internet of Things, big data analysis, and platforms are changing the economy but without a purposeful vision. Digital technologies can contribute to tackling challenges, from reducing global warming to increasing economic resilience. But only if decision-makers develop a clear vision of how society should put digital technologies in the service of providing decent living conditionsfor all while respecting the planetary boundaries.

#02 The **purpose of digitalisation** needs to be subordinated to the goals of a deep and sustainable transformation of society.

It is clear: Digital technologies alone will not solve the multiple crises at hand. But they can unfold their potentials under the right incentives, regulations and social conditions. For example, smart metres facilitate a distributed energy system only if renewables have precedence and fossil fuel sources are left in the ground. Business cases for circular production only succeed if repairing, reusing and recycling become profitable. And small-scale digital farming only prevails if biodiversity conservation and climate-friendly agriculture become a political priority. Therefore, policies for deep transformations must guide digital innovations, and the application of technologies must serve sustainability goals and policies. Instead of speaking of a twin transition, the logical next step for the EU is to transform the 'Fit for the Digital Age' package into a means to achieve the 'Green Deal'. In fact, what is needed is a 'Digital Green Deal'.

#03 A mission-oriented approach to digital innovations enables governments to **shape the future proactively.**

With a strong vision for the purpose of technologies, policymakers can start putting them to work. To this day, the spirit of 'the impartial state that solely sets the conditions for the market' is still too present. Instead, policymakers need to put themselves in the driver's seat. As reactions to the COVID-19 pandemic or the Russian war in Ukraine have demonstrated, exceptional circumstances legitimise bold interventions. This mindset must be applied to redress inequalities and avoid violation of planetary boundaries. Policymakers can use and expand their toolbox to attain clear legitimate goals. On the one hand, policies can much more actively support the digital technologies that facilitate deep sectoral transformations, e.g., those that initiate distributed energy systems, car-free and multi-modal mobility, or shared consumption of goods. On the other hand, governments can much more vigorously contain digital developments that run counter to the common good. For instance, dark patterns, abuse of personal data for commercial means, or the appropriation of public infrastructures can be contained by mandating and licensing critical digital services.

#04 **Foresighted and agile governance institutions** enable a primacy of politics above digital innovations.

Digital technologies and businesses are still characterised by a sense of lawlessness. As regulations are weak or simply non-existent, companies can do as they like and set the rules for the digital world. Policymaking usually lags behind. For instance, it took more than twenty-five years after the invention of the Internet for the EU to introduce its General Data Protection Regulation; and it took twenty years after the invention of social media to subordinate large platforms under political primacy through the Digital Services Act package.

Policymaking needs to get ahead of the tech curve in order to drive innovations towards the common good, before they become walled-off proprietary markets with global reach. This, however, requires strong new institutions that pursue 'anticipatory governance'. Technological developments must be supervised more carefully and systematically over time. Without taking creativity out of business and civil society to innovate new applications, technological developments should be shaped from the beginning instead of moving governance upstream in the innovation process. For instance, the EU could establish sector-specific 'Advisory Councils for Science, Technology and Innovation' as independent monitoring committees with the mandate to provide early advice to politics and ensure that the process of designing a technology is open, transparent and inclusive.

#05 Ensuring **technology design becomes a democratic process** will better balance individual aspirations with societal goals.

Today, the design of digital technologies is almost completely left to the market. Private companies determine the design of technical devices and what service platforms offer. In order to cater to their business, companies pay attention to user aspirations such as convenience, saving time, or increasing productivity. But they seldom build societal goals into the design, such as minimising digital divides in society or helping users to save energy and resources. Because digital technologies should help achieve a deep transformation, their design must transcend from a consumption-centred focus to a planet-encompassing focus. This requires making design a democratic process that includes many stakeholders and integrates diverse views. If civil society organisations, public institutions, citizens and science get a say in the design process, this will ensure that social responsibility becomes more important relative to individual utility. Further, if views and needs of diverse classes, genders and cultures are included, creative problem-solving will likely be considered more important than profit maximisation. In particular, technologies that provide public services – e.g., social media, internet search, e-commerce, app stores, learning platforms etc. – should be guided by mandatory accessibility requirements that ensure democratic co-designing.

#06 A **frugal use of digital technologies** keeps the environmental footprint of ICT at bay.

Production and operation of digital devices now account for a substantial amount of material consumption and greenhouse gas emissions. While processing units become ever more efficient, the sheer number of smartphones, laptops, smart devices and a multitude of gadgets, as well as the vastly increasing amounts of digital infrastructures, including mushrooming data centres, level out potential energy savings. Further efficiency improvements, durability, repairability, open source and recycling are all key to reducing the environmental footprint of ICT. But reflection upon the actual requirement of a technology is even more important. Not every digital device makes sense, and not every service needs to be digitalised. Gadgets in smart homes often serve convenience rather than energy efficiency. Autonomous vehicles that promise luxury and comfort foreshadow even more road traffic. The clear vision for the role of digital technologies as well as their subordination to deep sustainability transformations will also inform the extent to which ever more devices and applications are actually needed. Without question, a Digital Reset will veer away from a 'let's digitalise everything'-attitude towards a new mindset based on moderation and prudent use of technologies. Keeping the possibility to choose non-digital options may be regarded as welfare gain.

#07 Getting the most out of digital technologies means using them for **sufficiency and circularity.**

Deep transformations that live up to the severity of the climate and biodiversity crises require not only efficiency advances but also strong strategies for sufficiency and circularity. Some digital technologies may have the potential to help reconcile environmentally sustainable and decent standards of living in such transformations. For example, smart logistics facilitate mobility, itinerary planning and the switch from personal automobile transportation to public and shared transportation. Intelligent building designs and sharing platforms provide the required space for all users while reducing the resource-intensive construction of new buildings. Further, second-hand and sharing tools make it possible to reduce the necessity of purchasing new goods while satisfying consumption desires. They do so with the collateral benefit of redressing global and intergenerational equalities: Sufficiency-oriented lifestyles and business models are much more affordable while also leaving more room for future generations to satisfy their needs. However, as of now, most technological developments aim at efficiency improvements instead of sufficiency improvements. Therefore, politics is well advised to develop coherent strategies for digital sufficiency and circularity for each sector.

#08 The business models of **Big Tech companies need to change profoundly** and be aligned with the goals of a deep sustainability transformation.

A handful of Big Tech companies determine the shape and design of many digital technologies today – and attain the largest share of the economic value. As shareholder companies, their business models aim at maximising profits, binding users to their services and extracting unsolicited data. To make technologies serve a deep sustainability transformation, the intrinsic motivation and the business models of digital protagonists must be bound to nurture the common good. With the Digital Services Act package, the EU has taken giant steps to change the rules of the game in the digital economy. But keeping big companies in check is not enough. It is high time to force walled-off proprietary markets to open up to fair competition, e.g., by setting mandatory standards for data accessibility and interoperability and equipping competition law with tools to address data monopolies and platforms with cross-market power. The other key lever is to help alternative organisations become serious protagonists in the digital economy. This requires proactive and rigorous support of public companies, civil society-run networks, and cooperatively owned platforms. Because such forms of organisation usually follow other logic than mere profit maximisation, they often aim much more directly at fostering the common good. Meanwhile, for-profit tech companies can increase their Corporate Social Responsibility and Corporate Sustainability ambitions, such as radically reducing greenhouse emissions not only from their own operations but from the widespread application of their services in society.

#09 Ambitious **governance to share data** among stakeholders is key to unleashing technologies' potential.

In many cases, data is the true basis for digital innovations. Hence it comes as no surprise that many firms stockpile, guard, and monetise data, be it by vertical integration in agriculture, buy-ups in artificial intelligence or proprietary markets in social media. Access to data, however, is a crucial ingredient for digital innovations that serve sustainability. For example, multi-modal mobility apps require data on the availability of transport options, matching of supply and demand, and management of passenger movements. Circular business models rely on the products' information to repair, reuse and recycle. And applications for optimal matching of variable electricity supply and demand can only succeed with real-time knowledge of electricity markets. The key in data governance is facilitating the access of many actors while protecting sensitive information and guaranteeing privacy. Hence, data governance for the common good comprises a three-fold strategy: First, to more effectively restrict and regulate data use for purposes that aggravate social and environmental risks – most notably those that undermine digital sovereignty. Second, to carefully draft legislation that opens up data monopolies in order to increase accessibility for all. And third, to establish new institutions that improve sharing of data and a commons-oriented application of data-based products. The EU Data Act and EU Data Governance Act provide important first steps but need to be amended to comprehensively address these strategies with a view to deep transformations in various sectors and fields of applications.

#10 **Now is the time.**

Today's societal challenges are tremendous. Yet business leaders, politicians, and ordinary citizens do not need to fall into paralysis. Although digitalisation, in its current and mainstream form, has turned into a worrying development, this report does not advocate giving in or giving up. On the contrary, at the beginning of the 3rd millennium, it is up to us to determine where the Information Revolution will take us. We can use it to correct the errors of the Industrial Revolution – namely, its skyrocketing environmental footprint – and eventually fulfil its promise of a decent life and prosperity for all. It is entirely possible that future historians ponder the 2020s as the key turning point when amidst multiple crises, steps were taken for a Digital Reset that is fully focused on solving these crises. What are we waiting for?

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DIGITAL RESET

Redirecting Technologies for the Deep Sustainability Transformation

Time seems out of joint. The world society has experienced a centennial pandemic, the global thermometer has displayed a sequence of hottest years on record, and Russia's war on Ukraine has shattered political order. Unsurprisingly, the economy is severely affected.

Governments worldwide **hope that digital technologies can provide key solutions**. Yet this report shows that digitalisation, in its current and mainstream form, is rather aggravating than solving many of the pressing social and environmental crises at hand. **What is needed instead is a deep sustainability transformation** that fundamentally reorganises the economy and all its sectors – agriculture, mobility, energy, buildings, industry, and consumption.

The report "Digital Reset" shows how digital technologies can support the quest for such a deep sustainability transformation. **The report provides a blueprint for the European Union** on how to reconceptualise digitalisation so that it first and foremost contributes to achieving carbon neutrality, resource autonomy and economic resilience while supporting equity and fully respecting citizen's rights and privacy.

The report is the outcome of the two-year international science-policy dialogue "Digitalization for Sustainability" (D4S), and presents an up-to-date comprehensive analysis of opportunities, risks and governance options regarding digitalization and sustainability.

D4S Digitalization for Sustainability Science in Dialogue