DIGITAL RESET

Redirecting Technologies for the Deep Sustainability Transformation

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

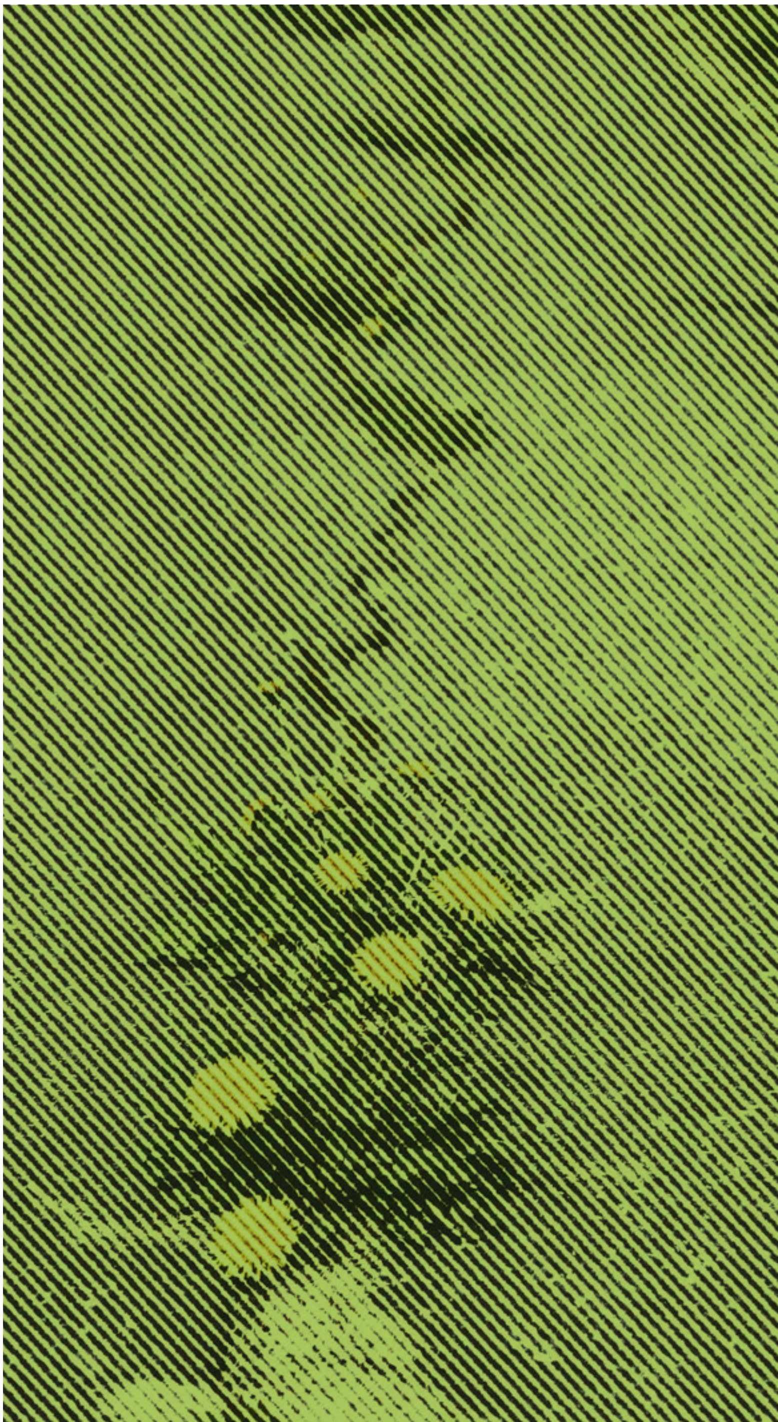
Introduction

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.

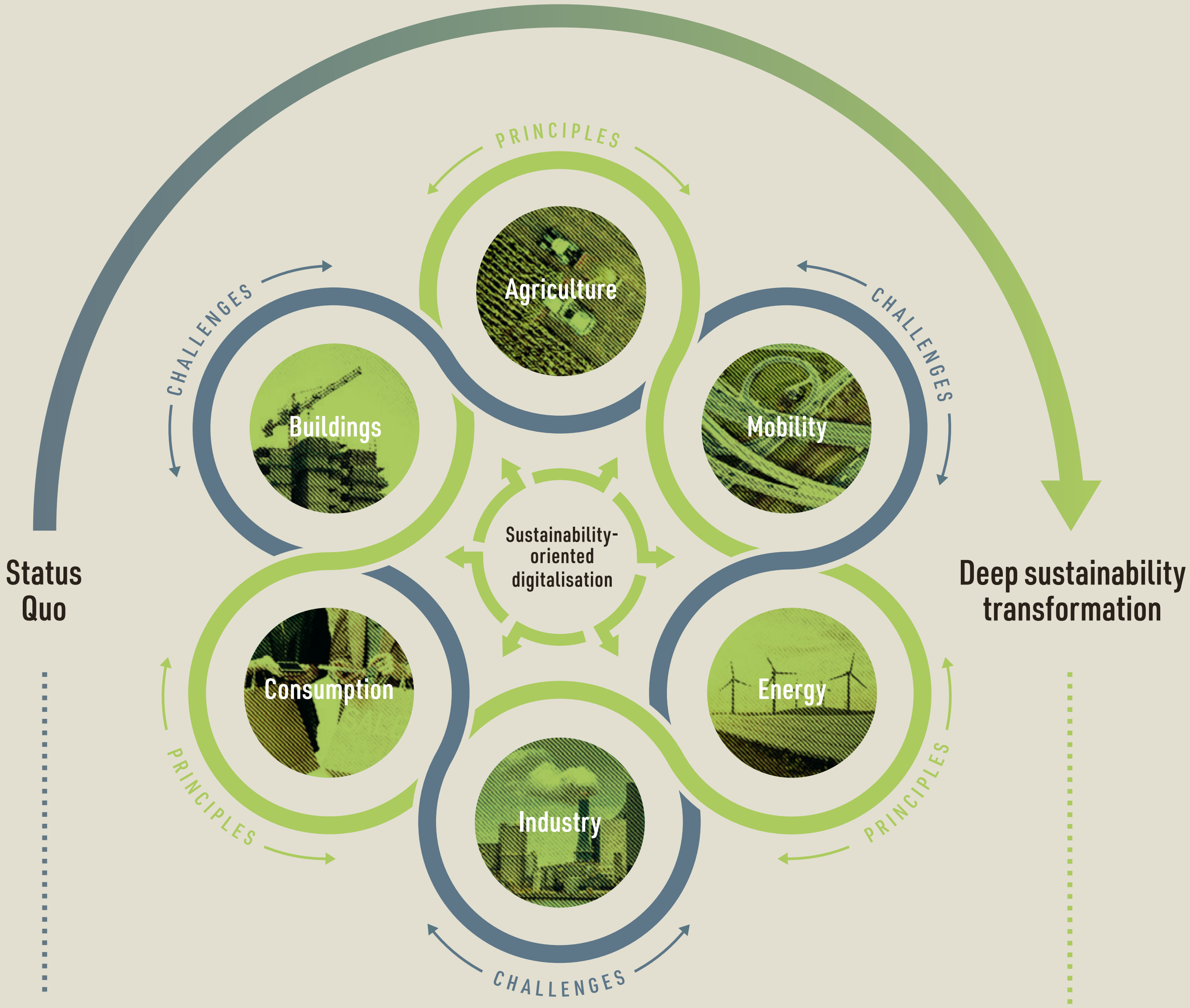
To ensure digitalisation delivers for a deep sustainability transformation, it needs to be shaped according to a set of new principles. These principles are outlined at the end of Part 1, based on a systematic analysis of why digitalisation is currently failing to avail of the chances of such a transformation. 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


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]

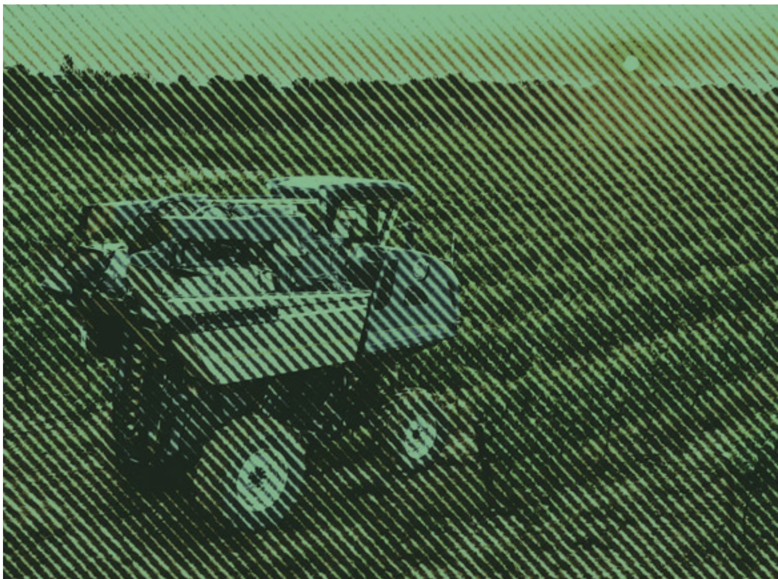
‹ A purpose for digitalisation in agriculture

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:

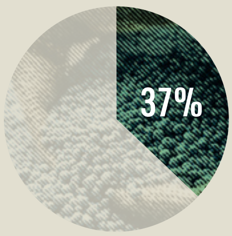
Seed Sales

- 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%

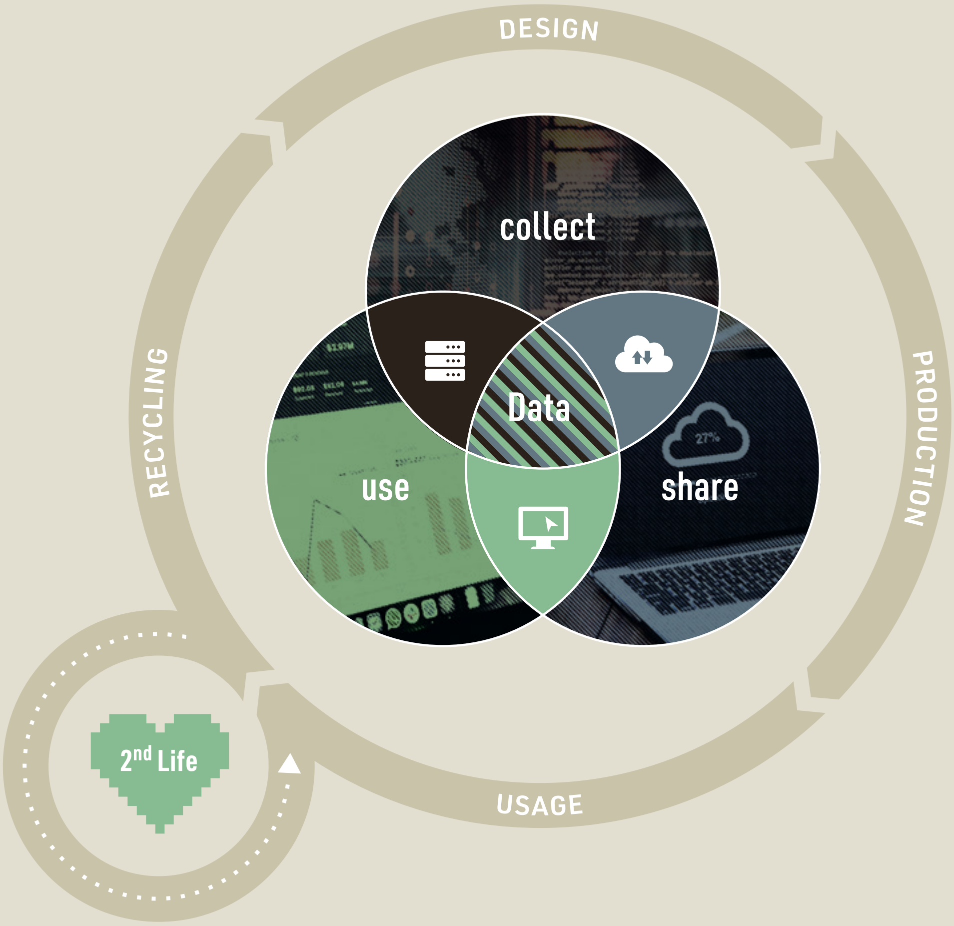
Circular business models account for only a small fraction of output, usually no more than 5-10%.[86]

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

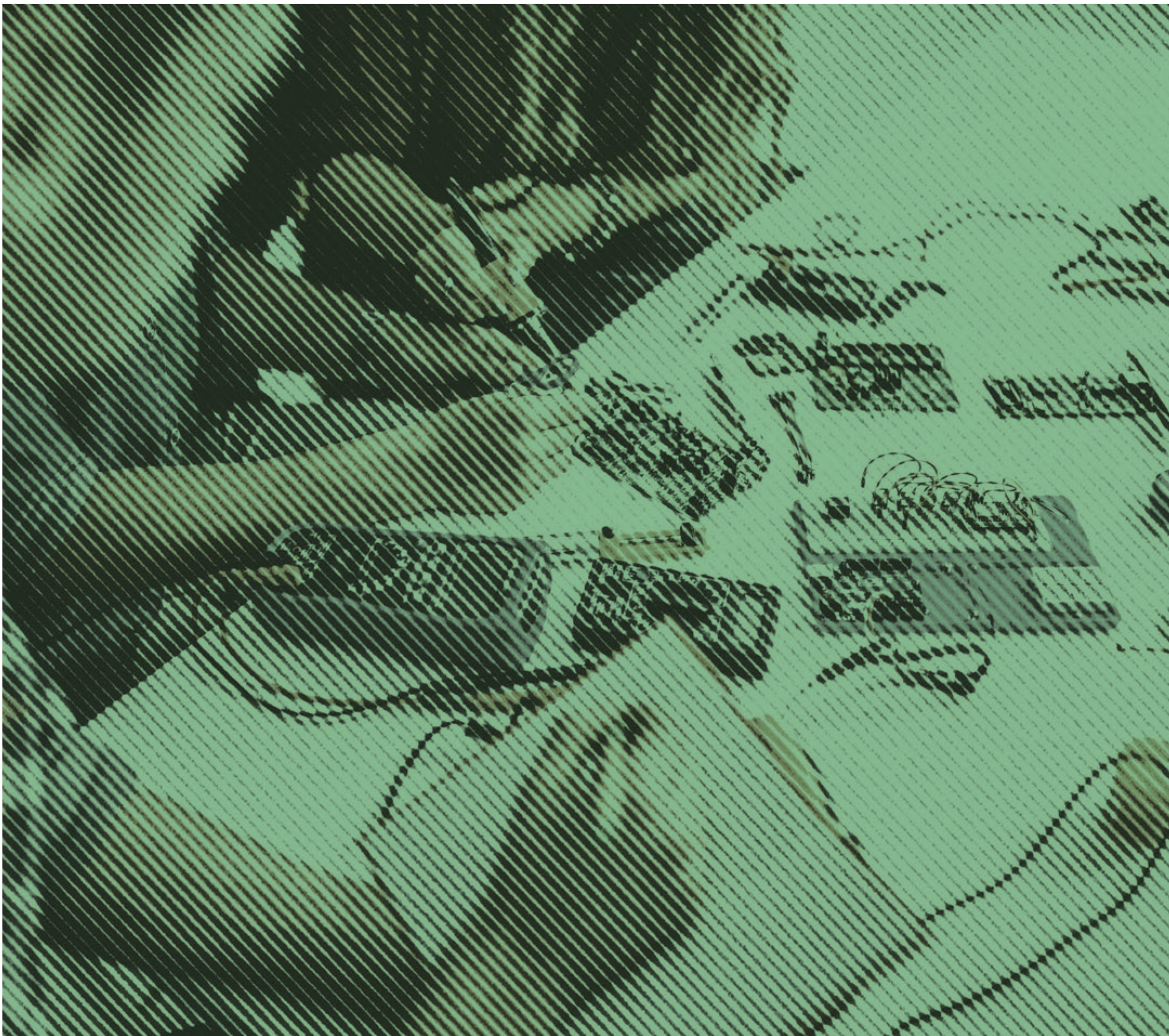
- Producers create repair and maintenance information (RMI)
- Producers share RMI data via API
- Repairers use RMI to faciliate product recovery and prolonged lifetime

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.

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.

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

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.

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.

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D4S Digitalization for Sustainability Science in Dialogue