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Recommendations on Using Digitalisation for Our Common Future

A Report by the Policy Network on Environment and Digitalisation

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Contents

About the PNE **2**

Report Acknowledgments **2**

Reader's Guide **3**

Executive Summary **4**

Introduction **6**

1.1 Relevance and Structure 6

1.2 Scope and Terminology 7

Overview of Opportunities & Risks **13**

2.1 Digitalisation Trends 13

2.2 Opportunities & Risks of Digitalisation for the Environment 14

Recommendations **20**

3.1 Environmental Data 20

3.2 Food & Water Systems 30

3.3 Supply Chain Transparency and Circularity 39

3.4 Overarching Issues 46

Conclusion **58**

References **60**

About the PNE

This report constitutes the first output document of the Policy Network on Environment (PNE). The PNE is an initiative of the United Nations (UN) Internet Governance Forum (IGF) launched in spring 2021 after the first session dedicated to the nexus of environment and digitalisation received much attention at IGF 2020. In 2021, the topic of environment and digitalisation was again a key issue at the annual forum, with two dedicated main sessions and several workshops organized by third parties. The vision of the PNE is a world in which digitalisation is used as a force for good, and where progress is made towards the UN 2030 Sustainable Development Goals (SDGs). The PNE's work in its initial phase was spearheaded by a Multistakeholder Working Group (MWG) consisting of stakeholders from across the globe dealing with the intersections between environment and digital technologies. The monthly meetings of the PNE 2021 were co-chaired by Daniel Akinmade Emejulu (Microsoft), Kathryn Sforcina (IV. AI) and Przemysław Typiak (Chancellery of the Prime Minister, Poland). In 2021, the PNE has welcomed Guest Speakers Mr. Michael J. Oghia (SDIA), Mr. Elliott C. Harris (UN DESA) and Mr. Jacob Malthouse (Foresight Cleantech Accelerator). For more information about the PNE, visit: https://www.intgovforum.org.

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Reader's Guide

Abbreviations and Acronyms

AI	Artificial intelligence
CARE	Collective benefit, authority to control, responsibility, ethics
CO2	Carbon dioxide
COP26	2021 United Nations climate change conference
COVID	Coronavirus disease
DLT	Distributed ledger technology
DPP	Digital product passport
EPR	Extended producer responsibility
EuroDIG	European dialogue on internet governance
FAIR	Findable, accessible, interoperable, reusable
FAO	Food and agriculture organization
G20	Group of 20 (19 countries and the European Union)
GBIF	Global biodiversity information facility
GHG	Greenhouse gas
GSMA	Global system of mobile communications association
ICT	Information and communication technologies
IEA	International energy agency
IGF	Internet governance forum
ILK	Indigenous and local knowledge
IPBES	The intergovernmental science-policy platform on biodiversity and ecosystem services
IPLC	Indigenous peoples and local communities
ITU	International telecommunication union
MWG	Multi-stakeholder working group (of the IGF)
OECD	Organisation for economic co-operation and development
PNE	Policy network on environment
SDG	Sustainable development goals
SG5	Study Group 5
UN	United Nations
UNCTAD	United nations conference on trade and development
UNDP	United nations development programme
UNECE	United Nations Economic Commission for Europe
UNEP	United nations environment programme
UNESCO	The United nations Educational, Scientific and Cultural Organization
UNFCCC	United nations framework convention on climate change

Executive Summary

Climate change, biodiversity loss, increasing pollution and their catastrophic consequences for the planet and communities continue to unfold in tandem, with UN scientists sounding "code red for humanity" as they warn that the climate will heat up beyond 1.5 degrees Celsius within the next 20 years [1]. Another megatrend characterising the 21th century is digitalisation; the entry of technological devices and applications of information and communication technologies (ICTs) - hardware and software - into various areas of life and business [2].

Digital technologies present opportunities for climate protection…

Environmental data can provide a more accurate and complete picture of the state of the environment, which can be used to drive more effective policy and decision-making. Economic sectors such as agriculture can also benefit - guided by technological innovations, farmers can boost productivity by using natural resources more efficiently. Digitalisation can enable more circular business models with improvements in tracking, traceability and data analytics for resource management. Digitalisation increasingly impacts transport and mobility, where - in the long term and in a best-case scenario - increased efficiency due to automation and car-sharing might cut today's energy use levels in half [3] (IEA, 2017).

However, these resource and efficiency gains are threatened to be offset by more frequent or more intensive use of products or services, also called rebound effects.

…but they also cause a large environmental footprint that needs addressing by the global community.

Digital does not mean immaterial: We are witnessing an overproduction of devices and related overuse and loss of resources when devices have reached the end of their lifespan. The environmental footprint of the digital world is estimated to virtually amount to about a 7th continent (or up to 5.6% of humanity's global footprint) [4], and operations related to ICT are expected to consume up to 20 percent of global electricity demand by 2030, with one-third stemming from data centers alone [5]. In the form of e-waste, improperly discarded digital objects contribute to the degradation of the environment: in 2020, a record number of 53.6 million metric tons (Mt) of electronic waste was released into the environment [6]. E-waste is the world's fastest growing waste stream, and it is estimated that by 2030 the amount will reach 74 million Mt. Faced with these realities, the environmental impact of technology needs to be thoroughly investigated and adequately addressed if we expect digital transformation to deliver on its promises. Adopting the vision that nature and the internet are global public goods, and their supporting resource-systems must be governed as global commons to ensure they reinforce each other. The transformative effect of digitalisation can be seen in the efficiencies derived from it in nature, in caring for nature when developing digital technologies, infrastructures, data and services, and in the improved governance that digitalisation brings to the coexistence of people and nature.

Recommendations on using digital technologies for the common good

The authors of the Policy Network on Environment and Digitalisation (PNE) would like to offer guidance in proposing a spectrum of 15 concrete, actionable policy recommendations (see Fig. 1 for an Overview) to ensure that the opportunities processes of digitalisation present can take full account of the challenges. The recommendations are sorted thematically by four issue areas: Environmental Data, Food & Water Systems, Supply Chain Transparency and Circularity, and Overarching Issues.

For **Environmental Data**, the authors stress the importance of Findable, Accessible, Interoperable and Re-usable (FAIR) data. For existing and new datasets to be leveraged ethically and effectively, strong data governance guidelines and regulations from both people-centered and technical perspectives are deemed to be essential. The data must be accessible and presented in forms that make sense for diverse stakeholders. The technologies used to gather, manage, prepare, analyse, and distribute the data should be designed to support cooperation between all stakeholders as well as producers and distributors of the data to maximise the impact of digitising environmental information.

Regarding **Food & Water Systems**, it is recommended to apply digitalisation with contextual specificity and sensitivity, respecting and complementing traditional systems. Governments are encouraged to commit significant resources to local community-based initiatives that are increasing capacities at local levels to collect and use data to inform decision-making for food and water security, and climate resilience. Furthermore, the authors call for the implementation of risk management policies regarding the vulnerabilities associated with the digitalisation of food & water systems.

On **Supply Chain Transparency and Circularity**, the authors expand on how digital technology products depend on a very complex supply chain. The digitalisation of the details and chain of custody of materials, parts, production of devices, use and reuse, recycling and recovery of secondary materials, can bring transparency and accountability to the ICT supply chain. By enhancing supply chain transparency, ICT stakeholders can demonstrate their determination and accountability to sustainability. International standards are pointed out to be vital tools to achieve transparency and traceability in all supply chains; by knowledge sharing, best practices can be elevated from the local to the international level, and environmental requirements and specifications for ICTs can be identified. Finally, it is emphasised that the circular design of ICT products should be complimented with the implementation of circular business models such as offering refurbished second-hand products, ICT products as a service (e.g., leasing, collective ownership), product sharing and product buyback which incentivises producers to maximise the lifetime and durability of their products.

Finally, on the **Overarching Issues** identified - Competing Interests, Participation and Trust, Allocation of Resources, Technology Interoperability and Standards and Capacity Building - three more recommendations are suggested. One, to strive towards increasing inclusivity for individuals and communities. Two, to use data and digital technologies to foster evidence-based decision-making. And three, to have the courage to experiment with new approaches for participatory governance.

From policy recommendation to implementation: including a multitude of stakeholders is vital for public value creation.
UN Member States are expected to play a leading role in acting on these recommendations. However, if the fight against climate change wants to be successful, a multitude of actors need to assume responsibility. Adapted to a given context, the inclusion and cooperation of other public, private and civil actors in the process of determining which instruments are best suited to operationalise, and eventually implement the policy objectives proposed in this document, is therefore vital in order to generate real public value.

1. Introduction

The opening chapter is structured in three parts. First, we elaborate on relevance. Why do we need to talk about the environmental impact of digitalisation and policy measures that should be taken, and why are these issues highly relevant for the future of our societies? Second, we comment on the scope of and discuss the terminology used in the report, outlining our understanding of key concepts such as digitalisation, the environment and sustainability. In the third section, we address the issue of environmental policymaking, including a note on the stakeholders addressed in this report and our perspective on governance.

1.1 Relevance and Structure

Code red for humanity and other species. Climate change, biodiversity loss, increasing pollution and their catastrophic consequences for the planet and communities continue to unfold in tandem, with UN scientists sounding "code red for humanity" as they warn that the climate will heat up beyond 1.5 degrees Celsius within the next 20 years [1]. At the UN Climate Change Conference 2021 in Glasgow (COP26) governments expressed great concern over the fact that human activities have caused around 1.1 degrees Celsius of global warming to date and that impacts are already being felt in every region and reemphasized their commitment to keep climate change within manageable boundaries.

Despite that, effects of environmental damage and climate change are felt first and foremost in developing countries, which account for the lowest share of emissions and pollution historically. At the same time, the international community is striving to combat poverty and increase living conditions, which in turn will require growth and development. Balancing the need for development in the Global South as well as in the industrial "North" within real environmental limits, known also as planetary boundaries, is amongst the most complex challenges of our time. In general, our world has become increasingly complex, globalised, and interdependent – a situation that is only being exacerbated by the increasing demand and competition for natural resources.

Digitalisation can help. As another megatrend characterising the 21st century, digitalisation is providing us with devices and tools that can help us make sense of our world's complexity and the interconnectedness of issues. Communities can use digital networks, technologies, and solutions to help us better evaluate past and possible future consequences of our actions as well as take action to benefit the global community with long-term vision. However, while the precise direct and indirect digital impact is difficult to determine, the digital world and the environment (natural and human-made) are interconnected in significant ways.

Managing the world's digital footprint. The environmental footprint of the digital world is estimated to virtually amount to a 7th continent (or up to 5.6% of humanity's global footprint) [4]. Operations related to information and communications technologies (ICT) are expected to represent up to 20 percent of global electricity demand by 2030, with one-third stemming from data centres alone [5]. Faced with the realities of anthropogenic climate change (e.g., global warming, carbon emissions, deforestation), it is clear that the environmental impact of technology needs to be further investigated and adequately addressed by the global community.

Rapid action is needed. If we are counting on using digital technologies to reduce emissions such as greenhouse gasses and effectively tackle other environmental issues, the environmentally sustainable aspects of information and communication technologies need to be systematically embedded in all economic sector activities as well as governmental policies. With this report, the authors would like to offer guidance in proposing a spectrum of concrete, actionable policy recommendations to ensure that the opportunities processes of digitalisation present can take fuller account of the challenges.

The report is structured as follows:

The second part **gives an overview of the risks and opportunities** digitalisation presents for effectively preventing and tackling environmental issues.

The next part proposes a **range of policy recommendations**, aiming at reducing the environmental impact of digitalisation and/or using digitalisation to tackle environmental challenges.

The recommendations are sorted thematically:

- Environmental Data
- Food & Water Systems
- Supply Chain Transparency and Circularity
- Overarching Issues

In the final **section,** we present the **concluding remarks.**

1.2 Scope and Terminology

In this report, we focus on how the digital world – digital processes and digital technologies – can contribute to us, the global community, achieving the SDGs. The recommendations we propose thereby either target digital technologies, also referred to as information and communication technologies (ICTs), as a tool to achieve environmental sustainability, or the sustainability of ICTs themselves. The following figure (Fig. 1) provides a visual representation of the scope of the report.

In the following sections, we discuss the key concepts within the scope of our work and the terminology used. The section "What is Digitalisation?" discusses the context, the digital world, and how it is often linked with the notions of digitisation, digitalisation, and digital transformation. The section "Digitalisation, the Environment and Sustainability" revolves around our understanding of the object or goal: environmental sustainability. Finally, in the section "Environmental Policymaking, Stakeholders & Governance", we address the concept of policy recommendations, including a note on stakeholders and governance.

Figure 1: A Visual Representation of the Scope

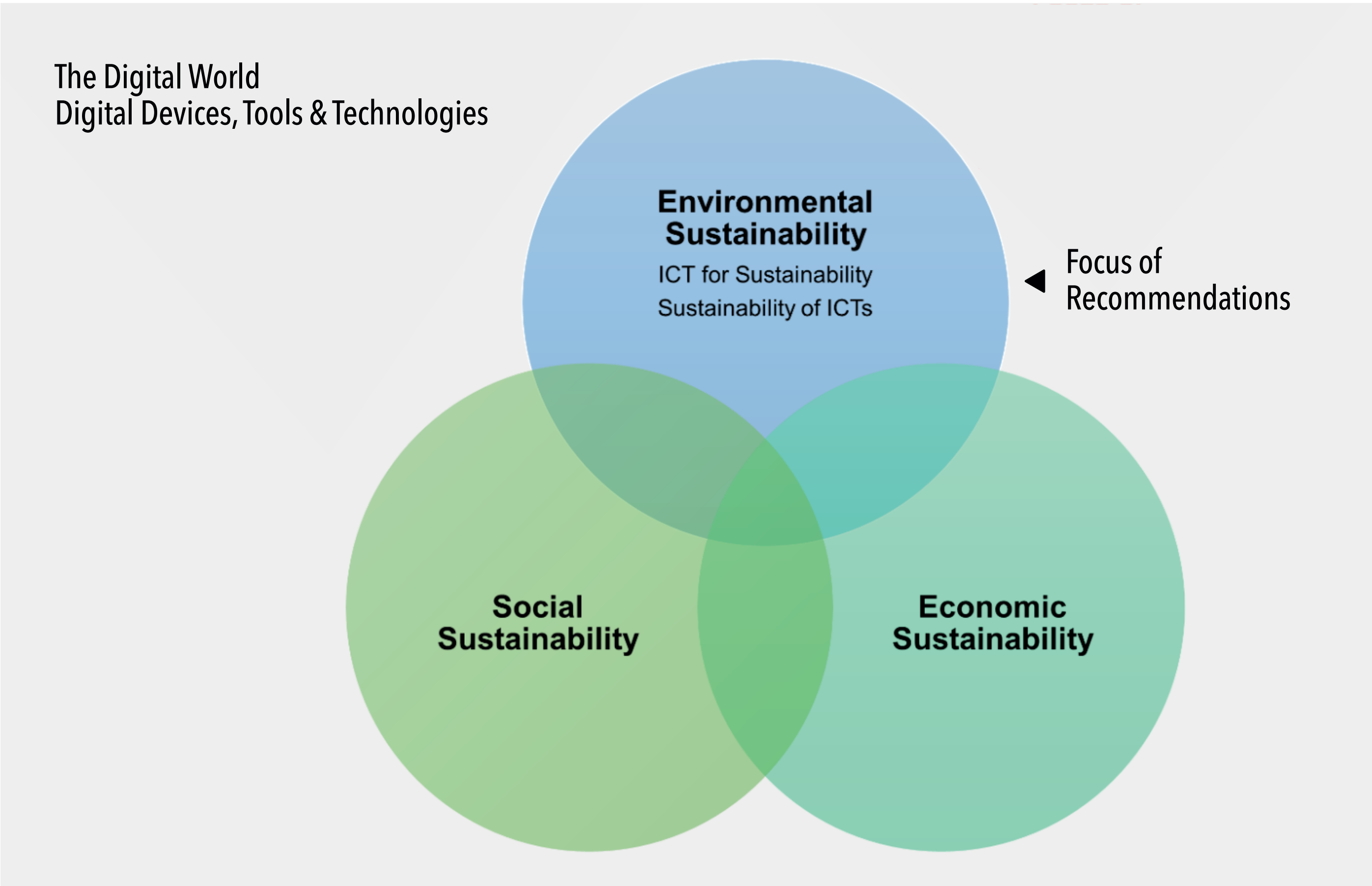


Table 1: Dimensions of Environmental Sustainability of ICTs

Environmental Sustainability	Definition
Environmental Sustainability of ICTs	The digital world has a considerable environmental footprint, associated especially to energy and resource use from resource extraction to manufacturing, use and disposal of devices. Within the scope of this report, we discuss measures that could be taken to increase the environmental sustainability of ICTs; focusing on the negative effects of digitalisation on the environment.
ICTs for Environmental Sustainability	Digital tools and devices can also have enabling effects on the promotion of environmental sustainability. Digital technologies are also expected to help us better understand and plan measures against climate change and to make progress with the Sustainable Development Goals. They can also be of use for the adaptation to some of the - possibly irreversible - effects of climate change we are already experiencing (instrumental perspective).

1.2.1 What is Digitalisation?

In the following section, we discuss the notions of digitisation, digitalisation, and digital transformation. While there are notable differences in the conception of digitalisation and digital transformation, in practice the two terms are often used almost interchangeably. With regard to the present report, both concepts are within our scope, and the choice of term in the recommendations chapters depends on the context and what the authors are striving to illustrate.

Digitisation

Digitisation refers to the act of converting an analogue artifact into a digital one, creating its digital representation. For example, the act of scanning a physical page of a book made of paper and saving it as an electronic file on a computer. Digitisation thus enables the creation of digital data needed to create value out of digitalisation processes. If digitisation, digitalisation, and digital transformation were to be ranked as part of a basic digital maturity model, digitisation would be situated at the bottom.

Digitalisation

The term digitalisation usually refers to the entry of technological devices and applications of information and communication technologies (ICTs) - hardware and software - into various areas of life and business [2]. Similarly, the OECD describes digitalisation as the "use of digital technologies and data as well as interconnection that results in new or changes to existing activities" [8]. Associated with the digital world are the following crucial three components: Data; carrying the digital information, Analytics; to generate insights and knowledge from digital data, and Connectivity; referring to the networks that facilitate data exchange among and between users, devices and machines [3].

Digital transformation

Digital transformation seems to refer to a more profound and radical use of digitalisation. Indeed, it is generally understood to be referring to the broad economic and societal effects of digitisation and digitalization [8]. Public and private sector actors use the term, digital transformation, with respect to activities in the private sector as well as the public sector, pointing at broad organizational and cultural changes, and new approaches to dealing with information [9]. As an important contrast to the concept of digitalisation, digital transformation is understood to be referencing a set of continuous processes that rely on digital tools and ICT infrastructure. While some results of these processes might be anticipated or aimed for - e.g., increased revenue, (public) value creation

Table 2: Policy Elements

Policy Element	Description
Environmental Policy Objective	What does the policy aim to do (reduce, prevent, combat, encourage, strengthen)?
Action	What is the action to be taken to achieve the environmental policy's objective?
Policy Instrument	What instrument is being used as part of the action to achieve the environmental policy's objective? Among the traditional policy instruments are (not mutually exclusive): • legislative / regulatory instruments • market-based, economic instruments (push measures; e.g., taxes, pull measures; e.g., subsidies) • voluntary approaches • motivational, information and education incentives It is said that good policy design necessarily contains a mix of policy instruments suited for the specific context the policy is applied to [23].
Policy Target	At what (measurable) point is the objective of the environmental policy achieved?
Policy Owners / Responsibilities	Who is responsible for carrying out and measuring the policy's success?

or overall performance [10] [11] - there is no way to really foresee their "end status" [9].

1.2.2 Digitalisation, the Environment and Sustainability

As a starting point let us clarify that a digital transformation can be called sustainable if all three dimensions of sustainability are valued: economic, social and environmental. In what follows, we discuss and suggest measures to improve the environmental dimension, but it needs to be assured, as a minimum, that the "do no harm principle" is fully applied to the other two dimensions.

(Environmental) Sustainability is a concept with a long history, emerging into the mainstream in the 1980s. According to the United Nations World Commission on Environment and Development, environmental sustainability is about acting in a way that ensures future generations have the natural resources available to live an equal, if not better, way of life as current generations. Ever since, we are witnessing an often-muddled understanding in practice, a phenomenon fueled by the use of the term as a vague corporate buzzword that means to elicit positivity without providing specific insight to concrete actions or achieved impact. Given these circumstances, the concept needs clarification as to its application within this report.

A Note on Sustainability

A concept with a long history. An understanding of sustainability can be found in most ancient cultures across the world, without anyone being able to make a claim for originality. The origins of the term sustainability, however, can be traced back to a handbook of forestry published in 1713, where the German term Nachhaltigkeit was introduced to describe a method of never harvesting more trees than the forest could regenerate - a mechanism in answer to decreasing forest resources in Europe

[12,13]. In "The Limits to Growth" [14], this idea of the necessity for a balance between nature and the economy was taken up again, with a team of interdisciplinary MIT specialists predicting overshoot and collapse of economy, environment, and population before 2070 if no actions were taken against continued growth and increasing use of resources. The writers, at times harshly criticized - New York Times journalists calling it "little more than polemical fiction" [15] and others wanting to assign it to the "dustbin of history" [16] - have since been largely vindicated by more recent climate research and obvious global environmental degradation (e.g., [17]). Another notable milestone in the history of sustainability is the publication of the "Our Common Future"[1] report of the World Commission on Environment and Development in 1987, in which Sustainable Development is being defined as development "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [18]. In 2005, the World Summit on Social Development subscribed to three components of sustainable development: economic development, social development and environmental protection [19], a trichotomy that can be traced back to decades before and is often displayed in a diagram with three circles (credited to Barbier [7]).[2]

The SDGs as an essential contemporary sustainability framework. In 2015, all three circles were addressed by the Sustainable Development Goals, adopted by the United Nations in 2015 as a "universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity" [20]. It is explicitly stated that the 17 Goals "recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability" [20].

The Sustainability Focus of this Report

In this report, environmental sustainability as a desired outcome takes center stage in our considerations. An early definition of environmental sustainability was provided 1996 by Robert Goodland (the first full-time ecologist at the World Bank), who has described it as the search "to improve human welfare by protecting the sources of raw materials used for human needs (...)" requiring us to "live within the biological and physical environment" [21, p. 1003].

Natural or raw materials include renewable resources such as water, and nonrenewable resources such as minerals, metals, and fossil fuels. Taking the SDGs as a reference framework, most goals could somehow be linked to information and communication technologies. The most obvious relationship, however, exists especially regarding the goals 7 ("Affordable and Clean Energy"), 9 ("Industry, Innovation and Infrastructure"), 11 ("Sustainable Cities and Communication"), 12 ("Responsible Consumption and Production") and 13 ("Climate Action"). Table 1 illustrates that when exploring the above relationship, both the environmental sustainability of ICTs as well as the use of ICTs for environmental sustainability are within the scope of our report.

From a human perspective, sustainability cannot be isolated from economic or social aspects. However, we argue that environmental sustainability is a condition for social sustainability, which is dependent on the preservation of our ecological environment and thus merits to be at the center of our attention. At the same time, we acknowledge that our focus simplifies the complex interplay between sustainability and digitalisation and underrepresents the massive social and societal implications of digitalisation, and issues related to human health and well-being. We thus broaden our perspective to consider

1 The report is also known as the "Brundtland Report", named after the former Norwegian Prime Minister Gro Harlem Brundtland, at the time Chairman of the Commission.

2 For a more comprehensive history of sustainability (and criticism of the concept) since the 1960s see for example Purvis et al., 2019, for an overview of the earlier discussion refer to authors such as Du Pisani, 2006; Grober/Cunningham, 2012; Caradonna, 2014 (see Reference List).

societal and economic aspects in Chapter 3.4 on Overarching Issues, exploring questions related to equity of access, citizen participation, capacity building, resource distribution and political advocacy of and for underrepresented actors.

1.2.3 Environmental Policymaking, Stakeholders & Governance

Environmental Policymaking

The term environmental policy is generally understood to be referring to a measure by a governmental or corporate agency or another public or private organization that targets the prevention or reduction of harmful effects of human enterprises on the world's ecosystem (e.g., [22]). When designing a policy, different elements are usually considered, ranging from the overall objective of the policy, to action and instruments used in the implementation of the policy objective, the definition of measurable target goals and the designation of the persons or entities responsible for policy implementation and evaluation [23]. Within the scope of this report, we mainly focus on the objective of proposed environmental policies, proposing policy recommendations from which stakeholders can derive actions. Due to the resources at our hands for this report, we are unable to specify policy instruments or formulate measurable target goals.

When it comes to environmental policy development, it is important to note that no policy measure exists in a neutral space, but context plays an essential role. "It is not necessarily a matter of developing new tools and instruments, but designing a 'mix' of policy instruments that is best suited to the circumstance" [23]. As such, the success of a specific policy not only depends on the complexity of issues addressed or the formulation of the policy, but also on the interests and capacities of the communities the policy targets or means to regulate. Policy instruments thus must be chosen carefully and by taking into account site-specific cultural, political and environmental context factors.

This report discusses the relationship between the digital world and the environment. Various issues and actions are identified in the following chapters that must be considered to ensure the health of our communities and the planet. These include both preventative actions and those in response to environmental concerns. In the following table, we describe a simple framework that positions issues, policies and technologies in a generic five-step process that is broadly applicable to recognising and addressing environmental concerns - displayed as a cycle, indicating that the process may not be linear and without clear start and finish (Fig. 2).

This process applies to the two broad scenarios involving environmental issues. The first is when an environmental issue has been identified and needs to be addressed. Climate change, air pollution and localised water pollution are examples. The second scenario is when (non-environmental) policies and initiatives are being formulated and we need to understand and prevent potential environmental damage. Examples here include infrastructure development projects, land use policies and new industry development. In both cases the process is essentially the same - the main difference being how the environmental concern is initially identified.

A Note on Stakeholders & Governance

All stakeholders contributing to the policy cycle are addressed. In the context of this report, the emphasis is on action that needs to be taken under the lead of UN Member States, who have committed themselves to the SDGs as part of their dedication to combat climate change. However, since the climate crisis is a global phenomenon, there is a necessity for global responsibility. Whereas governments are traditionally associated with having the primary responsibility for their citizens, private actors are increasingly called to responsible action too [24]. Consequently, while some recommendations proposed in this report might be more immediately relevant to one stakeholder over another, they mean to speak to all actors involved or affected by (environmental) policymaking processes (see Figure 3 above). This means public actors at all state levels, private actors, representatives of civil society (e.g., non-profit organisations) and institutionalised cooperative relationships formed between a mix of those actors (e.g., public-private partnerships).

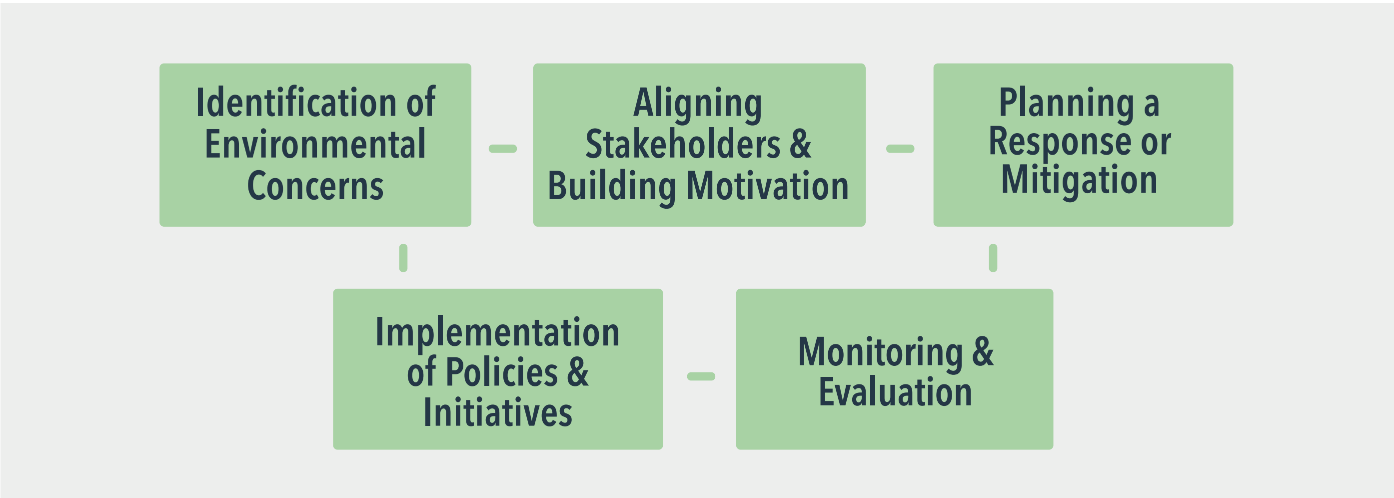
Nature and the Internet are global public goods to be governed as global commons. Both, the natural and the digital environment, specifically the internet, are critical infrastructures to social and economic development, interrelated by digitalisation and digital transformation [25]. Public goods are intended to be enjoyed by all people [26]. Nature is public by default and the Internet is public by design. Therefore, both can be qualified as global public goods.

"Digital public goods are essential in unlocking the full potential of digital technologies and data to attain the Sustainable Development Goals, in particular for low and middle-income countries." [27]

Public goods are ideally "non-rival", which means use by one person should not prevent use by another, but this is only an ideal. Both nature and the digital world are limited critical resource systems that impact all of us. Another way of putting it is that they are "global commons". This means we collectively need to manage them as global commons to preserve them as a critical resource for life as we know it. The transformative effect of digitalisation comes from the efficiencies that derived from it in nature, from caring for nature when developing digital technologies, infrastructures, data and services, and from the improved governance that digitalisation brings to the coexistence of people and nature. That is reflected by the concept of sustainability of ICT and nature just mentioned, a safe and just space for humanity [28], complying with "planetary boundaries" and "social boundaries". Therefore, both nature and the internet are global public goods, supported by resource-systems that must be governed as global commons, to ensure they reinforce each other. This is a role the Internet Governance Forum can play. Governance discussions and decisions relate and result in policy making, and both digital technology with the internet, and the natural environment, must be considered together as they are interdependent.

Adopting the perspective of participatory governance creating public value. From a traditional perspective on governing, the focus is on formal and institutional processes performed by governmental institutions operating at nation-state level [29]. Challenging this notion, the concept of governance has emerged. With its theoretical roots in various disciplines such as economics, international relations, political science and public administration, the term is today generally understood as an organizing framework [29] providing a fresh perspective on understanding governing processes in modern multi stakeholder societies. Environmental policies often involve a transfer of material (e.g., financial resources, subsidies) or immaterial goods

Figure 2: Five-Step Policy Process Regarding Technology and Environmental Issues



(e.g., opportunities) from one group to another [30]. The success of many environmental policies thus depends on public cooperation, making the need for inclusive and participatory governance seem obvious. Recent findings indicate that for example, when novel approaches such as citizen assemblies are incorporated into the policy cycle, the political feasibility of climate policies can be enhanced [31]. Following Stoker [29], five central and complementary aspects to governance can be identified (highlight added to the original source):

- Institutions and actors drawn from and beyond government;
- A blurring of boundaries and responsibilities between stakeholders;
- A power dependence involved in the relationships between institutions;
- The role of autonomous self-governance of networks of actors;
- New tools and techniques are available for government actors to steer and to guide, instead of commanding and using authority.

What is then the role of governance in sustainable development? Some might argue that the primary task of governance is to correct market failures. In the context of this report, a different perspective seems more fitting. Following Mazzucato's view on public institutions and the concept of an "entrepreneurial state" [32] governance is active instead of reactive: By fostering innovation, public institutions can play a major role in the shaping of markets and the production of public value [32]. When it comes to sustainable development, public value corresponds directly with the well-being of citizens [33]. In their extensive synthesis of Sustainability Science, Harvard authors Clark and Harley reason that to censure that well-being, it makes sense that governance for sustainable development should care particularly about the management of natural and anthropogenic resources [33].

2. Overview of Opportunities & Risks

2.1 Digitalisation Trends

Several trends are apparent from the increasing level of digitalisation currently occurring, many of which are closely related or dependent on each other in some way. These trends will likely continue to accelerate, having implications for the environment and natural resource and energy use. Underpinning several trends in ICT development is Software and Cloud Computing. Cloud-based software has already become integral to many areas of the economy in the past decade and is now embedded into many aspects of our lives. This trend will continue as more items and entire industries become connected to the internet, requiring greater energy needs and helping to generate enormous quantities of data.

Dependent on software and cloud computing are Big Data and Artificial Intelligence (AI). AI is software that has been programmed to analyze and use vast amounts of data for purposes of automation that can then be applied to cloud-based operations. It can also be used to track and provide analysis on a number of environmental and socio-economic indicators such as weather patterns, air quality, and urbanization, using data generated by satellite imagery, remote sensors, and other devices.

Much of the data used by AI programs will be generated by a proliferation of everyday items that are connected to the internet, commonly known as Internet of Things. This includes everything from household appliances to agricultural machinery to critical infrastructure, all of which will have networking capabilities that allow for information and communication to be shared across devices. With an estimated 23 billion devices being connected to the internet in 2021 and the number set to nearly double by 2025 [34] implications for natural resources used to manufacture these products and energy usage to power them remain important considerations.

Smart Cities and communities is a concept heavily dependent on all of the trends discussed until now. Through data generated by thousands or millions of connected devices, resources, services, and infrastructure needs for a city are provided and allocated more efficiently based on up-to-date information. This will have implications for areas such as transportation logistics, municipal waste, and water and energy usage.

Digitalisation is also enabling trends at an individual level. Driven in part by easier access to technology and an increasing concern for the planet and climate change, Citizen Science, the practice of public participation in research and science projects, has grown significantly in recent years. Using open access data, cloud-based data processing services, low-cost sensing technologies and consumer electronics (smartphones), these decentralized projects of varying size can bring attention to localized environmental issues and engage the public as active participants, as outlined further in section 3.1.4. This is further enabled by increases in Connectivity occurring throughout the world and especially in developing countries, where internet penetration has historically been lower. According to the IEA, they have been leading the more recent growth in connectivity, accounting for almost 90 percent of mobile broadband subscriptions registered between 2012 and 2017 [3]. Connectivity to online networks is essential if digital transformation is to occur at the individual and community level and can help bring existing local networks into the digital sphere.

Finally, Blockchain and distributed ledger technology is a trend that has attracted much attention in recent years, mostly from its association with cryptocurrencies like Bitcoin and how it currently requires huge amounts of electricity to process transactions. However, given that blockchain databases are decentralized and unchangeable with no single owner, its application could have significance for smart cities, citizen science, and supply chains to name a few.

2.2 Opportunities & Risks of Digitalisation for the Environment

2.2.1 Opportunities

Environmental Monitoring and Environmental Data

The trend of enormous quantities of data being generated by the proliferation of computing power and devices can be seen within issues pertaining to the environment. Data captured and analyzed can provide a more accurate and complete picture of the state of the environment, which can be used to drive policy and decision-making and inform initiatives to combat and adapt to climate change. Examples include data collected in rivers or forests of localized ecosystems and real-time data on emission levels collected by satellites and sensors. The core opportunity from this large increase in data is that it will allow experts to further understand environmental trends at a micro and macro level, potentially leading to better health outcomes, biodiversity conservation and an overall increase in sustainability.

Smart Agriculture

Digital technologies such as sensors, drones, satellites, and advanced tractors are increasingly feeding data into cloud-based artificial intelligence models that provide farmers with a detailed picture of conditions on the farm. This includes variables such as livestock, crops, soil, and weather conditions. By having access to these data, farmers are empowered to efficiently use natural resources—for example, water for precision irrigation that is guided by generated intelligence. This in turn boosts productivity and can reduce the amount of natural resources – like water – needed for a farming operation. Herein lies the biggest opportunity with smart agriculture, a chance to reduce the sector's global environmental footprint which accounts for a third of all GHG emissions, through improvements in productivity. However, as highlighted further in section 3.2, such changes must be context specific and with sensitivity to traditional food systems and ways of life, while also ensuring that an opportunity gap does not arise when obtaining access to these new technologies.

Case Study: Azure FarmBeats [35]

With Azure FarmBeats, Microsoft is contributing towards enabling data-driven farming. The belief is that data, coupled with the farmer's knowledge and intuition about his or her farm, can help increase farm productivity, and help reduce costs. However, getting data from the farm is extremely difficult since there is often no power in the field, or Internet in the farms. As part of the project, FarmBeats is building several unique solutions to solve these problems using low-cost sensors, drones, and vision and machine learning algorithms. According to FarmBeats principal researchers, FarmBeats wants to highlight something essential for the future: AI doesn't replace human knowledge; it augments it.

Circular Economy

The exponential rise in the number of digital devices has been accompanied by huge increases in electronic waste generated and a demand for raw materials necessary for their fabrication. This problem has created a need for a more sustainable model of production and extended use as the number of ICT devices in the world is set to continue to rise. The circular economy model is based on the idea of materials passing through the cycle of production, use, and reprocessing several times before dissipative losses or thermodynamic limitations during recovery cause them to have to be dropped out of the use cycle [36]. With regard to digitalisation, the aim is to reuse, repair, and repurpose digital devices currently in use to extend their product lifetimes, and recycle discarded digital devices through recovering embedded metals and materials that are still of critical value [37]. This approach promises to reduce emissions, toxic waste and the cost of production, and can be further accelerated by increased digitalisation. With improvement in tracking, traceability and data analytics for resource management, the circular economy can be optimized to help facilitate the digital transformation that is needed while minimizing environmental impact.

Case Study: Circular Economy Action Plan [38]

Recognizing the imperative to reduce natural resource consumption, which is seen as a primary driver of GHGs, the European Union is developing a new circular economy action plan. Its stated goal is to accelerate the transition towards a regenerative growth model by doubling the amount of circular material in use by 2030, while maintaining the economic competitiveness of the bloc. To implement this, the European Commission will propose legislation on sustainable products including in product design and further empowering consumers. The commission has identified key product value chains as targets within this plan that include ICTS, batteries, plastics, and textiles.

Energy Efficiency & The Transformation of the Electricity Sector

New technologies have brought about the possibility of employing autonomous cars, smart home systems and the use of machine learning, all of which have given rise to hope for massive efficiency gains. While digitalisation is relevant for most sectors, the International Energy Agency concludes that digitalisation might have the biggest impact on transport, where - in the long term and in a best-case scenario - increased efficiency due to automation and car-sharing might cut today's energy use levels in half [3]. However, rebound effects related to increased travel might also lead to a substantive increase in energy use. For buildings, the IEA predicts possible energy savings of about 10 percent if real-time data is used to improve operational efficiency; for example, to predict heating and cooling needs [3]. With regard to the energy use of digital technologies themselves, global trends in internet traffic show that for 2020, the share of electricity used by data centres and data transmission networks still only accounts for about 1 percent of global electricity use, despite a more than 40 percent increase in internet traffic and data center workloads - a phenomenon attributed to an accelerated progression in energy efficiency occurring at the same time [39]. Next to opportunities in the mobility and building sector, the IEA attributes the greatest transformational potential of digitalisation to the electricity sector itself, where they identify four specific opportunities [3]:

- The possibility of smart demand response - meaning interconnected electricity systems that allow users and devices more authority on when to draw electricity from the grid and when not to.
- A better integration of different renewables into the energy grid, by optimizing storage and digitally enabled demand response.
- The use of smart charging technologies for electric cars, enabling charging off peak, preventing in turn costly investments in additional electricity infrastructure.
- The development of distributed energy resources, e.g., solar electricity panels, the surplus energy of which producers could sell to the grid.

2.2.2 Risks

The digital world does not only bring about opportunities for the protection and conservation of our natural world, but also presents major challenges. Digital does not mean immaterial: We are witnessing an overproduction of devices and related overuse and loss of resources when those devices have reached the end of their lifespan. In the form of e-waste, improperly discarded digital objects contribute to the degradation of the environment, with catastrophic effects on local and regional ecosystems, including human health.

Measuring the environmental impact of the digital world

When it comes to quantifying the environmental impact of the digital world, different environmental indicators can be used to illustrate resource use. Following a life cycle analysis approach, four indicators are among the most common [4]:

- Abiotic Resource Depletion (ADP): The contribution to the depletion of nonrenewable resources (especially minerals), expressed in kg extraction;
- Global Warming (GWP): The emission of greenhouse gases in the atmosphere contributing to global warming, expressed in kg CO2;
- Water: Stress on water resources caused by the digital world, expressed in volume of blue water (l or m2 of water);
- Primary Energy (PE): Different sources of primary energy are tapped to produce the energy required to power the digital world (e.g., nuclear reaction, coal combustion or solar radiation), expressed in Megajoules or KWh per unit of time.

While electricity consumption is not an environmental indicator per se, it is an important factor to consider when assessing the environmental impact of technologies, since without a constant supply of energy, technology would not be possible as we know it today. As an indicator, electricity is usually expressed in kilowatt-hour (kWh) per unit of time.

The following figure (Fig. 3) shows an overview of the contribution of the digital world to the overall footprint of humanity. While the percentages might not seem as major in comparison, it can be imagined that the overall impact would represent about a seventh continent, two to three times the size of France [4]. Focusing on greenhouse gas emissions, the digital world's carbon footprint is about the same size as the aviation industry's [40].

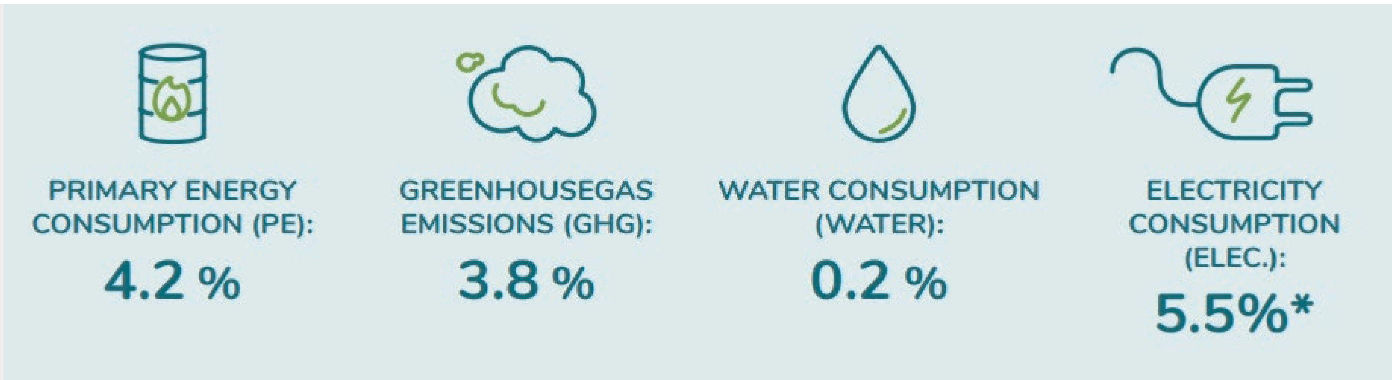
According to trend forecasts, the overall impact of the digital world is expected to increase to about double or triple the current amount in the upcoming years [4]. The largest increase is expected to be in greenhouse gas emissions, mainly due to (excluding the growth in number of users) an increase in connected objects, a doubling of size of screens, declining energy efficiency gains, and the equipment of developing countries [4]. Depending on the source, more or less drastic increases in energy consumption attributed to data centers are predicted, ranging from increases to three or up until 21 percent of the total electricity demand by 2030 [3] [5].

Next to considering specific environmental indicators, the environmental impact of the digital world can be further broken down by tier (e.g., user equipment, data centers and networks) and by lifecycle stage (e.g., manufacturing, use, disposal). When analyzing the different indicators along the life cycle, a similar picture emerges: At the moment, the main source of impact stems from the emissions produced in the manufacturing of user equipment and the electricity production to power it, attributed to between 59 and 84 percent of the total impact [4]. The depletion of resources and impact on water have an especially strong link with manufacturing of user equipment [4]. The manufacturing of equipment is leading the hierarchy of impact sources, which is unsurprising considering the sheer number of devices manufactured - at least 34 billion in 2020 (eight per user if the equipment was equally distributed) [4]. Among the most prevalent devices are smartphones (approx. 3.5 billion), other phones (approx. 3.8 billion), televisions and computer screens (approx. 3.1 billion) and connected objects (approx. 19 billion) [4].

The Exploitation of Critical Minerals

As the manufacturing of user equipment is associated the most with environmental impact (see section above), it merits a closer look. The digital devices we use today are host to a complex mix of materials, with screens alone being made up of 14 different elements [41]. Of major importance to digital transformation are the following seven elements: Gallium (e.g., used for semiconductors), Germanium (e.g., used in fiber optical cables), Indium (e.g., used for LCD displays), rare earths (Dysprosium, Neodymium and Praseodymium), Selenium (e.g., used for thin-film photovoltaics), Tantalum and Tellurium (e.g., used for thermoelectric cooling devices and solar cells) [41]. Despite these resources being used in small amounts in the individual devices, the sheer number of devices makes up for a massive environmental impact in total. Resource

Figure 3: The contribution of the digital world to the global environmental footprint
(Source: Bordage, 2019 [4])



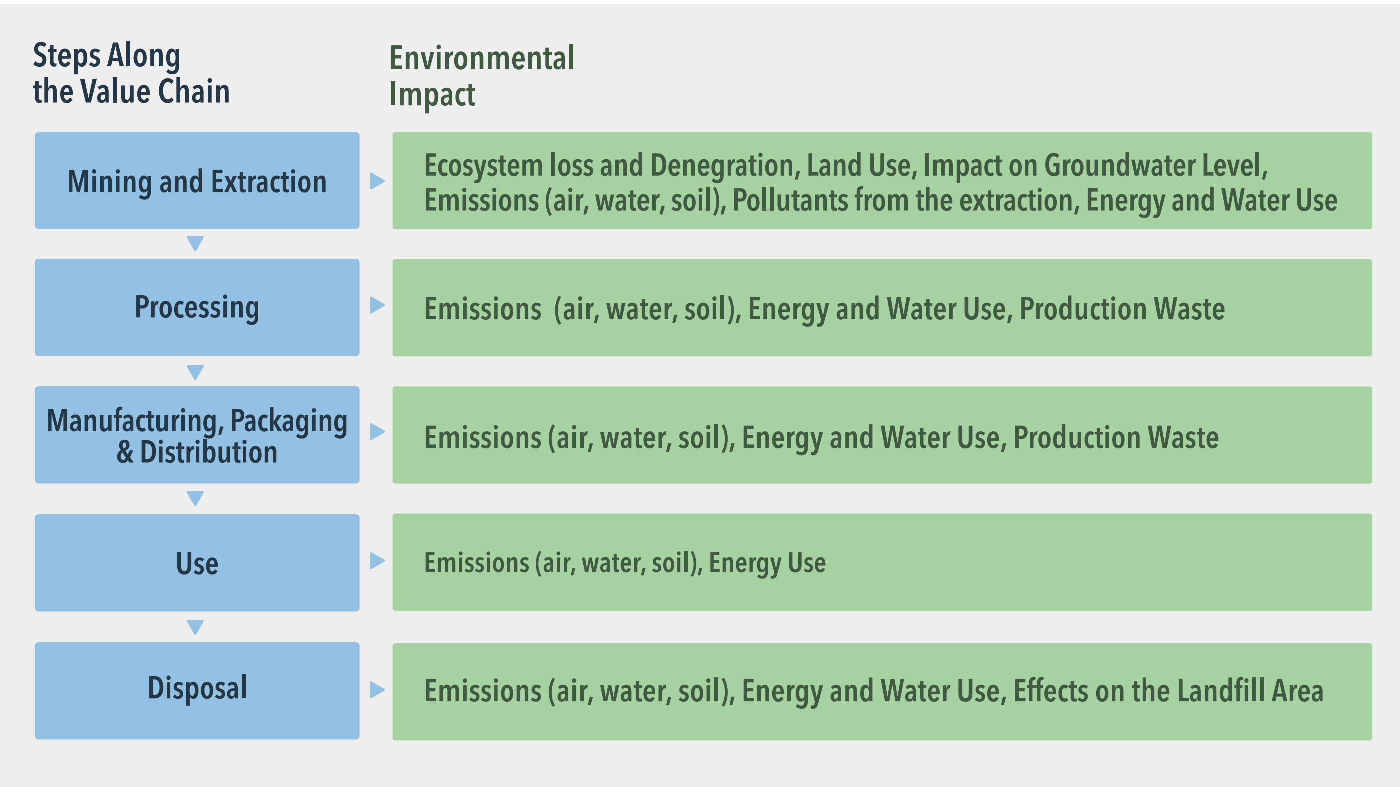
extraction and manufacturing play an important role in current environmental degradation processes occurring over the globe, and not just with regard to digitalisation, but in general. According to a report by the 2019 International Resource Panel, about 90 percent of the total biodiversity loss and water stress can be attributed to extraction and processing of resources [42]. The following figure (Fig. 4) provides an overview of the different kinds of environmental damage along the resource value chain.

As can be taken from Figure 4, the exploitation of resources causes a host of environmental challenges, ranging from carbon emissions fueling climate change, land use impacting biodiversity (with endangered species being displaced or losing their habitat entirely), water overuse and pollution through acid mine drainage, the discharge of wastewater and disposal of tailings and finally general mining waste (e.g., radioactive material, heavy metals) [3]. There is a growing need to tackle emissions from mineral extraction, not least because the transition to cleaner energy pursued by many states is also heavily reliant on the same minerals. Because the above-mentioned risks associated with mining and extraction are also expected to potentially lead to supply disruption, it is crucial they are addressed - otherwise the successful transition to clean energy could be delayed [3].

End of Life Resource Loss & E-Waste

With increased digitalisation comes an increase in the amount of devices manufactured. As discussed above, this causes considerable environmental impact: When a device is bought, significant pollution of the environment has already occurred. Long-term (re-)use and salvaging of resources therefore are crucial. In reality however, when devices reach their end-of-life phase, they are often discarded without any of the valuable material that could be repurposed for future use recovered. In 2019 alone, losses from secondary resources within the e-waste stream was estimated to be $57 billion USD, with a record number of 53.6 million tons of electronic waste released into the environment [6]. E-waste is the fastest growing waste stream within an already very wasteful

Figure 4: The Environmental Impact of Resource Extraction along the Value Chain



society: Humanity has deposited an estimated 2500 gigatons of waste and emissions in the environment since 1900, with almost a third of it having been generated over the past 20 years [43]. E-Waste is an especially problematic type of waste, due to several reasons: For one, much of the e-waste is often being shipped illegally to developing countries where it is less likely to be disposed of safely. And then, many e-waste components are toxic and corrosive, and can have adverse health effects on those exposed to it at high levels, which is the case for most of the local populations living unprotected around nonregulated e-waste dumping grounds. Due to complex material compositions in tech equipment, the safe disposal of e-waste requires industrial level recycling capacity, which is most often not present in the regions the waste is disposed of. This cycle can have significant environmental and social costs at a local and global level that could be exacerbated as digital adoption increases. Next to general overproduction and overconsumption, e-waste at its core is also a crisis of responsibility: Goods are produced without the producers taking responsibility for the waste they are also producing, sometimes outright designed into the products (planned obsolescence). It is here that the promotion of a circular mindset and business model need to play a crucial role.

Rebound-Effects

Rebound effects refer to efficiency or resource gains that are partially or completely offset by a more frequent or more intensive use of a product or a service. For example: Under some circumstances, it might save more carbon emissions if a consumer orders online than if they take the car to the trip to the store and back. If the possibility of e-commerce however entices more people to consume more and possibly more frequently than they would have, if there was no option to order and return for free, any emissions saved are largely offset by the emissions caused by the mass of online orders having to be delivered. For example, for the US, the return of goods is cited to contribute to a pollution of an estimated 16 million metric tons of CO_2 in 2020 [44], more than the emissions of three million cars in one year.

Another interesting example of a rebound effect in the digital world is television screens: While the energy consumption of television screens dropped significantly over the last years [45], the overall power increased due to an increase in screen size. If screens are bought more often because the technology has become more efficient and thus more attractive, this is a direct rebound effect. On an interesting historical side note, the first description of rebound effects can be found in the economist William Jevons Staneleya book “The Coal Question”, in which he predicted a gradual depletion of the British coal deposits due to a more effective use of the energy contained in coal [46]. Today, the Jevons paradox refers to the phenomenon of an increase in demand for a raw material after an increase in the effectiveness of use of that same material (in William Jevons’ time this was the use of steam engines to burn coal).

3. Recommendations

3.1 Environmental Data

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"How can we ensure data positively impacts sustainability?"

Numerous sources of data have the potential to be leveraged for monitoring the state of, and changes to the environment, driving decision-making, and promoting adoption of actions that increase planetary sustainability. These data cover a wide range of environmental variables (Table 3) and, where fit for purpose, can effectively reduce gaps in knowledge required to inform environmental sustainability initiatives and to tackle and adapt to climate change. These sources of data can be of numerical nature. Data can also include non-numerical records, such as recordings of songs or dances of indigenous people, which make the interpretation of nature and its changes from different perspectives possible. These data are sometimes used to guide policy development and recommendations. However, data from different sources are often not openly accessible or in a standardised format that allows for easy consolidation, comparison, and use. Implementing data governance principles that take into account important ethical considerations could foster data practices that make more data widely and equitably available and used to inform effective evidence-based decision-making. There are two key sets of principles for data governance that our recommendations are centered around. One set advocates for ensuring data findability, accessibility, interoperability, and reusability, commonly referred to as FAIR Principles [47]. The second set is the CARE Principles for Indigenous Data Governance, which orients towards people and purpose, with tenets of collective benefit, authority to control, responsibility, and ethics, to ensure data supports Indigenous innovation and self-determination [48]. The CARE principles complement the previously established FAIR principles [49]. Both sets of principles are at heart of our policy recommendations with the intent to promote that environmental data be openly shared in a way that is appropriate for diverse cultures.

Here we offer three policy recommendations for environmental data:

1) Foster global standardisation & harmonisation of data;

2) Ensure environmental data access from collection to sensemaking;

3) Increase cooperation to maximize the impact of digitising environmental information.

There are a variety of existing environmental datasets that could be leveraged to understand the state of the environment and be used to inform policy (see Table 4 below). Additionally, evaluate whether and how candidate datasets have informed globally relevant research, initiatives, and policy. Evaluating how analysis of such datasets can align with existing policies or inform policies under development. Prioritize datasets that have global coverage. Consider whether datasets have sector-relevant copyright conditions. Also determine whether datasets are open access and hosted by trusted data providers. When assessing the appropriateness of using an existing dataset, consider whether the datasets follow the recommendations below.

Table 3: Common environmental data types and variables.

Types	Characteristics
Air, atmosphere	Atmospheric variables, air quality, measuring sites, inc changes over time
Land cover	Forests, trees, grasses, crops, desert, snow, built, degraded areas, inc changes over time and quality
Land use	Commodities (inc mining, plantations), conserved areas, agriculture, indigenous lands, transport inc changes over time
Biodiversity	Zones, habitat, animal species, change over time inc extinctions
Waste	Waste, contamination, pollution inc events and changes over time
Water	Rivers, streams, wetlands, mangroves, conserved areas, groundwater, dams, infrastructure, measuring sites, events (inc drought, floods), inc changes over time and quality
Marine	Oceans, seas, fisheries, reefs, conserved areas, temperatures, measuring sites, infrastructure, inc changes over time and quality
Cryosphere	Ice sheet extent, glaciers and mountain data
Climate	Climate forecasts, carbon emissions and carbon sources inc historical, seasonal and decadal forecasts
Weather	Forecast, current and historical weather and extreme events
Visual	Photographic records, time series photos, forest land mapping (use geospatial technology)
Indigenous and Local Knowledge (ILK)	Recordings of songs and dance, transcripts from questionnaires and inquiries, workshops and events, interpretation of weather patterns or events, interpretation of animal behaviour for decision-making, agricultural patterns
Alternative	Social media data, human sentiment and behaviour, financial and other non-traditional sources of data

Table 4: Environmental datasets and projects that could be leveraged to understand the state of the environment and be used to inform policy. Any listing here does not imply any compliance with FAIR or CARE principles.

Project Name	Brief Description	Stakeholder	Location	Link to website	Sponsors / Partners
Open Data Watch	Policy Advice, Data Support, Independent Watchdog	National Statistic Offices and Member states	Washington, DC	https://opendatawatch.com/	
CODES	CODES is an open multi-stakeholder community of change makers and practitioners that seek to collaborate in accelerating a digital planet for sustainability.	Private, Public, Citizen Science, Academia, NGOs	Geneva	https://www.sparkblue.org/CODES	UNEP, UNDP, the International Science Council, the German Environment Agency, the Kenyan Ministry of Environment and Forestry, Future Earth, and Sustainability in the Digital Age.
GESI	Gesi is the driver of the ICT sustainability agenda as measured by the development and use of its tools, broad member base and contributions to relevant policies.	Private Sector	Belgium	https://gesi.org/	
EU Copernicus - Climate data for policy makers	Annual report on the state of the environment for Europe and future risk	EU	ECMWF - Reading UK (Bolonia, Italy soon)	https://climate.copernicus.eu/climate-data-policymakers	EU
ISC, Future Earth	International research platform providing the knowledge and support to accelerate transformations to a sustainable world.	International Network	International	https://futureearth.org/ & https://council.science/what-we-do/affiliated-bodies/future-earth/	
UN Ocean Science Decade	Oceanographic and marine data	UN	Paris, France	https://www.oceandecade.org/	
EU IS-ENES3	Climate data infrastructure and dissemination	H2020 EU project	EU	https://is.enes.org/ & https://portal.enes.org/services	Major European climate and Met office services
US NASA CDS	Climate data services by NASA	USA gvt	USA		
Global Burden of Diseases	Harmonized human disease database by IHME	University	Washington, USA	http://www.healthdata.org/gbd/2019	
UK CEDA archive	Atmospheric data	UK gvt	UK	https://archive.ceda.ac.uk/	
UK CEH-NERC environmental database	Environmental data	UK gvt	UK	https://www.ceh.ac.uk/data	
OIE-WAHIS animal disease outbreak database	Animal disease data	International	Paris, France	https://wahis.oie.int/#/home	
Worldpop database	Gridded human demographics data	International	UK	https://www.worldpop.org/	https://www.worldpop.org/acknowledgements

Project Name	Brief Description	Stakeholder	Location	Link to website	Sponsors / Partners
NASA SEDAC	Gridded socio-economic, land use and other useful gridded data	USA gvt	New York	https://sedac.ciesin.columbia.edu/	NASA - Columbia University
Livestock Geowiki	Gridded livestock demographics data	ILRI	Kenya	https://livestock.geo-wiki.org/home-2/	FAO, IIASA, ILRI, CGIAR, CCAFS etc
World Ocean database	Oceanographic, climatic, and environmental marine data	NOAA-NCEI	Asheville, North Carolina.	https://www.ncei.noaa.gov/products/world-ocean-database	USA gvt (NOAA)
Global Biodiversity Information Facility (GBIF)	Biodiversity database (animal species)	International Network	International	https://www.gbif.org/	International network - initiated by OECD
NASA Earthdata	Open access environmental data (cryosphere, atmosphere etc)	USA gvt	USA	https://earthdata.nasa.gov/	USA gvt
World Bank Climate Change Knowledge Portal (CCKP)	Global Data on historical and future climates, vulnerabilities, and impact for policy makers	World Bank	Washington DC, USA	https://climateknowledgeportal.worldbank.org/	World Bank
World Bank data	Data on economics, vulnerability indicators etc	World Bank	Washingtom DC, USA	https://data.worldbank.org/	World Bank
IIASA database	Data on climate change and demographic scenarios	IIASA	Vienna, Austria	https://iiasa.ac.at/web/home/research/researchPrograms/Energy/Databases.en.html	IIASA
NASA Vital Signs of the Planet	Satellite data for several envt variables	NASA	JPL, California	https://climate.nasa.gov/earth-now/#/	USA gvt
NASA NSIDC	Cryosphere data (snow, glaciers, sea ice...)	NASA	Boulder, Colorado, USA	https://nsidc.org/	USA gvt
ESA Earth Online	Satelitte observation data (GOSAT carbon emissions, dust, land surface, forest fires...)	ESA	Paris, France	https://earth.esa.int/eogateway	EU
Data.world	Generic data repository - includes lots of environmental data etc	Private sector	Austin, Texas, USA	https://data.world/	Private company
FAOSTAT	Agriculture, livestock and land data	FAO	Rome, Italy	https://www.fao.org/faostat/en/	UN
ourworldindata	Research and data to make progress against the world's largest problems.	U. Oxford	Oxford, UK	https://ourworldindata.org/	International network

3.1.1 Policy Recommendation #1

> Foster global standardisation and harmonisation of environmental data.

This policy recommendation focuses on fostering the establishment of global and harmonised environmental data standards. This addresses how the design and the principles of data collection, processing, and usage, impact on the sensemaking of the data. Improving sharing and using data to inform sustainability-promoting policymaking, requires transparency, accountability, and accessibility around data management and governance (see also the Aarhus convention [50] and the related Escazu agreement [51]. Datasets must be broadly accessible and interoperable with complimentary data resources. This requires appropriate technological infrastructure and interfaces that facilitate an open exchange and integration of datasets.

For all practical purposes, data resource refers to a collection of data that meets a described standard. Data resources may be operated or owned by multiple entities and consist of multiple datasets. Additionally, data resources include those that fall under regulatory or governmental oversight. Others are often standardised within a particular industry or privately and others are openly accessible and unregulated. Our recommendation applies to all data sources. Datasets may, for example, be discrete or aggregate; or data may be collected autonomously via sensors and devices or directly by people. Development of strong guidelines for data governance, which follows FAIR and CARE principles, is a key to global standardisation and harmonisation of data. Data governance, for example, influences design of technology and data quality measures, which fosters data resource accountability and transparency.

Global standardisation and harmonisation are processes that should include multiple stakeholders as data is shared and interoperability is sought. When viable, transparent, and sustainable financial models should take place to encourage open access. Data should be collected, analysed and governed following the FAIR Principles, to ensure equitable access. Anyone should be able to explore and use the data without requiring specialist software, at no charge. The goal is to maximise use of data resources by citizens, schools, governmental institutions, and broader sectors. Additionally, data resources and governance principles should be created in accordance with the CARE principles which aim to guarantee the rights of the Indigenous peoples and local communities (IPLC) over the application and use of their Indigenous and Local Knowledge (ILK). The rights of knowledge holders and data owners must be carefully balanced with the need to follow FAIR principles. The Global Biodiversity Information Facility (GBIF), for example, is one dataset that follows FAIR principles. At present, GBIF staff are in consultation with stakeholders on how to best apply CARE principles. Table 4 illustrates the diversity of different datasets, databases and data characteristics used in the context of environmental data but does not imply any confirmation of their FAIR or CARE allegiance.

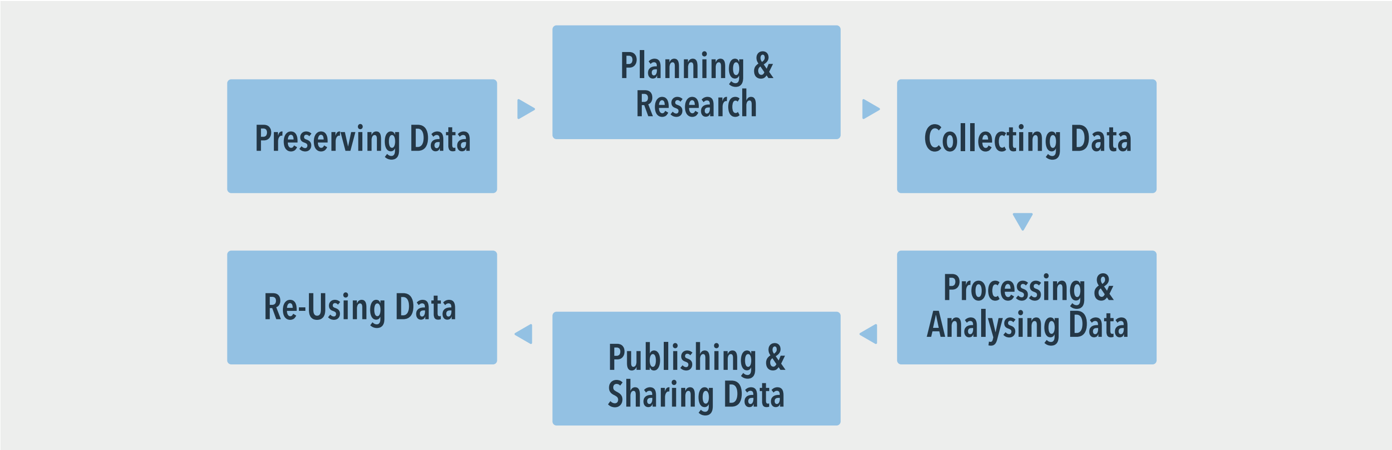
3.1.2 Policy Recommendation #2

> Ensure environmental data access from collection to sensemaking.

This recommendation describes considerations for creating policies aimed to ensure that diverse stakeholder groups will have access and be able to interpret environmental data in meaningful ways. For this to happen, access pathways need to be designed for all stages of the data life cycle (see Figure 5). These must empower all stakeholders to use the environmental data for sensemaking. It is critical to ensure all member states and actors can actively engage with the available data, allowing them to participate fully in the global sustainability effort.

When creating policies intended to promote access to environmental data for all, we need to plan for: i) data recently collected or analysed, ii) future forms of data yet to be acquired, and iii) existing data not currently/broadly shared. With new technologies continually emerging, pre-existing datasets can now be re-interrogated in new ways

Figure 5: Data Life Cycle



and in combination with new datasets to gain larger-scale, innovative environmental insights not previously possible. However, the design of such technologies is what drives who can collect, analyse, manage, and interpret data in meaningful ways. If designed for diverse stakeholders, such technologies hold promise to support us all making sense of environmental data and make informed decisions towards a sustainable future.

Policy considerations around environmental data should primarily revolve around the anticipated data users, in a broad range of use cases: Highest priority considerations include:

- Equity in access to environmental information, including data and interpretation of it, for diverse stakeholder groups (e.g., science; policy; industry; non-governmental; indigenous and local; and the public);
- Transparency to i) understand the underlying workflows used to collecting, analysing, and publishing the data; ii) understand the provenance of data in regard to chronology of the ownership, custody, and location via standard protocols; and iii) manage the ownership, release, and usage of the data;
- Convey and tailor information to both broad and particular audiences in meaningful ways, balancing broadscale interpretability of environmental data and analysis outcomes with needs of particularly relevant stakeholder groups.
- Development of an incentive framework that identifies limited access to open data, with the goal of encouraging diverse stakeholder groups to make data broadly accessible to others.

Access to data cannot be solely realised after the data has been collected and processed for distribution but needs to be included in all stages of the data life cycle. This includes the approach to how the data is collected, permissions during the data collection phase to release it when collected on private lands, usage of open-source software to make the preparation and analysis of the data transparent and reproducible, up to the point of designing access points (i.e. APIs for the low-level access and exchange of data) and the provision and planning of pathways to deliver that information to all relevant stakeholders for sensemaking and usage of that data.

In addition to making the data and its sampling and preparation methods findable and accessible from collection to sensemaking, we should also follow guidelines to make the data accepted by the user as well as to encourage the contribution of new data by data rights holders. Only if the data as well as the process of the collection and processing are transparent and accepted will it be available and used for sensemaking. Compliance with FAIR and CARE principles concerns all different life stages of the data life cycle (Fig. 5). We list several examples here:

- involving communities in the planning and tech design of the data collection processes;
- conducting the sampling in a manner which conforms with customs of local communities (e.g., the IPLC) and using transparent methods which can be repeated and re-assessed;
- Obtain the permission of communities to publish their data, confirm with them before the final publication, and make sure to attribute credit / acknowledge the source of the data in a way acceptable for the concerned groups;
- if sensitive data is included in the sampled dataset, anonymise the data in an appropriate way, but keep the non-anonymised data for access upon request and approval and lay out the rules on allowing or disallowing access to un-anonymised data;
- making the data available under a clear license which is FAIR and CARE compliant for the specific dataset; and,
- providing means for stakeholders to access their data in a way that makes it possible to make use of the data

People from diverse groups need to be able to make sense of data, whether decision makers, researchers, specific cultural groups, or other communities. Interface usability and data interpretability must be integrated workflows for each aspect of the data lifecycle (Fig. 5). When working with ILK and IPLCs, the principle of Informed and Prior Consent is paramount to doing any accepted work. To maximize usability and usefulness of interfaces for data sensemaking, key stakeholder groups need to be included in all stages of design and development of sensemaking tools. For instance, workshops with key stakeholder groups can elicit relevant ideas and experiences, as well as opportunities and barriers to people's perceptions of information presented. Doing so can foster trust and inform iterative design and development of data sensemaking tools.

Collaboratively exploring sensemaking tools with multiple stakeholder groups over time can also help to identify how design and development needs are similar or differ between key stakeholder groups. For example, design research to develop useful and enticing tools for identifying bird songs from audio recordings identified that ecologists, expert birdwatchers, and broader members of the public all need training tools, and how needs differ between respective groups [53] [54]. The transparency of the data collection and processing is paramount for people to make sense of the data, and to assess if datasets can be harmonised. This includes documentation of the data collection and analysing procedures in a way which enables a thorough review of the methodologies and processing pipelines used as well as information about the data quality and rich metadata.

Apart from the sampling and the preparation of the data, the dissemination of the data needs to be planned thoroughly. An assessment of the intended audience and its needs (i.e., how to access the data, which presentation is necessary, which media will be useful) should be conducted before any action is taken to implement it. It must be taken into account that internet access is an issue in many regions of the world, particularly remote areas. Consequently, dissemination channels need to be designed for potential users in those regions as well, and not for the ideal use scenario. This includes the compilation of narratives based on the data to be communicated to the stakeholders.

Establishing strong data governance practices allows for maximum use of open data and development of open technological solutions. Use of conservation technologies, for example, can be more powerful if global leaders unite in resourcing development of platforms that foster open collaboration between diverse stakeholders to share data, software, hardware, lessons learned, and more [55]. Experts across domains can more readily learn from each other's datasets and more easily forge collaborations. Some groups, such as OS-Climate Initiative [56] have goals to build a publicly available global platform of modeling and technical infrastructure, which decision-makers can use to model different scenarios. Likewise, the worldwide Digital Public Goods Registry [57] is also ready to increase access to open source software, open data, open AI models and open standards focused towards achieving the UN's Sustainable Development Goals. Availability of data allows for vital information needed to inform development of novel open software and hardware to collect, analyse, manage, interpret, and share data, as well as to guide decision-making.

Lastly, stakeholders must have access to interpretations of data that are meaningful to them. For instance, data may be interpreted through narratives, infographics, interactive visualisations, storyboards, or other online communication formats. Data interpretation tools should be planned carefully in relation to the target audience. Data shown by graphs and charts, for example, may be more accessible to a scientist who has training in interpreting such figures, than it will be for members of the broader public. Communication with particular audiences should be targeted, with a clear aim, whether to share information for communication, engagement, empowerment, mobilisation, education, or purposes.

Our World in Data [58]

Poverty, disease, hunger, climate change, war, existential risks, and inequality: The world faces many great and terrifying problems. It is these large problems that the site Our World in Data focuses on. The goal of Our World in Data is to make the knowledge on these problems accessible and understandable. The front page of Our World in Data lists the same big global problems every day, because they matter every day. Our World in Data is convinced that to understand issues that are affecting billions, we need data, available on an understandable and public platform. This allows everyone to see the state of the world today and track where we are making progress, and where we are falling behind. Through interactive data visualizations we can see how the world has changed; the summaries on scientific literature provided help us understand why.

3.1.3 Policy Recommendation #3

> Increase cooperation to maximise the impact of digitising environmental information.

We recommend facilitating cooperation between diverse stakeholders across agencies, institutions, organizations, and the broader public. Recent advances in cloud computing, data visualization techniques, and real-time data access via is democratising the ability to collect, analyse, and publish environmental data. The ability to openly exchange environmental information through technologies such as the Internet has allowed for new forms of collaboration to develop at local, regional, and global levels. Technological advances now allow diverse stakeholders to cooperatively exchange information, improve sensemaking, gain knowledge, and develop data governance practices.

In this section, we explore where cooperation is developing as a result of environmental information being digitised, and future considerations. First, we provide a suite of examples where international and cross-sectional cooperation is occuring with the goal to improve environmental sustainability. Next, we describe the need to facilitate support for stakeholders and under-represented/under-served communities through capacity building. Lately, we explore how accountability and transparency influence cooperative relationships and roles.

International and Cross-sectoral Cooperation

Networks across the globe are rapidly increasing, which foster cooperative sharing of environmentally focused data resources to support gaining insights and informing policy decisions. Examples highlighted below range in geographic scale from global, to regional and local scope.

Global:

- The newly established Coalition for Digital Environmental Sustainability (CODES) [59] is part of the broader follow-up to the UN Secretary-General's Roadmap on Digital Cooperation [27]. It connects practitioners with policymakers in a global multistakeholder process to convene a series of events to identify initiatives for sustainable digital transformations.

- The Global Partnership for Sustainable Development Data [60] works to ensure that data is used effectively to achieve the targets of the United Nations Sustainable Development Goals (SDGs).

- UNEP and partners are also spearheading the World Environment Situation Room [61] - an online data platform that can be used to monitor global and national progress towards key environmental SDG targets and Multilateral environmental agreements.

Regional:

- The African Development Bank has launched the Africa Climate Change Data Monitor service [62] which provides comprehensive coverage of climate change datasets on Africa. The service aims to support African countries and stakeholders to understand potential climate change impacts and opportunities.

- The Collaboratory for Indigenous Data Governance [63] aims to conduct research and education on institutional governance and ethics for Indigenous control of Indigenous data. It advocates the data governance framework that reviews institutional norms and practices that promote and inhibit ethical design, outcomes and approaches.

While the list of networks and initiatives is inexhaustible, these and several hundreds of other relevant data governance actors can be found in the upcoming Data Governance Ecosystem Benchmark activity coming out of the Datasphere Initiative [64], which is currently being incubated by the Internet & Jurisdiction Policy Network.

As one can see by looking at these diverse data initiatives, more needs to be done to enable harmonisation, coherence, synergies, and access to disparate datasets.

Facilitating support for stakeholders and under-represented/under-served communities through capacity building

Encouraging different actors such as governments, private sector, and civil society to contribute and share data from different resources with one another can be challenging. Nevertheless, it is imperative to support better understanding and decisions around protecting and enhancing our common data resources. There needs to be sufficient resources and facilities to support contributions by multiple stakeholders, especially those with limited resources in skills and technologies. An open-source, shared knowledge repository with clear data sharing guidelines as laid out in Section 3.1.1 and 3.1.2 will be essential to increase the co-operation between all stakeholders, including indigenous peoples and local communities (IPLCs), under-represented, and under-served communities.

Engaging the public as active participants in scientific inquiries, which is referred to as citizen science, can be a powerful way to provide access to ecological and environmental information at scales not otherwise possible. Members of the public submit observations, such as of plants, animals, and environments. Additionally, they commonly analyse large volumes of media, such as photos, video, and audio, from the environment. Both observations collected or media analysed by the public provide biodiversity and environmental information at unprecedented geographical and temporal scales. This data informs research, resource management, conservation actions, and policy. Additionally, such data often underpins development of artificial intelligence algorithms needed to rapidly draw insights from increasing data volumes that can support informed decision-making regarding conservation and planetary health [65].

As with all scientific data, citizen science data has biases which deserve careful evaluation. For example, data can be biased towards charismatic or easy to identify species. Additionally, the uptake of citizen science largely relies on people having access to adequate training resources, as well as information and communication technologies. Nevertheless, citizen science is rapidly growing and identified as playing a key role globally in achieving open science [66], sustainable development goals [67,68], and environmental democracy [69].

We also recommend encouraging youth participation in environmental dialogue and processes. To emphasize the importance of engaging youth stakeholders, the UN Secretary-General's Report "Our Common Agenda'' [70] lays out recommendations where governance improvements are needed across various sectors. One of the key commitments listed in the report is to "listen to and work with youth". Youths as a stakeholder group are increasingly recognized in formal intergovernmental dialogues and processes such as the Youth Track which was launched at the 3rd UN Science Policy Business Forum on the Environment [71] in February 2021. The IGF also has robust practices to engage the youth on topics related to Internet governance. These platforms can be similarly used to engage youth participants on issues related to environmental data.

All the above cannot be achieved without concerted capacity building efforts on the fundamentals such as digital and data literacy as well as the provision of access to reliable and fast communication and Internet infrastructure. More can be done to make climate data available in an appropriate format whether through layman interpretation or actionable insights for those with less data literacy. Governments and related actors should develop policy that supports learning about data and governance as part of the educational curriculum. An example of training is conducted by the UN Economic Commission for Africa's African Climate Policy Centre (UNECA-IDEP-ACPC) for African early career researchers [72]. Issues of participation, trust, and capacity-building are further explored in Chapter 3.4 'Overarching Issues' of this report.

Accountability and Transparency of Processes and Roles

For stakeholders and actors to cooperate effectively, we recommend developing guidelines for accountability of the various roles and processes. An example of such a guideline could be in the form of cybernorms (as used by the cybersecurity community to encourage ethical behaviours around Internet security) developed by a multistakeholder data community that would outline the ethical practices around gathering and use of data resources. Apart from developing norms, data providers could also work to agree on adhering to a set of open standards for environmental data. The issue here is to find an appropriate body or home where these standards could be developed. If a global data repository or access point is indeed established, there needs to be multi-stakeholder discussion on the roles and responsibility for operating such a repository. For instance, a body of "data guardians'' or a global ethics panel should be appointed to provide such oversight.

3.1.4 Future directions and exemplifications

In the following subsections, future trends and key areas for considerations around environmental data are highlighted. It is important to note that this list is by no means exhaustive, and the issues are overlapping. The topics discussed are mainly positioning the environmental data within a broader perspective. They are also linking to upcoming discussion points in the ensuing chapters 3.2 (Food & Water) and 3.3 (Supply Chain Transparency and Circularity).

Digital Product Passport

A digital passport, which documents the product's progeny in regard to all steps involved in the production of the product, needs to include environmental data to, for example, quantify the environmental/carbon impact of mining or production steps. The more data is available and accessible, the better these impacts can be estimated and documented for consumers. At the same time, these passports will only be reputable, if the data underlying them is reliable and accepted by all stakeholders.

Food and Water security

Food and water security is an issue which is at the base of all human well-being. It is heavily dependent on the accessibility of all kinds of information, data, and knowledge, ranging from weather data, other knowledge and understanding of local soil properties to the interpretation of the state of water quality. Most of these are based on environmental data and an increased availability and access to a whole range of data will make the sustainability of food and water availability more likely and easier to achieve.

Biodiversity conservation

Biodiversity conservation is heavily dependent on the availability of reliable environmental and other data. This applies to the science of biodiversity conservation as well as management of biodiversity. Adaptive management is a prime example, which can only work when reliable and timely data is available. Availability of data for scientists and other stakeholders is the foundation for successful conservation.

Health and Human Well-being

Nature does not only play an important role for food and water security as discussed above. A current example in which nature plays an essential role is the COVID pandemic. Access to environmental data and narratives is essential in understanding the pandemic and its dynamics, ways to deal with it, and steps necessary to minimize the chance of further future outbreaks. This not only includes access to the data by scientists, but also by all stakeholders. Additionally, human well-being depends on the accessibility of nature for non-monetary reasons, for example recreational reasons. To increase this appreciation of nature, awareness is essential and can be provided through narratives by the data.

3.1.5 Summary

For a sustainable future, we must understand what happened in the past, what is happening today, and what will possibly happen in the future. To be able to achieve this, having Findable, Accessible, Interoperable and Re-usable (FAIR) environmental data is paramount. Then data can support monitoring ecosystem changes, informing decision-making, engaging communities, and promoting adoption of actions that increase planetary sustainability. There are an infinite number of environmental variables that can be measured and documented, whether by people using smartphones, satellites autonomously, or other means. For existing and new datasets to be leveraged ethically and effectively, it's essential to implement strong data governance guidelines and regulations from both people-centered and technical perspectives (i.e., following CARE and FAIR principles). This data must be accessible and presented in forms that make sense for diverse groups of people who need or will use environmental information. The technologies used to gather, manage, prepare, analyse, and distribute the data should be designed to support cooperation between all stakeholders, including data producers and distributors. This will maximise the impact of digitising environmental information. Following such recommendations will allow for more people to engage with environmental information and advance efforts to improve sustainable development and planetary health.

3.2 Food & Water Systems

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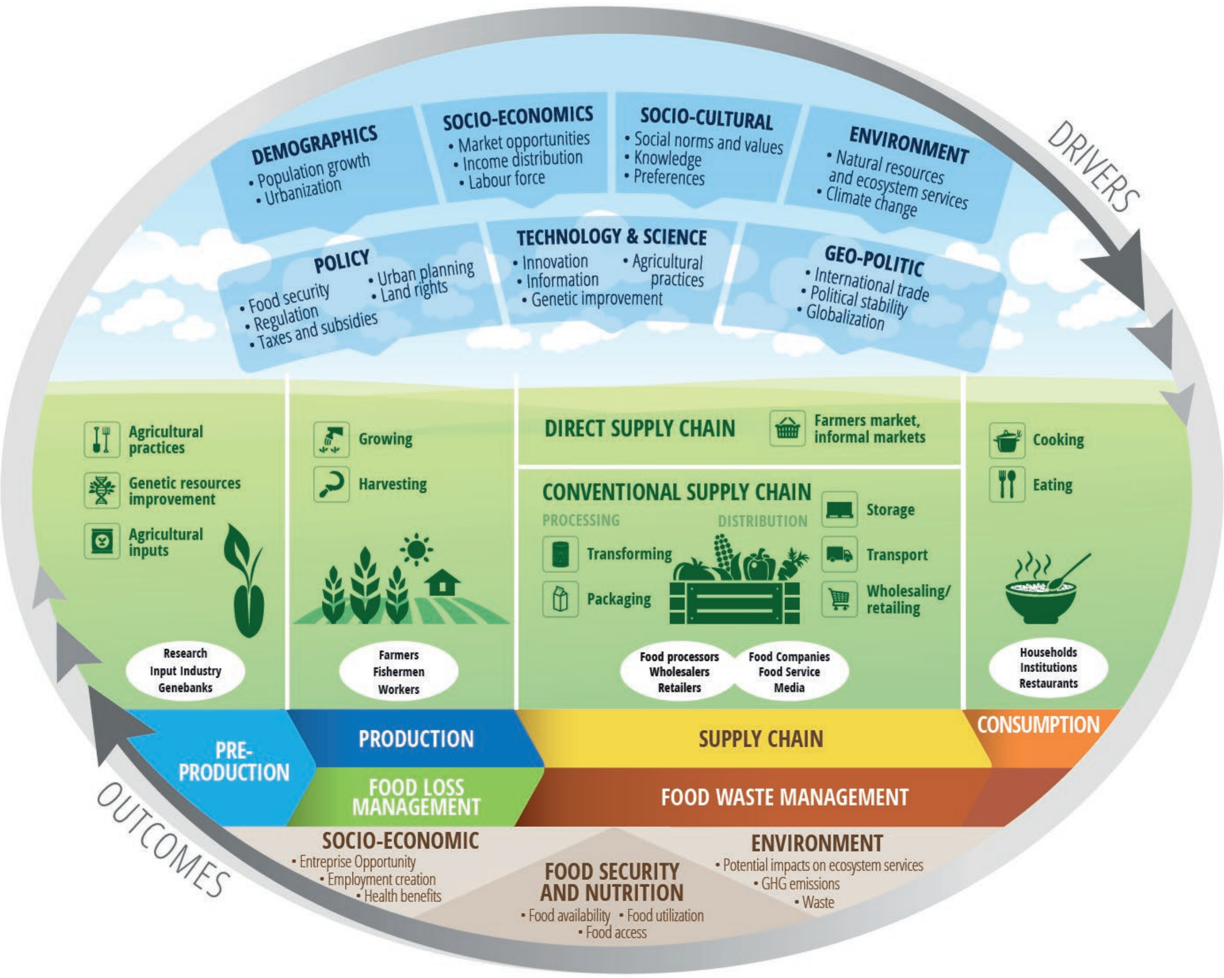
As highlighted by the recent UN Food Systems Summit (UNFSS), the term "food system" refers to, "the constellation of activities involved in producing, processing, transporting and consuming food. Food systems touch every aspect of human existence. The health of our food systems profoundly affects the health of our bodies, as well as the health of our environment, our economies and our cultures. When they function well, food systems have the power to bring us together as families, communities and nations" [73].

Across the wide-ranging and complex interactions of these activities, and the multiple actors who perform them, the food system (Figure 6) both significantly affects and is affected by environmental and societal pressures. As such, there is growing, widespread recognition and agreement that transforming our food systems is critical to shifting our collective trajectory to realize the 17 Sustainable Development Goals.

While this chapter focuses on digitalisation's contributions to the environmental aspects of food and water systems, it is critical to acknowledge that access to food and water are human rights [75] [76], not simply a commodity or system to be managed. As demonstrated by the COVID-19 pandemic, our food systems are not as resilient and secure as they once seemed [77]. With approximately 800 million people facing hunger, 12 percent of the global population severely food insecure in 2020 [77], and 2.2 billion lacking access to safe drinking water in 2019 [78], it is clear that we, as a global community, are far from realizing this universal right. Thus, to the extent that digitalisation

Figure 6: Global Food System
(Source: CIAT (2017) [74], CIATCC-BY-NC 4.0)



and broader technological transformations have roles to play in food and water systems, it is imperative that the right to food is central to our thinking and action. Otherwise, we risk technologizing deeply entrenched social challenges and structural inequities while further marginalizing the most vulnerable populations.

Food and Water Systems and the Environment

From an environmental perspective, according to both a new dataset from the FAO [79] and an independent recent study published in Nature [80], food systems are responsible for a third of global anthropogenic greenhouse gas emissions [81] with a similar proportion of food systems' total contribution coming from non-farm supply-chain activities. Farming is the most expansive human activity in the world, occupying 40 per cent of global land area, and it is the principal user of freshwater, responsible for 70 per cent of withdrawals [82]. Food production is the main driver of biodiversity loss and a major polluter of air, freshwater and seawater, and a leading source of soil degradation and deforestation [82]. Meanwhile, it is estimated that 80% of wastewater is released to the environment without adequate treatment [83].

The current environmental pressures from the global food and water system cannot be sustained, yet to meet projected demand in 2050, with current efficiencies, world agricultural production would need to increase by 50 per cent from 2013 levels with global crop demand forecast to increase 100-110 per cent over the same period [42], while water demand is expected to grow by 20-30% [84]. While the food system produces more than enough to feed the world's population adequately, it does not distribute it well [85] and we are seeing increases in all forms of malnutrition [77,86]. Around one in ten people globally are hungry or undernourished, almost a quarter of all children under 5 years of age are stunted, and one in three people are overweight or obese. Some 2.3 billion people do not have access to safe sanitation, resulting in 1.4 million deaths from pathogens related to polluted drinking water [82].

In short, the food and water systems are ripe for disruption: environmental, demographic, and societal pressures all demand systems that are much more equitable, sustainable, and resilient and which better support the health of all peoples and the planet [87]. Widespread application of current and future technologies and systemic innovations – many of them reliant on digitalisation – can, and must, play significant and varied roles in the profound transformation of food and water systems that is required. However, the spectre of increased digitalisation also brings myriads of downside risks that require recognition, scrutiny, and appropriate governance.

Food and Water Systems and Digitalisation

Unlike technological changes that have revolutionised food production in the past - including irrigation, mechanisation, and crop breeding - digitalisation-enabled changes have the potential to spread faster and wider throughout food systems, bringing both greater opportunities and challenges [88]. Potential applications of digitalisation in food systems range from food production, managing land use, emissions, and water efficiency, across supply-chain management and transparency, all the way to improving dietary outcomes and waste management [89]. These digital technologies include, to name just a few, autonomous field technologies and precision-farming robotics, soil sensors, improved climate forecasting and early-warning systems, traceability technologies, intelligent food packaging, artificial intelligence in inventory management, vertical and soilless agriculture, and dietary-biomarker sensors.

Although the need for change pervades all aspects of food and water systems, the roles for, and the risks and benefits from, digitalisation's contributions are uneven, precluding the universal imposition of techno-fix solutions. For example, many food and water systems are imbued with centuries of culture and traditional knowledge that should be respected and built upon. And the physical and societal characteristics and capacities of production landscapes vary enormously, requiring a deep understanding of context to affect positive change without causing unintended consequences. Digitalisation can be as applicable to bottom-up agroecological approaches as it can be to top-down industrialized approaches, but ensuring it contributes to positive outcomes demands genuine stakeholder ownership and engagement. In lower-income countries - where much of the world's food is produced - the potential impacts from food and water system digitalisation may be most significant, both for the winners and for the losers that risk being excluded and left behind [89]. It is in this context that we recommend five key priorities for ensuring that the transformative potentials of digitalisation within food systems are maximised.

3.2.1 Policy Recommendation #1

> Ensure context-specific and inclusive approaches co-developed with stakeholders to realise digitalisation's potential to enhance the environmental sustainability of food systems.

The importance of digital transformation of food systems has increasingly been acknowledged by national governments in international fora in recent years. Since the Chinese presidency of the G20 in 2016, each successive G20 Agriculture Ministers Meeting has formally recognised the vital role of digitalisation, ICTs, and artificial intelligence to sustainable agricultural development [90]. In 2019, 'Agriculture Goes Digital – Smart Solutions for Future Farming' was the official theme of the annual German-hosted Global Forum on Food and Agriculture, at which agriculture ministers from 74 countries initiated a global process under the auspices of the United Nations to create an international framework for digitalisation in agriculture [91]. This was established in 2020 as the International Digital Platform for Food and Agriculture [92], which, hosted by the FAO, is intended to be a voluntary and consensual coordination mechanism. It aims to "provide an inclusive, multi-stakeholder forum for identifying and sharing ways the world's food and agricultural sectors can harness digital tools ranging from e-commerce and blockchain transaction ledgers to the use of Artificial Intelligence for improved pest control and crop genetics, as well as tools allowing optimized management of natural resources and early warning of food security threats" [93]. As noted by the FAO Director General at the High-Level launch event, "The digital divide is nowhere more evident than in agriculture", and thus whilst the equity and efficiency of the global food systems stand to benefit enormously from digitalisation, ensuring that potential is realised requires coordinated and inclusive promotion of innovative techniques supported by policy frameworks that mitigate risks and assure that nobody is left behind [93].

We reiterate that key message and further note that sustainable digital transformation in food systems requires digitalisation approaches that are consensually developed and implemented with sensitivity to the social and environmental contexts in which they are applied. Without such bottom-up participation and understanding of local ecologies, there is a risk of further exacerbating, rather than resolving, existing inequalities and resource degradation trends. This is especially important for technologies that could be 'game-changing'. Asseng et al. [88] identify six such potentially game-changing technologies, of which three are directly reliant on digitalisation: artificial intelligence linked with big data, sensors and food systems knowledge to increase productivity, optimize resource use and minimize externalities in food supply chains; autonomous technologies (including robots and drones) throughout food supply chains; and vertical farming with controlled-environment production of crops, livestock and seafood [88]. As such technologies could spread rapidly, their potential for disruption, both positive and negative, is significant. Positively, they can reduce environmental externalities and improve resource-use efficiency; negatively, they introduce ethical concerns and risk perpetuating the significant existing structural and global inequities across countries and communities in terms of supply of and access to adequate, nutritious food [85].

Therefore, digital technologies cannot successfully be applied to food-system transformation in isolation. Rather, digital transformation requires building "socio-technical innovation bundles of mutually reinforcing technologies, policies, knowledge, social institutions and cultural norms" [94]. As access to, and control over, digital technologies are typically concentrated among fewer, better resourced, and more powerful individuals and organisations than all those that have a stake in sustainable food systems, broad participation in digital transformation is essential to co-create appropriate bundles in specific spatial, cultural, and temporal contexts.

3.2.2 Policy Recommendation #2

> Increase capacities for the use of space-derived earth science data for ensuring time-sensitive decision-making for local food and water security.

Climate change is expected to modify current hydrological cycles which will impact water security across the world [95]. Worldwide 70% of freshwater resources are inputs in the food system [95] making water security a necessary prerequisite for food security. Forecasting models based on open-source earth observation data are key for anticipating water stresses and natural disasters such as droughts and floods, which can act as early warning systems for informing decisive and urgent decision-making on a local, national, and international level [96]. The capacity to use targeted satellite data in a fast-changing climate is a crucial tool for protecting food security and livelihoods in an environmentally sound way, by a synergy of digital and nature-based solutions, within the scope of the food system as a whole [96]. E.g., Kenya's Regional Centre for Mapping of Resources for Development (RCMRD), based in Nairobi, as part of the SERVIR Eastern and Southern Africa (SERVIR-E&SA) program (in cooperation with NASA and USAID) is working on engaging local governments in training on the use of earth observation remote sensing data and collaboratively develop locally relevant satellite-based tools and services. These tools provide information for rapid agricultural management decisions at low cost. Likewise, by anticipating water scarcity or catastrophic events such as flooding and locust swarms, governments can act swiftly to mitigate potential harvest losses and provide assistance to local communities [97]. In this changing climate, policymakers should make full use of available data to inform timely actions on the ground for food and water security, as well as strengthening adaptation, resilience and community livelihoods.

3.2.3 Policy Recommendation #3

> Prepare national and regional plans and strategies to use digital tools for the optimisation of inefficient water systems, especially in developing countries.

Water systems, both natural and artificial, are complex systems with a long lifespan. This provides both a barrier and an opportunity for the applications of digital tools to increase efficiency of old water systems through retrofitting and its use in building up new infrastructure. Water shortages and flooding events can severely impact water systems' ability to supply the population with safe and clean drinking water. In addition, climate impacts have already started and will continue to make the situation worse. A recent synthesis analysis suggests that 92% of recent heatwave events, 58% of floodings and 65% of droughts have been made more severe due to climate change [98]. While technological solutions always seemed to be geared towards the developed countries, evidence suggests that potentials of digitalisation seem to be highest in inefficient systems in the developed and developing world, and can help to manage and improve complex, heterogeneous, and intermittently available infrastructure. As a foundation to meaningful application of more advanced technologies, building up a strong dataset through the use of sensors, earth observation data and citizen science, if possible, in real-time or near real-time, should be prioritized (see also chapter 3.1 Environmental Data).

There are several ways to use the data collected to make water systems more efficient:

- **Real-time data** allows for more efficient management, reducing waste by only pumping necessary amounts, and reducing leakage waste by monitoring flow and pressure levels and automating valves/shutdown;
- It facilitates **information-sharing** about disruptions in near real-time, for example anomalies in water supply for irrigation (as for example in Pakistan [99]) or water quality incidents (as for example in India [100]) through mobile messaging services which, when coupled with efforts to increase mobile coverage (see recommendation #4), can expand individual and community access to environmental data for decision-making;
- **Intelligent devices** (treatment, filtering) can eliminate the need for extensive infrastructure networks which may benefit developing countries with limited financial resources for investments in infrastructure [100] and reduce the exposure of water networks to extreme weather;
- The application of **artificial intelligence models** can be trained based on the dataset to detect issues automatically and identify inefficiencies in the system [101];
- **AI** can also provide simulations for drought planning, combined with sensors can reduce water waste through leak detection and automated shut-down [102] (see Case Study below);
- Digital technologies can contribute to the **monitoring of and planning for** disasters: flash flood and rainfall simulations, use of drones to build digital elevation models combined with large-scale particle image velocimetry to measure flash flood discharge, predictive models based on forecasts for Early Warning Systems [103];
- **Disaster Risk Reduction** measures and strategies tend to focus on either flood or drought despite them being two extremes of the hydrological cycle, meaning hazard reducing measures can have unintended effects on the opposite hazard [104]. An integrated approach to hydrological disaster planning can be supported by images from radar remote-sensing [105] and the sharing of open-source data [106] (see also Environmental Data 3.1.4).

Case Study: Combatting water losses using AI in Brazil

In Brazil, 38% of water from springs is lost during distribution. Brazilian start-up Stattus4 developed 4Fluid, a solution combining IoT sensors and Artificial Intelligence to detect possible leaks. By collecting vibration, consumption, and pressure data, the AI learns to distinguish between the expected vibrations of water flowing through pipes, and those indicating real losses through leakage and even apparent losses through illegal connections or damaged water meters, providing near real-time information to managers to support decision-making [107].

3.2.4 Policy Recommendation #4

> Develop/adopt tools and processes aimed at reducing inefficiencies so that the food system is better prepared for projected increases in demand and there is a more efficient allocation of food products.

Globally, agricultural productivity has increased steadily over time [108], but the sector in many countries remains unprepared for demand projections and future climate related challenges. Many farmers, especially in developing countries, do not have access to the best information and technologies that could contribute to improved crop yields and ensure fair compensation for their products. Further downstream in the food system, the problem of food loss and waste represents nearly a third of all food production and generates 8-10% of GHGs worldwide [109].

Increased consciousness of this problem has led to a growing demand by consumers to understand where the food they are purchasing comes from, a sentiment that is sometimes exacerbated by food related health scares. Changing consumption demands for the year-round supply of fresh produce has led to growth in trade for agricultural products, contributing to the food system becoming much more globalised [110]. Within this complexity, accessing timely and accurate information has been a challenge for producers and consumers alike, sometimes leading to a misallocation of supply and demand in global markets [111]. To reduce the inefficiencies mentioned above, there is a need to develop greater transparency throughout the food system. In many cases, improvements in access to existing technologies like mobile phones can improve connectivity, allowing accurate market knowledge that can improve efficiency and reduce waste [112]. Emerging technologies like big data and blockchain also show potential to improve transparency and provide verification for food products. Enabling the use of these technologies will be both a question of governance and investment to ensure proper coordination and equal access to technologies among stakeholders. Processes at both the domestic and international level that prioritize this could ultimately contribute to improved outcomes for farmers, consumers, and the environment.

Despite a general trend of increasing connectivity (see Digitalisation Trends 2.1), significant gaps remain, and a lack of connectivity currently represents a barrier to transparency and efficiency in the food system. With farms of all sizes participating in global value chains, knowledge on current market conditions and prices is crucial if integration is to be successful. In cases where connectivity is poor, outcomes have included lower yields, unsold products turning to waste and widening gaps in digital literacy [113]. For farmers with insufficient market knowledge that the internet helps provide, too much time and effort can be spent negotiating with intermediaries while getting their goods to market or even producing the wrong crops. While the direct cost of this is borne by farmers themselves, the risks of higher search costs and a misallocation of goods in the market are global [112]. Efforts to improve mobile coverage and internet access could help farmers reach markets, access financial services and improve their digital literacy. In Kenya, one trial showed that providing price information through a mobile application in some cases led farmers to change their cropping patterns and may have contributed to higher reported earnings [114]. Achieving this on a wider scale will require investment into infrastructure and training, and a concerted effort that access to these technologies is done equitably.

In the distribution and consumption phase of the food system, logistical inefficiencies and demand-side pressures are contributing to the need for the application of new technologies. Food loss and waste occurs at both of these phases and given the adverse effect this has on the climate and food availability, tackling this problem should be a priority for governments [115]. While still nascent within the food system, blockchain and big data technologies have been recognized as tools that could improve the food systems transparency and traceability and reduce the likelihood of food becoming lost during its post-harvest phase [111]. Relatedly, Blockchain can also help verify whether food meets health and safety standards, as well as verification for organic products, preventing companies from simply labeling food as such [116]. With the levels of globalisation now present in the food system, such measures could be crucial in preventing contaminated food from spreading far beyond its point of origin. Initiating this would require cooperation on the part of food producers to disclose information, or regulations that define minimum levels of transparency. To implement this, governments should coordinate and develop systems that clearly define health and transparency standards for food distributors to follow. Digitalisation and the application of the emerging technologies previously mentioned could make this a more feasible proposition.

Case Study: Blockchain-enabled sustainable rice production in India

Rice production, one of India's largest export commodities, requires vast quantities of water and contributes substantially to global warming through methane production. Food and agri-business Olam partnered with Indian blockchain platform TraceX to improve the sustainability of rice production in Haryana, India using a blockchain-based solution. TraceX allowed streamlined communication with farmers, rapid retrieval of audit data, and mutual transparency and trust across the value-chain. Farmers also reported up to 12% increases in income, and reduction of water consumption and pesticide use of around 85% on average thanks to the solution's data collection and recommendations [117].

3.2.5 Policy Recommendations #5

> Raise awareness and implement risk management policies regarding the cybersecurity vulnerabilities associated with the digitalisation of food & water systems. These sectors are categorized as critical infrastructure and could be potentially targeted and damaged via cyberattacks.

The digitization of the food & water systems brings about increased risk for keeping these systems cybersecure. A cyber-attack on these systems can mean that the systems are either temporarily or permanently damaged and the tasks reliant on these systems are impossible to deliver. With the increased digitization experienced in the latest years due to the increase in remote working structures due to COVID-19 measures, the cyber threat landscape also changed, and more attention is now given to the vulnerabilities on the part of the third-party providers [118]. The importance of the cybersecurity risk on the critical infrastructure could be also explained in other words as, no matter if a digital system is owned or developed by the public or private sector, as digitization requires interconnected systems, the cyber security of any system is dependent on the security of all involved third party suppliers. A key principle of network security emphasizes that every system is only as secure as its weakest link [118]. This principle is commonly associated today with human errors in keeping systems secure and with security vulnerabilities that occur due to third party providers. Given that both food and water systems are categorized as critical infrastructure sectors by the US Cybersecurity & Infrastructure Security Agency (CISA) [119], cyber-attacks to these systems can be targeted with malicious intent of putting a state or public service provider in significant distress.

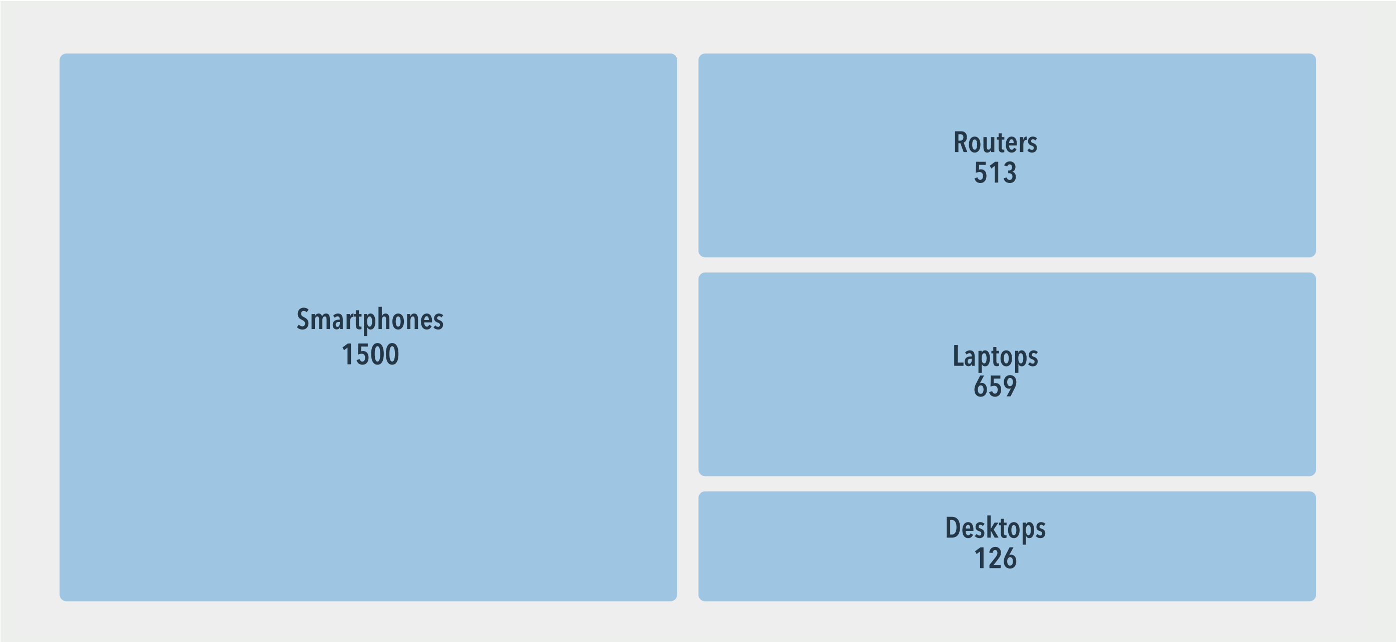
ICS-CERT report discloses that 25 water utilities reported cybersecurity incidents in 2015 [120], which then classified the water and wastewater sector, the third more targeted sector [121]. It is also observed as a key issue across sectors (also applicable in WWS) that the cybersecurity awareness among management, creation of security guidelines and employee trainings do not receive the attention that they should in order to provide a realistic risk assessment. Former cybersecurity attacks on water systems show that both insider threats (Maroochy Water Services hack, 2000, Australia) and outsider threats (Kemuri Water Company, 2016, US) demonstrate that these cybersecurity risks should be included in risk assessment while taking steps towards digitalisation. The Kemuri Water Company attack included the attackers taking control of valves that were in charge of controlling flow of chemicals. Therefore, as the amount of the connected systems increases, the control of these systems becomes ever more a cybersecurity vulnerability for the providers and users [122]. These attacks put at risk both the availability, access and quality of water and food provided to the users. Regarding food safety network security to guarantee availability as well as biosecurity can be listed as possible risks. Scholars emphasize that the cyber-attacks on food systems can be applicable to a variety of threats including on farm side as well as on supply chain or networking equipment and all these threats might put access to food of citizens at risk [123].

3.2.6 Summary

Digital technologies can contribute to food and water security in crucial ways, and much of the potential of these technologies depends on how they are used, by whom, and to what aims. Food systems around the world are imbued with centuries of traditional knowledge and diverse sources of evidence that must be respected as foundational for food and water security. There is significant tension in the field between the call for more industrialized approaches, and approaches based on agroecology. A growing body of evidence demonstrates the potential for agroecological approaches to dramatically improve food systems and sustainability, and it is important that information and communication technologies are harnessed for sustainability and not only for efficiency. **Digitalisation in food systems should always be applied with contextual specificity and sensitivity and should respect and complement traditional systems. The introduction and use of new technologies should involve and empower all communities, local to global, across all stages of technology utilisation.** Digital exclusion is an ongoing barrier to harnessing the potential of digitalisation to contribute to food and water security. Nearly half of the world's population still does not have access to the internet, and only 1 out of 3 smallholder farms in the world has access to 4G mobile coverage [124]. The Director of the Food and Agriculture Organisation (FAO) of the United Nations has stated that the "digital divide is nowhere more evident than in agriculture" [93]. Inclusive and innovative strategies are needed to address digital exclusion, supported by enabling policy frameworks.

Highly localized data and up-to-date information is increasingly crucial to anticipate and respond to stresses, disruptions, and scarcity in food and water systems, including urgent decision-making by local governments. There is a clear need for more local training and capacity-building activities, including the collaborative development of locally relevant tools and services. **National governments need to commit significant resources to local community-based initiatives that are increasing capacities at local levels to collect and use data to inform decision-making for food and water security, and climate resilience.** The digitization of the food & water systems increases risk around the safety and security of these systems. A digital attack can mean that the systems are either temporarily or permanently damaged and the tasks reliant on these systems are impossible to deliver. Cyber-attacks can be targeted with malicious intent of putting a state or public service provider in significant distress. The number and frequency of attacks on these critical systems shows an increasing trend [122] and further digitization of the food & water systems create further vulnerabilities for both insider and outsider threats [123]. In order to assure security of these systems, national governments should raise awareness and implement risk management policies regarding the vulnerabilities associated with the digitalisation of food & water systems. The digitalisation of water management systems requires significant attention to the complexities of existing infrastructure. Networked computing can support diverse stakeholders to manage and incrementally improve complex heterogeneous infrastructure, rather than focus primarily on efficiency. There are many opportunities for new technologies to support water security, such as systems that provide real-time monitoring and response to changes in demand and supply, artificial intelligence that can develop simulations and predictions, and blockchain that can protect increasingly connected water networks from cyber-attacks. National governments need to support the development of models, strategies and systems to ensure that water management is digitalised, flexible and resilient to scarcity and disruptions. Human rights to food and water are universal, and digital technologies have an important role in responding to the most urgent threats and dangers of environmental degradation. Digital transformation for food and water security requires building "socio-technical innovation bundles of mutually reinforcing technologies, policies, knowledge, social institutions and cultural norms" [87].

Figure 7: Million of units estimates (2021)
(Source: Treemap visualisation by Leandro Navarro, published with consent of the author. Data sources: GSMA (smartphones), ITU-T L.1024, weight estimates of devices from Wolfram Alpha [Smartphone: 0.136, Desktop: 8.165, Laptop: 2.313, Router: 0.5 Kg] and UN Global e-waste monitor)



3.3 Supply Chain Transparency and Circularity

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Digital devices (ICT devices, routers, switches, consumer products like smartphones, etc.) have significant environmental, social, and economic impacts at each stage of their life cycle, starting from the supply chain, including the reverse supply chain, to e-waste/end-of-life management. Currently, more than 6 billion new ICT goods are sold annually worldwide, with estimates of 1.5 billion smartphones. In 2021, 126 million desktop computers, 659 million laptops, and 513 million Wi-Fi routers were produced (ITU-T L.1024, 2020) [125], as shown in Figure 7. These numbers are expected to grow exponentially over the next five-to-ten years with new "smart" technologies.

In 2019, 53.6 million metric tonnes (Mt) of e-waste[3] (any discarded product with electronic components) was generated worldwide, an increase of 21 percent in just five years. E-waste is still the world's fastest growing waste stream, and it is estimated that by 2030 the amount will reach 74 million Mt. Most of it is discarded in the general waste stream, leading to a loss of secondary resources valued at US$57 billion in 2019. Additionally, e-waste is often shipped illegally to developing countries where the trace is usually lost in the informal sector and dumped in informal landfills. The following Figure 8 shows the estimates of e-waste for 2021 compared with the specific devices from the previous figure, translated into weight based on estimates of weight per unit. It shows how big the e-waste problem is, the amount of electronics in our lives, in comparison to the number of a few types of popular ICT devices produced.

The contribution of ICT in terms of energy use is another environmental aspect of digital

3 The term e-waste and waste electrical and electronic equipment (WEEE) are used interchangeably.

Figure 8: Millions of Kg (thousands of Tons) estimates for 2021.
(Source: Treemap visualisation by Leandro Navarro, published with consent of the author. Data sources: GSMA (smartphones), ITU-T L.1024, weight estimates of devices from Wolfram Alpha [Smartphone: 0.136, Desktop: 8.165, Laptop: 2.313, Router: 0.5 Kg] and UN Global E-Waste Monitor [6])

technologies that cannot be ignored. The advent of digital transformation has the potential to increase the ICT's share of global electricity and released GHG. Renewable energy or locally sourced energy can nevertheless help to reduce their GHG emissions. The material components of ICT's are also a major contributor to global warming. Upstream activities, including raw material acquisition, transport, and production, have the most environmental and sustainability impact. While ICTs and digital solutions can vastly improve energy efficiency, inventory management, transportation (e.g., telework and videoconferencing, substituting physical products by digital information, etc.), and other aspects of social and economic life, to fully realize these potentials, they need to be developed and implemented with sustainability in mind. As suggested in the international standard, Recommendation ITU-T L.1470, which defines the GHG emissions trajectories for the ICT sector compatible with the UNFCCC Paris Agreement, the digital world is part of the problem and may be part of the solution, requiring a major concerted political, social and industrial effort [126].

As this chapter will show, digitalising information on ICT sustainability at all stages, from raw material acquisition to waste management, can substantially improve ICT's reusability and recyclability. It can foster transparency and accountability across the ICT supply chain through methods such as impact assessments to account and limit environmental footprints. It also helps to integrate existing and new data for analysis and facilitate interoperability across the different actors involved. Together, digital infrastructure, products, and services can implement sustainability-driven mechanisms into digital technologies and have the greatest potential to maximise the positive outcome of digitalisation to all sectors of society and help respect environmental limits.

The Circular Economy

In light of increasing global supply chain uncertainty and growing e-waste concerns, companies in electronics and ICT, as in other human activity sectors, are shifting their attention toward a circular economy. The circular economy aims to design out waste and pollution by keeping products and materials in use for as long as possible. Through the application of circular design principles, such as designing for increased durability, ease of repair and modularity, remanufacturing and recycling and reduced toxicity, demand for virgin material is reduced thereby increasing supply chain resilience. Furthermore, ICT products that are designed with circular principles in mind, will result in reduced volumes of e-waste going to landfill or worse the environment.

A large share of ICT equipment recycling is currently taking place in developing countries. While the repair and refurbishment of used ICT equipment offers the benefit of access to digital equipment and services for people in low-income countries, these countries often lack adequate recycling infrastructure and specialised training with which to repair and recycle e-waste in a socially and environmentally safe manner. The scale up of circular product design and business models and addressing the issues of increasing e-waste will not occur on its own. It requires the strengthening of existing regulations and introduction of a suite of policies and legislation which create enabling conditions for them to prosper. Examples range from requiring extended producer responsibility (EPR) for ICT and electronic equipment, tax relief on repair and remanufacturing services, digital product passports and enhanced eco-design standards. Circular design thereby goes beyond current eco-design standards which have traditionally only focussed on improved energy efficiency of ICT and electronic products. The European Union's new eco-design approach now addresses both energy and material efficiency (e.g., durability, reparability/refurbishment, recycling). An example of adopting circular design for ICT is Fairphone and SHIFT, two ICT companies that manufacture phones from responsibly sourced materials based on a modular design that ensures ease of repair and lifetime extension. The circular design of ICT products should be complimented with the implementation of circular business models such as offering refurbished second-hand products, ICT products as a service (e.g., leasing, collective ownership), product sharing and product buyback which incentivises producers to maximise the lifetime and durability of their products. An example for ICT is Dell which offers a 'computer as a service' and refurbished ICT equipment including laptops, desktops, monitors and servers.

Circularity is critical to solving current and future ICT supply chain challenges. Equally, the scale up and realisation of a circular economy for all society sectors of activity is tightly coupled with the scale up of ICT and other digital services which enable real time transparent tracking of goods and materials throughout their entire life cycle from extraction to recycling as well as the implementation of circular business models and services (e.g., real time condition monitoring of equipment and offer products as a service).

3.3.1 Policy recommendation #1

> Maximise the environmental efficiency of digital technology: transparency and accountability of the supply chains through digital transformation.

Digital technology products depend on a very complex supply chain. The digitalisation of the details and chain of custody of materials, parts, production of devices, use and reuse, recycling and recovery of secondary materials, can bring transparency and accountability to the ICT supply chain. Many details, accessible in digital format, may allow and facilitate key processes related to environmental efficiency such as due diligence in procurement, traceability of lifespan (e.g., second-hand market) and e-waste processing. Policies, methods, responsibility, and incentives for the maximisation of the environmental efficiency of the ICT sector can be implemented based on the availability of trusted and verifiable digital information.

A digital product passport (DPP) is a structured collection of product-related data with predefined scope and agreed data ownership and access rights conveyed through a unique identifier, including details of all stages, ranging from raw materials to e-waste. A DPP can help integrate existing and new data, facilitate interoperability across different actors involved, as well as bring in quality (safety) properties such as transparency, traceability, verifiability, accountability of digital products, and therefore to infrastructures, and services that are the digital support to sustainable digitalisation.

Digitalisation through a DPP can bring several benefits across the value chain:

- Facilitate knowledge generation across the value chain: feed databases and datasets for data integration and analysis, automation of environmental impact assessment calculation, as well as to comply with national or regional regulations about the right to reuse and repair.

- Reduced paperwork and administrative burden: digitalisation can help streamline the administrative aspect of the electronics value chain, apart from the direct benefits such as reducing paperwork, record keeping, contracting, and human error, digitization efforts in the e-waste management sector will improve the accessibility of practical information in the field of e-waste.

- Digitalisation of information necessary to comply with the Prior Informed Consent Procedure for transboundary movements of e-waste under the Basel Convention.

- Creating a digital chain of custody of e-waste: integrate multiple layers of logistics, administration and approval processes into an efficient and effective e-waste management system; digitalise and automate operations to provide credible chain of custody, manage inventories, issue recycling certificates, financial calculations, settlements, and report creation for compliance purposes.

- Making monitoring and enforcement more efficient: virtual monitoring and auditing processes. Audits, previously carried out in person, can be now conducted virtually, digitally, remotely.

- Building capacity and creating awareness: provide information to inculcate a positive attitude towards circularity.

- Allowing citizens to have access to relevant and verified product information.

- Enabling services related to its remanufacturing, reparability, second-life, recyclability, enabling more sustainable business models (product as a service).

This readily available information can help promote, accelerate and ensure the maximisation of the environmental efficiency of digital technology.

3.3.2 Policy recommendation #2

> Support international standards for transparency and traceability in all supply chains: circularity and digital technology to increase transparency and reduce environmental impact.

The complexity involved in modern supply chains poses a challenge for manufacturers or those who procure any goods, including ICTs. Contracted suppliers may have sub-suppliers of their own, which can ultimately result in hundreds of suppliers for a single product, making transparency and traceability a difficult proposition [119]. Further downstream as a product reaches the end of its life and is disposed of similar challenges of transparency arise in regard to increasing circularity and reducing waste. As mentioned above, waste is often discarded unofficially with little consideration to processes that could improve traceability, creating challenges for those countries receiving end-of-life waste, and for the possibility to re-use material and implement circular models. Transparency in any supply chain can be defined as information that is readily available along each step of a value chain that allows for an understanding of all economic actors involved [127]. This aligns closely with SDG 12 on responsible and sustainable consumption patterns [127]. Additionally, both SDG 12 and a transparent supply chain align with the model of circular economy for ICTs, as it limits the amount of raw materials necessary for production.

To achieve this, an international effort at implementing policies that define an acceptable level of transparency and facilitate independent verification is recommended. Furthermore, this same set of policies should require members to incorporate a circular model when possible. These policies could take a form similar to that which the UN Economic and Social Council is proposing in supply chains for the garment and shoe industries [128]. Here, the ECOSOC is recommending defining minimum levels of transparency and traceability across supply chains, a process which does not currently exist for ICT production or many other sectors. It is also recommended to implement research and development (R&D) incentives in order to support scaling-up innovative solutions to advance transparency and traceability targets. Within the second component of the proposal, there are already digital technologies available but require application at a larger scale. Specifically, distributed ledger or blockchain and AI technologies can be of particular benefit to improving supply chain transparency due to their remarkable ability to track and analyze complex data. The application of these technologies is not limited to ICT supply chains, and their use could be beneficial to the supply chains for other industries, as challenges of transparency and circularity often remain the same. Moreover, they are not confined to any one area of logistics and have potential from the raw material phase to final consumption to recycling and reuse.

The use of distributed ledger or blockchain could enable the establishment of 'red flags' of suppliers who are associated with environmental abuses, making tracing such instances much more effective, and a higher degree of accountability and verifiability on agreed-upon standards could be expected [129]. The main challenge with blockchain would be to get companies throughout the supply chain to share information on their own respective suppliers, as they may perceive such action as diminishing their competitiveness. Within the goal of transparency and circularity must come the understanding that many supply chains as they are currently designed are extremely complex and difficult for humans to effectively manage with a high degree of certainty [130]. In conjunction with these efforts at increasing transparency and taking advantage of new technologies, a circular strategy for goods is needed along supply chains, or otherwise known as reverse supply chain. The ability to reuse, remanufacture, or repurpose some or all components of a particular good would have obvious environmental benefits while still contributing to growing business. One study [131] showed that 70% of supply chain leaders planned to invest in circular economy practices in 2020. The same study also showed that only 27% are using digital technologies to facilitate reverse supply chains. Blockchain and AI data analytics could be of use for reverse supply chains by giving each product its own digital identity and record proofs about relevant events, making it easier to track over time.

International standards coupled with adoption of the aforementioned emerging technologies can have a significant contribution to increasing supply chain transparency and circularity in production of ICT and non-ICT goods. This set of standards could be developed by states voluntarily through standards developing organisations such as the ISO (International Standards Organizations) or ITU (International Telecommunication Union), or in a multilateral forum. An outcome could be more favourable terms of trade for states and companies who apply principles of transparency, accountability, circularity and interoperability in their supply chains. The proposed standards could draw from the OECD guidance on responsible supply chains for conflict minerals in the ICT sector but be applied more broadly to include downstream components of supply chains, circularity, and the assistance provided by beneficial digital technologies. Ideally, the proposed standards will result in environmental, human rights, and financial benefits, while spurring the innovation needed to address the global challenges present in all supply chains today.

3.3.3 Policy Recommendation #3

> Use international standards to improve e-waste management and guide the implementation of circularity across the ICT supply chain.

The circular economy is a powerful tool for aligning the values of the ICT supply chain with sustainability [132]. In a circular model, ICT products, equipment, and infrastructure are designed and implemented with circularity in mind. From designing for recyclability, repairability and upgradability to implementing extended producer responsibility policies for end-of-life management, both the ICT sector and policymakers could work hand-in-hand to boost environmental sustainability across the ICT supply chain and unlock the full benefits of digitalisation for all. These circular characteristics can also reduce the generation of e-waste and minimise its adverse impacts.

International standards play a critical role in the successful implementation of circularity in ICT and a sustainable e-waste management system. Standards contain technical recommendations and measurement tools that enable ICT companies to adopt circularity regardless of their level of development. With the right standards, ICT companies could measure and define circularity based on a set of parameters agreed by international experts. They could benchmark their sustainability progress based on global targets such as the Sustainable Development Goals. Policymakers could also adopt EPR systems and e-waste management strategies that are proven to be effective. Standards are key instruments for creating a shared vision of the circular economy for ICTs and elevating best practices that would enable common growth. Several international groups have already developed standards for implementing circularity in ICT. The International Telecommunication Union (ITU) Study Group 5 (SG5) is among the first international groups to have developed international standards on the circular economy tailored to the ICT context. For example:

- Recommendation ITU-T L.1020 on "Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks'' provides a general overview on how ICT operators could work with their supply chain partners to define and improve the CE aspects for ICT goods and networks.

- Recommendation ITU-T L.1021 "Extended producer responsibility - Guidelines for sustainable e-waste management" details guidelines that policymakers can use for implementing an EPR system to enhance the end-of-life management of ICT.

- Recommendation ITU-T L.1023 "Assessment method for circular scoring" provides a methodology for assessing the circularity of ICT goods based on a scoring system. ICT designers would be able to use this standard to improve the circularity of their product at the earliest stage of its life cycle.

- Recommendation ITU-T L.1030 "E-waste management framework for countries" contains details on designing an e-waste management system at the national level, including the general requirements, roles of different stakeholders, and more.

- Recommendation ITU-T L.1050 "Methodology to identify the key equipment in order to assess the environmental impact and e-waste generation of different network architectures" provides an assessment framework for identifying the environmental impacts of network architecture. It enables ICT operators to identify where circularity is needed to take appropriate actions accordingly.

Building on chapter 3.1, circular economy principles could also provide a powerful foundation for a digital product passport for sustainability. The European Commission already recognizes in its Circular Economy Action Plan that designing a sustainable product passport is a viable action to incentivize sustainable actions and boost sustainability performance.

ITU-T SG5 is already working to study the standardisation requirements of digital product passports for ICT goods. These requirements include identifying a set of product characteristics that are relevant to the management of an ICT product throughout its lifecycle while taking into consideration the circular economy principles. It is strongly recommended that the ICT sector and policymakers take advantage of existing international standards to implement circularity across ICT and digitalisation.

3.3.4 Policy recommendation # 4

> Set up dedicated support to developing countries to tackle e-waste challenges and upgrade industrial repair and recycling activities.

Many countries in the developing world have become dumping grounds for the electronic waste the world throws away. Low- and middle-income countries will require dedicated support to reduce the negative environmental and social impacts of e-waste trade and recycling. Many developing countries do not have the means to recycle their own and the imported e-waste formally and e-waste is recycled in informal ways. Currently, as little as 17 percent of global e-waste is recycled in formal recycling centers with adequate worker protection, according to the Global E-Waste Monitor [6]. There is clear scope to improve e-waste recycling practices, reduce the potential harmful impacts to workers and their families through exposure to toxins and other harmful materials, and control the pollution to the environment stemming from unsafe facilities. The informal e-waste sector often uses sites where the extraction of valuable components of electronics happens using suboptimal recycling and disposal methods. Alleviating e-waste burden in developing countries can take advantage of the large existing collection networks of informal recyclers and utilize these to integrate their collective e-waste into the formal supply chains. But currently, investment in recycling facilities lags the growth in new electronic products, especially in low- and middle-income countries. Lack of access to credit and commercial finance is one of the biggest barriers preventing informal e-waste organizations from participating in safer and value-adding circular economy repair and remanufacturing activities in the electronics value chains. As long as informal refurbishers, recyclers and waste pickers lack access to finance to improve operations and equipment, work conditions cannot improve, and resource recovery will be sub-optimal.

A dedicated international fund could provide the necessary investments in facilities and financing for repair and recycling of electronics around the world, especially informal sector initiatives in the global south. International funds are needed to establish and operate organised take-back schemes and licensing schemes for sorting, dismantling, and recycling of e-waste. In addition to public funds, private investments are needed. Companies that are responsible for producing and generating e-waste should contribute funds and investments to address e-waste challenges in low- and middle-income countries. International cooperation between countries and coordination by the UN system to support national governments with the design and implementation of specific legislation on management of e-waste is important, as it is still lacking in many developing countries. Few countries have e-waste legislation published, such as EPR, but enforcement of legislation and policies is very challenging. These extended responsibilities can level the playing field for circular businesses. Yet, implementing EPR systems for e-waste in low- and middle-income countries based on models used in high-income countries have faced many challenges. This indicates a need for an alternative phase-in approach whereby developing countries are able to move gradually towards EPR systems. Finally, technical capacity building for institutions in developing countries such as customs officials and enforcement agencies is needed to increase transparency and reduce the amount of e-waste illegally shipped to developing countries.

3.3.5 Summary

The ICT sector and its approach to supply chain management can greatly impact the environmental performance of digital technologies. Among these impacts are increasing energy consumption from ICT equipment and infrastructure as well as the generation of e-waste. Developing countries are particularly vulnerable to these impacts as they are the least equipped to tackle the challenges. This chapter demonstrated that adopting a circular approach to supply chain management in ICT can greatly improve ICT's reusability, recyclability, upgradability, and circular principles. By enhancing supply chain transparency, ICT stakeholders can demonstrate their determination and accountability to sustainability. Moving forward, digitalisation and innovations themselves can also be expected to play a vital role in enhancing supply chain transparency, the traceability of materials and products as seen in the case of digital product passports and more. International standards are vital tools for the purpose of knowledge sharing, elevating best practices from the local level to the international level, and identifying the environmental requirements and specifications for ICTs.

3.4 Overarching Issues

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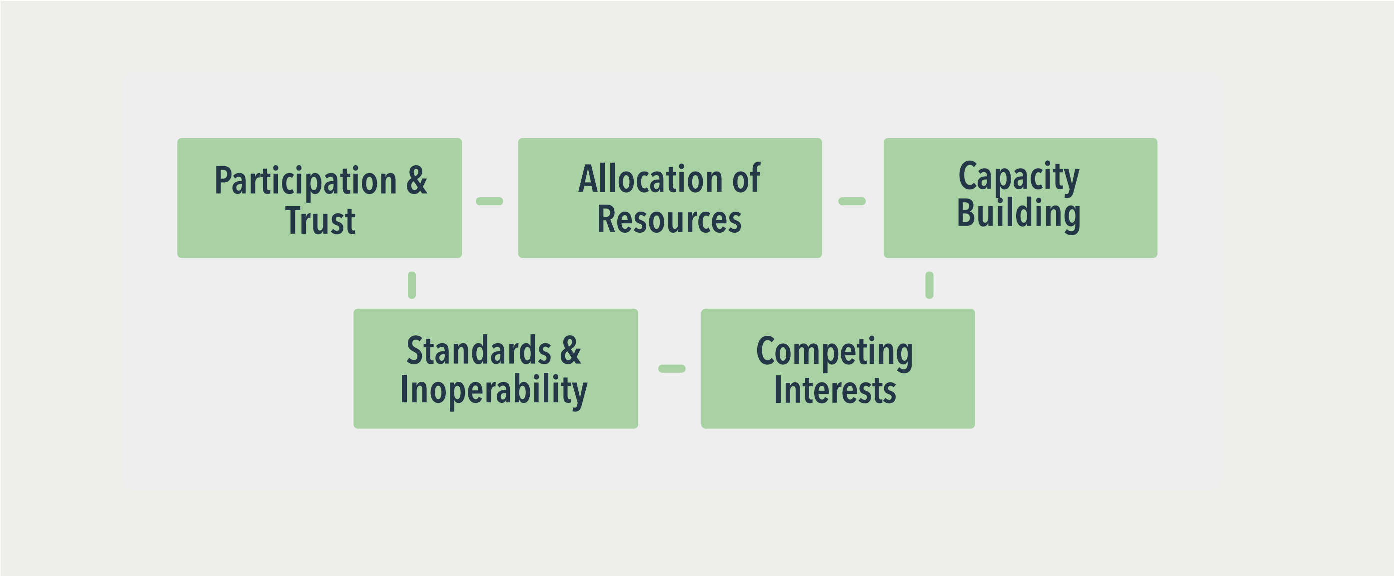
In Part 2 we discuss the opportunities and risks associated with digitalisation and the environment. We then proceed to formulate policy recommendations regarding environmental data, food and water systems and supply chains. Some issues generally impact the ability to use digital technologies for the common good, and thus also are relevant for the nexus of digitalisation and the environment. These issues cannot be assigned to only one specific thematic area (even though they are referenced throughout the report) but are overarching. To these issues and the relationship between them this chapter is dedicated. Although there are certainly more to discuss, we have chosen to suggest recommendations on dealing with the following overarching issues (see Figure 9).

Since the issues are overlapping, we begin by making the case for why these issues are important to be considered when developing policies targeting the nexus of environment and digitalisation, and then proceed to present our recommendations. The overarching issues in this chapter can also be placed into the five step framework presented in the introduction (see Chapter 1.3) to help understand at which steps in the framework they are most impactful. It is important to note that if not addressed, any of these overarching issues can inhibit the ability for effective policies to be developed and implemented.

Figure 9: Overarching Issues



3.4.1 Competing Interests

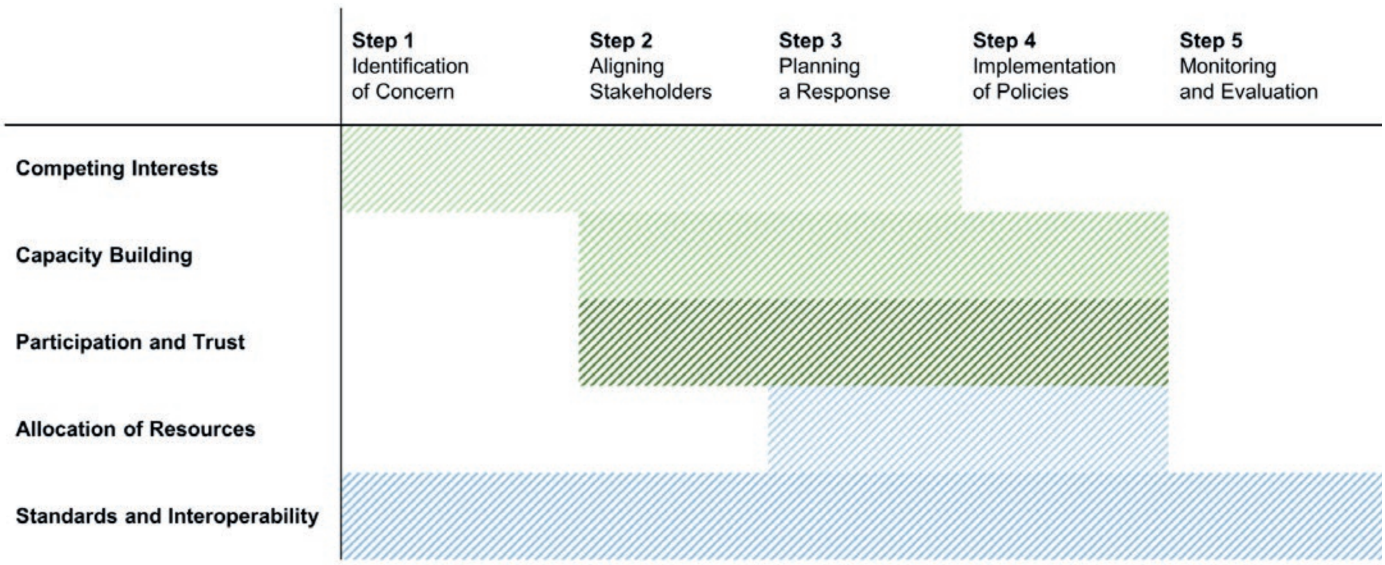
Sustainable Development relies on political will. Sustainable development is often discussed in the context of money and technology. However, even with the financial and technological resources present, whether sustainable policies can get implemented depends on the political will of the key decision makers. This was acknowledged by the so-called "Brundtland Report", in which the World Commission on Environment and Development (WCED) developed the guiding principles for sustainable development, stating in paragraph 30 that:

"(...) in the end, sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. We do not pretend that the process is easy or straightforward. Painful choices have to be made. Thus, in the final analysis, sustainable development must rest on political will" [18]

Where governments act as representatives of their population and strive to be re-elected, political will has much to do with the preferences of the largest stakeholder groups and organized interests. Interests can differ between, but also within stakeholder groups and be assigned on a vertical dimension - between the national, regional and local level - and/or horizontal dimension - between representatives of government, industry and civil society. Whoever wants to develop and implement a new policy has to take into account these stakeholder groups and find ways to reconcile their interests.

Technology can further magnify the reach and influence of concentrated interests. Opposing or competing interests and motivations are a normal part of the agenda setting and the policy development process. However, not all interests have the same weight in the political arena, which is largely due to unequally distributed lobbying power. While often a helpful resource for political actors, lobbying - for example by vested interest groups with some form of privileged access - can result in skewed decision-making and resource distribution [133]. A greater role for ICT and social media reliance can further distort the political discourse and facilitate certain forms of manipulation, resulting in potentially detrimental effects on the sustainability agenda because minority interests might be privileged. See for example, Chapter 3.2.1. for a nuanced description of how such competing interests show up in the context of digitalisation and food systems. From an international perspective, lobbying is also problematic. While the global south would be

Figure 10: The Overarching Issues Along the Policy Making Cycle



most in need of advocates to help combat and alleviate the effects of climate change, it is the largest per capita emitting countries (typically the industrialized, higher income countries) who tend to have the most resources at their disposal and whose geographical location make them less exposed to direct climate-related risks [134]. When competing interests are being discussed "behind closed doors", this also affects trust in governmental actors, who play a major role in the fight against climate change (see 3.4.3).

Technology can increase polarisation of politics, but also facilitate a more inclusive dialogue. Another risk is that if political conversation increasingly shifts to online environments, an amplification of more extreme positions and views ensues leading to heightened societal polarization [135]. Of course, this depends to some degree on the algorithms and practices of the most widely used (social media) platforms. Intensified political polarization bears risks for the capacity of state institutions to devise and implement environmental policies in a timely swift manner which is required by a timeline that allows for a sufficiently fast transformation into climate neutral economies. On the other hand, technological innovation can facilitate NGO and civil society communication and links across countries [136]. This could arguably help counterbalance the politically influential organized interests that profit from a non-sustainable status quo [137].

3.4.2 Participation & Trust

In this section, we want to explore the relationship between digital technologies, participation, and trust. We argue that the instruments of/or possibilities for participation and the level of trust are important factors contributing to the success (or failure) of environmental decision-making, placing a special focus on the role of technology given the scope of this report. In recent years, a range of international agreements has acknowledged the importance of participation.

In 1992 the Rio Declaration was globally adopted, and this contained Principle 10, which stated: "Environmental issues are best handled with participation of all concerned citizens, at the relevant level. At the national level, everyone shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided." Principle 10 of the Rio Declaration was reaffirmed by the United Nations Conference on Sustainable Development (2012) and has also been furthered through the Guidelines for the Development of National Legislation on Access to Information, Public Participation and Access to Justice in Environmental Matters (Bali Guidelines 2010) [138].

Representing the only legally binding global instrument, the Aarhus Convention has established several minimum standards and rights of the public regarding the environment, including: the right to receive environmental information that is held by public authorities, the right to participate in environmental decision-making, and the right to review procedures to challenge public decisions made disrespecting the first two rules [69]. Since its adoption in 1998, the Aarhus Convention has been signed and ratified by 40 countries, mainly from Europe and Central Asia. Finally, Article 12 of the Paris Agreement (2015), adopted at the twenty-first session of the Conference of Parties to the United Nations Framework Convention on Climate Change, once again emphasises the importance of public awareness, public participation, and public access to information in the context of climate action.

What participation means in practice, differs vastly from context to context. Whereas there is sometimes a distinction made between public and stakeholder participation, for the sake of simplicity we are working with the term stakeholder participation, considering the public to be one of a set of different stakeholders (others could be, for example, organised private interests). Drawing from the literature overview Luyet et al. provide, the following list provides an overview of important principles to structure successful participatory processes [139]:

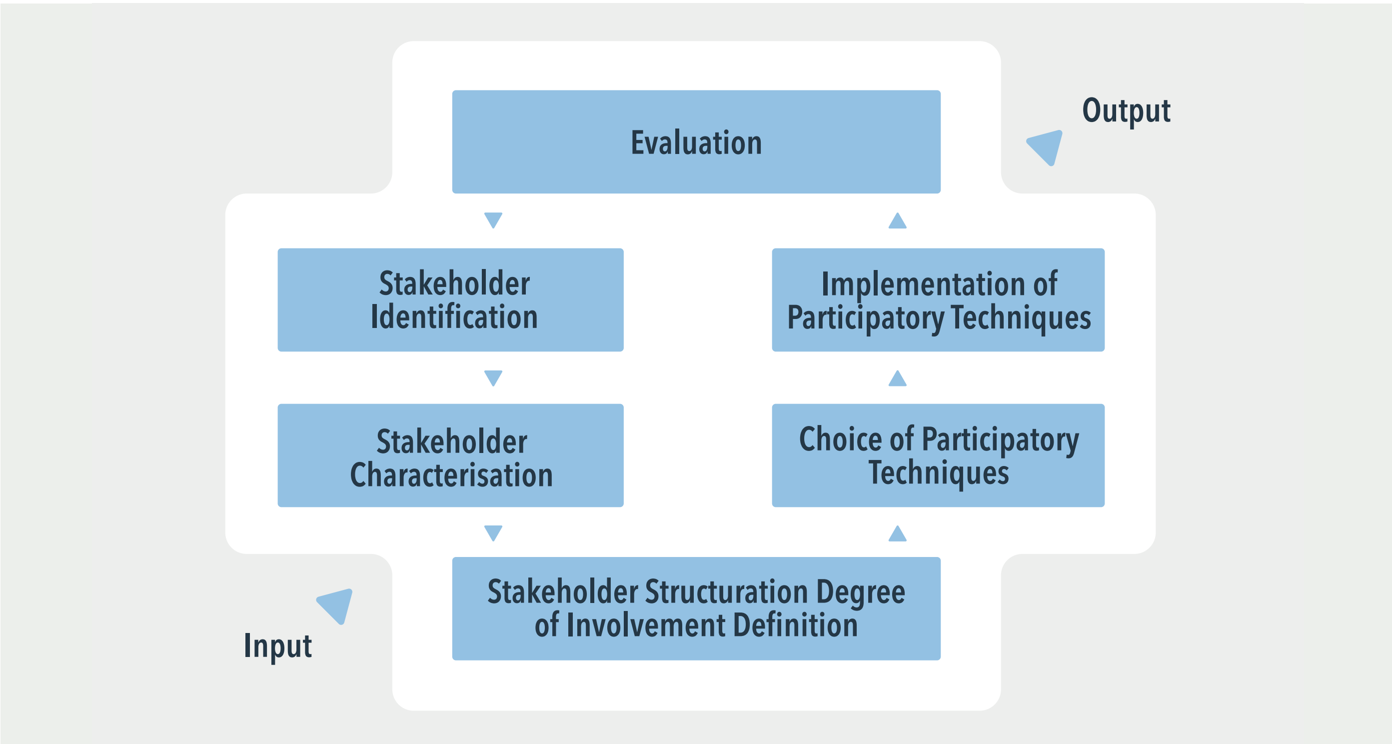
- fair, equal and transparent processes promoting equity, learning, trust and respect among stakeholders;
- an integration of local and scientific knowledge;
- an establishment of rules in advance;
- an early involvement of all concerned stakeholders;
- the involvement of experienced moderators in the process;
- the availability of adequate resources, including time.

As stressed earlier in Chapter 1.2.3 (Policymaking on Technology and Environmental Issues), the context plays an important role: The cultural, political and historical context should be considered [139]. Based on their state-of-the-art review of literature on stakeholder participation in environmental policies, Luyet et al. propose the following framework for stakeholder participation in Figure 11.

There are different forms of stakeholder participation. They can be classified from institutionalised (e.g., voting) to non-institutionalised forms and according to their degree of citizen involvement. From low to high degree [139]:

- Information (e.g., Newsletter);
- Consultation (e.g., Public Hearings, Workshops);
- Collaboration (e.g., Participatory Mapping, Field Visit and Interactions);
- Co-Decision (e.g., Citizen Jury);
- Empowerment (e.g., Consensus Conference).

Figure 11: Framework for stakeholder participation
(Source: Luyet et al. (2012) [139])



Most of these techniques could be supported by the use of digital tools and technologies [140]: ICT can be used to promote virtual deliberation among citizens, to facilitate experimenting with technology-supported (remote) voting and participation and encourage local/subsidiary governance structures [141].

Case Study: Participatory Budgeting "Stadtidee" (Zurich, Switzerland) [142]

The project called "Stadtidee" (city idea) was launched in 2021 as part of Zurich's Smart City Strategy as the first city-wide participatory budget of the City of Zurich. Between July and September 2021, residents of Zurich were invited to submit ideas for changes in the Zurich neighbourhood with a connection to climate, nature and children and youth. The ideas were submitted via an online participation platform based on the Open-Source-Software "Decidim" (from Barcelona), competing for the distribution of a total of 540'000 Swiss Francs. 167 ideas for Zurich were submitted as part of the project, of which 135 made it to the final selection and were later voted on. The winning ideas will be implemented in 2022. This democratic tool was not invented in Zurich. It was first tried out in Porto Alegre in Brazil in 1989. A similar procedure has also become established in many German cities under the term "participatory budgeting". In the meantime, most participatory budgets take place online: for example, Reykjavik after the 2008 financial crisis, Barcelona or Helsinki. In Switzerland, the city of Lausanne has also tried it out.

As mentioned in Chapter 1.2.3, recent findings indicate that for example, when novel participatory approaches such as citizen assemblies are incorporated into the policy cycle, the political feasibility of ambitious climate policies can be enhanced [31]. In line with the principles for successful participation listed above, the authors find that the effect depends on the design of the citizen assembly, and the level of public awareness and informedness about the procedure [31]. The importance of the linkages between meaningful data access and participation (Chapter 3.1.2.), cooperative and participatory data governance frameworks for sustainability (Chapter 3.1.3.), and inclusive co-developed approaches to enhance sustainability of food systems (Chapter 3.2.1) have been discussed earlier in the report.

The circular effects of democratic structures, civil participation, and trust. When it comes to successfully developing and implementing policies around technology and sustainability, we argue that another important factor is trust. Trust is generally considered to be an important component to democratic societies, which are relying on citizen's active participation in political processes. The link between trust and participation has been examined many times in literature, with different ways of operationalising trust and participation leading to inconclusive results. The form of trust most relevant for the success of environmental policies is probably best represented in the concept of generalized trust. The concept is described by Bäck and Christensen [143] as a

> "moral value based on shared identity and norms, [not depending on] personal experiences of specific people, but rather faith in the 'generalized other' and the feeling that 'most people can be trusted'. (…) Generalized trust (…) may get people involved in their communities as 'trusting people are more likely to join civic groups and have more social connections than people who don't trust others'" [143].

Trust might not only be a catalyst for participation, but also vice versa – with authors finding that nations exhibiting stable democracies show higher levels of trust, correlated with political activism [144]. Findings indicate that the relationship between trust and participation could also be different for institutionalised and non-institutionalised forms of participation: While political trust might lead to more active form of conventional participation such as voting, distrust in the political system and elite actors might motivate to participate more in elite-challenging, non-institutionalised forms of participation (e.g., signing a petition, or joining a demonstration) [145]. Furthermore, there is an important link between trust, participation and political (internal) efficacy, a concept describing a person's self-assessment of their capacities to understand and partake in the political process. To quote Hooghe/Marien [145]: "One's level of political trust is irrelevant, if one does not feel capable to participate."

"Trust bubbles" could encourage polarisation and hinder the sustainability agenda. Trust as a concept can also be regarded from a horizontal perspective – in our context among citizens – or from a vertical perspective – between citizens and the state, which is often termed "political trust" [146]. Horizontally, one can distinguish between a narrower notion of "ingroup/clan trust" and a broader and more demanding notion of "outgroup/societal trust" where an individual also trusts any randomly drawn co-citizen [147]. The latter is in line with the concept of generalized trust referred to above. This broader kind of societal/outgroup trust should provide a better foundation for more constructive (environmental) political processes, whereas strong ingroup trust alone can incite tensions between different groups and result in more polarized politics which stand in the way of constructive SDG-related policies [148]. Also, according to a recent study, intolerance against other groups is associated with increased climate skepticism [149]. Hence, If the expansion of digital technology augments societal divisions and reinforces ingroup communication and organizing, this could pose obstacles for the realization of a broad and civil political debate around the formulation of environmental policies and initiatives [150].

If truthful information is broadcast, digital technologies could foster trust. To the extent that digital technology promotes the generation, provision, and dissemination of factual measures and data that are widely accepted as truthful records, these technologies could foster broad-based societal trust. For instance, obtaining information in a decentralized manner using open-source platform – relying on sensor data from thousands of individual citizens and businesses can provide real-time estimation of air quality and outperform centralized sensors. Such platforms can allow for countrywide sensemaking at scale thereby facilitating community participation in environmental policy, potentially fostering mutual trust. Across the world, suites of ethical trustworthy technologies are emerging and being used (though in a limited overall manner at the moment) for movement building and social organising, including on key sustainability and socio-ecological justice issues and campaigns [151, 152]. In societies where public authorities are trusted by their citizens, the populace would more readily delegate and assign to the state a more active and guiding role in the transition and ultimately transformation towards a carbon-neutral society and economy [153]. In the top-down direction, if state authorities can rightfully expect that citizens are likely to follow (new) laws and regulations without costly enforcement being necessary, then the roll-out of environmental policy reform can be more easily achieved [154].

Case Study: Early Deforestation Alerts

The Amazon Rainforest is a crucial element of the world's ecosystem, containing incredible biodiversity while capturing 123 billion metric tons of carbon. While the indigenous people of the region have been supporting conservation efforts, e.g., by patrolling their home territories for logging and other illegal activities, rapid deforestation continues.
A recent study conducted in the Peruvian Amazon investigated whether deforestation rates could be reduced with the help of technology, equipping the local population with satellite-based "early deforestation alerts", allowing individuals to signal illegal activities to the authorities from a distance [155]. Participating in the program helped reduce tree cover loss (effects were stronger in the first year compared to the second year of the study) and the reductions were largest in communities facing more imminent threats. Over the course of the two years,

the communities patrolling with the help of satellite data averted the logging of an estimated 456 hectares (1,127 acres) of forest cover, preventing the release of more than 234,000 metric tons of CO_2 emissions. Consequently, the study showed that community monitoring of forests using satellite data and smartphone technology can help reduce Amazon deforestation and might also be an effective strategy elsewhere. It is important to note that for this approach to work, communities must have enough trust in state enforcement authorities to activate them in case of high threat intruders [156]. State capacity and determination might not be existent to a sufficient degree in every area. In the same vein, even if the program is successful, there is a risk of illegal activities shifting to less monitored parts of the forest.

3.4.3 Allocation of Resources

Allocating adequate resources to environmental issues is challenging. For climate change alone it is estimated that only about 20% of the required $2.4T annual investment is being made - and that is typically spent within the borders of wealthy countries [157]. Financial and other resources are required to build capacity, implement and maintain environmental initiatives and to monitor and evaluate environmental impacts and benefits. It is important therefore to develop policies and supporting digital capabilities to ensure that the right resources are brought to bear in the right way, at the right places and at the right time. This is the case whether directly addressing environmental issues or when seeking to minimise the environmental consequences of other investments or initiatives.

Valuing the Environment. The total environmental impact and the cost of protecting and maintaining the state of the environment is often not factored into investment modelling. Reasons for this include (1) climate and environmental-related factors are treated as externalities and therefore excluded from cost analyses of infrastructure projects, (2) environmental impacts of infrastructure projects and products are often felt well beyond the initial construction and operational phase of a project, (3) the cost of rehabilitating the environment may be underestimated or not costed at all, and (4) "whole of supply chain" environmental costs are not always accounted for (an good example of this is "Grey Energy" [158] - the total energy used to produce a product and its consequent environmental impact). An underlying cause of many of these reasons is a lack of clear responsibility for the environment or an assumption that it is "someone else's" responsibility. This is often referred to as the "tragedy of the commons", where the environment is a shared resource with no clear responsibilities defined to maintain it. "Living infrastructure resources"; our air and water are prime examples of this, although there are others. Fortunately, there are good examples of approaches to addressing these issues from which others can learn. Environmentally responsible reporting such as Volvo Cars whole of life cycle carbon reporting helps consumers make informed buying decisions [159]. Fisheries quota trading systems can ensure both sustainable wild fisheries and commercial prosperity [160]. In all these cases digital technologies and capabilities are necessary to measure, evaluate and monitor the effectiveness and impacts of projects, policies and other investments.

Resource Prioritisation. Governments have limited resources and must therefore ensure that resources used to solve environmental issues are allocated wisely. The use of objective data and analysis allows comparison of costs, benefits and impacts between competing projects. This becomes harder when faced with investment allocation across multiple sectors of an economy. For example, when comparing agricultural, industrial, transportation and energy infrastructure investments. Prioritisation of resources between countries is also difficult, particularly with global issues such as climate change. Mechanisms have been proposed where large emitters and countries with more resources help out smaller countries suffering from climate change: "Herefore, the rich countries, which are responsible for most of today's global environmental damage (e.g.,

CO_2 accumulation, ozone-shield damage), and whose material well-being can sustain halting or even reversing throughput growth, must take the lead in this respect" (Goodland, 1996, p. 1004). In both of the cases above it is important to identify standardised measures that allow comparison of the alternatives. One example is the use of Marginal Abatement Cost Curve [161] analysis to evaluate and compare the environmental benefits and cost of different decarbonisation investments across different sectors in an economy and potentially between countries.

Efficiency, Coordination and Collaboration. Governments cannot afford to be inefficient with the resources they do allocate to environmental issues. Collaboration between governments and with industry and the community can have productivity benefits in both the efficiency and effectiveness of allocated resources. Economies of scale can be realised when multiple countries or communities collaborate to solve common environmental issues with technological solutions. When environmental issues span borders, for example in many river systems, coordination between all users of the river in general provides better and more equitable outcomes for both the environment and the populations who rely on it. The effectiveness of resources can be maximised when actors in a collaboration contribute according to their strengths. For example, innovation collaborations between government, industry, community and academia bring a diverse range of capabilities together. This can be more effective than a single one of these actors working alone. The example of Mission Based Innovation, referred to in 3.4.6. later in this chapter, further highlights the importance of collaboration to both efficiency and capacity challenges.

Resource Availability. All countries can find it difficult to allocate adequate resources to the environment. Developing and less wealthy countries however find this particularly problematic and may not be able to address either local environmental issues or those issues they share with other countries. Also, for some shared issues it may be that the highest environmental benefit comes from investment in those countries with the least resources. In those cases, governments should explore how low-income countries, LDCs, SIDS, and related states can attract financing for critical projects that relate to environmental and/or infrastructure projects (see also Chapter 3.3.4. for related analysis of e-waste and developing countries). Digital technologies and infrastructure can play an important role in evaluating, implementing and monitoring approaches that address all of these resourcing challenges. help ensure that resources are allocated in the right way at the right time. The private sector is also playing an increasingly important role in providing technologies and knowledge to solve environmental issues.
The insurance and technology sectors are two examples of where companies have commercial interests in addressing environmental issues.

Case Study: Microsoft Climate Innovation Fund [162,163]

With the Climate Innovation Fund, Microsoft has launched an initiative in 2020 aimed at helping suppliers and customers around the world reduce their own carbon footprints and fund innovation to accelerate the global development of carbon reduction, capture, and removal technologies. According to Microsoft, funding in investments will be based on four criteria: Climate impact, underfunded markets, shared alignment and climate equity. The Climate Innovation Fund was launched in the context of Microsoft's commitment to be carbon negative by 2030, and to remove from the environment, by 2050, all the carbon the company has emitted either directly or by electrical consumption since it was founded in 1975. To reach these goals, Microsoft has launched a program to cut carbon emissions by more than half by 2030, both for direct emissions and for the entire Microsoft supply and value chain. This will be funded in part by expanding the internal carbon fee, in place since 2012 and increased in 2019.

3.4.4 Technology Interoperability and Standards

As described in this report, digital technologies can underpin our ability to recognize and respond to environmental issues. Environmental issues often span jurisdictional boundaries and require increased collaboration to resolve. Technology interoperability underpins the ability of the internet, telephone systems and email to function as globally connected systems. In the context of the environment and the common good, technology interoperability strengthens multi stakeholder collaboration by allowing stakeholders to communicate, share data and information. Other benefits of interoperability relate to technology development adoption. These include (1) avoiding duplication of effort in developing new systems - thus saving resources, and (2) speeding up technology adoption and “future proofing” technology investments by reducing obsolescence. Interoperability also plays an important role regarding other overarching issues such as enabling common value and goal creation, global ownership and transparency; improving quality and confidence in data and digital systems and those who use them helps build trust and participation. Technology Standards are generally defined by international bodies according to the type of technology concerned. Examples include internet communications, cellular networks, environmental monitoring, data sharing, supply chain data exchange, etc. Standards are continually being developed to cater for new technologies and new societal needs. Standardisation reduces costs by reducing duplication of effort and the need to build technology components to interface otherwise incompatible systems. Where possible build on existing projects, initiatives, organisations and technologies. Increased and more widespread adoption of existing approaches reduces costs to establish new approaches and drives interoperability. The important role of international standards for environmental data and harmonisation thereof (Chapter 3.1.1.), for transparency and traceability in all supply chains of ICTs (Chapter 3.3.2.), and to improve e-waste management and guide the implementation of circularity across the ICT supply chain (Chapter 3.3.3.) have been discussed in detail earlier in this report.

Standards may lag innovation. Innovators and early adopters will deploy new and somewhat immature technologies to obtain some direct benefit. They do this knowing that standards may lag new technology development by up to several years. There are several ways to obtain the immediate benefits of the new technology while also getting some of the benefits that standards bring. These include using temporary “bridging technologies”, “de-facto” standards and budgeting for technology updates when standards and standardised products become available.

Competing standards can co-exist. In many cases there will be a single standard that is universally used by all participants. Although this is the ideal situation it is not always possible. Different countries and industrial participants may have different emphasis and perspectives for historical or commercial reasons. This can become an inhibitor to interoperability and cooperation in cross jurisdictional initiatives. If multiple, competing standards apply, then select those that enable interoperability in the situations and between the relevant jurisdictions. Although not ideal, harmonisation or bridging approaches can be developed to achieve interoperability between competing standards.

Standards need to be inclusive - both in development and adoption. Participation by member states in standards setting bodies helps ensure that those standards are “fit for purpose” for local conditions. This however requires commitment of resources that not all countries can afford. Countries with more resources need to make deliberate efforts to include and support the needs of all countries including those with less resources. Increasing adoption of standards can be done by promoting standards use, encouraging open access to standards and requiring standards compliance as part of procurement processes. This enables participation of broad stakeholders without large means and enhances transparency and trust.

3.4.5 Capacity Building

In the context of environmental issues, capacity represents the ability for individuals, institutions and communities to undertake programs and create meaningful improvements in environmental outcomes. Governments have a role to play in building each of these types of capacity. Capacity building in the context of environmental data has been addressed earlier in this report in Chapter 3.1.3.

Individual Capacity is the ability for individuals to make meaningful contributions to not only their own life but also to the environmental and other issues affecting the communities in which they live. Individual capacity is a combination of personal skills, empowerment and the motivation to engage with important issues. In the digital age, digital literacy is a core enabling skill for individuals. Governments must therefore foster digital literacy at all levels from children through to adults (both vocational and tertiary education). An important point is that digital literacy is more than technical skills - it includes the human aspects of technology such as needs analysis and user experience design. Equitable and affordable access to internet technologies and infrastructure is a necessary enabler of individual capacity.

Institutional Capacity is the ability for institutions to recognise or pre-empt environmental issues and put in place appropriate policies, processes and infrastructure. Governments have a range of tools at their disposal - funding, regulation, policy and leadership can all play a role. As with individual capacity, digital "literacy" in organisations is important and is manifested as evidence-based decision-making cultures, processes and programs that use digital technologies to analyse, measure, track and report on issues and responses. Staying current with new technologies such as machine learning, artificial intelligence is necessary and requires ongoing commitment. In recent years, "mission based" innovation programs such as those described by Prof. Mariana Mazzucato [32] have been put forward as approaches that governments can use to address public good issues. These programs focus on outcomes and position the government as a leader that can frame problems and opportunities in terms of desired outcomes. Individuals and private enterprises can then propose innovative approaches. Commercial outcomes, jobs growth and further capacity building in industry and non-government organisations are additional benefits of these programs.

Societal capacity is an extension or combination of individual and institutional capacities together with supporting infrastructure. In this context it is the ability for a community to recognise and deal with environmental issues relevant to that community. As societal capacity grows there is a change in the relationship between government and the community such that each provides resources and leadership on environmental issues according to their strengths. The supporting infrastructure can be digital infrastructure such as accessible internet services or "CivicTech"-platforms that enable community participation (see for example the case study on Participatory Budgeting in 3.4.3). By sponsoring community-based initiatives focusing on local environmental issues, governments can help build capabilities within communities.

Capacity building takes time, and needs resources, but it's worth it. Capacity building is of course over different timescales - from short term in response to immediate needs to generational timescale in the case of youth skills development and large-scale societal capacity building. Governments must recognise therefore that sustained investment in long term capacity building programs will achieve the greatest impact. Governments have a role in building and supporting capacity in all three of these areas and should realise there are direct benefits for governments in doing this. Governments have limited resources. Building capacity in communities and industry provides greater opportunity to leverage government investments in environmental programs. Over time it is possible to shift some functions to communities and take pressure off government resources. Digital technologies and infrastructure are required to build and enable capacity. Examples include communications infrastructure, data sharing and performance measurement systems. If implemented well, these technologies increase reach, productivity and impact of capacity building initiatives. Adding to that, it is important that less developed countries and individuals receive the necessary assistance in building capacity. This is important not just for addressing local issues but also shared environmental issues (e.g., e-waste).

Case Study: Public participation in Tiritiri Matangi Island project [164]

Tiritiri Matangi Island has attained an international profile as a successful ecological restoration project and is often cited as a model of environmental stewardship. Ecological restoration on the island has always involved, and been dependent on, voluntary public involvement. The Tiritiri Matangi Island project is an example of how public participation not only reinforces existing links between the public and scientific communities, but also facilitates even greater understanding of ecological concepts outside the professional and academic worlds. Enhanced ecological advocacy, ecological research and biodiversity management are cited as outcomes of the collaborative involvement among the island's stakeholders, ultimately leading to the development of a 'public ecology'.

Based on the overarching issues identified in this report, we would like to propose three recommendations relating to digital technologies and environmental issues, spanning multiple aspects of this report. Because the overarching issues are all seen to be interlinked (think back to Fig. 9), we prefer to deliver the recommendations all in one section instead of individually.

3.4.6 Policy Recommendation #1

> Increase Inclusivity for individuals and communities

According to ITU, an estimated 37 per cent of the world's population – or 2.9 billion people – have still never used the Internet (ITU, 2021). If we count on realising digitalisation's promises and for them to be of use in tackling urgent environmental issues, we need to make sure that access to digital resources and skills are globally distributed, and enable everyone to partake. Inclusivity is necessary when developing policies and working with new digital technologies and tools not only at an individual level, but at the level of communities and even countries too. Specific actions that could be taken include, for example:

investments in digital literacy (see also Chapter 3.1. on Environmental Data on the importance of capacity building);

implementing policies to ensure digital infrastructure is available to all;

promoting open-source software, open data, common service obligations and net neutrality for communications infrastructures.

In this context, wealthy countries are encouraged to commit to building digital capabilities that can also be adopted by and transferred to others.

3.4.7 Policy Recommendation #2

> Use data and digital technologies to foster evidence-based decision-making, ideally including participatory governance approaches.

As described in previous chapters, the availability of data and digital technologies are enablers of employing increasingly sophisticated analytical, modelling and reporting technologies. It is suggested to invest in (policy-relevant) data collection where additional data is needed. This can be helpful in supporting decision-making based on evidence - using objective data to evaluate and monitor the environmental impacts of policies and investments (also relates to the issue of standards/standardisation, discussed especially in Chapter 3.1 and 3.3). Provided however, the necessary capabilities to read, interpret and make sense of the data to come to a decision are available (referring back to the recommendation made in Chapter 3.1.2). Of course, in the spirit of what was emphasised in previous chapters, a participatory governance is recommended: Not only the traditional (state-level) decision-makers can benefit from the support of these tools, but they can also be used for multistakeholder decision-making or consultation, providing structure to otherwise very complex processes. That way, decisions can be taken based on science and evidence, while allowing a wide range of actors to participate. An idea is to pilot test digital tools for reducing barriers for diverse societal stakeholders to voice their preferences, which can be a measure to counterbalance vested interests favoring status quo and non-sustainable practices. Enabling citizen participation can potentially have positive effects on optimal resource allocation, if subsidiary principles are applied and environmental investments are tailored to local contexts. Integrating citizens can help identify what the local capacity-building needs are. Finally, participatory processes are also expected to be trust-building (under the right circumstances), potentially constituting a valuable basis for the successful implementation of swift environmental reforms.

3.4.8 Policy Recommendation #3

Experiment with new approaches

As the environmental situation we are currently in is looking to be quite dire, rapid solutions by the global community to stop - or at least slow down climate change - are required. Because of the need to act urgently, and possibly in new ways, agile approaches are suited best. Meaning we need to be designing and implementing policies and initiatives quickly and understand that they might need adjustment as experience is gained. What might seem obvious but still needs to be emphasised: In the context of ever evolving and new attractive tools, both these new approaches employed and the effectiveness of decision-making overall need to be evaluated routinely. This requires performance monitoring and feedback loops, based on the collection and evaluation of data, and the use of measurable leading and lagging indicators. To achieve target goals, exchange of information and experiences should also be encouraged to take place across and between governance units, with the possibility of using benchmark indicators to compare progress. Finally, existing tools for performance monitoring and citizen feedback should also be made use of.

Conclusion

With this report, the 2021 established Policy Network on Environment and Digitalisation proposes 15 policy recommendations aimed at reducing the environmental impact of digitalisation and or using digitalisation to tackle environmental challenges. The recommendations are sorted thematically in four chapters: Environmental Data, Food & Water Systems, Supply Chain Circularity and Transparency, and Overarching Issues. In these concluding remarks we will not repeat the entire thought processes that have led the authors to provide the specific recommendations, but rather focus on the recurring themes. Finally, we will provide comments on what next steps with the policy recommendations that are proposed in this report could look like.

International standards play an essential role in using ICT to promote sustainability as well as improving the sustainability of ICT. The necessity for international standards has been highlighted with regard to environmental data, where the authors describe how data from different sources are often not openly accessible or in a standardised format that allows for easy consolidation, comparison, and use. Implementing data governance principles that take into account important ethical considerations (following the FAIR and CARE principles) could foster data practices that make more data widely and equitably available and be used to inform effective evidence-based decision-making. Importantly, these standards should have a global reach and be internationally harmonised. In terms of Food & Water, the authors highlight especially health and transparency standards as an important element accompanying the constructive use of new technologies (e.g., Blockchain). Standards are also essential in creating increased transparency and traceability in ICT supply chains, in improving e-waste management and in guiding the implementation of circularity across the ICT supply chain, e.g., by enhanced co-design standards. In this context, the authors stress that true circular design goes beyond current eco-design standards traditionally focused only on improved energy efficiency of ICT, by addressing both energy and material efficiency (e.g., durability, reparability/refurbishment, recycling). Such standards could be developed by states voluntarily through standards developing organisations such as the ISO (International Standards Organizations) or ITU (International Telecommunication Union), or in a multilateral forum. Ideally, the proposed standards will result in environmental, human rights, and financial benefits, while spurring the innovation needed to address the global challenges present in all supply chains today.

We are under pressure to rapidly find solutions. Overall, this report is contextualised by a sense of urgency: UN scientists have sounded “code red for humanity”, warning that the climate will heat up beyond 1.5 degrees Celsius within the next 20 years. Faced with the harrowing realities of anthropogenic climate change; global warming, overall biodiversity loss and increasing pollution, the global community needs to act, and act rapidly. While digitalisation is currently part of the problem - advancing and contributing to climate change with its increasing environmental footprint - it can be part of the solution too, if done right. For example, digitalisation and environmental data can support policymakers in quick(er) and more effective decision-making when it comes to environmental issues. For this to happen, an agile approach to projects and the ability to quickly assess new information and adjust the path as needed is paramount.

Participatory and multistakeholder approaches should be encouraged, making investments in capacity building necessary. At the same time, the need for speed and efficiency needs to be balanced with the importance of stakeholder participation and inclusivity - another recurring theme in this report. Regarding Environmental Data, the important linkages between meaningful data access and participation are emphasised; with global standardisation and harmonisation requiring the inclusion of multiple stakeholders. For Food & Water, inclusive co-developed approaches to enhance sustainability of food systems are a focal point of discussion. In policymaking, ICT can be used to promote virtual deliberation among citizens, to facilitate experimenting with technology-supported (remote) voting and participation and encourage local / subsidiary governance structures. While broad stakeholder inclusion might slow a decision-making process down in some ways, it can pay off later: recent research indicates that participatory approaches such as citizen assemblies can increase the political feasibility of ambitious climate policies.

However, the best laid out participatory processes will be ineffective if stakeholders lack capacities - there needs to be sufficient resources and facilities to support contributions by multiple stakeholders, especially those with limited resources in skills and technologies. Capacity building should take into account the ability of individuals (individual capacity), institutions (institutional capacity) as well as communities (societal capacity) to undertake programs and create meaningful improvements in environmental outcomes. Governments have a role to play in building each of these types of capacity - ensuring concerted capacity building efforts on the fundamentals such as digital and data literacy as well as the provision of access to reliable and fast communication and Internet infrastructure. More can be done to make climate data available in an appropriate format whether through layman interpretation or actionable insights for those with less data literacy. Governments and related actors should develop policy that supports learning about data and governance as part of the educational curriculum. It is thus recommended to pay special attention to youth, focussing on the facilitating of youth participation in environmental dialogue and processes.

As a next step, the recommendations can be developed into concrete actions and context-specific instruments. Following this report, all stakeholders are encouraged to reflect on actions that can be derived from the recommendations, and possible instruments to implement them. Returning to the quote in Chapter 1 on Environmental Policymaking: "It is not necessarily a matter of developing new tools and instruments but designing a 'mix' of policy instruments that is best suited to the circumstance" [23]. These circumstances depend on cultural, economic, environmental, and political context factors, as well as the capacities available to institutions or individuals targeted by the policy measure. And again, since new policies require the cooperation of many different stakeholders, the participation of these stakeholders in the policymaking process is key.

Finally, a note on leadership. Regarding tackling urgent environmental challenges, poor (international) leadership and lack of courage is oftentimes lamented. However, leadership does not have to come only from global leaders but can just as well originate from grassroot and local role models, supported by vibrant civic associations and highly active and engaged individuals. Digitalisation has brought us the tools and technologies necessary to connect these otherwise smaller civic actors with each other and with actors from the private sector - another valuable source of knowhow and financial capacities needed to bring about systemic change. By doing so, these actors can develop into a true global community that facilitates knowledge and resource sharing - the building blocks of a more sustainable future for all of us.

References

[1] IPCC. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2021.

[2] Lange S, Santarius T. Smarte grüne Welt?: Digitalisierung zwischen Überwachung, Konsum und Nachhaltigkeit. München: oekom verlag; 2018.

[3] International Energy Agency. Digitalization and Energy; 2017.

[4] Bordage F. The Environmental Footprint of the Digital World; 2019.

[5] Andrae A, Edler T. On Global Electricity Usage of Communication Technology: Trends to 2030. Challenges 2015;6(1):117–57. doi:10.3390/challe6010117. Available from: <https://giswatch.org/sites/default/files/gisw2020-th-cireco.pdf>.

[6] Forti, Vanessa, Baldé, Cornelis P., Kuehr R, Bel G. The Global E-Waste Monitor 2020: Quantities, flows, and the circular economy potential. Bonn/Geneva/Rotterdam; 2020.

[7] Barbier EB. The Concept of Sustainable Economic Development. Environmental Conservation 1987;14(2):101–10. Available from: <http://www.jstor.org/stable/44519759>.

[8] Going Digital: Shaping Policies, Improving Lives: OECD; 2019.

[9] Mergel I, Edelmann N, Haug N. Defining digital transformation: Results from expert interviews. Government Information Quarterly 2019;36(4):101385. doi:10.1016/j.giq.2019.06.002. Available from: <https://www.sciencedirect.com/science/article/pii/S0740624X18304131>.

[10] Cordella A, Paletti A. ICTs and value creation in public sector: Manufacturing logic vs service logic. IP 2018;23(2):125–41. doi:10.3233/IP-170061. Available from: <https://content.iospress.com/articles/information-polity/ip170061>.

[11] Bannister F, Connolly R. ICT, public values and transformative government: A framework and programme for research. Government Information Quarterly 2014;31(1):119–28. doi:10.1016/j.giq.2013.06.002. Available from: <https://www.sciencedirect.com/science/article/pii/S0740624X13001184>.

[12] Purvis B, Mao Y, Robinson D. Three pillars of sustainability: in search of conceptual origins. Sustain Sci 2019;14(3):681–95. doi:10.1007/s11625-018-0627-5. Available from: <https://link.springer.com/article/10.1007/s11625-018-0627-5>.

[13] Edmund A. Spindler. The History of Sustainability The Origins and Effects of a Popular Concept. In: Sustainability in Tourism; 2013, p. 9–31.

[14] Meadows DH, Meadows D, Randers J, Behrens W, Club of Rome. The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind. New York: Universe Books; 1972.

[15] Passell,Marc, ByPeter. The Limits to Growth. The New York Times 1972, 2 April 1972. Available from: <https://www.nytimes.com/1972/04/02/archives/the-limits-to-growth-a-report-for-the-club-of-romes-project-on-the.html>. [December 23, 2021].

[16] Lomborg B, Rubin O. The Dustbin of History: Limits to Growth. Foreign Policy 2009, 9 November 2009. Available from: <https://foreignpolicy.com/2009/11/09/the-dustbin-of-history-limits-to-growth/>. [December 23, 2021].

[17] Turner GM. A comparison of The Limits to Growth with 30 years of reality. Global environmental change human and policy dimensions 2008;18(3):397–411. doi:10.1016/j.gloenvcha.2008.05.001. Available from: <https://www.sciencedirect.com/science/article/pii/S0959378008000435>.

[18] World Commission on Environment and Development. Our Common Future: Report of the World Commission on Environment and Development. Available from: <https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

[19] United Nations (ed.). Resolution adopted by the General Assembly on 16 September 2005: 60/1. 2005 World Summit Outcome; 2005.

[20] UNDP. Sustainable Development Goals. Available from: <https://www.undp.org/sustainable-development-goals>.

[21] Goodland R. The Concept of Environmental Sustainability. Annual Review of Ecology and Systematics 1995;26:1–24. Available from: <http://www.jstor.org/stable/2097196>.

[22] Encyclopedia Britannica. environmental policy | History, Concepts, Instruments, & Examples. Available from: <https://www.britannica.com/topic/environmental-policy>.

[23] Cocklin C. Environmental Policy. In: Kitchin R, Thrift N, editors. International Encyclopedia of Human Geography. Oxford: Elsevier; 2009, p. 540–545.

[24] Korab-Karpowicz WJ. The United Citizens Organization: Public-private partnerships in global governance; 2020.

[25] Circular Tech. Module 10: An introduction to environmental rights as an advocacy framework. Available from: <https://circulartech.apc.org/books/a-guide-to-the-circular-economy-of-digital-devices/page/module-10-an-introduction-to-environmental-rights-as-an-advocacy-framework>.

[26] Kaul I. Providing global public goods managing globalization. Oxford: Oxford Univ. Press; 2004. Available from: <http://worldcatlibraries.org/wcpa/oclc/177339632>.

[27] United Nations. Secretary-General's Roadmap for Digital Cooperation; 2020.

[28] Raworth K. A Safe and Just Space for Humanity: Can we live within the doughnut? Available from: <https://www-cdn.oxfam.org/s3fs-public/file_attachments/dp-a-safe-and-just-space-for-humanity-130212-en_5.pdf>.

[29] Stoker G. Governance as theory: five propositions. International Social Science Journal 2018;68(227-228):15–24. doi:10.1111/issj.12189.

[30] Coenen, Frans H. J. M., Huitema D, O'Toole LJ. Participation and Environment. In: Coenen, Frans H. J. M., Huitema D, O'Toole LJ, editors. Participation and the Quality of Environmental Decision Making. Dordrecht: Springer Netherlands; 1998, p. 1–20.

[31] Kuntze L, Fesenfeld LP. Citizen assemblies can enhance political feasibility of ambitious climate policies; 2021.

[32] Mazzucato M. Mission economy: A moonshot guide to changing capitalism. London: Allen Lane an imprint of Penguin Books; 2021.

[33] Clark WC, Harley AG. Sustainability Science: Toward a Synthesis. Annu. Rev. Environ. Resour. 2020;45(1):331–86. doi:10.1146/annurev-environ-012420-043621.

[34] Statista. Number of mobile devices worldwide 2020-2025. Available from: <https://www.statista.com/statistics/245501/multiple-mobile-device-ownership-worldwide/>.

[35] Microsoft Garage. FarmBeats. Available from: <https://www.microsoft.com/en-us/garage/wall-of-fame/farmbeats/>.

[36] Kranert M, Baron M, Behnsen A, Bidlingmaier W, Cimatoribus C, Clauß D et al. Einführung in die Kreislaufwirtschaft: Planung -- Recht -- Verfahren / Martin Kranert, Mechthild Baron, Andreas Behnsen, Werner Bidlingmaier, Carla Cimatoribus, Detlef Clauß, Heinz-Josef Dornbusch, Katherina Eckstein, Nicolas Escalante, Martin Faulstich, Alexander Feil, Klaus Fischer, Sabine Flamme, Anna Fritzsche, Bernhard Gallenkemper, Gerold Hafner, Kai Hillebrecht, Julia Hobohm, Hans-Dieter Huber, Martin Kranert, Kerstin Kuchta, Paul Laufs, Thomas Pretz, Martin Reiser, Gerhard Rettenberger, Manfred Santjer, Jan Henning Seelig, Helmut Seifert, Erwin Thomanetz, Jürgen Vehlow, Torsten Zeller. Wiesbaden: Springer Vieweg; 2017.

[37] APC. Global Information Society Watch 2020: Technology, the Environment and a Sustainable World: Responses from the Global South.

[38] European Commission. A new Circular Economy Action Plan for a Cleaner and More Competitive Europe: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels; 2020.

[39] International Energy Agency. Data Centres and Data Transmission Networks – Analysis. Available from: <https://www.iea.org/reports/data-centres-and-data-transmission-networks>.

[40] Jones N. How to stop data centres from gobbling up the world's electricity. Nature 2018;561(7722):163–6. doi:10.1038/d41586-018-06610-y. Available from: <https://www.nature.com/articles/d41586-018-06610-y>.

[41] Digital economy growth and mineral resources: implications for developing countries. Available from: <https://unctad.org/system/files/official-document/tn_unctad_ict4d16_en.pdf>.

[42] Oberle B, Bringezu S, Hatfield-Dodds S. Global Resources Outlook 2019: Natural Resources for the Future We Want.

[43] Krausmann F, Lauk C, Haas W, Wiedenhofer D. From resource extraction to outflows of wastes and emissions: The socioeconomic metabolism of the global economy, 1900-2015; 2018.

[44] Optoro. Returns Report: Powering Resilient Retail in 2020; 2021.

[45] Howard AJ, Baron Z, Kaplan K. Transformation of an Industry: A History of Energy Efficiency in Televisions. ACEEE Summer Study on Energy Efficiency in Buildings 2012. Available from: <https://www.aceee.org/files/proceedings/2012/data/papers/0193-000292.pdf>.

[46] Łucja Waligóra. The problem of energy efficiency, known as the Jevons paradox. undefined 2019. Available from: <https://www.semanticscholar.org/paper/The-problem-of-energy-efficiency%2C-known-as-the-Walig%C3%B3ra/

[47] Wilkinson MD, Dumontier M, Aalbersberg IJJ, Appleton G, Axton M, Baak A et al. The FAIR Guiding Principles for scientific data management and stewardship. Scientific data 2016;3:160018. doi:10.1038/sdata.2016.18. Available from: <https://www.nature.com/articles/sdata201618.pdf>.

[48] Research Data Alliance International Indigenous Data Sovereignty Interest Group. CARE Principles for Indigenous Data Governance; 2019.

[49] Carroll SR, Herczog E, Hudson M, Russell K, Stall S. Operationalizing the CARE and FAIR Principles for Indigenous data futures. Sci Data 2021;8(1):108. doi:10.1038/s41597-021-00892-0. Available from: <https://www.nature.com/articles/s41597-021-00892-0>.

[50] European Commission. Aarhus Convention. Available from: <https://ec.europa.eu/environment/aarhus/>.

[51] United Nations. Escazu Agreement: Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean. Available from: <https://www.cepal.org/en/escazuagreement>.

[52] Mosconi G, Li Q, Randall D, Karasti H, Tolmie P, Barutzky J et al. Three Gaps in Opening Science. Comput Supported Coop Work 2019;28(3-4):749–89. doi:10.1007/s10606-019-09354-z. Available from: <https://link.springer.com/content/pdf/10.1007/s10606-019-09354-z.pdf>.

[53] Oliver JL, Brereton M, Watson DM, Roe P. Listening to Save Wildlife. In: Harrison S, Bardzell S, Neustaedter C, Tatar D, editors. Proceedings of the 2019 on Designing Interactive Systems Conference. New York, NY, USA: ACM; 06182019, p. 1335–1348.

[54] Oliver JL, Brereton M, Turkay S, Watson DM, Roe P. Exploration of Aural & Visual Media About Birds Informs Lessons for Citizen Science Design. In: Wakkary R, Andersen K, Odom W, Desjardins A, Petersen MG, editors. Proceedings of the 2020 ACM Designing Interactive Systems Conference. New York, NY, USA: ACM; 07032020, p. 1687–1700.

[55] Lahoz-Monfort JJ, Chadès I, Davies A, Fegraus E, Game E, Guillera-Arroita G et al. A Call for International Leadership and Coordination to Realize the Potential of Conservation Technology. BioScience 2019;69(10):823–32. doi:10.1093/biosci/biz090.

[56] OS-Climate. OS-Climate at COP26. Available from: <https://os-climate.org/>.

[57] Digital Public Goods Alliance. DPG Registry. Available from: <https://digitalpublicgoods.net/registry/>.

[58] Our World in Data. Our World in Data. Available from: <https://ourworldindata.org/about>.

[59] CODES. A Digital Planet for Sustainability: In support of the UN Secretary General's Roadmpa on Digital Cooperation. Draft Version; 2021.

[60] Global Partnership for Sustainable Development Data. Global Partnership for Sustainable Development Data. Available from: <https://www.data4sdgs.org/>.

[61] UNEP. World Environment Situation Room: Data, Information and Knowledge on the Environment. Available from: <https://data.unep.org/>.

[62] African Development Bank Group. Environment and Climate Change Data Portal: Data Repository. Available from: <https://africaclimate.opendataforafrica.org/>.

[63] Collaboratory for Indigenous Data Governance. Collaboratory for Indigenous Data Governance: Research, Policy, and Practice for Indigenous Data Sovereignty. Available from: <https://indigenousdatalab.org/>.

[64] The Datasphere. Datasphere Initiative. Available from: <https://www.thedatasphere.org/>.

[65] Ceccaroni L, Bibby J, Roger E, Flemons P, Michael K, Fagan L et al. Opportunities and Risks for Citizen Science in the Age of Artificial Intelligence. Citizen Science: Theory and Practice 2019;4(1). doi:10.5334/cstp.241. Available from: <https://theoryandpractice.citizenscienceassociation.org/articles/10.5334/cstp.241/>.

[66] UNESCO. UNESCO Recommendation on Open Science; 2021. Available from: <https://en.unesco.org/science-sustainable-future/open-science/recommendation>. [December 22, 2021].

[67] Fritz S, See L, Carlson T, Haklay M, Oliver JL, Fraisl D et al. Citizen science and the United Nations Sustainable Development Goals. Nat Sustain 2019;2(10):922–30. doi:10.1038/s41893-019-0390-3. Available from: <https://www.nature.com/articles/s41893-019-0390-3.pdf>.

[68] Fraisl D, Campbell J, See L, Wehn U, Wardlaw J, Gold M et al. Mapping citizen science contributions to the UN sustainable development goals. Sustain Sci 2020;15(6):1735–51. doi:10.1007/s11625-020-00833-7. Available from: <https://unece.org/sites/default/files/2021-08/ECE_MP.PP_2021_20_E.pdf>.

[69] UNECE. Content of the Convention. Available from: <https://unece.org/environment-policy/public-participation/aarhus-convention/content>.

[70] United Nations. Our Common Agenda: Report of the Secretary-General. New York; 2021.

[71] UNEP. Third Global Session of the UN Science Policy Business Forum on the Environment. Available from: <https://www.unep.org/events/online-event/third-global-session-un-science-policy-business-forum-environment>.

[72] United Nations Economic Commission for Africa (ed.). Climate Research for Development in Africa (CR4D) Side-Event: Highlight Research Outputs from the CR4D Postdoc Fellowship; 2021.

[73] United Nations. Food Systems Summit 2021. Available from: <https://www.un.org/en/food-systems-summit/about>.

[74] CIAT. Sustainable Food Systems. 2017. Available from: https://ciat.cgiar.org/about/strategy/sustainable-food-systems/

[75] United Nations Treaty Collection. 3. International Covenant on Economic, Social and Cultural Rights. Available from: <https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=IV-3&chapter=4>.

[76] UNDESA. International Decade for Action 'Water for Life' 2005-2015. Available from: <https://www.un.org/waterforlifedecade/human_right_to_water.shtml>.

[77] FAO, IFAD, UNICEF, WFP and WHO. In Brief to The State of Food Security and Nutrition in the World 2021: Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All. Rome: FAO, IFAD, UNICEF, WFP and WHO.

[78] WHO. Drinking-water: Key facts. Available from: <https://www.who.int/news-room/fact-sheets/detail/drinking-water>.

[79] FAO. FAOSTAT: Emissions shares. Available from: <https://www.fao.org/faostat/en/#data/EM/visualize>.

[80] Tubiello FN, Karl K, Flammini A, Gütschow J, Obli-Layrea G, Conchedda G et al. Pre- and post-production processes along supply chains increasingly dominate GHG emissions from agri-food systems globally and in most countries. Earth System Science Data Discussions 2021:1–24. doi:10.5194/essd-2021-389. Available from: <https://essd.copernicus.org/preprints/essd-2021-389/>.

[81] Crippa M, Solazzo E, Guizzardi D, Monforti-Ferrario F, Tubiello FN, Leip A. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat Food 2021;2(3):198–209. doi:10.1038/s43016-021-00225-9. Available from: <https://www.nature.com/articles/s43016-021-00225-9>.

[82] UNEP. Global Environment Outlook 6; 2019.

[83] United Nations World Water Assessment Programme (WWAP). The United Nations World Water Development Report 2017: Wastewater: The Untapped Resource. Paris: Unesco; 2017.

[84] Boretti A, Rosa L. Reassessing the projections of the World Water Development Report. npj Clean Water 2019;2(1):1–6. doi:10.1038/s41545-019-0039-9. Available from: <https://www.nature.com/articles/s41545-019-0039-9>.

[85] Downs SM, Fox EL. Uneven decline in food system inequality. Nat Food 2021;2(3):141–2. doi:10.1038/s43016-021-00247-3. Available from: <https://www.nature.com/articles/s43016-021-00247-3.pdf>.

[86] 2020 Global Nutrition Report. Action on equity to end malnutrition. Bristol, UK; 2021.

[87] Barrett CB, Benton TG, Cooper KA, Fanzo J, Gandhi R, Herrero M et al. Bundling innovations to transform agri-food systems. Nat Sustain 2020;3(12):974–6. doi:10.1038/s41893-020-00661-8. Available from: <https://www.nature.com/articles/s41893-020-00661-8.pdf>.

[88] Asseng S, Palm CA, Anderson JL, Fresco L, Sanchez PA, Asche F et al. Implications of new technologies for future food supply systems. J. Agric. Sci. 2021;159(5-6):315–9. doi:10.1017/S0021859621000836. Available from: <https://www.cambridge.org/core/services/aop-cambridge-core/content/view/55181A3B0B5248767BF88C4D33457E89/S0021859621000836a.pdf/implications-of-new-technologies-for-future-food-supply-systems.pdf>.

[89] Herrero M, Thornton PK, Mason-D'Croz D, Palmer J, Benton TG, Bodirsky BL et al. Innovation can accelerate the transition towards a sustainable food system. Nat Food 2020;1(5):266–72. doi:10.1038/s43016-020-0074-1. Available from: <https://www.nature.com/articles/s43016-020-0074-1>.

[90] G20 Research Group. G20 Meetings of Agriculture Ministers. Available from: <http://www.g20.utoronto.ca/agriculture/>.

[91] Federal Ministry of Food and Agriculture. Global Forum for Food and Agriculture 2019: Agriculture Goes Digital - Smart Solutions for Future Farming. Summary of the Results; 2019.

[92] FAO. Realizing the Potential of Digitalization to Improve the Agri-Food System: Proposing a New International Digital Council for Food and Agriculture. A Concept Note. Rome; 2020.

[93] FAO. International Platform for Digital Food and Agriculture can bring huge benefits to the sector, high-level panel says. Available from: <https://www.fao.org/news/story/en/item/1338985/icode/>.

[94] Barrett CB, Benton TG, Cooper KA, Fanzo J, Gandhi R, Herrero M et al. Bundling innovations to transform agri-food systems. Nat Sustain 2020;3(12):974–6. doi:10.1038/s41893-020-00661-8. Available from: <https://www.nature.com/articles/s41893-020-00661-8>.

[95] FAO. Water for Sustainable Food and Agriculture: A Report produced for the G20 Presidency of Germany. Rome; 2017.

[96] Campbell, Amanda, Woodley, Nathan. Opinion: Satellites as a powerful tool in managing global land use. Devex 2021, 26 November 2021. Available from: <https://www.devex.com/news/sponsored/opinion-satellites-as-a-powerful-tool-in-managing-global-land-use-101950>. [December 23, 2021].

[97] Johnson K. Satellite Data Aids Rapid Response, Food Security for Kenya’s Farmers. Available from: <https://agrilinks.org/post/satellite-data-aids-rapid-response-food-security-kenyas-farmers>.

[98] Carbon Brief. Mapped: How climate change affects extreme weather around the world. Carbon Brief 2021, 25 February 2021. Available from: <https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world>. [December 23, 2021].

[99] Hamdi M, Rehman A, Alghamdi A, Nizamani MA, Missen MMS, Memon MA. Internet of Things (IoT) Based Water Irrigation System. International Journal of Online & Biomedical Engineering 2021;17(5):69–80.

[100] N. Kedia. Water quality monitoring for rural areas- a Sensor Cloud based economical project. In: 2015 1st International Conference on Next Generation Computing Technologies (NGCT); 2015, p. 50–54.

[101] Broering A, Niedermeier C, Olaru I, Schopp U, Telschig K, Villnow M. Toward Embodied Intelligence: Smart Things on the Rise. Computer 2021;54(7):57–68. doi:10.1109/MC.2021.3074749.

[102] Stankovic M, Hasanbeigi A, Neftenov N. Use of 4IR Technologies in Water and Santitation in Latin America and the Caribbean: Technical Note IDB-TN-1910; 2020.

[103] DPRI. Wadi Flash Floods: Challenges and Advanced Approaches for Disaster Risk Reduction. Kyoto; 2021.

[104] Ward PJ, Ruiter MC de, Mård J, Schröter K, van Loon A, Veldkamp T et al. The need to integrate flood and drought disaster risk reduction strategies. Water Security 2020;11:100070. doi:10.1016/j.wasec.2020.100070. Available from: <https://www.sciencedirect.com/science/article/pii/S2468312420300109>.

[105] De A, Upadhyaya DB, Thiyaku S, Tomer SK. Use of Multi-sensor Satellite Remote Sensing Data for Flood and Drought Monitoring and Mapping in India. In: Kolathayar S, Pal I, Chian SC, Mondal A, editors. Civil Engineering for Disaster Risk Reduction. Singapore: Springer Singapore; 2022, p. 27–41.

[106] Fasihi S, Lim WZ, Wu W, Proverbs D. Systematic Review of Flood and Drought Literature Based on Science Mapping and Content Analysis. Water 2021;13(19):2788. doi:10.3390/w13192788. Available from: <https://www.mdpi.com/2073-4441/13/19/2788>.

[107] 4FLUID. Soluções 4Fluid – Stattus4. Available from: <https://stattus4.com/solucoes-4fluid/>.

[108] Our World in Data. Agriculture value added per worker. Available from: <https://ourworldindata.org/grapher/agriculture-value-added-per-worker-wdi?tab=chart&country=OWID_WRL~CHN~IND~IDN~BEN~BWA~MWI~CMR~NER~NGA>.

[109] UNEP. UNEP Food Waste Index Report 2021; 2021.

[110] Nguyen H. Sustainable food systems: Concept and framework.

[111] Joint Working Party on Agriculture and Trade. Digital opportunities for trade in agriculture and food sectors; 2019.

[112] World Bank. World Development Report 2016: Digital Dividends. Available from: <https://www.worldbank.org/en/publication/wdr2016>.

[113] Trendov N, Varas S, Zeng M. DIGITAL TECHNOLOGIES IN AGRICULTURE AND RURAL AREAS: BRIEFING PAPER. Rome; 2019.

[114] Baumüller H. Assessing the Role of Mobile Phones in Offering Price Information and Market Linkages: The Case of M-Farm in Kenya; 2015.

[115] Rezaei M, Liu B. Food Loss and Waste in the Food Supply Chain. Nutfruit 2017.

[116] Rejeb A, Keogh JG, Zailani S, Treiblmaier H, Rejeb K. Blockchain Technology in the Food Industry: A Review of Potentials, Challenges and Future Research Directions. Logistics 2020;4(4):27. doi:10.3390/logistics4040027. Available from: <https://www.mdpi.com/2305-6290/4/4/27/htm>.

[117] TraceX. How Olam used traceability for sustainable rice production. Available from: <https://tracextech.com/how-olam-used-traceability-for-sustainable-rice-production/>.

[118] Ritesh K. Digital Risks In 2021. Forbes 2021, 18 February 2021. Available from: <https://www.forbes.com/sites/forbestechcouncil/2021/02/18/digital-risks-in-2021/?sh=40a68bda4fef>. [December 23, 2021].

[119] Cybersecurity and Infrastructure Security Agency. Building a More Resilient ICT Supply Chain: Lessons Learned During the Covid-19 Pandemic; 2020.

[120] Homeland Security. NCCIC/ICS-CERT Year in Review: National Cybersecurity and Communications Integration Center/ Industrial Control Systems Cyber Emergency Response Team; 2015.

[121] Hassanzadeh A, Rasekh A, Galelli S, Aghashahi M, Taormina R, Ostfeld A et al. A Review of Cybersecurity Incidents in the Water Sector. Journal of Environmental Engineering (United States) 2020;146(5):3120003. doi:10.1061/(ASCE)EE.1943-7870.0001686. Available from: <https://scholars.houstonmethodist.org/en/publications/a-review-of-cybersecurity-incidents-in-the-water-sector>.

[122] Marshall D. Abrams, Joe Weiss. Malicious Control System Cyber Security Attack Case Study: Maroochy Water Services, Australia. Available from: <https://www.mitre.org/publications/technical-papers/malicious-control-system-cyber-security-attack-case-study-maroochy-water-services-australia>.

[123] van der Linden D, Michalec OA, Zamansky A. Cybersecurity for Smart Farming: Socio-Cultural Context Matters. IEEE Technol. Soc. Mag. 2020;39(4):28–35. doi:10.1109/MTS.2020.3031844. Available from: <https://research-information.bris.ac.uk/en/publications/cybersecurity-for-smart-farming-socio-cultural-context-matters>.

[124] Mehrabi Z, McDowell MJ, Ricciardi V, Levers C, Martinez JD, Mehrabi N et al. The global divide in data-driven farming. Nat Sustain 2021;4(2):154–60. doi:10.1038/s41893-020-00631-0. Available from: <https://www.nature.com/articles/s41893-020-00631-0>.

[125] ITU. L.1024 The potential impact of selling services instead of equipment on waste creation and the environment - Effects on global information and communication technology. Available from: <https://www.itu.int/rec/T-REC-L.1024-202101-I/en>.

[126] Freitag C, Berners-Lee M, Widdicks K, Knowles B, Blair GS, Friday A. The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. Patterns 2021;2(9):100340. doi:10.1016/j.patter.2021.100340. Available from: <https://www.sciencedirect.com/science/article/pii/S2666389921001884>.

[127] Gardner TA, Benzie M, Börner J, Dawkins E, Fick S, Garrett R et al. Transparency and sustainability in global commodity supply chains. World Development 2019;121:163–77. doi:10.1016/j.worlddev.2018.05.025. Available from: <https://www.sciencedirect.com/science/article/pii/S0305750X18301736>.

[128] Economic Commission for Europe. Recommendation No. 46: Enhancing Traceability and Transparency of Sustainable Value Chains in the Garment and Footwear Sector. Geneva; 2021.

[129] OECD. OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas: Third Edition. Paris; 2016.

[130] NotiziarioTecnico. 5G & Supply Chain. Available from: <https://www.gruppotim.it/content/tiportal/it/notiziariotecnico/edizioni-2020/n-3-2020/7-5G-Verticals-Abilitatori-Package/approfondimenti-1.html>.

[131] Gartner. Gartner Survey Shows 70% of Supply Chain Leaders Plan to Invest in the Circular Economy: Only a Minority Link Their Digital and Circular Economy Strategies. Available from: <https://www.gartner.com/en/newsroom/press-releases/2020-02-26-gartner-survey-shows-70--of-supply-chain-leaders-plan>.

[132] Ellen MacArthur Foundation. Climate and a circular economy. Available from: <https://ellenmacarthurfoundation.org/topics/climate/overview>.

[133] Oates W, Portney PR. The political economy of environmental policy; 2003.

[134] Mott G, Razo C, Hamwey R. Carbon emissions anywhere threaten development everywhere. Available from: <https://unctad.org/news/carbon-emissions-anywhere-threaten-development-everywhere>.

[135] Barbera P. Social Media, Echo Chambers, and Political Polarization. In: Persily N, Tucker JA, editors. Social Media and Democracy: The State of the Field, Prospects for Reform: Cambridge University Press; 2020, p. 34–55.

[136] Hall N. Transnational Advocacy in the Digital Era: Oxford University Press; forthcoming.

[137] Kirchgässner G, Schneider F. On the Political Economy of Environmental Policy. Public Choice 2003;115(3/4):369–96. doi:10.1023/A:1024289627887. Available from: <https://link.springer.com/article/10.1023/A:1024289627887>.

[138] UNEP Implementing Principle 10 of the Rio Declaration. United Nations Environment Programme Fri, 2017, Fri, 14 July 2017. Available from: <https://www.unep.org/news-and-stories/story/unep-implementing-principle-10-rio-declaration>. [December 23, 2021].

[139] Luyet V, Schlaepfer R, Parlange MB, Buttler A. A framework to implement Stakeholder participation in environmental projects. Journal of Environmental Management 2012;111:213–9. doi:10.1016/j.jenvman.2012.06.026. Available from: <https://www.sciencedirect.com/science/article/pii/S0301479712003416>.

[140] Coleman S, Blumler JG. The Internet and Democratic Citizenship. Cambridge: Cambridge University Press; 2009.

[141] Dryzek JS, Niemeyer S. Deliberative democracy and climate governance. Nat Hum Behav 2019;3(5):411–3. doi:10.1038/s41562-019-0591-9. Available from: <https://www.nature.com/articles/s41562-019-0591-9>.

[142] Stadt Zürich. Stadtidee - «Mitwirken an Zürichs Zukunft». Available from: <https://mitwirken.stadt-zuerich.ch/processes/stadtidee/steps?locale=en>.

[143] Bäck M, Christensen HS. When trust matters—a multilevel analysis of the effect of generalized trust on political participation in 25 European democracies. Journal of Civil Society 2016;12(2):178–97. doi:10.1080/17448689.2016.1176730. Available from: <https://www.tandfonline.com/doi/pdf/10.1080/17448689.2016.1176730?needAccess=true>.

[144] Almond GA. The civic culture: Political attitudes and democracy in five nations. Newbury Park, Calif: Sage Publications; 1989.

[145] Hooghe M, Marien S. A Comparative Analysis of the Relation between Political Trust and Forms of Political Participation in Europe. European Societies 2013;15(1):131–52. doi:10.1080/14616696.2012.692807. Available from: <https://www.tandfonline.com/doi/pdf/10.1080/14616696.2012.692807?needAccess=true>.

[146] Harring N, Jagers S. Should We Trust in Values? Explaining Public Support for Pro-Environmental Taxes. Sustainability 2013;5(1):210–27. doi:10.3390/su5010210. Available from: <https://www.mdpi.com/2071-1050/5/1/210>.

[147] Fukuyama F. Social capital, civil society and development. Third World Quarterly 2001;22(1):7–20. doi:10.1080/713701144.

[148] Birch S. Political polarization and environmental attitudes: a cross-national analysis. Environmental Politics 2020;29(4):697–718. doi:10.1080/09644016.2019.1673997.

[149] Johansson A, Berggren N, Nilsson T. Intolerance predicts climate skepticism. Energy Economics 2022;105:105719. doi:10.1016/j.eneco.2021.105719. Available from: <https://www.sciencedirect.com/science/article/pii/S0140988321005697>.

[150] Zhuravskaya E, Petrova M, Enikolopov R. Political Effects of the Internet and Social Media. Annu. Rev. Econ. 2020;12(1):415–38. doi:10.1146/annurev-economics-081919-050239.

[151] Ho C-C, Chen L-J, Hwang J-S. Estimating ground-level PM2.5 levels in Taiwan using data from air quality monitoring stations and high coverage of microsensors. Environmental pollution (Barking, Essex 1987) 2020;264:114810. doi:10.1016/j.envpol.2020.114810. Available from: <https://pubmed.ncbi.nlm.nih.gov/32559863/>.

[152] Tickell P. Technology for community organising - Phoebe Tickell - Medium. Medium 2021, 7 March 2021. Available from: <https://phoebetickell.medium.com/technology-for-community-organising-6e62af2b054c>. [December 23, 2021].

[153] Fairbrother M, Johansson Sevä I, Kulin J. Political trust and the relationship between climate change beliefs and support for fossil fuel taxes: Evidence from a survey of 23 European countries. Global Environmental Change 2019;59:102003. doi:10.1016/j.gloenvcha.2019.102003. Available from: <https://www.researchgate.net/publication/336965521_Political_trust_and_the_relationship_between_climate_change_beliefs_and_support_for_fossil_fuel_taxes_Evidence_from_a_survey_of_23_European_countries>.

[154] Marien S, Hooghe M. Does political trust matter? An empirical investigation into the relation between political trust and support for law compliance. European Journal of Political Research 2011;50(2):267–91. doi:10.1111/j.1475-6765.2010.01930.x. Available from: <https://ejpr.onlinelibrary.wiley.com/doi/full/10.1111/j.1475-6765.2010.01930.x>.

[155] Slough T, Kopas J, Urpelainen J. Satellite-based deforestation alerts with training and incentives for patrolling facilitate community monitoring in the Peruvian Amazon. PNAS 2021;118(29). doi:10.1073/pnas.2015171118. Available from: <https://www.pnas.org/content/118/29/e2015171118>.

[156] Scheidel A, Del Bene D, Liu J, Navas G, Mingorría S, Demaria F et al. Environmental conflicts and defenders: A global overview. Global Environmental Change 2020;63:102104. doi:10.1016/j.gloenvcha.2020.102104. Available from: <https://www.sciencedirect.com/science/article/pii/S0959378020301424>.

[157] Yeo S. Where climate cash is flowing and why it's not enough. Nature 2019;573(7774):328–31. doi:10.1038/d41586-019-02712-3. Available from: <https://www.nature.com/articles/d41586-019-02712-3>.

[158] Deutsche Welle (DW). Ecological footprint: How 'gray energy' is totally underestimated. Available from: <https://www.dw.com/en/ecological-footprint-how-gray-energy-is-totally-underestimated/a-43261811>.

[159] VOLVO Car Australia. Volvo Cars reveals ambitious new climate plan. Australia; 2021.

[160] Department of Primary Industries and Regions, South Australia. Marine Scalefish quota trading. Available from: <https://pir.sa.gov.au/fishing/commercial_fishing/fisheries/marine_scalefish_fishery/reform/marine_scalefish_quota_trading>.

[161] ClimateWorks Australia. How to read a marginal abatement cost curve. Available from: <https://www.climateworksaustralia.org/resource/how-to-read-a-marginal-abatement-cost-curve/>.

[162] The Official Microsoft Blog. Microsoft will be carbon negative by 2030. Available from: <https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/>.

[163] Microsoft. Climate Innovation Fund. Available from: <https://www.microsoft.com/en-us/corporate-responsibility/sustainability/climate-innovation-fund?activetab=pivot1%3aprimaryr6>.

[164] Galbraith M. Public and ecology – the role of volunteers on Tiritiri Matangi Island. New Zealand Journal of Ecology 2013. Available from: <https://newzealandecology.org/nzje/3107.pdf>.

Annex:
An overview of all case studies received and consulted is available at the IGF website.[1]

1 https://www.intgovforum.org/en/content/policy-network-on-environment-pne. Not all case studies are directly references in the report. However, they were carefully taken into consideration when the report was designed and have been put at the disposal of public for further reading.

ANNEX

The PNE report contains a number of inputs received from various stakeholders. The report aimed for a balanced overview of inputs per regional and stakeholder groups. While all received inputs were carefully analysed and taken into account during the development of the report, for the mentioned reason of balance, not all inputs were directly referenced in the report. However, we encourage everyone to review all received inputs, listed below (cited as initially submitted by the contributors or interpreted by the PNE report editor).

- The United Nations Secretary-General's Roadmap for Digital Cooperation
- IGF 2020 Messages on Environment
- EuroDIG: Intersessional project 2020/2021, EuroDIG Greening the Internet Governance Part II
- SDIA's Roadmap to Sustainable Digital Infrastructure by 2030
- Global Information Society Watch: Technology, The Environment and A Sustainable World: Responses from the Global South
- For further reading, please refer to this wiki (composed by Michael J. Oghia, SDIA).

OVERVIEW OF THE RECEIVED CASE STUDIES

CONTRIBUTOR/SOURCE	INPUT
European Commission	Circular Economy Action Plan "Recognizing the imperative to reduce natural resource consumption, which is seen as a primary driver of GHGs, the European Union is developing a new circular economy action plan. Its stated goal is to accelerate the transition towards a regenerative growth model by doubling the amount of circular material in use by 2030, while maintaining the economic competitiveness of the bloc. To implement this, the European Commission will propose legislation on sustainable products including in product design and further empowering consumers. The commission has identified key product value chains as targets within this plan that include ICTS, batteries, plastics, and textiles."
Global Change Data Lab	Our World in Data "Poverty, disease, hunger, climate change, war, existential risks, and inequality: The world faces many great and terrifying problems. It is these large problems that the site Our World in Data focuses on. The goal of Our World in Data is to make the knowledge on these problems accessible and understandable. The front page of Our World in Data lists the same big global problems every day, because they matter every day. Our World in

	Data is convinced that to understand issues that are affecting billions, we need data, available on an understandable and public platform. This allows everyone to see the state of the world today and track where we are making progress, and where we are falling behind. Through interactive data visualizations we can see how the world has changed; the summaries on scientific literature provided help us understand why."
Group of academic editors	Combating water losses using AI in Brazil "In Brazil, 38% of water from springs is lost during distribution. Brazilian start-up Stattus4 developed 4Fluid, a solution combining IoT sensors and Artificial Intelligence to detect possible leaks. By collecting vibration, consumption, and pressure data, the AI learns to distinguish between the expected vibrations of water flowing through pipes, and those indicating real losses through leakage and even apparent losses through illegal connections or damaged water meters, providing near real-time information to managers to support decision-making."
TraceX	Blockchain-enabled sustainable rice production in India "Rice production, one of India's largest export commodities, requires vast quantities of water and contributes substantially to global warming through methane production. Food and agri-business Olam partnered with Indian blockchain platform TraceX to improve the sustainability of rice production in Haryana, India using a blockchain-based solution. TraceX allowed streamlined communication with farmers, rapid retrieval of audit data, and mutual transparency and trust across the value-chain. Farmers also reported up to 12% increases in income, and reduction of water consumption and pesticide use of around 85% on average thanks to the solution's data collection and recommendations."
Stadt Zürich	Participatory Budgeting "Stadtidee" "The project called "Stadtidee" (city idea) was launched in 2021 as part of Zurich's Smart City Strategy as the first city-wide participatory budget of the City of Zurich. Between July and September 2021, residents of Zurich were invited to submit ideas for changes in the Zurich neighbourhood with a connection to climate, nature and children and youth. The ideas were submitted via an online participation platform based on the Open-Source-Software "Decidim" (from Barcelona), competing for the distribution of a total of 540'000 Swiss Francs. 167 ideas for Zurich were submitted as part of the project, of which 135 made it to the final selection and were later voted on. The winning ideas will be implemented in 2022. This democratic tool was not invented in Zurich. It was first tried out in Porto Alegre in Brazil in 1989. A similar procedure has also become established in many German cities under the term "participatory budgeting". In the meantime, most participatory budgets take place online: for example, Reykjavik after the 2008 financial crisis, Barcelona or Helsinki. In Switzerland, the city of Lausanne has also tried it out."
Group of academic authors	Case Study: Early Deforestation Alerts "The Amazon Rainforest is a crucial element of the world's ecosystem, containing incredible biodiversity while capturing 123 billion metric tons

	of carbon. While the indigenous people of the region have been supporting conservation efforts, e.g., by patrolling their home territories for logging and other illegal activities, rapid deforestation continues. A recent study conducted in the Peruvian Amazon investigated whether deforestation rates could be reduced with the help of technology, equipping the local population with satellite-based "early deforestation alerts", allowing individuals to signal illegal activities to the authorities from a distance [155]. Participating in the program helped reduce tree cover loss (effects were stronger in the first year compared to the second year of the study) and the reductions were largest in communities facing more imminent threats. Over the course of the two years, the communities patrolling with the help of satellite data averted the logging of an estimated 456 hectares (1,127 acres) of forest cover, preventing the release of more than 234,000 metric tons of CO_2 emissions. Consequently, the study showed that community monitoring of forests using satellite data and smartphone technology can help reduce Amazon deforestation and might also be an effective strategy elsewhere. It is important to note that for this approach to work, communities must have enough trust in state enforcement authorities to activate them in case of high threat intruders [156]. State capacity and determination might not be existent to a sufficient degree in every area. In the same vein, even if the program is successful, there is a risk of illegal activities shifting to less monitored parts of the forest."
Microsoft	Microsoft Sustainability Calculator "Managing data is one of the biggest pain points in the sustainability journey of many organizations. There is a torrent of data from all areas of the value chain, and unfortunately much of it currently is often poor quality, siloed and difficult to share. The very real risk is that even with the best of intentions, carbon emissions data is meaningless if it cannot be properly ingested for analysis and action. We experienced this across Microsoft as we work toward our own commitments to become carbon negative, water positive and zero waste by 2030. We soon realized that we needed to bring our world-class data and environmental science teams together with our engineering and product teams to build new and better digital technology not just for ourselves, but for our customers. This was the origin for the Microsoft Cloud for Sustainability."
Microsoft	Climate Innovation Fund "Investing for new carbon reduction and removal technology: We will deploy $1 billion of our own capital in a new Climate Innovation Fund to accelerate the development of carbon reduction and removal technologies that will help us and the world become carbon negative."

	"With the Climate Innovation Fund, Microsoft has launched an initiative in 2020 aimed at helping suppliers and customers around the world reduce their own carbon footprints and fund innovation to accelerate the global development of carbon reduction, capture, and removal technologies. According to Microsoft, funding in investments will be based on four criteria: Climate impact, underfunded markets, shared alignment and climate equity. The Climate Innovation Fund was launched in the context of Microsoft's commitment to be carbon negative by 2030, and to remove from the environment, by 2050, all the carbon the company has emitted either directly or by electrical consumption since it was founded in 1975. To reach these goals, Microsoft has launched a program to cut carbon emissions by more than half by 2030, both for direct emissions and for the entire Microsoft supply and value chain. This will be funded in part by expanding the internal carbon fee, in place since 2012 and increased in 2019."
Microsoft	Planetary Computer "The Planetary Computer combines a multi-petabyte catalog of global environmental data with intuitive APIs, a flexible scientific environment that allows users to answer global questions about that data, and applications that put those answers in the hands of conservation stakeholders."
Microsoft	FarmBeats "FarmBeats: Several studies have demonstrated the need to significantly increase the world's food production by 2050. However, there is limited amount of additional arable land, and water levels have also been receding. Although technology could help the farmer, its adoption is limited because the farms usually do not have power, or Internet connectivity. We are working towards an end-to-end approach, from sensors to the cloud, to solve the problem. Our goal is to enable data-driven farming. We believe that data, coupled with the farmer's knowledge and intuition about his or her farm, can help increase farm productivity, and also help reduce costs. However, getting data from the farm is extremely difficult since there is often no power in the field, or Internet in the farms. As part of the FarmBeats project, we are building several unique solutions to solve these problems using low-cost sensors, drones, and vision and machine learning algorithms." "With Azure FarmBeats, Microsoft is contributing towards enabling data-driven farming. The belief is that data, coupled with the farmer's knowledge and intuition about his or her farm, can help increase farm productivity, and help reduce costs. However, getting data from the farm is extremely difficult since there is often no power in the field, or Internet in

	the farms. As part of the project, FarmBeats is building several unique solutions to solve these problems using low-cost sensors, drones, and vision and machine learning algorithms. According to FarmBeats principal researchers, FarmBeats wants to highlight something essential for the future: AI doesn't replace human knowledge; it augments it."
Microsoft	SunCulture "SunCulture: SunCulture develops irrigation and farming technology solutions to help smallholder farmers in Africa maximize yields and increase earnings. SunCulture combines intelligent hardware, IoT, big data, and neural networks to help farmers practice precision agriculture."
Microsoft	Contributions to Fit for 55 "A technology-based solution in action can be seen in a project run by a Swiss company called Climeworks. Using only renewable energy, Climeworks' technology captures carbon dioxide from the air, at which point it can be used for products such as synthetic fuels, greenhouse agriculture, and carbonated beverages, or it can be permanently stored underground in volcanic rock using a mineralization process."
Microsoft	Microsoft Carbon Removal - Lessons From an Early Corporate Purchase "Our first ever carbon removal procurement project. Learnings show, there is no real existing carbon removal ecosystem and the world must build a new market on an unprecedented scale and timeline, starting from almost scratch."
Microsoft	Microsoft named Principal Partner for COP26 - Microsoft On the Issues "Microsoft SDG Report 2021 contains all Microsoft's technology-sensitive sustainability commitments for 2030: Carbon negative by 2030, Zero Waste by 2030, Water positive by 2030 and to contributions to preserving and protecting the biodiversity and health of the world's ecosystems."
Mel Galbraith, New Zealand Journal of Ecology 2013	Public participation in Tiritiri Matangi Island project "Tiritiri Matangi Island has attained an international profile as a successful ecological restoration project and is often cited as a model of environmental stewardship. Ecological restoration on the island has always involved, and been dependent on, voluntary public involvement. The Tiritiri Matangi Island project is an example of how public participation not only reinforces existing links between the public and scientific communities, but also facilitates even greater understanding of ecological concepts outside the professional and academic worlds. Enhanced ecological advocacy, ecological research and biodiversity management are cited as outcomes of the collaborative involvement among the island's stakeholders, ultimately leading to the development of a 'public ecology'."