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The circular economy: Going digital

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ABOUT THE EPC

The **European Policy Centre (EPC)** is an independent, not-for-profit think tank dedicated to fostering European integration through analysis and debate.

The Sustainable Prosperity for Europe (SPfE) programme explores the foundations and drivers for achieving an environmentally sustainable and competitive European economy. While the climate crisis is a complex challenge to be addressed, non-action is not an option. Prospering within the planetary boundaries requires rethinking the existing take-make-dispose economic model, reducing pollution and being smarter with the resources we have.

The Paris Agreement and the Sustainable Development Agenda provide a direction for travel, and SPfE engages in a debate on the needed measures to achieve a fair transition to an environmentally sustainable economy and society. It focuses on areas where working together across the European Union (EU) can bring significant benefits to the member states, citizens and businesses, and ensure sustainable prosperity within the limits of this planet.

ABOUT THE PROJECT

The EPC Task Force on the Digital Roadmap for Circular Economy explored the linkages between digitalisation and the circular economy, the opportunities created by data and digitally-enabled solutions, and the challenges associated with harnessing their full potential for the transition to a circular economy. The project consisted of 10 multi-stakeholder workshops held between 2017 and 2019, and brought together representatives of the public and private sectors, academics and civil society actors, and experts on digital and environmental issues to have an open exchange on these relationships. This Task Force has been a pioneering endeavour in exploring the interconnections between these two global transformations and considering the implications for EU policymaking.

This publication builds on the Task Force findings and makes recommendations for the EU institutions for the next five years. A shorter version of this study, "Creating a digital roadmap for a circular economy", was published as a Discussion Paper on 5 July 2019.

The Task Force has been supported by Aalto University and the Natural Resources Institute Finland (Luke) (members of Helsinki EU Office), Central Denmark Region, EIT Climate-KIC, the Estonian Ministry of the Environment, Estonian Environment Investment Centre, HP, Orgalim – Europe's Technology Industries, the Province of Limburg, UL, Fondazione Cariplo and Cariplo Factory.

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LIST OF TERMINOLOGY

- **Algorithms** are a set of instructions used to solve a problem, especially by a computer.

- **Applications** or **apps** are computer software or programmes designed to perform a specific function, and are most commonly used and designed for mobile devices.

- **Artificial intelligence (AI)** is broadly understood as a machine's capability to perform tasks which would normally require human intelligence. It allows machines and programmes to 'learn' and alter their operations based on previous 'experience'.

- **Big data** are large datasets that can be used to analyse and reveal patterns, trends and associations.

- **Blockchain** is a distributed ledger that can be used to record and share information securely and enable online transactions. Information can be managed in a decentralised way.

- **Cloud computing** is the practice of using a network of remote servers hosted on the Internet to store, manage and process data.

- **Circular economy (CE)** is an economic system which aims to maintain the value of products and materials for as long as possible, and minimise resource use and waste by increasing the repair, recovery, reuse and recycling of materials and products. Novel business models and responsible consumers enable it.

- **Dematerialisation** is the reduction of materials to achieve greater prosperity.

- **Digitalisation** of our economy and society builds upon increased connectivity and data gathering, sharing and analysis, with the aim of maximising its value to produce better products and services. It starts with digitisation, or converting information from a physical format (e.g. paper, images) into digital data. Increased connectivity (e.g. via the Internet) allows data to be managed and used across borders and the globe. Digitised data and digitally-enabled solutions can be used to improve business models, processes, products and services; to change thinking; and even disrupt current practices.

- **Digitally-enabled solutions** include physical hardware combined with software (e.g. computers, the Internet of things) or virtual software (e.g. apps, artificial intelligence) that use data and can be continuously modified. Some solutions are already in use (e.g. apps, sensors, online platforms), while others (e.g. related to artificial intelligence, the Internet of things, blockchain, 3D printing) are still under development.

- **Digital twins** are virtual models or digital replicas of things from the physical world (e.g. goods, processes, services). They can be used to predict and optimise production systems before investments are eventually made in prototypes, for example.

- **Internet of things (IoT)** and **connected devices** are everyday physical objects or devices that are connected to the Internet and can identify themselves to other objects. The Internet of things can, for example, be used to predict when machines need maintenance or to micromanage energy usage.

- **Lifecycle assessments (LCAs)** are the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product throughout its lifecycle.

- **Machine learning** is a subpart of artificial intelligence, whereby a machine is trained to use large amounts of data and algorithms to find connections and perform tasks.

- **Online platforms** are used for a variety of activities, such as information exchange, trading and price comparison.

- **Radio-frequency identification (RFID)** uses electromagnetic fields to automatically identify and track tags attached to an object.

- **Sensors** are devices that detect and respond to input from or changes in its physical environment (e.g. light, heat, motion, pressure). The data/information they gather is often transmitted to other electronic devices, such as a computer.

- **3D printing** or **additive manufacturing** are computer processes which join or solidify materials to create a three-dimensional object, often using less material in comparison to traditional manufacturing methods.

LIST OF ABBREVIATIONS

AI	artificial intelligence
AI HLEG	High-Level Expert Group on Artificial Intelligence
BAT	best available technique
BIM	building information modeling
BREF	Best Available Techniques reference document
B2B	business-to-business
B2C	business-to-consumer
CCMS	Circular Content Management System
CE	circular economy
CEF	Connecting Europe Facility
CF	Cohesion Fund
COSME	Competitiveness of Entreprises and Small and Medium-sized Entreprises
DEP	Digital Europe Programme
DISC	Digital Innovation and Scale-up Initiative
DSM	Digital Single Market
EAP	Environment Action Programme
ECHA	European Chemicals Agency
EEA	European Environment Agency
EEE	electrical and electronic equipment
EIB	European Investment Bank
EME	Excess Materials Agency
EPR	extended producer responsibility
EREK	European Resource Efficiency Knowledge Centre
ESIF	European Structural and Investment Funds
ETS	emissions trading system
GDPR	General Data Protection Regulation
GHG	greenhouse gas
GPP	green public procurement
H2020	Horizon 2020
ICT	information and communications technology
IED	Industrial Emissions Directive
IoT	Internet of things
IPCEI	Important Projects of Common European Interest
IPR	intellectual property right
IT	information technology
I4R	Information for Recyclers Platform
JRC	Joint Research Centre
LCA	lifecycle assessment/analysis
Luke	Natural Resources Institute Finland
MFF	Multiannual Financial Framework
OECD	Organisation for Economic Co-operation and Development
PEF	product environmental footprint
PP	public procurement
PUE	power usage effectiveness
QR	Quick Response
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RFID	radio-frequency identification
RTD	real-time data
R&I	research and innovation
SDG	Sustainable Development Goal
SME	small and medium-sized enterprise
VAT	value-added tax
WEEE	waste electrical and electronic equipment; e-waste
WFD	Waste Framework Directive
WTO	World Trade Organization
5G	fifth-generation network technology

Introduction

Ensuring long-term sustainable prosperity is the challenge of our lifetime. The stakes are high. The European Union (EU) is currently faced with a series of challenges that risk undermining people's long-term prosperity. Ongoing climate and environmental crises are threatening the planet, people's well-being and prospects for businesses. Moreover, global competition is getting tougher and European players are constantly being put under the test. The EU must align its goals and means, take a close look at its governance framework and economic instruments, and build on its strengths when addressing these challenges.

The global science community is united in its dire caution: our planet is on the verge of climate catastrophe. The world is not on track to limit global warming – on the contrary, if things go unchanged, the global temperature is expected to increase 2°C by 2060, which would lead to unprecedented economic, societal and environmental costs. Our activities impact the wider environment around us directly. For example, the extraction and processing of raw materials account for half of the world's carbon emissions and 90% of biodiversity loss.[1]

While environmental challenges are global problems, Europe has a major role to play. As a result of the continent's production and consumption patterns, Europeans consume more resources and contribute more to global environmental degradation than most world regions. Furthermore, as demonstrated all too clearly in the European Environment Agency's report on the state of European environment, the EU is currently failing to meet its own sustainability goals.[2]

Things do not look rosy on the economic front either.[3] Global competition over both human and natural resources is growing fiercer. The EU has lost its position as the world's largest economic bloc to the US and China. It has never fully recovered from the economic crisis of 2008. Investments are only slowly increasing, as is its productivity growth. Economic growth has been sluggish or stagnant since 2014, with real GDP only growing at a yearly rate of around 2%.[4] Coupled with rising inequalities across the EU, social cohesion is also under increasing pressure.

Further concerns surround the Union's lag in the digital race compared to China and the US and in capturing the benefits of digitalisation. In other words, there is a risk that Europe becomes a follower rather than a leader in shaping future digital solutions and global standards. This could have significant negative implications on the EU's competitiveness, security and prosperity.

ALIGNING GOALS AND MEANS

As the EU seeks to address the climate and environmental challenges as well as its economic and societal woes and catch up in the digital race, traditional silo thinking simply will not do. Global commitments linked to the Paris Agreement and the UN's Sustainable Development Goals (SDGs) provide the basis, vision and direction for measures to be taken. The Paris Agreement sets the ambition of achieving a climate-neutral world by mid-century. The SDGs define objectives for achieving long-term sustainable economic, social and

environmental prosperity. Understanding what is at stake, recognising the critical action points and joining efforts across borders while building on the European strengths could help the EU address these multiple challenges simultaneously.

As this publication will demonstrate, it is time to align agendas that have so far been overlooked. In fact, Europe is in the middle of two transitions that can provide the means to address these multiple challenges – as long as they are managed together well. Firstly, efforts are being taken across the EU to achieve a more circular economy (CE): maintaining the value of products and materials for as long as possible, minimising resource use and waste and thus enhancing sustainable competitiveness. Secondly, the EU, its member states and businesses are engaged in the digitalisation of our economy and society, which builds upon increased connectivity and the gathering, sharing and analysis of data; and maximising its value to produce better products and services.

Europeans consume more resources and contribute more to global environmental degradation than most world regions. Furthermore, the EU is currently failing to meet its own sustainability goals.

While policymakers are yet to actively link digitalisation with wider sustainability efforts when developing policies and financing projects, there is a growing awareness that more could be done to align the circular and digital agendas.[5] It is in the EU's interest to use data and digitally-enabled solutions to change people's and businesses' mindset as well as the processes, products and services needed for the creation of a more sustainable CE. Some believe that digitalisation could ultimately help reduce resource use and even lead to dematerialisation, all for the benefit of the planet, industry and people.[6]

It is high time to align the agendas, goals and means to enhance sustainable competitiveness that also benefits the economy, society and environment and supports the EU's goal of becoming climate-neutral by 2050.

The basis for action is strong. The member states have, in principle, agreed to make the EU climate-neutral by 2050.[7] The European Commission's proposals for a European Green Deal and making a "Europe Fit for the Digital Age" – its long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050, and its reflection paper on achieving a sustainable Europe by 2030 – provide important starting points for dialogue and action.[8] The Green Deal recognises that a CE and strong involvement from industry is central to making the EU's economy sustainable. The Commission also acknowledges that digital technologies are a "critical enabler for attaining [...] sustainability goals".[9]

As the EU institutions are expected to advance the climate, CE, digital and overall industrial agendas over the coming years, this is an occasion to bring a more systemic and comprehensive approach to these efforts. It is high time to align the agendas, goals and means to enhance sustainable competitiveness that benefits the economy, society and environment and supports the EU's goal of becoming climate-neutral by 2050.

Combining circular and digital agendas – resulting in what could be called a digital CE – should arguably contribute to mitigating climate change, address environmental challenges like resource depletion and pollution, increase competitiveness and innovation, contribute to industrial modernisation and security, and support social cohesion. As such, it should ultimately deliver on the European Green Deal (see Figure 1).

The EU has a great toolbox at its disposal, and as this book will demonstrate, there is a strong rationale for coordinated action at the EU level. The Union can use its convening power – its fora and platforms – to bring together the relevant stakeholders. It can apply its governance and economic instruments to guide and incentivise change. EU-level coordination could help create a level playing field for businesses and make the EU a global leader and standard-setter in developing a digitally-enabled CE. The window of opportunity is wide open, and the time to act is now.

WHY FOCUS ON A CIRCULAR ECONOMY?

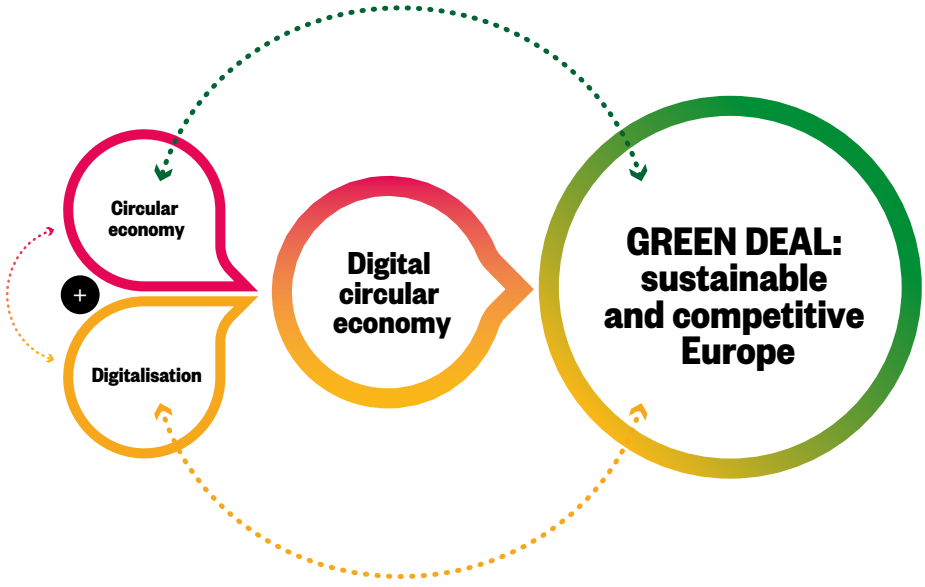
The climate crisis, depletion of natural resources, competition over resources and pollution are affecting Europe and the world more generally, posing a threat to our economy and society. The challenges are manifold and systemic. They are closely linked to how our economies and societies are structured, economic activities and current lifestyles, and unsustainable production and consumption patterns – which are not easy to change. It is estimated that at this moment the world is only 8.6% circular.[10]

However, there is a growing recognition amidst politicians, citizens and the industry that changes are dire. A shift from a linear take-make-dispose model to a CE, smarter use of resources, and achieving more sustainable production and consumption patterns could bring multiple benefits and help address the multiple challenges listed above.

Maintaining the value of products and materials for as long as possible; minimising resource use and waste; and increasing repair,

Fig. 1

Interactions between a circular economy, digitalisation and the European Green Deal



recovery/reuse of materials and products as well as recycling rates would reduce pressures on Europe's (and global) resources and decrease greenhouse gas (GHG) emissions. For example, it is estimated that around half of the carbon dioxide emitted by the EU's heavy industry by 2050 can be prevented by making the industry more circular.[11] Looking at the global level, 40% of carbon dioxide emissions from key materials (i.e. cement, steel, plastics, aluminium) almost 50% from the food sector, 40% from construction and 70% from the mobility sector could be reduced if these sectors are made more circular by 2050.[12]

Smarter use of resources would allow Europeans to manage materials better and create more value from their use. Indeed, greater circularity is rightly being seen as the means to future-proof resource-intensive industrial sectors while simultaneously enhancing competitiveness and industrial modernisation. It has been estimated that the transition would create new markets, jobs, products and services, boost EU's GDP by 7% and generate a net economic benefit of €1.8 trillion by 2030.[13]

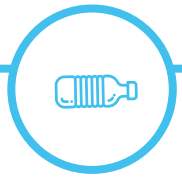
Addressing the sustainability crisis and accelerating the transition towards a sustainable, climate-neutral and circular economy will require actions across the economy and society. There is a need for a more comprehensive and systemic approach and actions across value chains. That being said, an overview of the challenges in the different sectors can also help demonstrate the magnitude and complexity of the problems that must be addressed.

The transition to a CE would create new markets, jobs, products and services, boost EU's GDP by 7% and generate a net economic benefit of €1.8 trillion by 2030.

The global **construction industry** uses 41 billion tonnes of (scarce) minerals, ores and other resources per year. This amounts to almost half of the global total of extracted raw material and is expected to only increase, especially due to demand in growing economies.[14] Extracting, transporting and processing construction materials (e.g. concrete) consumes much energy,[15] and in effect, the construction industry accounts for a quarter of global GHG emissions.[16] Conventionally, used materials are usually landfilled, incinerated or downcycled (e.g. used in road pavements). In Europe, 450 to 500 million tonnes of construction and demolition waste is generated per year.[17] While the EU has recovery targets for the aforementioned waste, recent analysis shows that its implementation has been inadequate.[18]

The **textile industry** has a significant environmental impact due to inter alia water use and energy consumption.[19] 73% of all clothes that have reached their end-of-life stage is landfilled or incinerated, while less than 1% is used to produce new apparel. In the EU, 5.8 million tonnes of textiles are annually discarded by consumers, and only 26% is recycled. The business-as-usual scenario depicts a further increase in textile production, thereby tripling the global consumption of fossil fuels and adding 22 million tonnes of microfibres to marine waters by 2050.[20]

Digitalisation is not a silver bullet that can immediately solve all of the challenges. However, digitalisation can be an enabler and accelerator for positive change – as long as it is managed well.



Around 5 to 13 million tonnes of **plastics** end up in the oceans per year. Tiny particles known as 'microplastics' can persist for centuries, enter the food chain and cause harm to marine life and potentially human health.[21] The EU is a major producer of plastics, accounting for a fifth of the global plastics production. It recycles roughly 30% of its plastic waste today, while only 6% is integrated into new products. Around a third of Europeans' plastic waste is exported and treated in other parts of the world; often leading to negative environmental impacts due to lower recycling standards and weaker enforcement of environmental law in recipient countries.[23] The EU's plastic litter causes significant pollution inter alia in the Mediterranean and North Seas and parts of the Arctic.[24] The EU releases 80 to 220 thousand tonnes of microplastics into the environment annually.[25]

Food systems depend on natural resources (e.g. water, soil, minerals) and energy, and are a notable source of GHG emissions (i.e. agriculture generates 10% of all EU emissions)[26] and pollution (e.g. due to fertilisers, pesticides). Retailers find it often impractical and costly to distribute surplus (unsold) food, which means valuable nutrients are wasted. In the EU, around 88 million tonnes of food are wasted in the EU every year, which is equivalent to 173kg per person and 20% of all produced food.[27]

In the **mobility sector**, the heavy reliance on motor vehicles leads to significant consumption of materials, GHG emissions and waste. Europe accounts for a fifth of the global production of motor vehicles. Used vehicles account for around 7 to 8 million tonnes of yearly waste in the EU.[28] Shipments of this waste outside of the EU can lead to pollution if it is not treated properly in the recipient countries. The current trend for electric vehicles could lead to reduced GHG emissions, but could also increase the consumption of (critical) materials and raises concerns over the treatment of used lithium-ion batteries.[29] Moreover, it has been estimated that vehicles in Europe are parked 92% of the time and, even when in use, only 1.5 of the available five seats are occupied, leading to structural waste in the mobility system.[30] It is widely recognised that more sustainable mobility revolves around public transport and multimodal approaches (e.g. combining walking, cycling, rail and vehicles).

When it comes to **electronics**, around 44.7 million metric tonnes of e-waste was generated (6.1kg per person) in 2016, with an expected global annual growth rate of 3 to 4%. Multiple device ownership, the growth of cloud computing services and short replacement cycles are paving the way towards a growing e-waste generation,[31] as well as GHG emissions due to electricity consumption. Electronics contain critical materials and precious metals as well as iron and aluminium, which together with plastic components could, to a large extent, be recovered. Overall, it is estimated that the secondary raw materials contained in e-waste may be worth €55 billion.[32] Given that electrical and electronic equipment (EEE) contains substances of concern (e.g. mercury, lead, flame retardants), landfilling, incineration or littering may result in adverse effects on the environment and human health.

As the EU and the Commission are starting to explore ways to align the agendas, this book aims to shed light on some of the possibilities, challenges and prospects for the way forward.

WHAT IS HINDERING US FROM ACHIEVING A SUSTAINABLE CIRCULAR ECONOMY?

Addressing the global and European sustainability challenges is arguably one of the most complex and trying tests of our time. When considering a transition to a more sustainable CE in the EU, several fundamental barriers should be addressed:

► **The existing economic model** does not value natural capital, internalise the externalities related to the likes of pollution, or reward actions that lead to social and environmental benefits. The model enforces linear and unsustainable take-make-dispose patterns for production and consumption, with society often bearing the brunt of related costs.

► **Sustainability goals and criteria** are made of a complex mix of issues, and the synergies between circularity and sustainability are not always straightforward. When designing policies and adopting measures, finding a comprehensive approach that benefits the planet can be difficult because of competing priorities and/or insufficient evidence for needed measures. This can lead to unwanted results. While greater circularity can help achieve a more sustainable, competitive and climate-neutral economy, the measures taken do not necessarily help reduce emissions or change production and consumption patterns. This can sometimes lead to trade-offs. For example:

- restricting certain materials (e.g. plastics) can lead to the introduction of those that are more energy-intensive in the production phase and during transportation (e.g. glass, metal);[33]
- transitioning to service-based business models may lead to higher energy consumption during the product's use phase (e.g. electronics, vehicles);
- simply increasing recycling does not ensure the quality of recycled materials or demand for secondary raw materials;
- focusing on durability can lead to lower recyclability, and vice versa;
- product features like greater durability or recyclability do not automatically lead to lower energy use or emissions during the use phase.[34]

► The current regulatory and economic incentives are not inciting companies enough to **design** more sustainable, circular products. Such products use materials with lower environmental and climate footprints and address the sustainability crisis during their lifetime.

► **Information does not travel** with products and materials down the value/supply chains or is of insufficient quality, thus hampering circular practices like maintenance, reuse, repair and recycling.

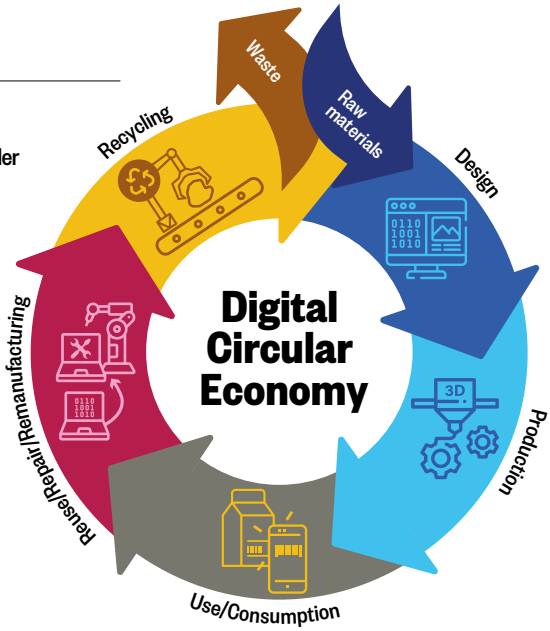
► In addition to a lack of information, it can be costly, time-consuming and difficult to **maintain, reuse or repair a product**. Component replacement may not be easily available. If software updates or replacement parts are no longer being produced, otherwise reusable and/or repairable products become obsolete.

► Some products, materials and substances on the EU market contain banned **substances of concern**, either because they were introduced before being banned or due to a lack of enforcement. The misalignments in EU chemicals, product and waste legislation and the presence of certain chemicals hamper efforts to recycle and reuse products and materials.[35] Subpar quality of and insufficient quality criteria for secondary materials can weaken the demand for recycled materials (e.g. plastics) compared to virgin material.

► The lack of common definitions for **waste**, including hazardous waste, hinder shipments

Fig. 2

Digitalisation as an enabler for a circular economy



of waste across member states. Illegal waste incineration or shipments, different levels of ambition across the EU in reducing landfills and meeting the agreed recycling targets, and the overall underdeveloped waste management infrastructure are serious challenges which rear its heads at the end of product lifecycles.

► Many technologically-enabled solutions contribute to circular business models (e.g. providing services instead of products), improving products (including design and production processes) and their end-of-life treatment (e.g. reuse, repair, remanufacturing, recycling, waste collection and sorting). However, challenges still remain with regard to **the development and scalability of solutions** due to inter alia a lack of (public) investments, adequate regulatory framework and/or sufficient market demand.

► The lack of awareness, capacities and convenience makes it difficult for **consumers** to actively contribute to a CE (e.g. to use a product as long as possible, repair and recycle it). Moreover, the overload or lack of information on products complicate consumers' ability to make sustainable choices.

► **The global market and value chains** complicate policy steering at the EU level and the development of sustainable production and consumption patterns. The EU, European industry and consumers are fully integrated into the global market – while this provides the means to influence international developments, it also implies that to bring about change, the Union and its citizens must engage and collaborate with its global partners.

► Lack of awareness, skills and capacities, a regulatory framework and economic considerations can hinder **the uptake of new circular and sustainable business models**, like product-as-a-service.

DIGITALISATION AS AN ENABLER FOR A CIRCULAR ECONOMY

As demonstrated above, achieving a sustainable CE is one of the most complex challenges of today. Digitalisation is not a silver bullet that can immediately solve all of the challenges listed above. However, as this publication demonstrates, digitalisation can be an enabler and accelerator for positive change and help address many of these obstacles – as long as it is managed

well. As digitalisation is designed to address complexities, gearing the use of data and digitally-enabled solutions to address the sustainability crisis offers many possibilities.

The digital transformation is taking place fast. Around 60% of the global population has access to the Internet. Around two-thirds uses a mobile.[36] Digitalisation is transforming our economies, societies, communications, jobs and necessary skills for today and tomorrow.[37] There is no turning back. The question that remains is whether we will embrace the many possibilities digitalisation generates, and create framework conditions which maximise them and minimise unwanted consequences, or not.

In real life, data and digitally-enabled solutions like online platforms, smart devices, artificial intelligence (AI), the Internet of things (IoT) and blockchain are already used to support a transition to a sustainable CE. They are used to improve design, production, consumption, reuse, repair, remanufacturing and waste management, including recycling (see Figure 2).

But the potential is even greater. If adequately steered, data and digitally-enabled solutions could contribute to a system-wide transition and further enhance connectivity and the sharing of information across the value chains; make products, processes and services more circular; and empower citizens and consumers to contribute to the transition. Moreover, while helping to accelerate change in the economy and society, they can improve the implementation of policies needed for a digital CE.

That being said, it is essential to stress that digitalisation does not automatically lead to greater sustainability or circularity. While data and digitally-enabled solutions can be used to change thinking and processes and even disrupt current practices, digitalisation is not without problems. If it is not properly guided and governed, there is a risk that it will result in unwanted rebound effects, such as overdrive of an unsustainable linear take-make-dispose economy (e.g. people using e-commerce platforms to consume more). The energy and raw materials required for digitalisation also raise concerns.

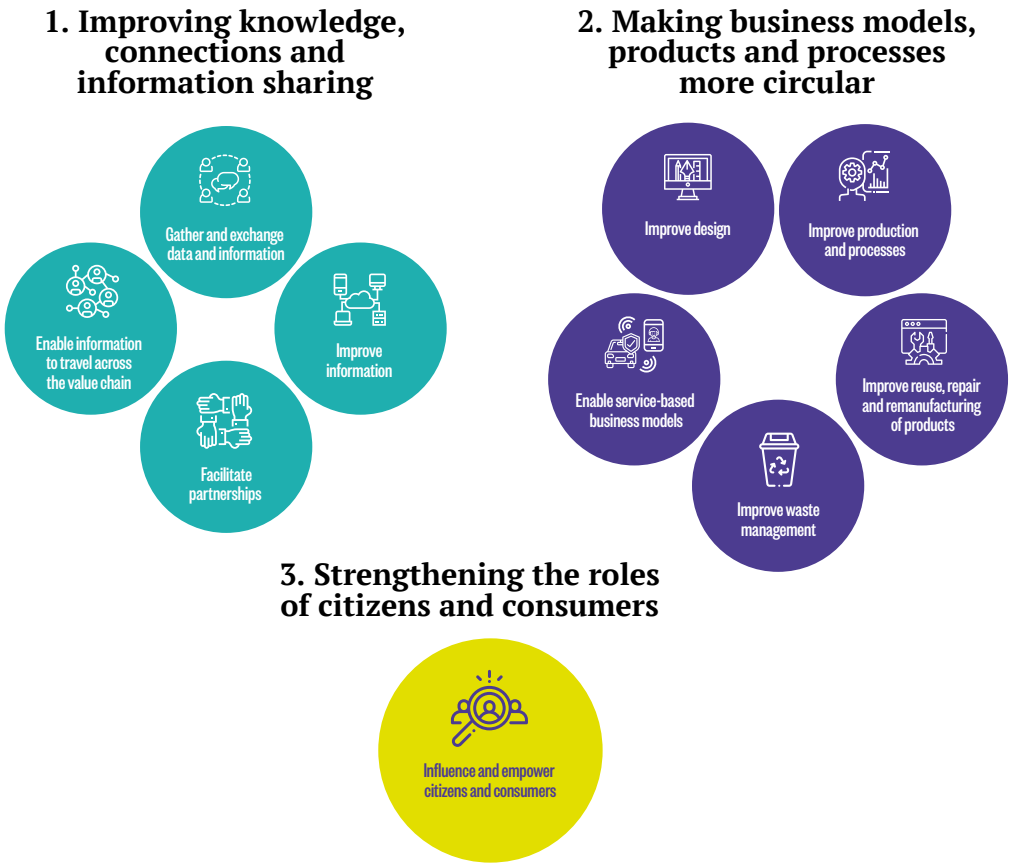
As the EU is finding its way in using and improving digitalisation and capturing its value for society and the economy, it should recognise that digitalisation is not the end goal; it is the means.[38] At their best, digitally-enabled solutions can accelerate the transition to a sustainable, competitive economy. And as the EU and the Commission are starting to explore ways to align the agendas, this book aims to shed light on some of the possibilities, challenges and prospects for the way forward, by focusing on digitalisation as an enabler for a CE.[39]

This book will reflect on how the value of data can be maximised, and existing and new digitally-enabled solutions can be employed to tackle some of the main barriers to a CE and accelerate the transition. The case studies listed in this publication aim to raise attention on the wide scope of possibilities that already exist or are emerging, while also considering the challenges and respective measures to align the digital and circular agendas. The different approaches to using digitalisation in the transition to a CE have been divided into three categories and will be elaborated in the relevant chapters (see Figure 3):

1) **Improve knowledge, connections and information sharing.** Better management of data with a view of improving information and knowledge could raise awareness and guide action, as well as improve policymaking and the implementation of existing legislation. Digitally-enabled solutions can facilitate connections and partnerships between stakeholders, and help information travel with products and materials down the value chains.

Fig. 3

Using digitalisation in the transition to a circular economy



2) **Make business models, products and processes more circular.** Better management of data and digitally-enabled solutions could contribute to greater circularity by supporting more sustainable business models and improving how we design, produce, use, reuse, repair and ultimately manage waste (including recycling).

3) **Strengthen the role of citizens and consumers.** Digitalisation can be used to inform, educate and influence people, enable them to make sustainable choices and convert them into active participants in the data economy and co-creators of knowledge.

As this book will suggest, it is high time for the EU to align digitalisation with its sustainability goals. It should aim to benefit from the digital revolution and use data and digitally-enabled solutions to change the mindset, business models, processes, products and services needed for a more sustainable CE.

Aligning the agendas would come with multiple benefits. It would help create a competitive advantage for Europe when supplying the global market with products and services for a CE, which are increasingly in demand. Europe is already a hub for digitally-enabled solutions for a CE, with valuable human capital and a strong

innovation base upon which it can build. Combining digitalisation with its values of privacy, trust and sustainability could help it create its own model for digitalisation.

OBJECTIVES, METHODOLOGY AND STRUCTURE

The **objectives** of this publication are to:

► **link and align** two (often separate) discussions that are taking place between experts on the circular and digital transitions, and recognising that both transitions should provide the means to greater sustainability and competitiveness;

► **demonstrate what digitalisation means in the context of a CE** (e.g. how data, big data, digital platforms, smart devices and apps, digital services and emerging technologies are already supporting/could further support the transition to a CE), while also considering the related barriers, challenges and risks;

► **consider what a greater focus on sustainability would mean for the digital transition**, including challenges and opportunities for the information and communications technology (ICT) industry;

► **consider the role of EU policy framework, tools and initiatives** in steering a (digital) transition towards a (digital) CE and make recommendations for EU institutions for the next five years, focusing on areas with the biggest room for improvement and low-hanging fruits.

In terms of the **methodology**, this publication builds on the findings gathered by the Task Force on the Digital Roadmap for a Circular Economy. Between 2017 and 2019, the EPC organised 10 multi-stakeholder discussions, invited 73 speakers and gathered participants from 176 organisations to share their expertise and views. The information gathered has been coupled with desk research and further analysis by the EPC team. Throughout the project, the Steering Committee – an advisory body comprising project partners and relevant experts – convened four times to provide feedback and thoughts on the direction of the project and its findings.

During this research, several case studies illustrating how digitalisation can be an enabler for a more circular economy have been identified. These cases include both 'low-hanging fruits' (i.e. existing solutions) as well as emerging solutions that are yet to prove their utility. The focus has been on positive cases; nonetheless, their challenges and limitations are also highlighted. Identified case studies cover a wide range of industries and practices, the common thread being the circularity challenge and the potential for digitalisation to overcome these challenges.

Several specific sectors are also put under the spotlight throughout the study; namely construction, plastics, electronics, textiles, mobility and food. They deserve particular attention because of their impact on and potential for data and digitally-enabled solutions to address and overcome the current challenges. In other words, Chapters 1 to 3 include case studies (including both existing and emerging solutions) that aim to illustrate how digitalisation can support a CE.

The **structure** of the study is as follows:

► Chapter 1 explores how better data management and digitally-enabled solutions could improve knowledge, connectivity and information sharing by enhancing the gathering and exchanging of information, improving information, facilitating partnerships and enabling information transfer.

► Chapter 2 explores the potential of digitalisation to make business models, products and processes more circular by incentivising service-based business models; improving the design, production, reuse repair,

disassembly and durability of products; and improving waste management.

► Chapter 3 investigates ways in which citizens and consumers can be influenced and empowered during the transition.

► Chapter 4 considers some of the fundamental barriers to a digital economy and challenges and risks related to the ongoing digital revolution which must be addressed if the EU is to avoid unwanted consequences when linking digitalisation with a CE.

► Chapter 5 provides an overview of the EU framework for action, including under the climate action, CE, digital and industrial agendas (including the Single Market); and consumer affairs and research and development. It considers how the EU could utilise its governance, economic instruments and convening power to enable a transition to a sustainable digital and CE.

► Following final reflections for the way forward, Chapter 6 concludes with a set of key recommendations for the EU institutions for the next five years.

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Improving knowledge, connections and information sharing

1

A transition to a CE could benefit greatly from enhanced access to better information, improved connections between relevant stakeholders across the value chain, and solving issues around information sharing – all major hurdles currently impeding a CE. Digitalisation has the potential to play a major role in addressing these barriers.

The digital revolution implies that more digital data is being generated than ever before. Numerous digitally-enabled solutions (e.g. digital sensors, mobile phones, connected devices, satellites) are being used to generate and collect new data, including for specific purposes such as establishing a CE. In order for this data to be turned into information or knowledge and thus gain value, it must be managed – that is, mined, systematised, processed, analysed and shared.

Better management of data and information could help address complexities related to creating a more sustainable economic model and take a more comprehensive approach when developing sustainability goals and criteria and designing needed measures. Gathering and exchanging information can help raise corporate and consumer awareness and thus improve production and consumption patterns. Digitalisation also provides opportunities to improve policymaking and the implementation of and compliance with existing rules.

Digitally-enabled solutions already play a central role in improving connections and information sharing between relevant stakeholders, including producers, recyclers, public sector authorities and consumers. They enable the exchange of data and/or information, facilitate partnerships and enable relevant information to reach those that need it. In the future, finding a way to ensure efficient and secure information sharing – thereby enabling information to travel down the value chains with products and materials while respecting companies' intellectual property rights (IPRs) – could provide a breakthrough for the creation of a CE.

This chapter lists several case studies which exemplify how data and digitally-enabled solutions can help to advance the circular agenda. Some of these solutions are developed or used to help address challenges with construction, plastics, electronics, mobility, food systems and textiles. Considering these areas' environmental and climate footprints (see Introduction), these opportunities are illustrated with icons. It should be noted, however, that many of the solutions are also applicable beyond the highlighted sectors. Moreover, while some of the related barriers, challenges and risks are mentioned here, they are elaborated further in Chapter 4.

1.1. Gathering and exchanging data and information

Several databases and platforms for collecting and exchanging data and information for the benefit of a CE already exist and are targeted to different stakeholders. These can be used to raise awareness amidst relevant stakeholders, support research and analysis, and help businesses comply with EU rules, thus facilitating the transition and implementation of policies for greater circularity.

RAISING AWARENESS

Existing solutions

The EU has several ***websites*** and ***platforms*** that gather data and information and are accessible to European and national policymakers, businesses and citizens. The latter can learn about the rationale, progress and challenges for achieving a CE, as well as exchange good practices. The **European Environment Agency** provides extensive information on the state of play of resource efficiency and waste in Europe. The **European Commission**'s website lists all recent policy developments related to a CE. The **European Circular Economy Stakeholder Platform** is a virtual open space which aims to facilitate dialogue among stakeholders and disseminate information and good practices.

The **European Resource Efficiency Knowledge Centre** (EREK) ***platform*** provides information to businesses, especially small and medium-sized enterprises (SMEs), about improving resource efficiency and turning waste into assets. It suggests ways for businesses to manage their energy, water and material costs, and demonstrates returns on investment related to resource-efficient measures.

The **Natural Resources Institute Finland** (Luke) provides agriculture-related ***data*** via the EconomyDoctor ***online platform***. This can be used by researchers as well as policymakers to access statistics to support research and analysis.

The UN Environment's **International Resource Panel Global Material Flows Database** (or International Resource Panel) provides ***data*** about the linkages between the world economy, population and material use.

The UN Environment's **International Resource Panel**'s ***website*** contains numerous scientific assessments (e.g. Global Resources Outlook) which help map and create awareness about global natural resource use and management.

The **Circular Economy Club** maps circular initiatives across the world and incorporates them into a large open-source ***database*** for a CE.

IMPLEMENTATION OF EU RULES

Existing solutions

The European Commission's **monitoring framework of a CE** currently collects ***data*** and measures member states' progress across 10 indicators. The indicators cover production and consumption (self-sufficiency of raw materials for production in the EU, green public procurement (GPP), waste generation, food waste), waste management (recycling rates, specific waste streams), secondary raw materials (contribution of recycled materials to raw material demand, trade of recyclable raw materials), and competitiveness and innovation (private investments, jobs and gross value added, patents related to recycling and secondary raw materials).[1]

The European Chemicals Agency's (ECHA) **International Uniform Chemical Information Database** aims to trace information on chemicals in a structured and harmonised way, and is used for reporting under REACH EC 1907/2006 (Registration, Evaluation, Authorisation and Restriction of Chemicals). The ***database*** is developed and maintained in collaboration with the Organisation for Economic Co-operation and Development (OECD) and is used by both regulatory bodies and the chemical industry. On the downside, the database alone does not ensure the full, adequate enforcement of REACH.[2] Moreover, while the database is well developed, the collected data and/or information at the start of the supply chain does not travel with the materials and products along the value chain.

BOMcheck is an industry-led shared ***database*** which was founded by Siemens, Philips and GE Healthcare. It is used by numerous companies to manage their supply chains and comply with regulatory requirements (e.g. REACH, the Restriction of Hazardous Substances Directive 2002/95/EC). BOMcheck enables suppliers to provide data to manufacturers and can track and report substances, chemicals and materials (including critical materials) in products in a standardised and automated manner. BOMcheck currently has 9,000 users (i.e. suppliers and manufacturers). One of its challenges – common for many databases – is to ensure the actual quality of and access to data, in this case from small sub-suppliers.

In order for data to be turned into information or knowledge and thus gain value, it must be managed – that is, mined, systematised, processed, analysed and shared.

Several large automotive companies[3] have established the **International Material Data System**, a ***global data repository*** that contains information on materials used in the industry. The data are collected, maintained, analysed and archived in order to facilitate compliance with existing standards and legal obligations. The system also facilitates the recycling of end-of-life vehicles and their materials and is a good demonstration of how collaboration within a given sector can support greater circularity across the supply chain.

The EU has several websites and platforms that gather data and information and are accessible to European and national policymakers, businesses and citizens.

EC4P is a British web ***platform*** that helps companies comply with recycling regulations for waste electrical and electronic equipment (WEEE), batteries and packaging across the EU and world. It uses secure cloud-based ***software*** to monitor changes to legislation and manage companies' data on compliance.

Some possible challenges related to the development and uptake of these solutions:

- Targets, indicators and legislation greatly influence what data is collected and how progress is measured. However, the focus is not always right. For example, the European Commission's current CE indicators fail to measure the reduction of overall consumption and use of secondary raw materials for value creation.
- A lack of standards on data collection and exchange hampers collection and analysis.
- If data is to be of value, it should be managed and turned into knowledge that businesses, public authorities and people can utilise and turn into action.

1.2 Turning data into information and knowledge

Better management of data can help convert it into valuable information and knowledge for the benefit of a CE. If the enormous amounts of data collected, including environmental and CE-related data, are not properly managed and analysed, their real value will remain limited. Ideally, big data will become the fuel for a sustainable economy.

Better management of data holds enormous possibilities for a system-wide transformation of our economy. It can help make sense of the complexities surrounding the current economic model and support the development of sustainability goals, criteria and needed measures comprehensively (e.g. by improving lifecycle assessments, or LCAs).

Moreover, having better access to more accurate and quality information can support decision-making, monitoring and evaluation processes that benefit policy implementation. When information becomes actionable knowledge (i.e. providing concrete tools or guidance for businesses, public authorities or people), this can enable them to act and promote a CE more effectively. As will be exemplified in the case studies below, this can help optimise the usage of products, prolong durability, support value retention of secondary raw materials, enhance industrial symbiosis and address waste problems.

IMPROVED POLICYMAKING AND IMPLEMENTATION

Existing solutions

As part of the Horizon 2020 (H2020) project **CLAIM** (Cleaning Litter by developing and Applying Innovative Methods in European seas), **FerryBoxes** are being installed on boats. This technology collects samples and monitors the environmental parameters – that is, ***big data*** – of marine litter and water quality. The data collected and its subsequent analytics supports policymaking on the needed measures to clean seas and prevent further littering.

Emerging solutions

Web crawlers browse the Internet to index ***data*** and could also investigate potential breaches of law, including unwanted products and materials. As such, web crawlers could enhance surveillance of the European market.

Comprehensive LCAs are an important information tool for more sophisticated decision-making and could be made more efficient and accurate with the help of improved data management. ***Softwares*** like **SimaPro**, **GaBi** and **openLCA** are already being used to execute LCAs in industries and academia, for example, and digitally-enabled LCAs clearly have the potential to support policymaking, too. However, it is important to first ensure comprehensive and quality data to obtain better LCAs.

ACTIONABLE KNOWLEDGE

Existing solutions

Evolution3 is an advanced ***sensor system*** for tires developed by Michelin. The tires communicate their temperature and pressure conditions in real-time via email or text messaging to operators, thus converting the data into actionable knowledge that can be used to prevent tire damage, and prolong their lifespan and optimal usage of the vehicle.

Luke has developed an online database called **Biomass Atlas** which displays

spatial data for different biomasses in a single interface that is accessible to everyone. The collected information on land use, forest resources, arable crop production, manure and biodegradable waste, and sludge from industry and communities can be used, for example, to plan investments and raw material purchases, support industrial symbiosis and help decision-makers develop energy, industrial and CE policies.

GrainSense helps manage farming by enabling the collection and processing of real data from the field. Grain samples are inserted in a ***near-infrared device*** that sends information about the samples (e.g. on moisture, protein) to a ***mobile app***, which analyses the results. This approach accelerates the collection of valuable information about crop quality, thus optimising farming practices and resulting in better resource efficiency and less pollution.

The European ***database*** **Urban Mine Platform** shows valuable materials made available from high-tech products (e.g. vehicles, electronics, batteries). The database aims to improve the traceability, recovery and value retention of secondary raw materials by creating a harmonised inventory of products, materials and waste. The database contains data about the quantities and compositions of products (e.g. product type, materials, components, elements) put on the market and flows of waste generated per year. It is a result of the ProSUM project, which identified several challenges in the development of the database in its project report, incldluing the quality and interoperability of datasets and its narrow scope which results in data on recoverability and materials (e.g. plastics, construction, demolition waste) not being covered.[4]

Emerging solutions

Ellipsis uses ***drone technology***, ***algorithms*** and ***artificial intelligence*** (AI) to map and detect plastics and marine litter around the world. The aim is to establish a global inventory – a heat map – of marine plastic pollution to help raise awareness and contribute to waste clean-up.

The recently amended Waste Framework Directive 2018/851 (WFD) stipulates that the **ECHA** should develop a ***database*** on hazardous substances in products and materials. It is envisaged to be primarily used by consumers for information and waste operators to improve waste treatment.[5]

The Swedish company **Northvolt** is exploring the possibility of introducing ***IoT*** for (vehicle) batteries. By installing sensors coupled with smart analytics on a battery, the company would be able to gather data and provide customers with information on battery performance. It would enable predictive maintenance and thus extend battery life.

Some possible challenges related to the development and uptake of these solutions:

- Data is often used to understand current practices and bring about incremental changes to the existing economic model, rather than transform the model in its entirety. Collected data and the consequent knowledge provided reflect the level of ambition set in the targets and indicators which measure progress.
- The lack of standards on data collection and sharing affect the quality and interoperability of datasets. For example, using limited or inadequate data will lead to insufficient LCAs.
- The presence of data, information and even knowledge does not automatically lead to the desired action.

1.3. Facilitating partnerships

Modern value chains are extremely complex, and the CE is unobtainable as long as there are no partnerships and collaboration between stakeholders, including business-to-business (B2B) and business-to-consumer (B2C). Digitally-enabled solutions already play – and will continue to play – a major role in connecting relevant stakeholders (i.e. producers, recyclers, consumers) for the benefit of a CE.

For example, online platforms and apps can connect different partners in the value chain – buyers and sellers of products and services, as well as donors and recipients – with each other and across borders. They can be used to exchange information and good practices, as well as enable more sustainable production and consumption patterns.

Europeans have positive experiences of digital solutions enhancing B2B partnerships, although more could certainly be done. An illustrative example is industrial symbiosis and using platforms to share assets between different industrial sectors and businesses. In addition to the examples listed below, several related case studies can be found in Chapter 2, section 1.

Ideally, big data will become the fuel for a sustainable economy.

The CE is unobtainable as long as there are no partnerships and collaboration between stakeholders, including B2B and B2C.

REUSING, RECYCLING, UPCYCLING AND MINIMISING WASTE

Existing solutions

Upmade is an Estonian company that enables the upcycling of textiles, thus avoiding new material production and reducing waste. The company has developed ***software*** to help brands carry out a product-based analysis on its materials and design. Meanwhile, manufacturers can create Upmade-certified garments and are connected with brands via Upmade.

FoodCloud is an ***online app*** and ***platform*** which facilitates the donation of surplus food from retailers to local charities in Ireland. Charities are automatically notified about unsold food surpluses, can collect the surplus food from the retailers and distribute it to those in need. The app is currently in use in the UK and Ireland and cooperates with major retail chains. The network comprises 3,200 supermarkets and 9,500 charity partners.

Too Good To Go is another initiative which saves surplus food from waste by redirecting it to interested consumers. The ***mobile app*** connects retailers, restaurant owners and consumers with each other and facilitates the distribution of surplus food. The initiative is supported by around 1,900 stores in the UK alone. So far, around 800,000 meals have been saved, which equals to around 2 million CO_2/kg.

OLIO is another British ***online app*** that shares surplus food as well as non-food household items by connecting not only citizens to local businesses but also neighbours with each other.

SHARING ASSETS

Existing solutions

New business models that support a sharing/collaborative economy (e.g. sharing, renting, swapping products and services in peer communities) can support circular objectives. **Zen Car**, **Poppy**, **Lime** and **CarAmigo** are examples of ***online platforms*** that connect service providers with customers, thus enabling shared mobility. This kind of sharing of assets can reduce material consumption and decrease associated emissions, but may also have rebound effects that should not be ignored (e.g. increased usage of cars instead of public transport.)

Organix is a French ***digital platform*** launched by SUEZ. It is a marketplace for organic waste, whereby producers of waste are connected with methane producers to convert their waste into energy. The aim is to facilitate "the recovery of waste and the production of new energy and organic resources via local distribution channels, for the benefit of the circular economy."[6]

Emerging solutions

Excess Materials Exchange (EME) is an ***online platform*** that enables companies to exchange excess materials with each other. For example, EME uses ***resources passports*** and tracks and traces materials by using ***Quick Response*** (QR) ***codes*** and ***chips*** to support matchmaking.

BE CIRCLE is an ***online platform*** which supports industrial symbiosis. The software enables users to visualise nearby industrial facilities, their materials, and water and energy stocks and flows in view of exploiting potential synergies. The project is currently in its experimental phase and involves the industrial zones of the Port of Dunkirk, INSPIRA (France) and Höchst (Germany).

The Swiss Re-think Resource has developed **Circado**, a cross-industrial trading ***platform*** for industrial side-streams, which promotes the upcycling of materials for new products of higher value.

Some possible challenges related to the development and uptake of these solutions:

- Diverging national legislative frameworks and definitions of waste can hamper the development of new business models, industrial symbiosis and donations.
- New forms of partnerships which enable a sharing economy (e.g. food donations, sharing of cars between citizens) can raise concerns about the liability, accountability and safety of products.

1.4. Enabling information to travel across the value chain

Information sharing is one of the major barriers to achieving a CE. Consumers would benefit from having necessary information on how to maintain, repair and recycle a product. The reuse of materials and products would be encouraged if there was better information about their quality and maintenance. Recycling would be improved if waste operators had the necessary knowledge of used materials or substances. Designers would design better products if they knew more about the lifecycle of their products, including the barriers that consumers and recyclers face when aiming for greater circularity.

Digitalisation can play a central role in these efforts. For example, QR codes, barcodes, watermarks and radio-frequency identification (RFID) chips are already being used to improve the tracking of materials throughout the supply chain. Solutions that would provide stakeholders in a value chain (i.e. consumers or recyclers) with specific information on buying, using, maintaining, repairing, reusing and/or recycling products – while still allowing companies to safeguard their commercial and strategic information – are currently being developed, and could form the basis for digital product passports in the future. For instance, blockchain-enabled solutions can store and share data securely and efficiently, and should they be adopted on a large scale, they could enhance information flows across value chains and improve monitoring and verification processes. Digitally-enabled solutions can also enable feedback loops from which product designers learn about the lifecycle of their products and use the knowledge to improve their products further.

The prospects for information sharing are interesting, but several hurdles still remain to be addressed: access to relevant, reliable and standardised data; ensuring trust between stakeholders across the value chain; and finding a fair balance between enabling access to and the sharing of data. The use, reuse and disposal of different materials and products also require different information, depending

Solutions that would provide stakeholders in a value chain with specific information on buying, using, maintaining, repairing, reusing and/or recycling products are currently being developed.

on elements such as service life and the presence of international standards. Moreover, as value chains are often global, this means that imported products and materials should include the necessary information – which is easier said than done. These challenges are further elaborated in Chapter 4.

ENABLING TRACKING AND TRACING

Existing solutions

Circular Content Management System (CCMS) is an **online platform** developed by the Dutch aWEARness, which aims to close the textile cycle by encouraging collaboration across the value chain, maintaining a ***database*** and tracking materials. CCMS relies on **QR** codes to trace data throughout a product's lifecycle.

The German **circular.fashion** system consists of a Circular Design Software, circularity.IDs (i.e. ***tags*** integrated into garments) and reverse supply chain intelligence. The system aims to provide greater transparency and access to knowledge and resources, support services for extended product life and enable digital product identification for recycling.

TrusTrace is a ***blockchain***-powered collaboration platform which aims to increase product traceability and transparency within the fashion industry value chain. Approximately 35 product line chains have been traced using TrusTrace. Fashion brands, retailers and consumers gain access to data on the substances and materials used in the production of apparel. The platform is also promoting the renting, repair and reuse of apparel in cooperation with brands and original equipment manufacturers.

TagItSmart is a ***digital service platform*** that allows stakeholders across the value chain – producers, customers, recyclers – to track items and provide additional information. This solution uses ***IoT*** and ***QR*** codes with a sensitive ink (i.e. 'functional tags') to trace, track and monitor products throughout the supply chain and its lifecycle. TagItSmart is already in use in nine companies in eight EU member states.

FiliGrade is a Dutch company that has developed a system of imprinting ***watermarks*** onto plastic products, which can be scanned via a smartphone, for example, to retrieve valuable information on the product. Filigrade's watermarks can also be used to make waste sorting and thus recycling much more efficient.

Minespider is a ***blockchain*** which traces raw materials back to their source, in view of increasing transparency and contributing to responsible mineral sourcing. It also takes into account environmental concerns.

Emerging solutions

Walmart, **Auchan** and **Carrefour** are either using or have announced their intention to use ***blockchain*** to trace their food products in view of greater safety of their products. Tracing food via blockchain can help identify and redirect surplus stocks to those in need while avoiding waste.

The Belgian **foodcareplus** is developing a ***blockchain*** for food systems which will enable the tracking and monitoring of food throughout a supply chain. Receiving real-time data (RTD) on food (e.g. outdoor temperature during transportation) is important for retaining the quality of food and saving energy and resources.

The H2020 project **Buildings As Material Banks** has evaluated the feasibility and prospects of developing ***digital material passports*** for the construction sector.

CircularTree is developing ***blockchain*** solutions which promote more sustainable supply chains. For example, HazChain aims to support communication on chemical safety and compliance information, while SustainBlock aims to track the origins of mineral supply chains.

ENABLING FEEDBACK LOOPS AND REVERSE LOGISTICS[7]

Existing solutions

The French food retail group **Auchan** uses ***RFID*** technology to track plastic crates for reverse logistics. According to their evaluations, reusing plastic RFID containers reduces crate loss and saves tons of waste, resulting in a 30% decrease in carbon emissions.

Pack and Sea uses ***RFID*** to track fishing crates and their contents. This integrated tracking system involves the participation of and collaboration between 10 Danish harbours. Pack and Sea currently has a stock of approximately 260,000 crates. By tracking the crates, their optimal usage is at maximum capacity and crate loss reduced.

The Information for Recyclers Platform (I4R) is an ***online platform*** that enables recyclers to access information (provided by producers) about the WEEE that is relevant to properly treat this waste stream.

Information exchange is easier within a closed supply chain of trusted partners. Expanding the collaboration to more complex and international supply chains will be much more difficult.

ENABLING SECURE INFORMATION SHARING

Emerging solutions

The Dutch **Circularise** uses ***blockchain*** to improve transparency and communication across circular value chains. Its Smart Questioning technology enables stakeholders to perform Q&As on products via secure communication. It allows for more efficient data sharing while also addressing the industry's need for data protection.

The UK-based **Provenance** is a ***blockchain***-enabled digital platform that gathers and shares knowledge about products and their supply chains. ***RFID tags*** on products (e.g. fish, cotton) can guarantee their ethical and safe sourcing: the products' journeys are documented in the blockchain as they travel down the supply chain; and the customer can verify its origins, journeys and impact via a ***mobile app***. This software stores tons of verified information on an open registry, aiming to make it secure, trustworthy and accessible.

Some possible challenges related to the development and uptake of these solutions:

- The lack of standards on data sharing between different stakeholders across value chains.
- The lack of trust on data sharing between different stakeholders. This is hampered by concerns over data protection (e.g. personal data, IPRs).
- The scale-up of technologies like blockchain and concerns related to their energy consumption (see Chapter 4, section 2).
- Information exchange is easier within a closed supply chain of trusted partners. Expanding the collaboration to more complex and international supply chains will be much more difficult.

1. *Eurostat*, "Circular economy indicators" (accessed 15 January 2030).

2. See Oertel, Angelika; Katrin Maul; Jakob Menz; Anna Lena Kronsbein; Dana Sittner; Andrea Springer; Anne-Katrin Müller; Uta Herbst; Kerstin Schlegel and Agnes Schulte (2018), "REACH Compliance: Data availability in REACH registrations Part 2: Evaluation of data waiving and adaptations for chemicals ≥ 1000 tpa. Final Report (Final Report)", Dessau-Roßlau: German Federal Institute for Risk Assessment, p.172.

3. Specifically Audi, BMW, Daimler, DXC, Ford, Opel, Porsche, Volkswagen and Volvo.

4. Downes, Sarah; Jaco Huisman; Pascal Leroy; Maria Ljunggren Söderman; Duncan Kushnir; Amund N. Løvik; Patrick Wäger; Vera Susanne Rotter; Paul Mählitz; Perrine Chancerel; Johanna Emmerich; Anders Hallberg; François Tertre and Daniel Cassard (2017), Prospecting Secondary Raw Materials in the Urban Mine and mining wastes (ProSUM) Recommendations Report, Brussels: ProSUM.

5. *European Chemicals Agency*, "New database on Candidate List substances in articles by 2021" (accessed 24 June 2019).

6. SUEZ, "Organix®, the marketplace for organic materials launched by SUEZ, now available on the whole national territory", 06 March 2018.

7. Reverse logistics is the process of moving goods or materials from the consumer back to the point of origin, recapturing its value or disposing it properly.

Making business models, products and processes more circular

2

Decoupling economic growth from resource consumption implies a reduced material footprint. This requires making products, processes and services more circular; changing how we design, produce, use, reuse, repair, remanufacture and recycle products; and adopting new circular business models.

Digitalisation can make a significant contribution to all of these components of a CE. It is already affecting how businesses operate and the products and services they provide. It can support smarter use of resources, including the sharing of assets. It can facilitate more sustainable design and production processes; extend the lifecycles of products; and encourage the reuse, repair and recycling that are central to a CE. It can facilitate new circular business models and strengthen the business case for related activities (e.g. by lowering or removing transaction costs). It can contribute to dematerialisation, achieving more or the same with fewer resources and with less impact on the environment.

Digitalisation is already affecting how businesses operate and the products and services they provide.

While this chapter takes a closer look at service-based business models, it is worth noting that other circular business models exist – some of which are showcased throughout this publication. Some companies are making a profit from recovering resources and producing materials from waste through downcycling or upcycling (e.g. Upmade). Others are using bio-based or renewable materials to replace non-renewable materials. Some enable reuse, repair or remanufacturing, thus helping to extend the lifecycle of a product. Digitalisation can enable all of these business models deliver the desired results.

Going ahead, there is great potential in rethinking business models with a consumer perspective. People do not need to own lamps, they need light. They do not need to own cars, they need mobility.

The case studies below aim to give a taste of some of the possibilities digitalisation can offer. The challenges linked to developing and uptaking related solutions are further elaborated in Chapter 4.

2.1. Enabling service-based business models

Business models are increasingly shifting from producing goods to delivering services, and digitalisation plays a major role in this development. Servitisation can facilitate the transition toward a CE. In its simplest form, existing products

can be combined with value-added services that enhance durability, for example.

An example of a service-based business model that has a strong circular component is products-as-a-service, where consumers purchase the desired result rather than just equipment, resulting in resources being used more smartly. Customers can pay for the usage of products that are provided by suppliers (e.g. cars, clothes, home appliances). As renting and sharing reduces the need for individuals to own every product, this decreases the demand for continuous production. Solutions also exist for product owners to monitor their performance and take timely, predictive maintenance measures when needed.

Going ahead, there is great potential in rethinking business models from a consumer perspective. People do not need to own lamps, they need light. They do not need to own cars, they need mobility. They do not need to own washing machines, they need to wash clothes. Farmers do not need pesticides or fertilisers to produce nutritious and healthy food, they need healthy plants.

Numerous examples of digitalisation enabling such new business models already exist. These practices can encourage product longevity, reusability and sharing; reduce demand for materials and negative externalities (e.g. waste); and ultimately support dematerialisation. Simultaneously, shifting to servitisation would help businesses benefit from stronger customer relations and thus generate more stable revenue streams.

SMARTER USE OF RESOURCES

Existing solutions

As part of its **BlueMovement** initiative, the German Bosch provides washing and drying machines for a monthly subscription fee. This includes delivery, installation and repair. This kind of a service-based business model – where suppliers have an interest to manufacture more durable and more easily repairable products and maintain them when necessary – can result in the prolonged lifetime of a product and smarter use of resources.

Mobility as a service is attracting growing interest, especially in cities, and can be provided via the likes of ***apps***. For example, in Helsinki, residents can use **Whim** to access multiple transportation modes (e.g. train, taxi, bicycle). Users can either opt for monthly subscriptions or the pay-as-you-go method. Multimodal transportation can decrease the usage of cars or optimise their use, resulting in lower GHG emissions, cleaner air and greater increased resource efficiency. Instead of producing cars, materials and/or energy will be conserved and/or used for other purposes. This service is also an example of how public data can be of valuable use when made available.[1]

PREDICTIVE MAINTENANCE

Existing solution

HP Instant Ink is an ink cartridge replacement service that enables printers to send ink level information to HP via ***connected machines***. When ink levels are low, the company automatically ships replacement cartridges to the user.

ENCOURAGING RENTING AND SHARING

Existing solutions

Clothing-as-a-service ***online platforms*** are growing in Europe and beyond. **Tale Me** is a Belgian rental service for maternity and children's clothes. The Dutch brand **MUD Jeans** rents and recycles denim clothing. **Urban Outfitters** is starting a rental service, Nuuly.

Online platforms like **Bundles** enable home appliances to be rented.

EkoRent is a Finnish ***online platform*** which facilitates electric car sharing. This can contribute to lower ownership of cars and GHG emission rates. However, possible rebound effects must also be considered. For instance, it may incite people who do not usually use cars (i.e. pedestrians, cyclists) to use e-cars due to convenience.

Some possible challenges related to the development and uptake of these solutions:

- While service-based business models could greatly benefit the transition to a more sustainable CE, servitisation will not automatically lead to more sustainability. It can also result in environmental rebound effects if it is not adequately steered.
- Many businesses are slow to transform their businesses due to a lack of framework conditions, knowledge and skills. Economic considerations related to changing a business model may also create concern if a company already has a well-established model for selling products.
- Different rules for online platforms across EU member states can hamper the scale-up of innovative, circular business models across borders. If the policy framework and/or economic considerations do not incentivise the decreasing of consumption of natural resources, many businesses are likely to continue producing products rather than shift to less resource-intensive services.

2.2. Improving design

The design phase, where major features of materials or products are defined, is central to ensuring that materials and products put on the market are sustainable and contribute to circularity and reduced emissions. This phase greatly determines what the environmental and climate footprints of products will be across their lifecycle, including during their use and end-of-life phases.[2] In fact, it is estimated that up to 80% of a product's environmental impact is determined at the design phase.[3] Designing products, materials and even buildings that are more sustainable, durable, reusable and easily disassembled, upgraded and/or recycled is central to the creation of a CE and "designing out waste".[4]

Despite all of the benefits, this is easier said than done. Designing products and materials are complex exercises, and much work remains to be done to improve the processes themselves and their outcomes.

For materials alone, there is a growing list of criteria (often made up of interdependent variables) which producers need to consider, starting from the sourcing of raw materials. Criteria on materials must consider product requirements and support the needed behaviour or performance of a product. Materials should meet the set health and safety standards and contribute to the fulfilment of climate and energy goals. End-of-life management and wider environmental considerations add another layer of issues to be considered.

Digitalisation and digitally-enabled solutions can arguably help address some of these complexities within design.

Though it is still early, emerging solutions are already promising.[5] 3D modelling in design, construction, use and deconstruction processes provide interesting prospects. AI can be used to improve design processes by allowing designers to play with numerous materials and structures and test and refine design suggestions. It can be used to manage the complexity associated with harmful chemicals and materials and suggest new materials, based on LCAs.

Moreover, as Chapter 1, section 4 on information transfer demonstrates, integrating digital technologies into the design of a product could provide numerous possibilities. QR codes, barcodes, watermarks and RFID supported by data-sharing systems are already being used to improve the tracking of materials across the value chain. They can be used to transmit valuable information about the product to different stakeholders in the value chain, thereby encouraging greater circularity throughout the product's lifecycle.

ENHANCING DESIGN PROCESSES AND OUTCOMES

Emerging solutions

Building information modelling (BIM) is a process of designing, planning and constructing a building using digital ***3D modelling software***.[6] BIM enables more efficient gathering and sharing of information and collaboration between architects and engineers. It helps reduce raw material consumption, construction and demolition waste, and energy needed during the construction, use, maintenance and deconstruction of a building. There are also subsets of BIM (e.g. **Green Building XML**) for architects and engineers that focus specifically on sustainability factors.

The **Accelerated Metallurgy** project funded under H2020 aims to identify environmentally-friendly metal alloys and create new materials via ***AI***. As AI can accelerate the navigation through the different variables needed to create materials, this is helping to reduce alloy development time from a handful of years to under one. Although not directly linked to sustainability, this project demonstrates how data and digitally-enabled solutions could also be applied to develop more sustainable materials.

The **Citrine Platform** uses ***AI*** and ***algorithms*** to accelerate the material design process, namely developing new chemicals and materials for high-performance applications (e.g. in aerospace industries). AI can learn from previous experiments, thereby augmenting the traditional trial-and-error process and reducing lab work from years to days. Although this platform does not have circularity as its immediate goal, such technology could very well be directed towards developing more circular materials.[7]

DESIGN FOR CIRCULARITY

Emerging solution

The **Committee for European Construction Equipment's tower crane manufacturers** embed crane parts with ***RFID sensors*** that can send information about the performance of the equipment remotely. This can prolong their lifetime (e.g. by enabling predictive maintenance).

2.3. Improving production and processes

The production of food, materials, components and final products can be energy- and resource-intensive and lead to significant amounts of waste. That being said, producers also have a strong, built-in interest to optimise production and processes, not least because resource efficiency can lead to significant economic savings. Thus, different business sectors are already full of examples of digital tools like robotics, IoT and AI being used to optimise production and processes, resulting in less waste and emissions, and energy and resources consumed.

Digital tools like robotics, IoT and AI are being used to optimise production and processes, resulting in less waste and emissions, and energy and resources consumption.

Europe is a global leader in industrial IoT (i.e. machine-to-machine communication).[8] IoT is used to monitor the functioning of machines, make them operational at off-peak times, enable predictive maintenance and so on. This existing expertise provides a strong base for Europe to enhance the use of IoT for more sustainable processes.

3D printing, coupled with automation, is expected to become more mainstream in construction as the technology and standards continue to develop.

Digitally-enabled solutions like 3D printing offer interesting prospects as they can also boost the development of local bottom-up solutions by helping local manufacturers produce and deliver products and services to customers on demand. 3D printing can help cut costs and optimise production by using only the exact amount of material needed.[9]

Moreover, digitalisation can help facilitate industrial symbiosis and the sharing of assets (e.g. surplus energy, materials) with other stakeholders, thus helping to avoid waste.

OPTIMISING PRODUCTION FOR GREATER SUSTAINABILITY

Existing solutions

Adidas and additive manufacturing company Carbon have developed **Futurecraft 4D**, a new ***3D printed*** shoe. 3D printed footwear uses fewer materials and easily recyclable parts. Using 3D technology speeds up the production process to 20 minutes per shoe. The full recyclability of the shoe[10] and its price (currently around $300 per unit) are remaining challenges.[11]

Libelium is a company that provides farmers with ***sensor technology*** and an ***IoT***-based platform to observe, measure and respond to the environmental conditions, diseases and pests that affect their agricultural production. Such 'precision agriculture' enables growers to match farming practices to crop needs, thereby reducing the use of pesticides, fertilisers and water while still boosting yields.

AeroFarms is an agricultural company that uses ***sensors*** to optimise agricultural production, leading to the reduced consumption of fertilisers, soil and energy.

Emerging solution

3D printing produces spare parts that are necessary to make an entire component or product function again, thus extending its lifetime. This can facilitate remanufacturing and be especially useful when the manufacturer no longer produces the spare parts. Moreover, 3D printing makes localised production possible and spare parts more accessible while simultaneously benefiting the local community by providing new income and jobs, and reducing transport-related emissions for new products. However, the high cost of 3D printing means that it is currently less accessible to SMEs, for example.[12]

OPTIMISING PROCESSES FOR GREATER RESOURCE EFFICIENCY

Existing solutions

GreenLab is an industrial park developed as a public-private partnership in the Danish municipality of Skive. Members of the industrial park rely on the integrated intelligent infrastructure to enable energy exchanges between businesses.

The Finnish **Prometec** has developed ***automated sampling robots*** to determine the level of moisture in solid biofuels. They enable efficient collection of quality samples from cargos arriving in a particular power plant, thus enhancing the processing of biofuels in the facility and ensuring the best use of materials (e.g. if the biomass stock is too moist, it will not be unloaded).

Emerging solutions

Companies such as **Bosch** and **Siemens** are developing and rolling out ***smart digital factories***, that are built on ***AI*** and ***IoT***. These will help reduce energy consumption and waste during production processes. However, without strong corporate commitment towards greater sustainability, the aforementioned technologies can also be used to accelerate production and thus the consumption of materials and energy.

The Shanghai-based company **Winsun** applied ***3D printing*** in Suzhou Industrial Park's garden villas. Using 3D printing meant that construction material usage was cut by 30% to 60% and costs were halved.[13] However, the company faces challenges in commercialising the solution due to a lack of regulatory standards and the designers', project developers' and owners' scepticism about the products' safety. Nevertheless, 3D printing, coupled with automation, is expected to become more mainstream in construction as the technology and standards continue to develop.[14]

Some possible challenges related to the development and uptake of these solutions:

- The development and deployment of digital technologies (e.g. AI, 3D printing) in production and processes are limited because of the cost of solutions.
- Diverging national legislative frameworks and definitions of waste as well as lack of awareness about the shared benefits can hamper industrial symbiosis.

2.4. Improving the reuse, repair and remanufacturing of products

Extending the lifecycles of products like electronic appliances by reusing, repairing and remanufacturing is central to a CE. Several new and emerging digitally-enabled solutions are already contributing to these efforts.

European industry has traditionally been strong in industrial IoT and industrial AI. If the EU is serious about strengthening its efforts in product repair, then these dual assets must be bolstered.

Online platforms facilitate the reuse of products, components and materials, giving them a second life. Durability can be enhanced and repair facilitated via connected machines that provide RTD on the conditions, state and availability of products, for instance. When data is used to identify problems with a product, this can contribute to predictive maintenance and potentially more efficient reparations, too. European industry has traditionally been strong in industrial IoT and industrial AI. If the EU is serious about strengthening its efforts in product repair, then these dual assets must be bolstered.

Europe has been slow to build on the potential of remanufacturing, design products for remanufacturing and use digitalisation in these efforts.

Digitalisation can also support remanufacturing, which entails interventions at the end of a product's lifecycle (e.g. dismantling, repairing or replacing parts, reassembling) to bring it back on the market, usually accompanied by a warrant.[15] Remanufactured products are generally regarded as more valuable compared to secondary raw materials obtained via recycling or energy recovery. Remanufacturing also reduces the demand for new products, hence saving energy and materials that would otherwise be used in production.

The European remanufacturing market is currently valued at €30 billion – a significant sum, albeit still a negligible share compared to the entire manufacturing sector (2%).[16] The potential is great: the value of this market could grow to €100 billion by 2030, save 21 megatonnes of carbon dioxide emissions and create around 500,000 new jobs.[17]

ENCOURAGING REUSE

Existing solution

Numerous ***online trading platforms*** serve as marketplaces for used products (e.g. eBay, Gumtree, Amazon, 2emeMain), specialised replacement parts or excess materials (e.g. EME).

Emerging solution

The Danish **Gen Byg Data** is an online ***platform*** that provides data on available materials and enables pre-demolition asset-tracking of a building with the help of a geographic information system developed by Skive Municipality.

ENABLING REPAIR

Existing solutions

iFixit is an open-source ***online platform*** for repairing electronics and machinery, especially car components. It contains repair guides, Q&A forums and user-generated updates on existing and prospective equipment. Their challenge is that they cannot provide a guarantee on the reliability of the information posted. There are also questions surrounding liability in the case that repairs should go wrong.

Augmented reality glasses, such as the ones developed by **DAQRI** and **SCOPE**, can provide workers with the necessary information on how to repair a product and best handle hazardous waste.[18] This technology can provide remote, on-the-ground interactions between experts and non-experts. It can also provide more convenient (visualised) instructions whereby the software itself guides the user on how to solve a particular problem.

IMPROVING PREDICTIVE MAINTENANCE AND DURABILITY

Emerging solution

The German **ThyssenKrupp** gathers elevator data and uses ***IoT*** to enable predictive maintenance.

Some possible challenges related to the development and uptake of these solutions:

- It is not always easy for consumers to find information about repairing, gain access to needed replacement parts or access affordable repair services.
- People may be reluctant to use second-hand products because of concerns over their condition and lack of information on their quality.
- People may be hesitant to donate and/or sell electronic devices to be reused if they contain personal information.
- Europe has been slow to build on the potential of remanufacturing, design products for remanufacturing and use digitalisation in these efforts. Overall, there is a lack of awareness about the possibilities and measures needed to enhance remanufacturing.
- Using digitally-enabled solutions for repair and remanufacturing requires skills and training.
- Manufacturers can be concerned about external repair services, as they can raise questions about accountability and liability should the repairs go wrong.

ENHANCING REMANUFACTURING

Emerging solution

Digital technologies like ***3D printing*** can improve the remanufacturing of products by manufacturing the necessary spare parts. Data exchange via ***online platforms***, ***IoT*** or ***blockchain*** enables the identification and safe recovery of equipment that can be remanufactured; and prevent it from being recycled, dismantled or repurposed for a lower value function. Advanced remanufacturing holds many possibilities, and the US and Asia have been building on related opportunities – arguably more so than Europe.[19]

2.5. Improving waste management

While the recycling rates of municipal waste, packaging waste and WEEE are increasing in the EU, waste is still a significant problem.[20] Around 750 million tons of waste is generated annually, out of which only around 50% is recycled.[21] Moreover, only around 10% of said recycled materials are brought back into the economy.[22] When waste is incinerated, landfilled or shipped outside of the EU, it loses great amounts of potential secondary raw materials (e.g. metals, wood, glass, paper, plastics).

The Commission has rightly proposed that the EU should take responsibility for its own waste.[23] If done properly – starting with waste prevention as laid out in the 'waste hierarchy', followed by reuse, recycling, energy recovery and (only as a last resort) landfilling –, waste management can help retain the value of end-of-life products and materials, keep them within the economy, and avoid pollution and other costly externalities.

Digitally-enabled solutions can be used to improve and modernise waste management and thus help solve the EU's waste problem. They offer interesting possibilities, especially for supporting waste collection, sorting and recycling as well as innovative business models, such as resource recovery (i.e. producing secondary raw materials from waste).

IMPROVING WASTE COLLECTION

Existing solutions

Waste collection can be made more efficient with real-time, waste-monitoring sensors. The Bulgaria-based **ConnectedBin** uses ***sensors*** and ***IoT*** systems for smart waste management. Waste collectors can access data (e.g. on waste quantities) from all of the bins, thereby optimising waste collection.

Rezycl is a custom-designed software for companies to handle their waste. The ***online platform*** and ***app*** facilitate access to pertinent data and waste statistics and the ordering of waste collection, and decrease the administrative burden for businesses (e.g. waste disposal reporting).

Enevo uses an ***IoT*** platform to monitor, analyse, collect and treat its clients' waste. Collecting waste data with wireless sensors, Enevo can measure and forecast fill levels in waste containers to determine where waste collection can be further streamlined and costs reduced.

Rubicon Global is a ***cloud***-based waste and recycling company. It provides waste, recycling and smart city solutions to businesses and governments worldwide. It aims to find inefficiencies in waste streams and develop new and innovative ways to reduce, reuse and recycle waste. Rubicon has also developed a ***mobile app*** to provide on-demand trash pickup.

IMPROVING WASTE SORTING AND RECYCLING

Existing solutions

SUEZ is using advanced waste characterisation with multi-sensor ***data*** to improve waste sorting and recycling in its facilities. ***Infrared technologies*** help enhance waste sorting, while ***digital twin*** technology enables sorting machines to learn based on the digital image of waste items provided by the software. SUEZ is also experimenting with ***blockchain*** technology to ensure the real-time traceability of waste flows.[24]

The Swiss **Novamet** applies an ***IoT*** system which analyses RTD to guide aluminium recycling. Sensory equipment monitors the smelting process in furnaces and sends the data for more precise planning and decision-making on future aluminium recycling.

In Spain, TagItSmart, EVRYTHING, recycl3r and Circular Lab have developed the ***mobile app*** **Recicla Ya**. It allows Carrefour customers to scan products with their smartphone to receive information on waste sorting and recycling schemes, and are rewarded loyalty points for their actions.

Emerging solutions

The Belgian waste operator **Recupel** has developed ***AI*** which sorts out e-waste using waste image recognition. By the end of 2019, this AI was able to do basic device recognition. Advanced functions are currently being developed (e.g. enhanced device recognition, identification of hazardous materials in waste).

The Finnish **ZenRobotics** uses ***AI-supported robots*** for fast and precise waste sorting, including bulkier waste (e.g. construction and demolition waste).

ENFORCING COMPLIANCE WITH EU RULES

Existing solution

Earth observation via remote ***sensing technologies*** like ***satellites*** already monitor and assess the status of and changes in the environment. Satellite imagery has even been used in court cases to enforce environmental legislation.[25] The EU and its member states could also use satellite imagery and drones to detect illegal landfills and thus eliminate them.

Some possible challenges related to the development and uptake of these solutions:

- More investments in and a greater uptake of digitally-enabled solutions (i.e. digital twins, automation, infrared) would help improve waste management processes.
- The shipment of products to be recycled and of secondary raw materials across EU member state borders can be hindered by diverging national definitions (of e.g. waste).
- The existence of hazardous substances hampers recycling and the quality of secondary materials.

1. See also *Helsinki Smart Region*, "Is Whim the Netflix of Mobility?" (accessed 02 August 2019).

2. Schweitzer, Jean-Pierre (2019), "Climate action needs better products", *Euractiv*, 04 November 2019.

3. European Commission (2012), Ecodesign your future: How Ecodesign can help the environment by making products smarter, Brussels, p.3.

4. See Wilson, Simon, "Let's design out waste for a real Circular Economy", *Euractiv*, 23 June 2016.

5. See Ellen MacArthur Foundation (2019), "Artificial Intelligence and the Circular Economy; AI as a tool to accelerate the transition", Cowes.

6. Lorek, Sarah, "What is BIM (Building Information Modelling)?", *Constructible*, 17 July 2018.

7. *Ibid.*, p.13.

8. *IoT Business News*, "Europe extends its lead in the industrial IoT with three times more extensive implementations versus the U.S.", 20 December 2018.

9. 3D printing (i.e. additive manufacturing) creates an object layer-by-layer by adding just the necessary amount of material to produce an item, rather than eliminating surplus material to get the desired product, thus minimising waste in the production process.

10. *Design Life-Cycle*, "Futurecraft 4D shoes: Production Life Cycle" (accessed 29 July 2019).

11. Cheng, Andria, "How Adidas Plans to bring 3D Printing to the Masses", *Forbes*, 22 May 2018.

12. Golisano Institute of Sustainability (2017), "Technology Roadmap for Remanufacturing in the Circular Economy", Rochester.

13. Ellen MacArthur Foundation (2018), "The circular economy opportunity for urban & industrial innovation in China", Cowes, p.47.

14. De Laubier, Romain; Marius Wunder; Sven Witthöft and Christoph Rothballer (2018), "Will 3D printing remodel the Construction Industry?", Boston Consulting Group, 23 January 2018.

15. Jansson, Kim; Saija Vatanen; Iris Karvonen; Katri Behm; Rachel Waugh; David Fitzsimons; Erik Sundin and David Parker (2017), D6.3 Targeted Recommendations for Horizon 2020, grant agreement No 645984, January 2017, European Commission, p.11.

16. Conseil Européen de Remanufacture, "Remanufacturing: a Primer", Brussels.

17. Jansson *et al.* (2017), *op.cit.*, p.11.

18. See also Simpson, Will, "Augmented Reality comes to Waste Management", *Resource*, 02 September 2016.

19. See e.g. *Advanced Remanufacturing and Technology Centre*, "Advanced Remanufacturing" (accessed 17 February 2019).

20. European Environment Agency (2019a), Waste recycling, Copenhagen.

21. These figures do not include major mineral waste from construction and mining. With these additional amounts, the EU total equals more than 2.5 million tonnes of waste (including the UK, Iceland, Liechtenstein, Norway, Montenegro, North Macedonia, Serbia and Turkey). Mineral waste is not included in this discussion because of its uncertain quantities.

22. European Environment Agency (2019b), Paving the Way for a Circular Economy: Insights on Status and Potentials, Copenhagen, p.10;17.

23. European Commission (2019), Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal, COM(2019) 640 final, Brussels.

24. Versluys, Helen and Thomas Vandenhaute (2018), "Zo werkt de digitale circulaire economie", Brussels: Agoria.

25. For example, earth observation data can help courts decide on infringements of biodiversity law, as was the case in the European Court of Justice's judgment against the Polish government concerning degradation of the ancient Białowieża Forest. See *Commission v Poland (Forêt de Białowieża)*, Judgment of the Court of Justice of the European Union, C-441/17. Additional information on how satellite images can be used by courts is available in Sulyok, Katalin; Fruzsina Bögös; Tiina M. Paloniitty and Mariolina Eliantonio (2019), Summary Report: Analysis of the Questionnaire, Helsinki: European Commission, pp.7-9.

Strengthening the roles of citizens and consumers

3

The transition to a circular and climate-neutral economy will depend greatly on the contributions of consumers and citizens – how people live, consume, reuse and recycle products and materials.

Data and digital solutions are already being used to better inform and educate people to increase their awareness on sustainability issues, including recycling. Several solutions which help people make sustainable choices also exist. Sharing information on the environmental footprints of products (PEFs) is a positive example. Tools like platforms and apps can also be used to nudge people's behaviour towards buying more durable or recyclable products.

Moreover, encouraging people to use and collect data can convert them into active participants of the data economy and co-creators of knowledge and evidence. In turn, decision-makers, businesses, investors and fellow citizens can use this information. Monitoring the e-commerce market, for example, is extremely difficult for public authorities. Hence the argument for citizens partaking in the monitoring and the informing of authorities.

There is a growing public demand for solutions that are sustainable, convenient, safe and reliable. Providing people with the tools to have their wishes and concerns heard and be impactful could empower them to become active participants of the transition.

Overall, digitalisation can both influence and empower citizens and consumers to play a decisive role in the transition to a CE. However, this implies that digitally-enabled solutions are made accessible – starting with the Internet – and citizens have the necessary skills to use digital tools.

Moreover, not all solutions would necessarily work for Europeans. For instance, face recognition technologies are already under increasing scrutiny in Europe. China's Social Credit System is an example of how digitalisation can be used to monitor, reward and punish people based on their behaviour. It is highly questionable whether such solutions would be readily adopted in Europe, as they carry a risk of undermining people's fundamental rights and EU data protection rules.[2]

PROVIDING INFORMATION

Existing solutions

The **WikiRate Project** is the largest openly accessible ***database*** of environmental, social and governmental data. The collaborative ***platform*** enables academics, non-profit organisations, standard bodies, investors, companies and the general public to research, discuss and rate company performance.

The H&M Group-owned brand **COS** has launched a new line, called Restore, which focuses on repairing and repurposing old textiles. The company has asked a third party to provide ***data*** on their water, carbon dioxide and energy savings, which is then displayed in stores where the collection is sold. This creates awareness on the wider sustainability benefits of greater circularity.

Emerging solutions

Accenture is working on a ***blockchain-based app*** that allows consumers to trace products back to their origins and rewards companies that conserve natural resources.

ENABLING SUSTAINABLE CHOICES

Existing solutions

Veo is an 'earth-friendly' online ***platform*** and marketplace that connects consumers to sustainable and ethical products. It screens suppliers before allowing

them to join the marketplace to ensure that only responsibly produced goods are featured.

Amazon's **Second Chance** ***webpage*** provides instructions for recycling packaging, repairing equipment and purchasing (certified) refurbished products.

Bext360 uses ***blockchain*** technology to monitor the sustainability of supply chains (e.g. timber, minerals, cotton) comprehensively and measurably, and traces the consumer back to the producer.

Beat the Microbead is an UN-sponsored ***app*** which enables users to scan products to see if they contain microbeads, thus increasing consumer awareness and supporting more sustainable choices.

The German FP7 co-funded project **myEcoCost** aims to estimate a consumer's ecological footprint by using ***data*** across the whole value chain of a product.

Emerging solution

The **AskREACH** project aims to develop a ***database*** on substances of concern in articles provided by suppliers. The database will be connected to a ***smartphone app*** to facilitate access to the information.

NUDGING BEHAVIOUR CHANGE

Existing solutions

Impak is a ***platform*** which encourages responsible shopping. It contains a registry of sustainable businesses that consumers can use to guide their spending. Impak uses online questionnaires to screen businesses and determine via a rating system whether they are socially and environmentally responsible or not. The platform also operates its own cryptocurrency (i.e. impak Coin), rewarding consumers for making sustainable purchases.

Apps like **My Little Plastic Footprint**, launched by the Dutch Plastic Soup Foundation, help consumers reduce their personal plastic footprint by providing information about plastic waste and encouraging them to reduce their plastic consumption.

Giki is a ***mobile app*** that awards badges to products on the British market based on their impact on the environment and how ethically they were sourced and

Encouraging people to use and collect data can convert them into active participants of the data economy and co-creators of knowledge and evidence.

As data is increasingly being used to improve sustainability, it is important that people can access how, when and why data is used.

produced. Consumers can scan the barcodes of products before a purchase to determine how sustainable the product is. The app also suggests alternative brands or products which meet consumers' sustainability expectations.

INCENTIVISING RECYCLING AND TACKLING WASTE

Existing solutions

Chatbots like **Oscar** can be used to assist waste sorting.

The Canadian **Plastic Bank** project incentivises people to bring plastic waste to recycling export collection areas in return for ***digital currency***.

SIRPLUS uses an ***online platform*** to sell surplus, expired and deformed groceries for up to 70% less than its usual price, thus combatting food waste.

Emerging solution

Horizon 2020 projects **Waste4Think** and **PlastiCircle** use ***RFID*** and ***IoT*** technology to monitor waste fractions at the household level, to financially incentivise residents to sort recyclable waste.

CO-CREATING KNOWLEDGE

Existing solutions

MyData Global aims to empower citizens to strive to know what is done with their ***data***, and, in turn, have an impact on and benefit from the use. As data is also increasingly being used to address sustainability problems, having people know how, when and why data is used can increase their desire to share their data and thus contribute to co-creating knowledge.

LitterGram is an ***online app*** which seeks to reduce litter in the UK. Citizens are connected to their local authorities, to whom they can share photographs and locations of litter via the app so that it can be handled appropriately.

Litterati is another example of an ***online app*** used to tackle litter worldwide. The app enables the user to identify and geotag litter as a precondition of cleaning it up. So far around 3.7 million points of litter have been identified worldwide, of which almost a third are plastics.

The **FixMyStreet** ***websites*** and ***apps*** are used in several cities of the world, including Brussels, to enable people to report street problems like rubbish. The reports are sent to authorities. These kinds of solutions could be used to empower citizens to monitor and report other concerns, for example in the online market.

Some possible challenges related to the development and uptake of these solutions:

- Citizens and consumers do not always have access to digitally-enabled solutions, starting with the Internet.
- Citizens and consumers do not always have the awareness and skills to use digitally-enabled solutions to purchase more sustainable products, and maintain and dispose them in alignment with circularity goals. 'Appification' is not without its problems. While apps can help connect, inform, educate and even empower stakeholders, citizens and consumers, the market can be complex and overwhelming for citizens to navigate.
- Consumers spend on average 10 to 20 seconds when deciding on a purchase. Making a sustainable choice should therefore be the easy and default option – however, this is often not the case. Labels can help consumers, but are not easy to navigate through: the choices are abundant and the differences not always clear, which can reduce people's interest and trust in them. This also applies to the numerous apps that use different data and labels to rank products. For instance, some consider climate footprints, some environmental factors and others health impacts.
- There is a lack of regulatory and financial incentives for people to reduce their consumption.

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2. Kobie, Nicole, "The complicated truth about China's social credit system", *Wired*, 07 June 2019; European Commission (2020), White paper on Artificial Intelligence – A European approach to excellence and trust, COM(2020) 65 final, Brussels.

The barriers, challenges and risks of digitalisation

4

As the previous chapters have shown, digitalisation can help tackle barriers and accelerate the transition to a CE. However, it is also not without its problems. This chapter notes some of the barriers, challenges, existing contradictions and risks that must first be overcome if Europe is to develop a successful digital roadmap for a CE and avoid unwanted consequences for the planet, businesses and people.

4.1. The basic barriers to achieving a digital economy

Many of the basic challenges surrounding the management of data and use of digitally-enabled solutions for a CE are generally akin to those for the digital transition. The following are the most pertinent to the EU:

- **Digital infrastructure.** The EU's digital infrastructure for connectivity, including Internet coverage (i.e. high-speed broadband, 5G, fibre) and cybersecurity, is underdeveloped. This infrastructure forms the basis for managing data and using digitally-enabled solutions efficiently and securely. If the EU fails to invest in this basic infrastructure, it will not reap the full benefits of the solutions that digitalisation can offer.

- **Digital performance.** Digital transformation in the EU has been slow. Europe struggles with improving not only its connectivity but also business digitisation, e-commerce and digital public services. This is affecting the EU's competitiveness and ability to compete on the global stage.[1]

- **Data.** Analysing big data is not always simple. Even when digitised, data is not always systematised, meaning standardised or comparable. Different data formats or low-quality data lead to poor outputs. The lack of clarity on data ownership, diverging degrees of freedom on data flow, and the continuous search for a harmonious balance between information sharing and protecting citizens' and businesses' sensitive data all impact data economy developments, too.

- **Privacy, security and trust.** The private and public sectors' and citizens' are concerned with how data is being used and the purposes for which it is used. The lack of cybersecurity is often mentioned as the main barrier in transitioning towards a digital economy fully, thereby undermining the collective trust in digital developments. Without guarantees of cybersecurity and a safe digital environment, getting all of the actors necessary for the digital transition on board will remain difficult.

- **Digital Single Market (DSM).** Despite a wide array of legislation being adopted by the EU in recent years (on i.e. roaming charges, unjustified geo-blocking, rules for e-commerce, digital contracts, online purchases), many of these rules do not go far enough in dismantling regulatory barriers, while some even constitute additional administrative hindrances and affect SMEs and start-ups in particular.[3]

- **A lack of interoperability.** A lack of connection between data and systems can impair data flows and analysis. If data is fragmented across multiple isolated public and private databases, this can hamper the sharing of data and creation of relevant information and knowledge for a CE. Moreover, when new software is not compatible with old hardware, this can result in a lack of interoperability between them and, consequently a faster turnover of hardware and more e-waste.

► **Slow development and deployment of emerging technologies.** The EU risks falling behind in the digital race (in e.g. 5G, IoT, AI), especially vis-à-vis China and the US, which would have significant negative implications on its competitiveness, security and prosperity. The US and China continue to lead in the fields of AI and IoT research, patent applications and promising AI start-ups. Although European companies are well placed in 5G development, they are behind Asia and North America in its deployment. With a fragmented DSM, timidity to invest in emerging technologies and lack of digital skills, Europe risks becoming a follower rather than a shaper of future solutions and global standards.[4]

► **Capacities and skills.** Over a third of Europeans in the active labour force lack basic digital skills and e-literacy.[5] Furthermore, the lack of information technology (IT) and AI professionals is a hindrance to the digital transition.[6] Some even talk about a 'skills shortage crisis': the European ICT sector is expected to have 756,000 unfilled jobs by the end of 2020, and already 40% of ICT companies report difficulties in finding skilled workers in Europe.[7] The public sector's inability to apply digitally-enabled solutions is a hindrance to societal developments.

► **Barriers to digital services.** Geo-blocking, procurement rules (i.e. favouring products over services), standards and the difference in fees for services and products are examples of national obstacles that hinder the development of digital services uptake and can have significant impacts on circular business models like servitisation. Donating unused or reusable products from e-commerce, for example, is unattractive to businesses when they are charged with additional value-added tax (VAT). As a result, stakeholders (e.g. e-retailers) are incentivised to discard or destroy unsold products since it is cheaper than donating goods.

Many of the basic challenges surrounding the management of data and use of digitally-enabled solutions for a CE are generally akin to those for the digital transition.

4.2. The challenges of key technologies

As has been demonstrated in the previous chapters, emerging technologies (e.g. blockchain, AI, cloud computing, IoT) carry interesting possibilities for the transition to a CE. However, their development and deployment are not without their problems. Below is a list of some the technology-specific challenges:

BLOCKCHAIN

Blockchain is a distributed ledger that can be used to record and share information securely and enable online transactions. Information can be managed in a decentralised way and made available to those with access. For the CE, blockchain has already proven to be useful in improving transparency and communication across value chains and in storing and sharing information securely, thus addressing a major barrier to achieving a CE.

► Still, the current 'generation' of blockchain requires significant amounts of energy, which adds to doubts surrounding these solutions' scalability and efficiency. Bitcoin technology has created much negative publicity for blockchain, as its energy consumption has been estimated to be comparable to the energy consumption of countries like Switzerland or the Czech Republic.[8] New generations of blockchain are, however, being developed, and a contractual blockchain with a smaller number of mutually trusted parties is likely to be more interesting from a sustainability perspective for the time being.[9]

Not being at the forefront of AI development entails being a follower in adopting standards and rules that are developed elsewhere, which in turn may exacerbate Europe's position in other major technologies further.

► The initial information uploaded on a blockchain must be accurate from the beginning. Blockchains cannot address the quality of the initial input; it is an enabling technology, and the quality and accuracy of the content within it is still largely dependent on the input provided by people.

Fears of cyber threats and security breaches are often reported as a major limiting factor in using and adopting cloud computing services.

► While blockchain-enabled solutions could provide an attractive platform, especially for data and information sharing, this will not happen automatically. Companies need to first be convinced of the rationale and benefits in sharing their data (which can be supported e.g. via regulation and financial incentives). Sharing data in general, but also via blockchain may cause uncertainties in terms of data privacy, liability and competition; therefore, rules regarding who should have access to what data, when and how are necessary. Businesses and organisations should have clear rules to refer to make up for the uncertainty of sharing data.

► International standards and a common understanding of blockchain development are still lacking. This is an opportunity as well as a challenge for the EU if it wishes to encourage the technology's development and global usage.

ARTIFICIAL INTELLIGENCE

AI is broadly understood as a machine's capability to perform tasks which would normally require human intelligence. It

allows machines and programmes to learn and alter their operations based on previous experience. In order to function, AI is dependent on large amounts of datasets (i.e. big data) and advanced analytics which find patterns and trends that can be transformed into 'automated decision-making' processes. AI is already supporting the CE by enabling faster data management, improving connections and designing more circular products and services.

► Nonetheless, Europe is lagging in investing in and developing AI technologies, while the US and China emerge as frontrunners. Not being at the forefront of AI development entails being a follower in adopting standards and rules that are developed elsewhere, which in turn may exacerbate Europe's position in other major technologies further.

► Barriers to the free flow of data – which is crucial for AI – subsists within the DSM. While new EU rules on non-personal data and the reuse of public sector information may open up access to data, it only constitutes the first step. If interpreted too broadly, the definition of personal data under the General Data Protection Regulation (GDPR) may add unnecessary restrictions to the free flow of data.

► AI systems are fuelled by data. However, as mentioned above, data sets are not always standardised, comparable nor digital. Low-quality data may lead to poor outputs.

► AI is dependent on human expertise and skills. Competition over digital talent is growing, with even mentions of a "war for talent" over the same pool of highly-skilled experts being made. European universities are struggling to maintain talented computer scientists, and European companies to find qualified AI researchers. Silicon Valley continues to attract most digital talents from around the world, while Asian countries have also adopted a set of targeted initiatives.[10]

► Using AI entails potential risks, and while citizens fear the implications of algorithmic decision-making that could, for instance, lead to discrimination, many companies worry about the legal uncertainty and liability issues.

CLOUD COMPUTING

Cloud computing implies the delivery of computing services over the Internet. It can involve online services, storage, databases, networking and analytics, and often implies having online data centres simultaneously available to many users. Clouds can be limited to a single organisation or made accessible to several at the same time. Besides helping save IT infrastructure costs and maintenance, this technology may also allow organisations to run faster, be more connected and improve their management – issues that are core to the functioning of a CE as well.

► However, the technology also faces specific challenges. Fears of cyber threats and security breaches are often reported as a major limiting factor in using and adopting cloud computing services.[11]

► In addition to security concerns, businesses also mention the uncertainty of applicable laws, jurisdiction and dispute resolution mechanisms as the main reason for not taking up cloud computing.[12] Data may reside and be located across several jurisdictions, and few national and international rules clarify which jurisdiction would apply in the case of disputes.

► The public sector and SMEs are not always aware of the benefits cloud computing could bring, while awareness is stronger among large firms.[13] Insufficient knowledge among EU businesses is a main blocking factor for cloud computing technologies being adopted.

► The high cost of buying cloud services is

a major barrier, especially for SMEs.

► Energy consumption is becoming a major issue for the operation and maintenance of cloud data centres (see Infobox).

THE INTERNET OF THINGS AND CONNECTED DEVICES

IoT and connected devices are everyday physical objects that are connected to the Internet and can be identified by other objects. The technology can be used to predict, for example, the need for maintenance or support management of energy usage. As such, IoT and connected devices can represent great advantage in enabling a CE.

► Similarly to other emerging technologies, however, IoT faces a significant challenge in terms of cybersecurity and trust. With the multiplication of connected devices, there is a fear of cyber threats and hacks. Poorly designed devices could, in the worst cases, risk the health and safety of people.[14]

► The lack of skills is another major barrier for IoT deployment. Developing and deploying IoT applications both require knowledge and an understanding of complex digital connections and infrastructure.

► Regulatory complexity and requirements in Europe may slow the development of IoT. The regulatory frameworks relevant for IoT – notably on telecoms, broadband and 5G – pose more regulatory constraints in the EU than the US or China.[15]

4.3. The unwanted consequences and risks of digitalisation

In addition to the basic barriers to a digital economy, there are also several risks and potential contradictions that must be addressed in order to avoid unwanted consequences and build a comprehensive framework for action. Greater use of data and digital solutions do not automatically lead to higher levels of prosperity, reduced GHG emissions nor smarter use of resources. In fact, digitalisation can very well cause the opposite if it is not guided and governed well.

Firstly, digitalisation comes with the risk of a **digital divide,** where only the wealthy can access and utilise available technologies. There is already a growing gap in labour markets between high-skilled specialists who can use complex technologies and low-skilled workers who potentially face unemployment due to automation. The digital gap between large companies and SMEs that do not necessarily have the same resources to invest in reskilling programmes and adopt new technologies may also widen. Failing to take this challenge seriously could lead to (further) social polarisation.

Secondly, data sharing and digitally-enabled solutions **do not automatically lead to more sustainable production and consumption**. Data must be actionable in order to provide the basis for change. Digital services (e.g. e-commerce) can also contribute to increasing (unsustainable) consumption. Moreover, products imported from outside of the EU carry the risk of containing materials and substances that are not permitted in the EU and will be difficult to reuse and/or recycle.[16]

Thirdly, the digital transformation of our economy and society can have unwanted implications for our **security** (e.g.

Infobox: Unsustainable ICT?

Data centres, digital devices and digital infrastructures require (often critical) levels of energy and materials. ICT accounts for 5% to 9% of the total electricity demand, and could potentially increase to 20% by 2030 as the demand for data centres, cloud computing and other energy-intensive technologies (e.g. blockchain) increase.[18]

This has implications on GHG emissions – the ICT sector currently accounts for 2% of global GHG emissions, which is comparable to the aviation sector. The carbon footprint of data centres is growing, especially due to the increasing demand for Internet services and cloud computing developments.[19] Needless to say, if the data centres are powered by renewable energy sources and become more energy-efficient, their emissions can be reduced drastically.

Moreover, the sector's resource use and waste are a problem. As a significant user of critical and virgin materials, the sector contributes not only to the increase of GHG emissions[20] but also biodiversity loss and water stress due to resource extraction.[21] Computers, smartphones and other electronic devices eventually become e-waste, which is currently one of the fastest-growing waste streams. In 2016, around 44.7 million metric tonnes of e-waste was generated (i.e. 6.1kg per person), with an expected global annual growth rate of 3% to 4%. Multiple device ownership, the growth of cloud computing services and short replacement cycles are paving the way towards a growing e-waste generation.[22]

It is worth noting that software and its contents are also increasingly being recognised for its impact on energy and material consumption. For instance, some software programmes are only supported by one type of hardware and/or cannot be used for other/new types of equipment.[23] This can lead to multiple device ownership as well as shorter replacement cycles for the products.

E-waste leads to another missed economic opportunity, as enormous amounts of valuable and critical materials are thrown away. Electronics contain critical materials, precious metals, iron and aluminium which, together with its plastic components, could be largely recovered.[24] The landfilling and informal recycling of e-waste also create unwanted health and pollution impacts. Given that EEE contains substances of concern (e.g. mercury, lead, flame retardants), landfilling, incineration or littering may result in adverse effects on the environment and human health.[25]

The environmental and climate footprints of digitalisation must be addressed if the EU is serious about using digital tools in its quest for greater sustainability.

cyberattacks). Moreover, there is a growing concern about how digitalisation is affecting people's **health**. Radiation and exposure to hazardous substances have especially raised concern.[17]

Fourthly, digitalisation that relies on ICT has **a significant climate and environmental footprint** that cannot be overlooked. The energy and material implications are a cause of significant concern (see Infobox).

Greater use of data and digital solutions do not automatically lead to higher levels of prosperity, reduced GHG emissions nor smarter use of resources.

On a positive note, there is a growing awareness of the environmental footprint related to digitalisation.

On a positive note, there is a growing awareness of the environmental footprint related to digitalisation. Several companies working in the ICT sector are already making significant efforts to reduce their environmental footprint:

- **Google** data centres have focused greatly on improving their energy efficiency, consuming 50% less energy than others.[26] Although not without its limitations, this estimation is based on the widely used power usage effectiveness (PUE) methodology.[27] The company is also the world's largest purchaser of renewable energy, and the electricity consumption of its operations was matched with 100% renewable energy between 2017 and 2018.[28]

- **Fairphone** has developed a mobile phone that has a modular and reparable design that favours durability and contains recycled and fairly-sourced materials (e.g. plastics, gold). It has received the German ecolabel Blue Angel.

- **Apple** is aiming one day to use only recycled and renewable materials in their products and packaging. Some of the enclosure of their newest products are already made from 100% recycled aluminium. They have also run a 'Trade In' scheme that allows people to bring in their Apple phones in return for a credit. This allows Apple to either find a new user for the phone or recycle the materials. Moreover, they provide software updates for older phones and tablets.

Some challenges related to greening ICT:

- It is difficult to assess the exact environmental footprint of digitalisation. Pertinent challenges include collecting and analysing complex and diverse data on ICT, assessing the entire lifecycle of ICT devices and infrastructures, accounting for embedded carbon and assessing the effects of software on ICT energy consumption.
- Many digital products on the market have a limited lifespan because there are no software updates to ensure the functioning or security of the product in the long term.
- Several companies are progressing beyond the existing policy framework in terms of greening ICT, which means that the policy goals set and instruments used are often behind the current best practices.
- From a European perspective, a greater focus on sustainability could possibly contradict EU objectives for greater technological sovereignty, and vice versa. For example, pushing for local European data centres rather than using foreign digital infrastructure – which could at times be more sustainable – would have implications on the environment and climate.

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4. See e.g. World Intellectual Property Organization (2019), "WIPO Technology Trends 2019: Artificial Intelligence", Geneva.

5. European Commission (2019b), *op.cit.*

6. European Commission, Artificial intelligence, 07 December 2018.

7. Kiss, Monika (2017), Digital skills in the EU labour market, PE 595.889, Brussels: European Parliament, p.1.

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13. *Ibid*., p.47.

14. See *Help Net Security*, "Most organizations and consumers believe there is a need for IoT security regulation", 31 October 2017.

15. Brennan, Mark W. and Arpan A. Sura, "Study shows complexity and uncertainty of IoT regulation in Europe", Hogan Lovells, 20 March 2019.

16. European Consumer Organisation, "Two-thirds of 250 products bought from online marketplaces fail safety tests, consumer groups find", February 2020.

17. *World Health Organization*, "Electromagnetic fields (EMF) > Electromagnetic fields and public health: Exposure to extremely low frequency fields" (accessed 22 June 2019).

18. Enerdata (2018), "Between 10 and 20% of electricity consumption from the ICT sector in 2030?". Baldé, Cornelis Peter; Vanessa Forti; Vanessa Gray; Ruediger Kuehr and Paul Stegmann (2017), "The Global E-waste Monitor 2017: Quantities, flows and resources", Bonn/Geneva/Vienna: United Nations University/International Telecommunication Union/International Solid Waste Association, p.19.

19. Avgerinou, Maria; Paolo Bertoldi and Luca Castellazzi (2017), "Trends in Data Centre Energy Consumption under the European Code of Conduct for Data Centre Energy Efficiency", *Energies*, Volume 10, Issue 10.

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21. International Resource Panel (2019), "Global Resources Outlook 2019: Natural Resources for the Future We Want", Nairobi: United Nations Environment Programme.

22. Baldé *et al.* (2017), *op.cit.*, p.19.

23. Kern, Eva; Lorenz M. Hilty; Achim Guldner; Yuliyan Maksimov; Andreas Filler; Jens Gröger and Stefan Naumann (2018), "Sustainable software products—Towards assessment criteria for resource and energy efficiency", *Future Generation Computer Systems*, Volume 86, p.200. See also Kern, Eva; Lorenz M. Hilty; Achim Guldner; Yuliyan Maksimov; Andreas Filler; Jens Gröger and Stefan Naumann (2017), "Set of criteria for sustainable software", Öko-Institut, Hochschule Trier, Universität Zürich.

24. Overall, it is estimated that the secondary raw materials contained in waste from electric and electronic components may be worth €55 billion. *Ibid*., p.54.

25. While it is not possible to explore this further, digitalisation creates other health challenges as well. See e.g. *World Health Organization*, "Electromagnetic fields (EMF) > Electromagnetic fields and public health: Exposure to extremely low frequency fields" (accessed 22 June 2019).

26. Comment during workshop "Sustainable consumption and production and greening of ICT", as part of the EPC Task Force on a Digital Roadmap for a Circular Economy, 26 September 2019, European Policy Centre, Brussels.

27. *Ibid.* See also Yuventi, Jumie and Roshan Mehdizadeh (2013), "A critical analysis of Power Usage Effectiveness and its use in communicating data centre energy consumption", *Energy and Buildings*, Volume 64, pp.90-94; Flynn, Patrick, "Taking a Leap Forward in Efficiency with Real-Time PUE", *Data Center Knowledge*, 21 August 2013.

28. See *Google*, "Renewable Energy" (accessed 16 January 2020).

An EU framework for action and recommendations

5

Improved use of data and the ongoing development and uptake of digitally-enabled solutions are fundamentally reshaping our economy and society. The changes can be positive or negative – policymakers have the tools to steer and incentivise digitalisation in the desired direction. If the EU and its member states 'get this right', they can help create the conditions to enhance both green and digital transformations. They will benefit from digitalisation as an enabler for a more sustainable CE, which would bring enormous environmental, societal and economic gains and help address European – and global – sustainability challenges. Moreover, they would benefit from digitalisation as a tool which improves the implementation of policies needed for the transition.

Some of the instruments at the EU's disposal which should play a role in enabling a transition to a sustainable CE are listed in this chapter, together with reflections and recommendations for the way forward. *Governance* instruments include legislation, standards and soft (i.e. non-mandatory) rules to guide the behaviour of member states, businesses and citizens. *Investments* provide financial support to incentivise and enable the transition. The EU's *convening power* refers again to its ability to facilitate collaboration across value chains, for example by establishing multi-stakeholder platforms.

The recommendations listed below are primarily targeted to EU policymakers. However, many are also relevant for member states, subnational authorities and businesses. The timeframe in mind is 2020 to 2035, and the recommendations are divided into their short-term (1-3 years), mid-term (4-8 years) or long-term (9-15 years) priorities. Recommendations of relevance to specific sectors are marked by icons. While this chapter provides a more general overview of the EU framework and its needed measures, a selection of the key recommendations can be found in Chapter 6.

5.1. Climate action and the wider sustainability agenda

In 2015, world leaders committed to the **UN's 2030 Agenda for Sustainable Development** and **Paris Agreement**. Together they set a clear direction and goals to be achieved, from sustainable production and consumption to climate action. The EU is aligning its policies and actions with these goals. Its member states have in principle agreed to make its climate-neutral by 2050.[1] The European Commission's reflection paper Towards a sustainable Europe by 2030 and A long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 provide a valuable basis for further dialogue.

However, to date, policymakers have been weak and slow to recognise the benefits that digitalisation could offer for advancing the sustainability agenda: new economic thinking, improved exchange of information, greener products and services, and empowered citizens and consumers.

The new Commission under President Ursula von der Leyen has demonstrated strong motivation and willingness to step up the EU's sustainability efforts. Executive Vice-President Frans Timmermans is leading the work on the **European Green Deal**. The proposal for a Green Deal is expected to be instrumental in implementing SDGs and getting the EU on the path to sustainable competitiveness, with climate neutrality at its core. It aims to "transform the EU into a

fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use."[2]

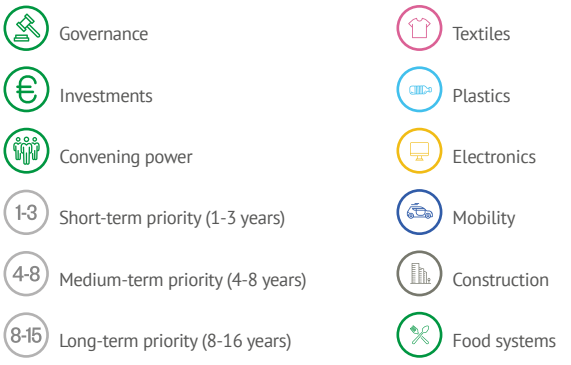
While the proposal provides the basis for a new growth strategy, it also recognises the roles of industry, CE, innovation and digitalisation as enablers for attaining sustainability goals. It aims to transform European ways of living and working, production and consumption while enhancing people's well-being and creating the conditions for businesses to prosper. While the details are still being ironed out, the proposal provides a valuable starting point for more comprehensive thinking and alignment of agendas.

Policymakers have the tools to steer and incentivise digitalisation in the desired direction.

The new Commission under President Ursula von der Leyen has demonstrated strong motivation and willingness to step up the EU's sustainability efforts.

The Green Deal proposal includes references to several initiatives and strategies that the European Commission is expected to work on, which could help achieve a digital CE, and vice versa. These include the **Farm to Fork strategy** for sustainable food; proposals for a **pollution-free Europe**, which cover air, water and noise pollution across the major sectors; a **chemicals strategy** for sustainability; work on renewables including the **EU Offshore Wind Strategy**; a **strategy for sustainable and smart mobility**; the Biodiversity Strategy for 2030; and the **European Climate Pact** for a new European 'climate culture' that convenes regions, local communities, civil society, industry and schools in climate action. Considering the amount of energy required for the digital transition (see Chapter 4), the **EU's energy transition** and ability to decarbonise its energy system as quickly as possible will have fundamental implications on how sustainable its digital transformation will be.

While the EU aims to mainstream climate and environmental considerations across its policies, it is worth noting that



it already boasts an extensive policy framework and various instruments at hand to implement its climate goals and wider environmental agenda. The **EU emissions trading system** (ETS) is often paraded as the cornerstone of the EU's climate action as it covers around 45% of its GHG emissions and aims to put a price on carbon emissions.[3] While it can be criticised for not delivering results fast enough, it is a tool for pricing pollution and thus can help to internalise externalities (e.g. environmental costs) that the current economic model does not automatically consider as costs. Moreover, the Commission's interest in exploring the possibilities associated with carbon border adjustment is welcome, as it recognises not only Europeans' production but also their the climate footprint of their consumption.[4]

The EU's toolbox of **environmental policies and legislation** aim to protect natural habitats, keep air and water clean, improve knowledge about toxic chemicals, ensure proper waste disposal, and so forth. The 7th **Environment Action Programme (EAP)** guides the EU's environmental policy until 2020. While it refers to the CE and highlights the importance of an "innovative, circular economy",[5] no interconnections have been made so far with the digitally-enabled solutions and pertinent policies. However, it could be noted that when it comes to managing purely environmental data and using digitally-enabled solutions like satellites to monitor compliance with the rules (e.g. Copernicus programme), the EU is a global leader.

Unfortunately, the existence of rules and tools do not automatically translate into results. In reality, the EU's sustainability goals and comprehensive legislation have been insufficient to bring about the needed and agreed change. The **European Environment Agency**'s (EEA) **report on the state of the European environment** is a shocking reality check: the Union is failing on almost all of its sustainability goals for 2020, including for energy savings, biodiversity and air, water, soil and chemical pollution. The reality is that EU member states are weak to comply with existing sustainability goals and legislation.[6] This provides a worrying context for the Green Deal and raises questions about the expected buy-in, commitment and implementation of future measures.

► Considering the scale of the challenge, it is in the EU's interest to set their sights high **to make the EU** a global leader in utilising data and digitally-enabled solutions to achieve a sustainable CE. This goal is not an environmental nice-to-have, but the basis for ensuring sustainable competitiveness and prosperity that is aligned with the Green Deal. It is essential that member states and businesses support the goal with a real buy-in and commit to its implementation.

► The EU and its member states must define and agree on **a vision for achieving a digital CE**, where the value of products and materials is maintained for as long as possible, and resources are used sustainably with the help of digitalisation. This should entail maximising the value of data and developing and deploying sustainable digitally-enabled solutions to improve products and services, as well as production (including design) and consumption patterns.

– The vision must be in line with the **UN's SDGs** and the EU's climate commitments under the **Paris Agreement** to become climate-neutral by 2050 while contributing to the creation of a more innovative, competitive and socially-cohesive Europe. The transition must happen 'within the limits of our planet' while creating added value for the European economy and society and the conditions for European industry to lead in the transition.

– A successful transition relies on a **systemic approach** that limits unwanted consequences and rebound effects and contributes to greater sustainability. It

requires fundamental changes to the design and implementation of policies. It requires greater consistency across policies and collaboration across sectors and value chains. The actions go far beyond the standard environmental, industrial and digital agendas, and ultimately must be in line with the set climate goals.

► This vision must be reflected in **action**. It should show in the **implementation of the European Green Deal**, including new CE, industrial action and digital agenda initiatives. It should also be reflected in the steps taken to enhance the sustainable food system and energy transition, including the uptake of renewables, sustainable and smart mobility, zero pollution and biodiversity. The EU should build on its strengths, including its value base, multidisciplinary approaches and technological knowledge, when designing measures that contribute to achieving a digital CE.

► As the sustainability of the digital transition depends greatly on the scope and speed of **the EU's energy transition**, its digital and energy agendas must support each other. They must lead to enhanced energy efficiency in the digital sector (i.e. data centres, digital solutions) and a decarbonised energy system, as they are the basis for a green digital transition.

► **Setting targets** can help guide direction, increase ambition and drive innovation. However, before developing concrete targets for aligning the digital agenda with that of the CE, there should be a comprehensive scientific assessment and a clear set of indicators which monitor progress.

► As data and digital solutions can be used to manage complexities, more should be done to use them to support **new economic thinking**. The EU should address the sustainability crisis systemically, internalise externalities and recognise the trade-offs between, for example, climate and environmental measures when apparent. It should utilise digitalisation to improve knowledge and design measures that align climate, CE, environmental, economic and social considerations.

– The starting point for a sustainable CE is to get the information 'right' for it to become actionable knowledge. This requires **asking the right questions**: carefully collecting and assessing the data needed for understanding systemic problems and thus better policymaking and implementation. Moreover, the EU should **combine climate, environment and societal data sets** more readily when developing policies.[7] At its best, better data management can capture societal needs and the environmental value of measures taken, and as such help in taking a more comprehensive approach. This would be especially valuable when developing sustainability goals and criteria, and designing the needed measures to reduce negative externalities and reward wanted results (e.g. carbon dioxide savings).

– The collected data must be reliable and comparable and **data analytics improved**. Using AI to improve the management of complex LCA data is a good example of how better data analytics could help to make the available information into fuel for new economic thinking.

– The EU should continue to explore how to **internalise external environmental costs** using digitalisation as an enabler:

  - As the European Commission explores ways to build on the ETS and focuses not only on production but also consumption (via carbon

border adjustment), access to reliable data will become imperative. Ensuring that the information provided is trustworthy will require international cooperation. Moreover, border measures will only work if they are enforced. Thus before adopting such measures, the EU should ensure that it has the will and tools to enforce its rules – and here it should rely on digitalisation to monitor the EU market.

- In an ideal world, consumers and policymakers would know not only the climate but also the wider environmental footprint of products. This knowledge could reduce Europeans' footprints and ensure that only sustainable products enter the EU market. Accounting for embedded GHG emissions and consumed resources (e.g. water, raw materials) in products is a complex exercise which requires global collaboration. Enhanced management and the sharing of data could provide the tools for this, and the EU should not shy away from aiming high. For example, the Global Footprint Network's data covering over 200 countries on humanity's demand on nature and nature's capacity to meet that demand could provide a valuable basis to build on. The EU should incorporate resource consumption monitoring in its CE monitoring framework.

The starting point for a sustainable CE is to ask the right questions: assessing the data needed for understanding systemic problems and thus for better policymaking.

In an ideal world, consumers and policymakers across the world would know not only the climate but also the wider environmental footprints of products.

► Creating the conditions for the European economy, society, industry and public sector to benefit from digitalisation when transitioning towards a sustainable and competitive CE requires **a comprehensive assessment of the existing and prospective tools** and ensuring that they are in line with the set goal and vision.

– The Commission's **8th EAP**, for example, should contribute to advancing the CE further, including by exploring cross-linkages between the CE and digital agendas and using digitalisation to support greater sustainability.[8]

– Moreover, as will be highlighted below, there are numerous tools under the **CE, digital and industrial agendas; consumer policy; and funding framework** that would benefit from a closer study.

► The EU should learn from its extensive experience in collecting environmental data, for example, for more informed policymaking and using digital solutions (e.g. satellites) to

enforce existing rules when exploring how data and digitally-enabled solutions can be used to **improve CE-related policymaking and implementation**.

► Considering the scale of global sustainability challenges, it is in the EU's interest to **engage and collaborate with international partners** in ensuring that digitalisation is serving the global goals for greater sustainability from the onset. Several multilateral fora (i.e. the UN, World Trade Organization, Group of Seven) and instruments (e.g. diplomacy, trade agreements, development aid) can be useful. The goals should include exchanging data and/or information for the creation of sustainable CE (i.e. ensuring that products and materials created outside of the EU are reliable while building on existing international collaboration on information sharing), reducing the environmental and climate footprints of digital technologies and using digital tools to improve customs controls.

5.2. The circular economy agenda

An industrial sector and all of its value chains take 25 years to transform; if the EU is to achieve its climate neutrality objective by 2050, actions must be taken in the next five years.

5.2.1. THE STRATEGIC AND LEGISLATIVE FRAMEWORK FOR THE CIRCULAR ECONOMY

The EU Circular Economy Action Plan, also known as the Circular Economy Package and adopted by the European Commission in 2015, has led to a series of policy measures to improve production, consumption, waste management, markets for secondary raw materials, innovation, investments and monitoring.[9] It has led to new legislation (e.g. Single-Use Plastics Directive 2019/904) and amendments to existing ones (e.g. Waste Framework Directive 2008/98/EC and Directive 94/62/EC on packaging and packaging waste). The current EU's legislative toolbox for achieving a CE contains a wide range of rules and policy instruments to align product design, production, consumption and waste management with the CE vision. The EU currently has 10 general indicators for monitoring progress with a CE.[10]

However, the work has only started. The Commission's Green

Deal and **new CE Action Plan** put a greater emphasis on product policy, new business models (e.g. provision of services), tackling false green claims and improving green public purchasing. Sectors such as textiles, electronics, construction and plastics are also emphasised. There is a recognition that achieving a climate-neutral and circular economy requires the full mobilisation of industry, and it must happen now. It takes 25 years to transform an industrial sector and its value chains; if the EU is to achieve its climate neutrality objective by 2050, actions must be taken in the next five years.[11]

As remarked by the Commission's Report on the implementation of the Circular Economy Action Plan, digitalisation provides opportunities to develop the CE further.[12] However, these interlinkages were overlooked in the past years. With the new Commission highlighting sustainability and digitalisation as its core objectives and the linkages being recognised in the new CE Action Plan, there are many avenues to explore for aligning the agendas.

► Building on the Green Deal, the EU should ensure that the follow-up to the **CE Action Plan** contributes to achieving a sustainable, climate-neutral and competitive economy. Respective measures should be based on a comprehensive assessment to avoid unwanted consequences, and tap on the possibilities generated by digitalisation to contribute to:

- reducing emissions and resource consumption (especially of critical materials);
- improving the design and design processes of products;
- preventing and minimising waste;
- improving the reuse, durability, reparability and recyclability of products;
- supporting people's ability to repair products;
- keeping valuable (critical) materials in Europe by establishing a single market for secondary raw materials and its by-products;
- preventing environmentally harmful products from being placed on the EU market.

► The EU should establish an **Observatory** to monitor and follow up on European and national efforts to link digitalisation to a CE. Collecting and sharing comparable data and information would contribute to mapping the problem as well as its solutions. The Observatory could be established as an extension of either the Circular Economy Stakeholder Platform or the EEA.

5.2.2. INFORMATION EXCHANGE

One of the greatest barriers to a CE is that the information consumers and recyclers, for instance, would need to make informed decisions does not travel with products, materials and substances across value chains. This availability of information has been recognised as a challenge by the new European Commission.[13]

An enormous amount of data and information is already gathered and made available (e.g. in the EU's extensive chemicals database, the **ECHA's International Uniform Chemical Information Database**). However, much of this information is lost along the value chain, instead of being converted into valuable information for relevant stakeholders.

Other instruments that could facilitate accessing relevant data for a CE include the **directive on public access to environmental information** 2003/4/EC, which requires public authorities to make environmental data available and is up for review. Moreover, the **INSPIRE Directive** 2007/2/EC lays down the rules for "the establishment of the Infrastructure for

Spatial Information [...], for [...] Community environmental policies and policies or activities which may have an impact on the environment."[14] The Directive covers monitoring facilities, production, industrial and agriculture facilities, and energy and mining, and has several implementing acts on how to standardise the generated CE and waste-related data.

There is a strong rationale for enhancing information exchange for a CE. However, there is still a long way to go before data collection and sharing across Europe are fully standardised for the benefit of a more sustainable CE. In this context, the Commission's proposal to develop a Common European Green Deal data space carries the potential of creating a new momentum and urgency for these efforts.

► The EU should use its **stakeholder platforms**[15] to increase awareness among member states, subnational authorities, academics and businesses regarding the interlinkages between digitalisation and a CE. They should also be used to encourage interested businesses (e.g. B2B and businesses within the same sector or value chain) to collaborate, especially on the required standards and ways to improve the sharing of information across value chains while responding to different challenges and needs.

- In the short term, interested businesses could be encouraged to look for ways to **create shared value and share the created value**. They could explore ways to:
  - improve information transfer between businesses operating within closed supply chains;
  - develop collaborative data exchange platforms that protect IPRs while enabling the transfer of data and/or information down value chains;
  - enhance collaboration between manufacturers and waste operators, for example, and promote industrial symbiosis;
  - use existing digital technologies (e.g. QR codes, watermarks) to track and trace materials and substances and include specified information down the value chain;
  - improve information exchange based on the principle of freedom of contract (i.e. parties agree on the terms and conditions that govern their relationship).
- EU platforms should **help businesses use shortcuts when possible**: CCMS (textiles), BOMcheck (chemicals) and the International Material Data System (vehicles) are established systems for information transfer that could be replicated in other sectors. A number of other structures for a data economy are already in use, like the International Data Spaces Association – their established rules for data sharing could provide a valuable basis for further reflection.

► If the existing platforms cannot provide sufficient space for dialogue and exchange, the EU should **establish a new platform** to facilitate dialogue on the development and uptake of digitally-enabled solutions for a CE between policymakers, developers of digitally-enabled solutions, manufacturers, waste operators, other industrial actors in the value chain and consumers. The Green Deal data space could be used to compile good practices and best available techniques (BATs) which support a digital CE.

► As the EU defines details for the Green Deal data space, it should aim to form a joint data space for a CE that incentivises and enables **fair access to and sharing of data/information**. It should help create conditions for sharing data/information

about products, materials and substances between producers, waste operators and consumers. The current work on ECHA's International Uniform Chemical Information Database is a good start.

- The EU should develop **guidelines or protocols for tracking products, materials and substances across value chains**. They should be feasible, with a set of minimum criteria for sharing data. The EU, member states and businesses should also contribute to ensuring that the data is standardised, comparable and digital. The provided information should be verifiable across the value chains.

- The EU and its member states should provide businesses with incentives to share data and ensure information flows across value chains.

    - Businesses should be made to know the rationale for data collection, what information is actually needed, how it is used and how data exchange can benefit them.

    - Public authorities could use guarantees and/or mandatory minimum requirements to encourage data sharing. Integrating requirements for minimum data disclosure in the EU rules on public procurement (PP) and its processes could provide a strong incentive for information exchange.

    - In the future, an option would be to couple a blockchain-enabled information system with 'tokenisation': a company that shares data (e.g. on chemicals) receives tokens based on a real currency (via e.g. the EU budget). These online tokens are then used as a tradable asset and transferred along the supply chain, thereby incentivising other stakeholders to share data of relevance for a CE.

- In the short term, companies could be encouraged to form **coalitions of the willing** and find partners that are interested in building on the first-mover advantage, and collaborate across the value chain to develop partnerships and improve information exchange.

- The long-term aim should be to establish an EU-wide **standardised system for information sharing across the value chains** by 2030, with agreed principles for data and/or information sharing and voluntary guidelines or mandatory requirements for tracking and tracing. This could be used as a basis for a digital product passport.

- The system should help ensure that the ECHA's knowledge base on chemicals is not lost down the value chain.

- The INSPIRE Directive and Directive on public access to environmental information could serve as a valuable basis for gaining access to data.

- Digital solutions like blockchain-enabled information transfer could be used to ensure that sensitive personal and corporate information is safeguarded.

► The EU and its member states should **enhance global collaboration** on the transfer of information to ensure that information created on products and materials outside of the EU is reliable, compatible and of use in the EU. The aim should be to encourage the global development of open, interoperable data and application solutions, thus enabling large-scale information sharing for circular processes.

- The EU should push for global guidelines for sharing data/information that is needed to create a CE (within e.g. the World Trade Organization, OECD).

- The EU should promote international collaboration on developing a common set of standards on data transfer across the value chains. This should build on existing work, such as the EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport) and EDIFICE (Global Network for B2B Integration in High Tech Industries) standards, and the Global Material Flows Database and Global Resources Outlook.

- When developing interoperable data models, existing solutions like the Open & Agile Smart Cities' Minimal Interoperability Mechanisms can provide valuable lessons and ideas for enhancing the interoperability of systems, data, and services.[16]

5.2.3. SUSTAINABLE DESIGN

The EU addresses sustainable design via several policy instruments, the most important being the 2009 **Ecodesign Directive** 2009/125/EC for products. It establishes "a framework for the setting of Community ecodesign requirements for energy-related products".[17] The requirements are defined in specific implementing measures (i.e. regulations) and supported by harmonised standards.[18]

The Commission is exploring possibilities to extend the scope of ecodesign to additional electronics (e.g. smartphones) and other products (e.g. furniture, packaging, textiles).[19] In 2019, the Commission adopted ecodesign rules for 10 new energy-related product groups,[20] including, for the first time, circularity requirements like durability, maintenance, reusability, upgradability, recyclability and waste handling of appliances.[21]

The European Parliament and European Economic and Social Committee have noted that digitisation and data sharing should be considered when integrating CE aspects into the product design, although they fail to elaborate what 'digitisation' and 'sharing' actually entail.[22] There are currently no requirements for producers to integrate digital technologies (e.g. digital tags) into their products.

In addition to products, digitalisation (e.g. AI, 3D printing) can also support more sustainable construction and renovation. This is recognised in the European Green Deal's proposal to amend the **Construction Products Regulation** 305/2011, to ensure a more circular design of new buildings coupled with increased digitalisation and climate-proofing of the building stock.

In the short term, interested companies could be encouraged to form coalitions of the willing and find partners that are interested in building on the first-mover advantage, develop partnerships and improve information exchange.

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► The EU should provide its member states with guidelines and potentially financial support to encourage the use of digitally-enabled solutions like AI and additive manufacturing to improve the **design processes** of products, buildings and more.

► The EU should assess how **integrating digitally-enabled solutions to product design** (e.g. digital tags for tracking and tracing, IoT for predictive maintenance) could help reduce a product's environmental footprint throughout its lifecycle. This could lead to the development of additional and non-mandatory standards for using digitally-enabled solutions under the ecodesign policy framework.

► Introducing new product requirements and guidelines for greater circularity under the ecodesign policy framework requires **scientific evidence** and **an assessment of complex sustainability criteria** (e.g. greater durability does not automatically lead to greater recyclability or energy efficiency). Making justified, evidence-based decisions to expand ecodesign to new products could benefit greatly from efficient management of existing data and evidence. The possibilities to use AI to conduct faster and more systematic collection and processing of data, and thereby improve ecodesign as an EU instrument, should be explored further.

5.2.4. EXTENDED PRODUCER RESPONSIBILITY

Extended producer responsibility (EPC) is a policy approach which assigns producers responsibility for their products, even after the products are sold on the market. While the focus has primarily been on the end-of-life phase (e.g. producers covering waste management costs), EPR can also be used to incentivise producers to design more sustainable products. WFD sets out general rules for EPR and, depending on specific legislation, different obligations. In addition, the 2018 amendments of the WFD introduced provisions stating that the EPR fee of the producers for their end-of-life products will depend on the durability, reparability, reusability and recyclability of their products (i.e. 'eco-modulation' rules).

Producers are responsible for informing consumers and waste operators about their products (e.g. how to handle products once they reach their end-of-life phase) under some specific EU legislation. This is an area where data and digitally-enabled solutions can play a major role. Digitalisation (e.g. digital tags in products, IoT, online platforms, databases) can facilitate such exchange of information, and is already happening voluntarily. For example, the I4R enables an exchange of information between producers of electronics and recyclers.

Certain legislation, such as the **WEEE** 2012/19/EU and **End-of-life Vehicles** 2000/53/EC **Directives**, already contain provisions that producers should inform recyclers on their products. However, the potential of interlinking EPR with digitalisation should be explored further.

► **EPR schemes** should be adjusted to include requirements (regulations and/or guidelines) that producers apply digital tools (e.g. digital tags on products, IoT or apps) which can be used to inform stakeholders down the value chain, including consumers and waste managers, about the properties of their products, and if and how a product can be reused, remanufactured or recycled. The solutions could also enable recyclers to provide feedback to producers to encourage improving product design, for example.

► The EU should explore possibilities of

linking eco-modulation with **ecodesign requirements** by using digitally-enabled solutions (e.g. online platforms, databases, AI). These solutions could update a producer's EPR fee automatically, based on the latest ecodesign requirements for a specific product, for instance.

5.2.5. LIFECYCLE ANALYSIS, PRODUCT ENVIRONMENTAL FOOTPRINT AND LABELLING

There is room to improve **LCAs** and integrate them into decision-making processes. A good starting point is the EU's ongoing work on the **PEFs**, which aim to gather data on all relevant environmental impacts of a product. When conducting LCAs and attempting to establish a PEF, AI especially could speed up the collection and processing of large amounts of complex and relevant data – as is already the case for impact assessments.[23]

That said, PEF development is currently hampered by complexities regarding individual products or product categories and data. Not all information can always be expressed quantitatively. Thus, PEFs may mislead decision-makers who lack pertinent data. Conversely, if PEFs contain too much and too complex information, this may discourage policymakers, businesses and citizens from taking action.[24]

One of the greatest benefits of LCAs and PEFs is that they could strengthen labelling schemes, like the **EU Ecolabel**, which aims to demonstrate a product's environmental footprint to consumers and hence enable them to make more sustainable purchasing decisions. As the Commission is considering extending the range of products covered by the **ecodesign and pertinent labelling rules** to also include non-energy using products, better management of data for assessing sustainability criteria could help the process greatly.

► The EU, its member states and businesses should **build on the environmental footprint** pilots and use digitalisation to make **PEFs** a tool that takes account of the whole lifecycle and provides a reliable way to quantify and compare environmental impacts.

- The starting point is to ensure that the data collected maps the relevant lifecycle impacts for products and services (including resource consumption, loss of biodiversity) and that the datasets are comparable across Europe.

- While using digitally-enabled solutions like AI for better data management, it is important to find a balance between simplifying information and considering complex data.

- Digitalisation should support timely updates of and enable inclusive and transparent development procedures for PEFs.

► Ideally, there would be only one or a few well-known **labels** which guide consumers in choosing products and services that not only have low climate and environmental footprints but are also beneficial for people's health. The EU could use digitally-enabled solutions like QR codes, apps or online platforms to clarify and communicate the information behind EU labels to answer consumers' questions and help them make sustainable choices.

5.2.6. WASTE MANAGEMENT

The EU has a comprehensive **policy framework for waste management** which is matched by its serious waste challenge (i.e. waste landfills, incineration, illegal shipments) and worsened by China's restriction on waste imports.[25] The amended **WFD**, for example,

envisages rules on separate collection and recycling (e.g. for textiles and sorting of construction and demolition waste) by 2024. The **Green Deal** puts forward a long-awaited recognition of the EU's own responsibility: the Commission suggests that the Union should manage its own waste and end shipping it away to third countries.

Digitalisation could do a lot to address the EU's waste problem and modernise its waste management. The Commission itself recognises that AI can "lead to new digitally enabled supply chains (e.g. for waste) and facilitate interactions within industrial clusters (industrial symbiosis)."[26] However, the EU has been slow to fully reap the benefits of using digitally-enabled solutions to improve waste management (including recycling) as of yet. The envisaged review of the **Waste Shipment Regulation** 1013/2006 could provide an opportunity to update the rules to facilitate better waste management, including the uptake of digital tools for that purpose.

As noted across this publication, it all starts with the data. If the data collected is not comparable, this will undermine data management, analysis and consequently, the measurement of progress and policymaking. Different methods of conducting and defining **waste statistics** is a well-acknowledged problem in not only the EU but also the world, as they are not easily comparable.[27] Waste can be classified by factors such as its sources, composition, characteristics, waste generation and collection streams.

Moreover, while official waste statistics include data on regulated waste streams, aspects like legal imports and exports, illegal waste collection and trade, illegal dumping, informal waste picking and private waste management are not included. Issues such as food waste and electronic waste may not be sufficiently covered, either.

► The EU and its member states must **improve statistics** on waste and recycling to provide reliable data for decision-making. For one, the EU should continue to improve and harmonise definitions and methodologies for waste statistics across its member states. Moreover, digital product passports, digital tags, IoT and the likes could be used to trace products throughout their lifecycles, including the end-of-life phase. Data about the products could be stored in online databases or blockchain-enabled information systems that public authorities would make accessible for statistics.

► The EU, its member states and businesses should **invest in, develop and deploy digitally-enabled solutions** (e.g. sensors for collection, online platforms for buying and selling waste and recycled materials, robotics and machine learning for sorting) **to improve waste collection, sorting and treatment**.

► The EU should facilitate **industrial symbiosis** across the EU member states by enabling the sharing of best practices and continuing its financial support for related projects.[28]

► **The review of the Waste Shipments Regulation** should aim to build on the benefits of using digitalisation to monitor and facilitate legal waste shipments and track and trace illegal ones. The EU and its member states should **facilitate legal waste transfers** across EU member states with the help of digitally-enabled solutions. For example, the EU and its member states must finally put the electronic notification procedure for waste that has been in development for years in place.

► The EU and its member states should **enforce compliance** with EU rules by using satellite imaging and drones, for instance, to detect illegal landfills and thus reduce them.

► The EU should use China's restrictions on waste imports as an opportunity to shift its global role in waste management fundamentally. It should **carry responsibility for its own waste and aim to become a world leader in reusing, recycling and upcycling** not only its own but also others' waste, using advanced technologies like robotics. The Green Deal's suggestion that the EU should manage its own waste is an excellent starting point. Furthermore, it should be recognised as a strategically important goal for the EU and be backed with investments into cutting-edge technologies for better waste management (i.e. collection, sorting, recycling).

The EU and its member states must improve statistics on waste and recycling to provide reliable data for decision-making.

5.3. The digital agenda

The DSM is far from complete: many of the DSM initiatives are still not correctly implemented in the member states.

5.3.1. THE STRATEGIC AND LEGISLATIVE FRAMEWORK FOR DIGITALISATION

The von der Leyen Commission puts a strong emphasis on making "a Europe fit for the digital age".[29] This builds on the EU's efforts to foster the development of a DSM in Europe,[30] and indeed much has already been done. The Commission has presented two DSM strategies in the past years, including a wide array of legislation which focuses on stimulating the creation of a European data economy, fostering cybersecurity and maximising the potential of online platforms (e.g. removing roaming charges and unjustified geo-blocking, modernising rules for e-commerce, digital contracts, online purchases).[31]

Initiatives have also focused on boosting data flows across Europe while simultaneously protecting personal data: the free flow of non-personal data and the reuse of public sector data can represent important first steps in opening data flows, while GDPR sets new common data protection rules for the EU. The EU's legislative, investment and cooperation initiatives have sought to improve connectivity, with initiatives like WiFi4EU, high-performance computing, the electronic communications laws, the rollout of 5G, a European Cloud and eGovernment.

The Commission's 2020 proposals for shaping Europe's digital future, a data strategy and a White Paper on AI aim to increase this ambition further.[32] With these proposals, the Commission aims to ensure that digital technologies and online platforms respect principles around transparency, liability and personal data. Moreover, it aims to create a single market for data. This would enable a free flow of data and establish specific data spaces in areas such as industrial manufacturing, mobility and the Green Deal. The latter would aim to make better use of data to address climate change and support the CE, zero pollution, biodiversity measures and more. The Commission hopes to enhance the sharing of data with this data space initiative, for instance between the private and public sectors.

However, in this regard, much still remains to be done. Europe faces notable challenges in grasping the opportunities digitalisation represents fully. Firstly, the DSM is far from complete and serious barriers to the free flow of data remain. As mentioned in Chapter 4, many of the DSM initiatives are still not correctly implemented in the member states. While an impressive amount of legislation has been passed, several previous Commission proposals have had their level of ambition diluted or weakened in negotiations with the Council and the Parliament.[33] Some of these initiatives have, therefore, not gone far enough to dismantle regulatory barriers across Europe.[34]

Secondly, the Commission has been slow to recognise the links between digitalisation and sustainability, including the role data and digital solutions could play in enhancing the CE.[35] Investments into digitalisation have often been made without considerations for sustainability. While the Commission's new digital package attempts to link the agendas better and focuses especially on greening the ICT sector, their work has only just started. As described in Chapter 4, section 2, digitalisation does not automatically lead to greater sustainability, and should be steered in the wanted direction. If the negative externalities associated with ICT and digitalisation are not adequately addressed, they may outweigh the benefits and hamper sustainable development.[36]

The Commission has proposed allocating 15% of the 2021-27 **Multiannual Financial Framework** (MFF) to the Single Market, innovation and digitalisation.[37] The proposed Digital Europe Programme (DEP) would focus on five major areas: supercomputers, AI, cybersecurity, digital skills and ensuring the deployment and the uptake of digital technologies.[38] In addition to the DEP, Horizon Europe, the InvestEU fund and Connecting Europe Facility (CEF) would make funds available for investing in digital technologies. The MFF and these programmes must help incentivise and support the development and deployment of sustainable, digitally-enabled solutions, to address our greatest sustainability challenges.[39]

► The EU and its member states should **use its policies and financial instruments to develop and deploy digitalisation in alignment with its sustainability goals**. Rather than consider it a goal in itself, digitalisation should be seen as the means to facilitate the transformation towards a sustainable and competitive economy. This should be reflected in the use of EU funds (i.e. the MFF and especially the DEP, Horizon Europe, the InvestEU fund and CEF).

- The EU should guide and incentivise the digital/ICT industry to become more sustainable.

- It should help create conditions for developing and deploying both existing and new solutions like blockchain, AI, and 3D printing to accelerate the transition to a digital CE.

► The EU should use **global fora** to showcase political leadership and promote global collaboration in the (digital) transition to a (digital) CE.

- As mentioned in the previous section on information transfer, the EU should enhance global collaboration on the exchange of information to ensure that the information on products and materials created outside of the EU is reliable, compatible and of use in the EU. It could also establish international norms for sharing information across global value chains, building upon existing international standards and databases.

- The EU should adopt a set of global ethical and sustainability guidelines for emerging technologies. In the case of AI, Europe's global approach should build upon the work of the High-Level Expert Group on Artificial Intelligence (AI HLEG).

5.3.2. DATA FLOWS

As this publication demonstrates throughout, a CE would greatly benefit from **a more open data economy and free flow of data**. Boosting data flows across Europe would benefit businesses that are developing digitally-enabled solutions for sustainability and circularity. It would support the optimal use of technologies that build on accessing and processing huge amounts of data (e.g. AI, IoT, cloud computing).

EU legislation on **a framework of the free flow of non-personal data** 2018/1807 and the **reuse of public sector information** 2003/98/EC have already removed certain obstacles concerning data sharing from the EU. Nonetheless, data sharing and processing are still limited due to business confidentiality, intellectual property, data privacy, personal data, restrictions concerning non-EU countries and the lack of common data standards (e.g. data formats, data content, interoperability between databases). All of these factors could hamper, for example, the optimal use of AI for gathering and processing data that could lead to more innovative sustainable products and services.

Start-ups are particularly vulnerable since they may lack the capacity to fully grasp the legal environment surrounding data sharing and hence opt out of using AI to process data. While complete data standardisation is hardly obtainable due to the specific contexts of local data ecosystems,[40] the current level of data fragmentation must still be addressed if the EU is to establish a true European data space.

GDPR represented a significant step in harmonising data protection rules across member states. It remains important nonetheless to ensure that it does not constitute a significant administrative cost and burden on European companies – especially on smaller firms and start-ups that do not always possess the skills, workforce and resources to cope with GDPR obligation.

The new European Data Strategy recognises many of these challenges and proposes several policy measures and funding to enhance Europe's data economy. The proposal to create a single European data space which is supported by a new governance framework, investments into digital infrastructure, digital skills and common data spaces in the strategic sectors (including the European Green Deal) provides a worthwhile point of reflection.[41] That being said, if the Commission is serious about its commitment to the Green Deal, its focus on managing data as a driver to sustainability could be stronger.

► Creating a knowledge base for sustainability would require monitoring progress with a (digital) CE, which again calls for adequate **indicators and the collection of relevant data and information**. This

should start by updating the European Commission's monitoring framework for a CE. The Commission could also use the digital, consumer conditions and Single Market scoreboards to assess the progress and keep track of the remaining barriers to a digital CE. One area that would especially deserve closer attention is the drivers and barriers to accelerating a shift to sustainable new business models, such as servitisation.

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The EU should use global fora to showcase political leadership and promote global collaboration in the (digital) transition to a (digital) CE.

► The EU should **encourage data standardisation** to enable more efficient access to and processing of data by AI-enabled solutions, for example. Keeping in mind that complete top-down standardisation is hardly obtainable, the EU could develop common guidelines with minimum content-related requirements that are supplemented by sector-specific requirements. These rules can also be mandatory for public entities (e.g. agencies, public universities) and private entities that are beneficiaries of EU financial support.

 | 4-8

GDPR represented a significant step in harmonising data protection rules across member states. It remains important nonetheless to ensure that it does not constitute a significant administrative cost and burden on European companies.

► Member states should **improve access to and the reuse of public data**.[42] The EU and its member states should explore which public statistics would be beneficial for the transition to a CE and be provided free of charge, especially for SMEs under the revised Open Data Directive 2019/1024. Public administrations should provide businesses with examples of how data is made available and shared while respecting the GDPR. National regulations may also need to be revised to provide access to data that is often needed to offer third-party services. A clearer definition of personal versus public versus commercial data and demarcation of who is in control of what data may also be needed.

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► The EU and its member states should aim to **minimise the obstacles to data sharing** when there is an overriding public interest. This can be achieved by establishing guidelines, innovation hubs (i.e. close collaboration between designers and public authorities), testbeds (i.e. publicly-funded facilities to test new ideas), and rules on sandboxing (i.e. relaxing legal enforcement when testing certain innovative solutions). The purpose of these tools would be to provide legal and technical support to and reduce regulatory burden for entities – especially start-ups – when designing more circular products and services, like product-as-a-service business models.

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► The Commission should avoid measures which might limit the **free flow of non-personal data** unnecessarily when introducing new data-related legislation (e.g. on AI, digital services, competition rules). A proportionality test for weighting the principles of data protection and transparency against that of free data flows could also be considered. The EU should explore ways to include cross-border data flows in Foreign Trade Agreements and international trade agreements negotiated under the World Trade Organization.

► **Additional guidance** and **a potential review of GDPR** might become necessary to ensure that the Regulation is applied and enforced across Europe equally. Particular emphasis should be put on supporting smaller firms and start-ups in coping with GDPR obligations, both financially and administratively. The GDPR definition of personal data remains wide and could potentially add unnecessary restrictions to the free flow of data.

► When following up on the implementation of the initiatives on the free flow of non-personal data and the Open Data Directive, the EU should also push for **global guidelines on data flows**, look into improving the usage of **public sector data**, and assess to what extent GDPR,[43] the Directive on Copyright in the Digital Single Market 2019/790 and proposed ePrivacy Regulation may add unnecessary restrictions and administrative burdens to businesses, and hinder their efforts to increase their sustainability.

5.3.3. SUSTAINABLE DIGITAL INFRASTRUCTURE

A modern, sustainable digital infrastructure (i.e. data centres, Internet coverage with high-speed broadband) is the basic foundation for connectivity and digitalisation and is crucial if Europe is to seize the related opportunities for sustainability and circularity.

There is a growing awareness of the environmental footprint of **data centres**, which has prompted the European Commission to look for ways to address this challenge. For one, a study on the energy efficiency of cloud computing has been launched. For another, a voluntary initiative called the **European Code of Conduct for Data Centre Energy Efficiency** – which aims to reduce the energy consumption of data centres and bring wider benefits for the environment, economy and energy security – was launched in 2008 and is managed by the Joint Research Centre (JRC). Data centres that are incorporated into these voluntary schemes have been evaluated to be more energy-efficient than their counterparts.[44]

However, it is worth noting that since data centres are a relatively new form of infrastructure, there is no exact statistical information on them. Due to this unreliable data, it has been difficult to implement policies for data centres on energy efficiency and lower carbon emissions. That being said, **GPP** criteria for data centres is being developed.[45]

While the focus has mostly been on data centres, other **connectivity infrastructures** have considerable environmental footprints, too. This implies that investing in modern ICT infrastructure can improve energy efficiency. For example, a shift from copper to fibre broadband – as envisaged under the EU's Gigabit Society – could increase the energy efficiency of optic infrastructure.[46] Fibre-to-the-home could result in 88% less GHG emissions per gigabit than the status quo, thanks to reduced electricity consumption.[47]

5G is crucial for technologies such as IoT, connected devices and AI. Besides Huawei's leadership in 5G, European companies like

Nokia and Ericsson are also significant global actors in deploying this technology. The EU has defined the **5G Action Plan** to launch 5G services in all EU member states by the end of 2020. The EU has catching up to do, however: China, South Korea and the US are leading globally in making 5G widely available for their businesses and consumers.[48]

► The EU and its member states should align its **investments in needed digital infrastructure with its sustainability goals**. While supporting infrastructure investments in broadband connectivity (e.g. 5G), cybersecurity and Internet coverage are a basic conditions for enhancing digitalisation, greater alignment with sustainability objectives is needed. For example, the EU's and member states' financial support for ICT infrastructure (e.g. broadband) should take sustainability issues (i.e. energy efficiency, materials used) into consideration.

► The EU should consider introducing mandatory measures to **improve the sustainability of data centres and cloud computing**:

- A clear set of criteria (i.e. **indicators**) should be established to determine their environmental impact, bearing in mind both energy and material efficiency, and building on existing initiatives, such as the German Key Performance Indicators for Data Center Efficiency.[49] The indicators should go beyond energy efficiency and study the entire lifecycle of data centres (e.g. materials to construct a data centre, cooling water consumption). The aim should be to facilitate the optimal development and use of data centres and reduce the need to construct additional facilities. And while energy efficiency remains important, the EU and its member states should do more to encourage the uptake of renewables as a source of electricity.
- The EU should continue to develop **ecodesign criteria** for data centres within the framework of the Ecodesign Directive. This would provide valuable criteria for the construction of data centres. The frontrunners' performance should also be gradually established as the minimum mandatory criteria.
- Additionally, the EU could consider including data centres in the list of facilities covered under the **Industrial Emissions Directive** 2010/75/EU (IED). This would mean that prior to the construction of a data centre, the proposed project would need to be assessed via an Integrated Pollution Prevention and Control procedure where an investor considers the BATs of the developed project. As such, the EU's BAT reference documents (BREFs) could guide investors, as is currently the case with facilities covered by the IED. However, including data centres under the IED would make the most sense if the scope of this directive was extended to also include GHG emissions. Bringing industry and experts together to discuss the scope of IED amendments and other needed measures would help propel this proposal forward.

► The EU should stick to its self-set ambitions in the 5G Action Plan: **launching 5G services throughout the bloc by the end of 2020**, and achieving uninterrupted coverage in urban areas and along main transport routes by 2025. The EU should play a leading role in facilitating **international cooperation on developing 5G standards** and cyber-proofing the technology.

5.3.4. EMERGING TECHNOLOGIES AND GREENER ICT SOFTWARE

AI is one of the most transformative emerging technologies, and the EU is

emphasising its development strongly, as part of its **Digital Agenda**. Its policy on AI (i.e. European approach to Artificial Intelligence and Robotics) envisages support for further research and the development and deployment of AI, including under current and/or future public investments (e.g. H2020/ Horizon Europe and DEP programmes). While the EU spent €3.2 billion on AI projects in 2016, it is expected to invest up to €20 billion per year under MFF 2021-27.[50]

The EU has put ethics and human-centred considerations at the heart of its approach to AI. However, **AI HLEG's ethics guidelines and investment recommendations** also recognise some of the links between AI and sustainability.[51] AI HLEG stresses that future AI development must consider environment and sustainability challenges to avoid adverse environmental effects and has called for the adoption of precautionary measures in these cases.[52]

The Commission's recent White Paper on AI lists possibilities to ensure an AI framework for the development of ethical or trustworthy AI. It envisages using instruments like standards or more strict regulation on high-risk AI, possibly in areas like healthcare, transport and energy.[53]

While the EU is lagging in the global competition of AI, it is ahead on the blockchain front. The **European Blockchain Partnership** established in 2018 aims to create a **European Blockchain Services Infrastructure** to support the delivery of cross-border, digital public services. The EU has also launched the **EU Blockchain Observatory and Forum** to map out the main initiatives and monitor and discuss relevant policies. While EU initiatives should address the main challenges to blockchain development and deployment, they should also explore ways to make blockchain more energy-efficient and into a driver for sustainability.

Finally, there is growing recognition of the relevance of **digital skills** for Europeans to benefit from digital solutions like emerging technologies. The significant disruption brought about by digital technologies will lead to a high level of interaction between workers and technology. This awareness is reflected in the Commission's **Digital Education Action Plan**, which includes 11 actions to support technology use and the development of digital skills in education.[54]

► The EU and its member states should **align its investments in digitally-enabled solutions with its sustainability goals**. This entails supporting and possibly earmarking financial support for the development and deployment of:

- sustainable, digitally-enabled solutions (e.g. future investments in AI should recognise the environmental and climate implications and apply safeguards when developing and deploying them);

- solutions that help accelerate the transition to a sustainable CE (i.e. encouraging the development and deployment of e.g. AI, IoT, 3D printing, blockchain, cloud, high-performance computing so that they contribute to CE enhancement, from design to waste management).

► The EU should become **a leader in developing AI for a sustainable CE** and forge its own path instead of following China or the US.

- The EU, its member states and businesses should improve AI and data analytics to improve business practices, logistics, and consumer behaviour for the benefit of a CE and invest in needed digital skills. The EU should actively recognise and build on these opportunities while working on a coordinated European approach on AI, and take on board the AI HLEG's ethics guidelines and investment

recommendations when suggesting new AI initiatives.

- Beyond defining the broad guiding ethics on AI, there has been little international cooperation on AI governance. This is an opportunity for the EU to be a leading voice on developing an international approach to and standards on AI and enhancing the development of AI for sustainability.

► The EU should develop **sustainability criteria for ICT software** (similarly to product ecodesign) which would encourage expanding software updates, thus enabling old hardware to be used for longer periods. However, instead of developing precise criteria for a particular software, a more general set of criteria could be applied to a variety of concrete software products.

► The EU, its member states and industry should continue to explore the potential of **blockchain and distributed ledgers to share information on materials and products to the recipient**. Current EU policy initiatives – such as the European Blockchain Partnership and International Association for Trusted Blockchain Applications – should consider circularity, climate and sustainability aspects. As these groups feed ideas into possible EU blockchain regulation, they should consider how blockchain could provide a trusted technology and incentivise circular and sustainable behaviour (e.g. via tokenisation).

► The EU, its member states and businesses should ensure that the major stakeholders in the transition to a CE – starting with citizens and workers – have the needed **digital skills** to contribute most efficiently. They should boost re- and upskilling initiatives in all relevant sectors, with a focus on SMEs. Vocational training should be adapted to better anticipate the changing nature of work that is expected to accompany digital technologies. For example, recyclers and waste managers will continuously need to update their knowledge of digital technologies to separate and treat waste more efficiently. EU should use the **Social and Cohesion funds** to address the increasing digital gap in Europe. The **Digital Education Action Plan** could be particularly useful in this regard, too.

5.3.5. GREENER ICT PRODUCTS

The European Commission is already aware of the challenges surrounding resource consumption (especially critical materials) and energy consumption related to ICT products like smartphones.[55] In its new digital proposals, the Commission rightly suggests stepping up efforts to green the ICT sector. The basis is there, and the EU has a number of tools it can use to steer developments in the right direction.

Ecodesign and the Restrictions of Hazardous Substances 2011/65/EU can be used to cut out the least sustainable products. As mentioned in section 2, the Ecodesign Directive is the most important EU policy instrument when it comes to product design, with a scope that covers many energy-consuming ICT products (e.g. computers, servers, data storage products). The Directive covers energy and material efficiency, which is especially relevant for a CE. For ICT, this means, for example, considering disassembly, repair and reuse when designing products.

Mandatory requirements are coupled with additional guidelines for computers, computer servers and harmonised standards. These requirements also cover circularity requirements, such as increasing lifespans

and improving the maintenance, reusability, upgradability, recyclability and waste handling of appliances.

Over time, the Commission has realised the difficulty of establishing energy and resource efficiency criteria for fast-moving ICT products like smartphones, tablets and smart appliances. While their lifespans may be limited, the average time needed to develop ecodesign rules is long. That is why the Commission plans to conduct more in-depth assessments and develop a **track for the ecodesign of ICT** that is separate from other energy-related products. This in-depth assessment will start with gateways (home network equipment), smartphones and ICT base stations (enabling communication between ICT equipment).

The WFD sets general rules for **EPR** as a tool to promote inter alia more sustainable product design and better end-of-life management of products. The **WEEE Directive** also sets specific rules for managing ICT waste. Producers (including manufacturers, distributors and importers) are responsible for taking care of their electronics in the end-of-life phase. Producers can fulfil this obligation by taking care of WEEE individually or as part of collective schemes (i.e. via producer responsibility organisations).

In reality, collective schemes are often favoured over individual ones as the latter can appear impractical due to reverse logistics and pertinent costs or existing legislative barriers that hinder the shipment of products across EU borders.[56] That said, since ICT products change very fast, establishing a separate **EPR** track that favours individual systems could be beneficial. If producers retrieve their own end-of-life products, this could provide them with an incentive to innovate and develop more sustainable electronics.

The WEEE Directive also sets **WEEE collection and recovery targets** for member states, as well as requirements for member states and/or producers to provide information that is relevant for better waste handling to waste operators and consumers. Currently, only a third of e-waste is properly collected and reported, which means that member states reaching their target of collecting 65% of EEE annually in the preceding three years is very unlikely.

► The EU should encourage its member states to introduce **financial incentives** for designing sustainable ICT products and supporting reuse and repair. For example, taxation rules could include VAT exemptions for secondary materials and VAT reductions when repairing an ICT product.[57] Companies (e.g. e-retailers) should not be discouraged from donating functioning (and reusable) ICT equipment due to VAT charges. The EU could support these developments by providing guidance and platforms for dialogue and exchange of good practices between member states.

► The EU and its member states should develop **ecodesign requirements and corresponding labels** for fast-moving ICT products like smartphones, covering aspects related to both energy efficiency and material efficiency. With the complexities of developing circularity criteria for ICT within ecodesign regulation in mind, the EU should look at the criteria holistically while not hindering operability.

- The principal aim should be to reduce environmental footprints across the lifecycle of a product. Durability, coupled with software support, service repair, minimising hazardous chemicals and schemes for reuse and recycling should all be borne in mind.

- The ecodesign criteria should encourage the use of materials with low(er) amounts of embedded carbon and recycling pathways. To achieve this, the EU and its

member states should connect ecodesign with instruments like **PEF** and **LCAs**, which provide useful methodologies to assess the environmental impacts of products.

► Producers could improve consumer awareness about the sustainable use of products greatly. The EU should consider obligating ICT companies to provide **information on repair, reuse and recycling schemes** with their products.

► The EU and its member states mustaddress the barriers that currently hinder the collection and treatment of WEEE.

► The EU and member states should provide **a level playing field for individual and collective responsibility schemes for WEEE**, and/or even create a separate legislative track for individual EPR systems.

► The EU and member states should consider introducing **deposit-refund schemes** for WEEE. The EU could develop guidelines and use its convening power, including stakeholder platforms, to facilitate the exchange of good practices in different member states.

► The EU should create the conditions for a true recycling market within the EU, where not only virgin materials but also secondary raw materials and used products (with recyclable materials) can easily move across borders. A starting point should be a clear definition of end-of-waste criteria at the EU level.

5.4. The industrial agenda

5.4.1. THE STRATEGIC AND LEGISLATIVE FRAMEWORK FOR INDUSTRY

The EU has in place a set of rules and financial instruments that could help European industry in its ongoing transition. This would support the development of digitally-enabled solutions for a CE on a bigger scale. The Commission's industrial strategy provides an opportunity to create framework conditions for EU industry to retain and enhance its sustainable competitiveness.

European industry must transform in order to become future-proof. The trends including increased competition over natural and human resources, volatile prices for energy and raw materials, climate change, digitalisation and automation are affecting the sectors. At the same time, the agreed global and EU commitments (i.e. SDGs, Paris Agreement, climate and energy targets, transitioning to a CE as the means to greater sustainability) signal the wanted direction of travel. The Union has several tools which can guide the industrial transformation and create conditions for industry to remain competitive in the changing world, and develop and deploy products and services that are in line with the political aspirations and commitments for the future.

However, it should be pointed out that there is an increased focus on technological sovereignty (e.g. localised data centres) in the EU, with Germany and France paving the way. This could undermine the EU's sustainability goals if the European solutions are less energy-efficient or clean than those of foreign competitors.

► The EU should promote an **industrial strategy** that enhances sustainable competitiveness, building on the possibilities that digitalisation and smarter use of resources could bring. It should create conditions for businesses to bring digitally-enabled products and services that address sustainability and circularity challenges on the market. It should help enhance the development and deployment of digitally-enabled solutions with a limited environmental footprint. It should align the EU's Single Market, innovation, digital, climate and circular policies for this effort.

European industry must transform in order to become future-proof.

When faced with new or old barriers, member states are not equally efficient in enforcing Single Market rules

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► As the EU defines its approach to **technological sovereignty** and provides funding for strategic priorities, it is essential that this does not contradict its sustainability goals and that the objectives are aligned.

► The EU and its member states should help the IT industry **consume and produce products and services more sustainably** and **reduce its negative externalities** on environment, climate, nature and natural resources, and such. For example, solutions developed under H2020's Sustainable Industry Low Carbon (SILC) Initiative should be replicated with IT industry when relevant.

► The EU and its member states should provide **platforms where industrial actors can exchange new circular business models** that could benefit from digitalisation, as well as the framework conditions for their development. The aim should be to assist businesses in future-proofing themselves and becoming standard-setters for circular products and services that help consumers contribute to the transition, by making the sustainable option the default option. Areas to be explored further could include the following:

- **Using digitalisation to enable sustainable business practices** (that help e.g. reduce energy and material use, source materials sustainably, use secondary raw materials

in production). For example, several companies are experimenting with and making use of **digital twin technology,** including in waste treatment. In addition, remanufacturing could benefit from solutions like embedded smart sensors and blockchain technologies to track and record changes during the product's lifetime, and 3D printing to create (locally produced) components and spare parts that facilitate remanufacturing. The EU, its member states and businesses must dialogue to ensure that the future policy framework and investments will create the conditions for using such solutions.

- **Developing sustainable, circular products.** This includes designing products that can be reused, remanufactured and recycled; as well as encouraging the reuse, recycling and recovery of parts and materials in the end-of-life phase via digitalisation.

- **Improving corporate knowledge (including start-ups') on EU and/or national legislation**, that may be relevant for developing new business models.

► The EU should encourage its member states to **use economic instruments** like tax breaks, credit and investment arrangements (including loans and guarantees) to enhance the development and uptake of sustainable, digitally-enabled solutions for CE practices.

5.4.2. THE SINGLE MARKET

The EU's Single Market represents the greatest added value for businesses and industry to flourish.[58] It is a home market for European solutions to compete and grow. Unfortunately, integration into the Single Market varies greatly across member states. The national and regional barriers to trade (e.g. technical requirements, requests for additional documentation, testing) are serious and, in some instances, worsening challenges that must be addressed.[59]

The Single Market faces the double challenge of re-emerging trade barriers and absent national enforcement. Over recent years, new trade barriers have taken the form of national or even local/regional technical requirements, additional documentation and other regulatory measures taken on the grounds of public safety, environmental or health concerns.[60] When faced with new or old barriers, member states are not equally efficient in enforcing Single Market rules – notable examples include the Services in the Internal Market Directive 2006/123/EC and PP rules.[61]

Given the importance of digitally-enabled services for a CE, what happens in **the EU's Single Market for services** is of consequence. Despite being the main component of member states' economies, trade in services only stands for 8% of EU GDP, compared to 25% for goods.[62] Furthermore, the implementation of the Services Directive remains weak.

The EU has established rules **on e-commerce** in order to boost the DSM further and break down the online barriers to provide access to goods and services to consumers across the Union. Rules on e-commerce are being updated, and a new revision of the e-Commerce Directive 2000/31/EC is expected in 2020.

Besides the benefits that harmonised rules on e-commerce bring to the European economy, there are also risks that increased e-commerce will lead to an overdrive of the linear economy (i.e. more goods being sold, increase in packaging waste) and complicate the enforcement of EU rules even more. Furthermore, the traditional end-of-life product take-back schemes (e.g. within the EPR setting) may not be fully applicable

if the product is purchased from online retailers or the supply chain stretches across member states and beyond the EU.

Needless to say, **market surveillance and customs controls** are essential for ensuring that goods produced in the EU or imported from third countries comply with the EU's requirements, including regarding sustainability. Some of the technical requirements are pertinent to a CE (e.g. ecodesign, restrictions of hazardous substances).

Non-compliance is currently very widespread, however. When it comes to chemicals legislation (i.e. REACH, the Restriction of Hazardous Substances Directive), a third of chemicals on the EU market do not comply with legal requirements.[63] Around 10% to 15% of the relevant products do not comply with ecodesign requirements and labels.[64] Given that the current requirements on ecodesign will be extended to circular requirements (durability recyclability), a lack of product compliance may pose an additional challenge to the Commission.

To address this challenge, the European Commission is already providing support to (national) market surveillance authorities via digital tools. For example, informal Administrative Cooperation Groups and the online platform Information and Communication System for Market Surveillance facilitate the coordination and sharing of information between market surveillance authorities. When it comes to ecodesign, the Commission is running an Energy Efficiency Compliant Products project to improve market surveillance regarding ecodesign and REACH requirements. Better management of data and digitally-enabled solutions could even enhance surveillance of the market (e.g. making use of and building upon web crawlers to systematically browse the World Wide Web for potential breaches of the law).

► The DSM has been artificially distanced from more traditional Single Market policies. Most DSM initiatives have focused on specific digital issues rather than the necessary market conditions for businesses like new digital firms and online platforms to thrive. These new businesses are often at the core of providing solutions for the transition to a more circular economy. The Commission should define **a new initiative which aims to *digitise* the Single Market** as an inherent part of a new holistic Single Market strategy. There is not a single area of the Single Market that does not contain a digital element, while many of the barriers are not necessarily digital in nature.[65]

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► Given the importance of services for a digital CE, a better **implementation of services rules** should be as a priority of the EU's agenda for the Single Market. The Commission could be bolder in referring cases to the ECJ[66] and considering how to move beyond the scope of the Services Directive to include additional services sectors.

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► The EU and its member states should **promote sustainable e-commerce**. When the EU promotes online platforms, removes unjustified geo-blocking and ensures the free flow of non-personal data, it helps boost e-commerce. It is important that this does not just accelerate the existing linear take-make-dispose model, but that e-commerce is also used to support a transition to a sustainable CE (e.g. enabling trade in secondary raw materials and used products, providing access to repair services). Recognising that e-commerce practices undermine compliance with EPR rules at times, it is important to ensure that online retailers take part in EPR systems, for example, by establishing take-back schemes or paying a fee for the management of end-of-life products they sold, and instructing consumers on

how to dispose of used products. The EU must ensure that further policymaking on e-commerce – such as the planned revision of the e-Commerce Directive in 2020 – contributes to attaining the EU's sustainability goals.

► The EU and its member states must improve **market surveillance** in order to enforce EU safety, health and sustainability standards and legislation.

The starting point is to ensure that firms' (including from third countries) claims of compliance with EU rules is true – blockchain-enabled solutions could be helpful in this regard.

Secondly, using the likes of digital tags which contain reliable information could enable market surveillance authorities and customs authorities to determine more easily if products comply with the EU's product requirements.

Thirdly, the EU and member states could apply, for example, advanced algorithms and AI in their surveillance. They should make use of and build upon web crawlers to systematically browse the World Wide Web for potential breaches of the law and restrict the Single Market from firms that do not respect these rules.

5.4.3. OTHER FRAMEWORK CONDITIONS FOR THE INDUSTRY

Several other EU tools can enhance framework conditions for European industry to scale up and take the lead in bringing products and services needed for a digital CE on the market. The Commission is helping **digitise European industry** via Digital Innovation Hubs and public-private partnerships. Its work on promoting **digital skills** is also extremely important (see section 3.4.).

New circularity requirements were introduced in 2015 via the **BREFs**[67] to improve energy consumption and material use, waste prevention and the recycling and reduction of hazardous chemicals in industrial installations. These requirements could benefit from better use of digital tools to make industrial processes more sustainable and circular. Moreover, **standards** for products, systems and services are valuable: they have proven to be powerful tools in promoting innovation, fostering competition and guaranteeing consumer safety in the Single Market. The **EU's Important Projects of Common European Interest** framework allows member states to support innovative projects in compliance with the EU's state aid rules. Initiatives on batteries, high-performance computing, automated vehicles and more are currently being developed.

Recognising the strong role of European start-ups and SMEs in driving a digital CE, it is worth noting that the EU has several tools to guide and support them. The **Competitiveness of Enterprises and Small and Medium-sized Enterprises** (COSME) **programme** and **Startup Europe** and **Digital Innovation and Scale-up** (DISC) **initiatives** aim to give these companies tools to scale up. The EREK aims to help European companies, especially SMEs, be resource-efficient and benefit from CE business models, thereby saving energy, material and water costs.

Lastly, it should not be forgotten that European industry operates in a global environment with complex and international value chains. Products on the European market comprise components and materials from across the world. Thus, what the EU does with its external toolbox – including diplomacy, trade and funding – matters. The EU is currently exploring how, for example, trade policy could drive sustainability, and stronger references to climate and

environmental goals could be included in its trade agreements.

► As the Commission seeks to **digitise European** industry, special focus should be given to those that contribute to achieving the EU's sustainability, circularity and competitiveness goals, with a focus on start-ups and SMEs. COSME, Startup Europe and DISC could also be used for this end.

► Considering the rapid development of emerging technologies and the speed at which goods and services are entering the European market, there is much scope to make better use of **EU standards**, especially for services (which currently only amounts to 2% of EU standards), and aim to become a global standard-setter for digitally-enabled solutions for a CE.

► It makes sense to use the current momentum on **IPCEI** to push for new areas for collaboration, including aligning digitalisation efforts with a CE. The EU should set up a strong governance structure within both the Commission and the Council to identify and promote additional strategic value chains, as well as ensure that projects already identified by the Strategic Forum on IPCEI would align digitalisation with CE considerations where needed.

► The JRC should **update BREFs** to include digital technologies (e.g. IoT, 3D printing) that can decrease the negative externalities of industrial facilities and processes.

► Explore and share good practices on using **taxation and other fiscal incentives** to create a market for sustainable digitally-enabled solutions for the CE. These could include little to no VAT for services with low environmental footprints.

► Value chains and European businesses are increasingly global; therefore, enhancing sustainable production will require **international collaboration**. The EU should use its external policy toolbox as well as international fora to create global interest in developing a digital CE.

5.4.4. PUBLIC PROCUREMENT

PP accounts for 14% of EU GDP and, if used properly, could stimulate the development of a market for valuable solutions. The European Commission has introduced rules, guidelines and initiatives for member states and subnational authorities to make full use of PP, but the actual application has only been partial and varies across the continent.[68] The EU has a legal framework – directive 2014/24/EU for the **strategic use of PP** as well as the voluntary **GPP Criteria** (for specific sectors, e.g. ICT) – to facilitate the mainstreaming of environmental criteria in the PP process. Since most PP is conducted at the national, regional and local levels, member states and subnational authorities should implement strategic PP and align their practices with EU rules and guidelines.

In reality, greater efforts are first needed to **digitalise PP**, as it could help simplify processes, increase transparency and enhance interaction with SMEs, which would be valuable for their business development. Second, using **PP as an investment tool** for digitally-enabled solutions for a CE would require that governments provide a political mandate for such use and incorporate goals in the processes. Procurers should also have the expertise to consider not just the price but also the lifecycle costs and environmental and social sustainability

when allocating contracts. A specific barrier for digitally-enabled solutions for a CE is the current rules which favour goods over (digital) services.

► The European Commission should, in general, promote **more innovative and strategic PP** while also relying on specific procedures and initiatives (e.g. European Innovation Partnerships, the Big Public Buyers and Networks Initiative,[69] procure2innovate, European Assistance for Innovation Procurement). It is important that member states provide a strong political mandate for using PP processes to incentivise development and uptake innovative and green solutions, and supporting new business models (e.g. remanufacturing, servitisation) that can benefit a sustainable CE. The goals should be incorporated into the PP processes from the beginning, and public procurers trained to apply the criteria. The EU should continue to provide guidance, training and platforms for the exchange of good practices.

► The EU should extend the **GPP** instrument to include services, including digitally-enabled services and new circular business models like servitisation, that can contribute to greater sustainability and circularity. The rules should not favour goods over (digital) services. Lifecycle costs and environmental and social sustainability impacts should be considered.

► The EU should encourage the development and use of tools like **standardised digital product passports** to help businesses validate their sustainability claims.

► **PP as an administrative process should be digitalised** to ensure efficiency and transparency and allow procurers to interact with the SMEs that are an important source of solutions for a digital CE. The EU and its member states must address the needs of start-up communities, such as the request made to the European Commission, Parliament and Council to set targets for pre-commercial procurement[70] and innovative solutions and monitor their implementation.

► The EU should carry out an **inventory of the state of sustainable procurement** in its member states and, if necessary, consider adjusting the current practices. The member states should be obligated to report on their implementation of sustainable procurement electronically. Data and information about national GPP practices could be compiled within a data space that facilitates the sharing of best practices between member states and subnational authorities, for instance. The effectiveness of these measures would be enhanced greatly if minimum GPP criteria, targets and monitoring requirements were introduced.

5.5. Empowering people and society

The (digital) transition to a more sustainable, climate-proof and digital CE will be disruptive and affect all levels of society. It will require collaboration between public and private stakeholders as well as citizens and consumers. It will also require partnerships, capacity building and skills. As demonstrated in Chapter 3, consumers and citizens are at the core of the transition to a sustainable CE, and digitalisation can help inform and empower them to contribute to these efforts. The EU has several tools it can use strengthen the role of people in the transition, but the work has only started.

A recent Commission study shows that although consumers generally look favourably on the CE, their actual engagement in CE practices remains rather low.[71] Around 36% of consumers do not repair products and around 90% have no experience renting, leasing or buying second-hand products.[72] As the study suggests, the reason for this discrepancy between willingness to contribute and actual behaviour is often driven by a lack of access to information and inconvenience.

The EU aims to empower consumers to make optimal consumer decisions, know their rights and be able to seek redress when necessary.[73] The **2019 consumer conditions scoreboard** which benchmarks consumer conditions in Europe showed that more than half of the consumers are influenced by green claims when making purchases.[74]

However, environmental claims are not always based on strong evidence (e.g. LCAs) and can, therefore, be misleading regarding the environmental performance and footprint of products, making it difficult for consumers to make informed decisions.[75] Furthermore, only around half of the consumers trust businesses' environmental claims.[76] The **Unfair Commercial Practices Directive** 2005/29/EC aims to address this by prohibiting misleading commercial practices vis-a-vis consumers, yet its implementation is not always easy. Moreover, as noted in section 2.5., building on LCAs and PEFs to strengthen labelling schemes like **Ecolabel** could help consumers make more sustainable purchasing decisions.

Increased **e-commerce** can lead to unsustainable consumption and make it more difficult to ensure that products only contain materials and substances that are permitted in the EU. If provided with the needed knowledge and tools, consumers could play an important role in reducing the environmental impact of e-commerce and helping surveillance authorities ensure that products in the e-commerce market meet EU rules.

There is also a wide recognition that for citizens and consumers to use digitally-enabled solutions and share data, the digital environment must be trusted and benefits for people demonstrated. Initiatives on **ePrivacy** and **cybersecurity** and the potential **GDPR** review must consider these objectives.

Lastly, the importance of skills cannot be stressed enough. The transition will require skills, including digital skills. This means that citizens and consumers should be able to handle digital tools (e.g. scanning QR codes, co-creating knowledge about the circularity of a product) as well as be capable of linking this know-how with the CE agenda (understanding e.g. lifecycle thinking, how to upload and access CE-related data).

► The EU and its member states should **analyse citizens' and consumers' data** to understand their behaviour and the effectiveness of policy measures relevant for a (digital) CE. The public authorities should simultaneously be transparent about data collection supporting a public interest (e.g. greater circularity), and even

use information campaigns and the likes to encourage people to share their data. Moreover, educating people on how to safeguard personal and private data is an important component of this process. Citizens and consumers need to be in control of their data in accordance with GDPR and ePrivacy rules.

► The EU, its member states, subnational authorities and businesses should **raise society- and economy-wide awareness** about the necessary measures to achieve a CE, and use digitally-enabled solutions such as online platforms, chatbots, games and apps to provide guidance and encourage citizens to play their part. For example, digitally-enabled solutions like smart packaging or smart tags can be used to **educate citizens and consumers** about responsible behaviour and guide them to use and recycle products as intended by manufacturers. Simultaneously, more emphasis needs to be put on providing information at the 'right moment' (e.g. at the time of the purchase) to encourage more sustainable behaviour.

► The EU and its member states should ensure that businesses' green claims are backed by recognised LCAs and PEFs, and consumers can use digitally-enabled solutions like QR codes, apps or online platforms to **verify claims and access other relevant information on reusing, repairing and recycling products**. Should consumers note unfair commercial practices or questionable green claims, they should be able to inform the relevant consumer bodies that can take the needed measures to safeguard consumer rights and ensure environmental protection.

► As the Commission plans to update the rules on **e-commerce**, it is worth exploring how consumers could be empowered with knowledge and tools, to play a stronger role in reducing the environmental impact of e-commerce and helping surveillance authorities monitor the products in the e-commerce market to ensure that they meet EU rules.

► The EU and its member states should develop ways to **scale up donations and donation channels from the private sector to consumers**. For example, removing VAT from donations could incentivise online retailers to donate and give a second life to products that would otherwise end up in landfills or be incinerated. Foodbank networks provide useful lessons on how to get products to those in need quickly, and which could be used as the basis to developing donation networks for durable products, too.

► As the EU uses **information from consumers** (i.e. consumer conditions and Single Market scoreboards) to develop new consumer policies, the EU should continue to explore the barriers that hinder their role in advancing a CE (including challenges with green claims, repairing products, contributing to sustainable e-commerce practices), and whether any new data, indicators or measures will be needed to achieve a (digital) CE.

► The EU must strengthen consumers' **right to repair** by enhancing their access to information, spare parts and affordable repair services. Ecodesign requirements (e.g. scannable product tags, online databases) could facilitate access to data and information. Meanwhile, investments into digitally-enabled solutions like 3D

printing could facilitate product repair and people's access to spare parts.

► To empower people to co-create knowledge, the EU should continue to **support citizen science activities** (via e.g. Horizon Europe, H2020). The aim should be to ensure that citizens provide reliable data (on e.g. waste littering, product incompliance with legal requirements). Conversely, the EU should ensure that citizens are aware of their rights under the Directive on public access to environmental information.

► The EU, its member states and subnational authorities should **increase citizens' and consumers' trust** in digitalisation. This can be supported by improving communication between officials and citizens; and educating citizens about the ways to safeguard ePrivacy, benefits of data exchange and use of digitally-enabled solutions for the environment/CE. These are elements that should also be incorporated in any update of the Digital Education Action Plan.

► The (digital) transition to a digital CE will be socially disruptive – managing it will require **partnerships, capacity building and skills**, and a consideration of stakeholders' different developmental stages when designing measures. The EU should use both top-down and bottom-up approaches and mobilise different stakeholders at the EU, national and subnational levels. Education and training will be crucial.

- As a digital divide could hamper the EU's social cohesion; the EU and its member states (supported by universities, businesses and subnational authorities) should **invest in people's digital literacy and skills** and monitor their progress (via e.g. the digital scoreboard). The ongoing and upcoming initiatives (e.g. new Skills Agenda for Europe, Digital Education Action Plan) and support from the European Structural Investment Funds (ESIF; which includes the European Social Fund), Erasmus+ and Just Transition Fund could play an important role in these efforts.

5.6. EU funding

The EU's financial instruments can play a significant role in facilitating the (digital) transition to a (digital) CE. These investments can facilitate the development and deployment of sustainable technologies, practices and business models that enable the transition to take place. They can also be used to mobilise additional public and private money for needed projects.

As the **2021-27 MFF** signals what the EU's priorities are, there should be a strong rationale to invest taxpayers' money in activities that help enhance the EU's competitiveness and sustainability.[77] research and innovation (R&I) support under the likes of **Horizon Europe** (i.e. around €100 billion), the DEP (around €9 billion), **CEF** and platforms like **European Innovation Partnerships** can provide the basis for multidisciplinary development of digitally-enabled solutions for a CE.

The new DEP aims to boost the EU's digital capacities and contribute to the deployment of digital technologies in Europe. It will focus on five crucial areas: supercomputers, AI, cybersecurity and trust, digital skills, and ensuring the deployment and uptake of digital technologies. The proposal mentions that supercomputers and AI *should* inter alia contribute to the EU's environmental goals. As a more general rule, when awarding grants under this programme, the environmental impact and the presence of a long-term sustainability plan should be taken into account 'where applicable'.

It is also worth highlighting that the **LIFE programme** envisages significant support for a CE (i.e. €1.3 billion) – although it does not refer to the potential opportunites provided by digitalisation. Moreover, the **ESIF** and especially **Cohesion Fund** (CF), **European Regional Development Fund, European Social Fund** and **Erasmus+** (possibly around €350 billion in 2021-27)[78] can contribute to the economic and societal transition by supporting R&I, SMEs, digital technologies, a low-carbon economy and the sustainable management of natural resources. For example, the **Smart Specialisation Platform** supports member states and regions with smart specialisation strategies and could increase their awareness on the links between a CE and digitalisation and their capacities to implement innovative, sustainable and circular solutions.[79]

The **European Investment Bank** (EIB) is the EU's main partner in financing European priority projects. The EIB and the five largest European national promotional banks and institutions have also launched an initiative which invests €10 billion for CE for the period of 2019-22. One portion would entail "the deployment of key ICT technologies, digitalization and services supporting circular business models and circular value chains."[80]

Moreover, the Commission proposed in the Green Deal that a **European Green Deal Investment Plan** (or **Sustainable Europe Investment Plan**) could mobilise at least €1 trillion of sustainable investments over the next decade, with the EIB playing a central role. **InvestEU** is expected to leverage around €279 billion of private and public investments over the next decade, by providing an EU budget guarantee that would allow the EIB and other implementing partners to invest in more and higher-risk climate and environment-related projects.

Tools like the **Innovation Fund**,[81] which covers the next decade, can also be interesting. This financial instrument is envisaged to support the development of innovative, low-carbon technologies. With revenues orginating from the ETS scheme, the Innovation Fund itself may amount to about €10 billion.

► EU funds should help **incentivise and support the development and deployment of sustainable digital solutions for a CE** to reduce the environmental footprint of data centres and solutions like AI and blockchain, and ensure that the solutions are used to accelerate the transition to a sustainable CE.

► The EU should consolidate its **financial tools**, including those under the 2021-2027 MFF, to support the development and deployment of sustainable, digitally-enabled solutions for the CE. The EIB's financing, the IPCEI framework and ETS Innovation Fund should be used to leverage further private and national funding.

► EU investments in existing and emerging digitally-enabled solutions (e.g. AI, robotics, digital twins, industrial symbiosis, blockchain) should contribute towards sustainability and circularity goals. The aim should be to make the digital/ICT industry more sustainable while using the solutions to accelerate change towards a

sustainable CE. For example:

- EU funds provided under **Digital Europe** should not support projects that would undermine the EU's sustainability and circularity goals.

- **EIB financing and the InvestEU Programme**[82] should leverage public and private funding in order to support digitally-enabled solutions for a sustainable CE.

- Funding under **LIFE programme** should explore possibilities to benefit from data and digitally-enabled solutions.

► While investing in basic **digital infrastructure** for connectivity (e.g. data centres), Internet coverage and cybersecurity measures, the climate and environmental footprints of digitalisation should be reduced. This should happen alongside the conditions for businesses and consumers to be safely connected and benefit from digitally-enabled solutions for a CE, both within and outside of urban areas, being provided.

► As the EU implements its industrial, CE and digital strategies, it must also create the conditions for a **sustainable industrial transition**, help industry reduce its environmental/climate footprints, and develop and deploy solutions for a sustainable digital CE.

► The **public sector's** application of digitally-enabled solutions (e.g. robotics, asset tracking) should be supported as the means to improve resource and waste management and reduce waste.

► Citizens, workers and SMEs should have the necessary **skills**, including digital skills, to contribute to the transition by building on existing initiatives (e.g. New Skills Agenda for Europe). The CF should especially be used to address the growing digital gap in Europe.

► The Big Data Value Association provides coordination and support to current and future **H2020 projects** on improving the use of big data within public-private partnerships. The Association could add the use of data for a CE on its agenda.

5

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Reflections on developing a digital roadmap for a circular economy

6

The climate crisis, environmental challenges, a lack of competitiveness, falling behind in the digital race, competition over resources and social woes: the EU faces multiple challenges that it will need to address if it is to ensure long-term sustainable prosperity for Europe. As this book has shown, there are two ongoing transitions – the creation of a CE and a digital transformation – that could provide the means to address these challenges, if they are managed well together. Digitalisation can be a valuable tool in enabling the transition to a sustainable CE and addressing several of the barriers that currently hinder progress. Aligning the agendas can lead to a digital CE that is a driver for the European Green Deal and a facilitator for achieving a sustainable and competitive Europe.

Europe is already a hub for digital solutions for a CE. Stakeholders across the EU are aiming to maximise the value of data. They are also developing and deploying digitally-enabled solutions to improve connectivity and information sharing; make products and services, processes and business models more circular; and empower citizens and

consumers to participate in the transition. This provides a strong basis to build on. Moreover, the European Green Deal and the Commission's follow-up proposals for updating the digital, industrial and CE agendas give high hopes that the EU is ready to harness the opportunities at hand.

By demonstrating the wide scope of possibilities and challenges in using data and digitally-enabled solutions, this book highlights the rationale for coordinated EU action. There is a strong rationale for the EU institutions, member states and businesses to join forces to make the EU a global leader in using digitalisation to support a CE, while avoiding unwanted consequences and enjoying related benefits.

However, the time to act is now and the EU needs to get this right. More can be done to use digitalisation to support the transition to a sustainable European economy and society. More can be done to use it as a tool to improve different segments of the CE (including design, production, consumption, reuse, repair and remanufacturing) and overall waste management (including recycling), thus fostering dematerialisation. More can be done to improve CE-related policymaking and implementation by building on the opportunities digitalisation offers. And more can be done to ensure that digitalisation itself, including the digital/ICT industry and technologies like blockchain, become more sustainable.

It is essential to keep in mind that digitalisation will not automatically lead to greater sustainability. The ICT industry and technologies have a growing climate and environmental footprint. Moreover, digitalisation may result in unwanted rebound effects, such as overdrive of a linear take-make-dispose economy and increase in GHG emissions. It is in the EU's interest to ensure that the ongoing digital transformation contributes to achieving its sustainability objectives and the ICT sector becomes more sustainable.

If the Union manages to enhance data economy and the development, deployment and scale-up of sustainable digitally-enabled solutions necessary for a sustainable CE, they would bring multiple benefits. This would enable Europe to enter the global digital race with a goal-oriented approach: to master digitalisation as the means to solve our greatest climate, environmental and societal challenges. Europe could simultaneously gain a competitive advantage in providing the market with products and services for a CE, which are increasingly in demand outside of the EU, too.

The following considerations set the basis for achieving a successful (digital) transition to a (digital) CE:

- **There must be ambition and vision, political will and commitment at the highest level.** A successful transition requires a systemic approach that limits unwanted consequences and rebound effects and contributes to greater sustainability. It requires fundamental changes to the design and implementation of policies. It requires greater consistency across policies and collaboration across sectors and value chains. The actions go far beyond the standard environmental, industrial and digital agendas, and ultimately must be aligned with the set climate goals. The CE and digital transitions must be co-managed and employed as the means to help the EU ensure long-term prosperity in accordance with the SDGs, the Paris Agreement and the Green Deal.

- **The transition will be disruptive and affect all levels of society.** Managing this will require partnerships, capacity building and skills, and considering stakeholders' different developmental stages when designing measures. To that aim, education and training will be crucial. The EU must use both top-down and bottom-up approaches and mobilise different stakeholders at the EU, national and subnational levels.

► **The EU must use governance and economic instruments to create the framework conditions for the transition.** As the EU defines its rulebook and the economic incentives needed for the Green Deal, they must help steer change for the better, contribute to improving production and consumption patterns, and creating a market for a digital CE. When designing measures, the EU should build on its strengths, including its value base, multidisciplinary approaches and technological knowledge.

► **Setting targets can help guide the direction, increase ambition and drive innovation.** However, before developing concrete targets to align the digital agenda with that of the CE, there should be a comprehensive scientific assessment and a clear set of indicators to monitor progress.

► **Modern value chains are complex and global.** Products on the European market comprise components and materials from across the world. The EU can aim to be a leader in using digitalisation to make its economy more sustainable and circular, and use the related benefits to attract wider interest in its approach. But in the end, enhancing sustainable production and consumption with a real impact will require international collaboration.

► **Becoming more consistent in aligning the digital and CE agendas must start with:**

1. A digital review of the CE transition

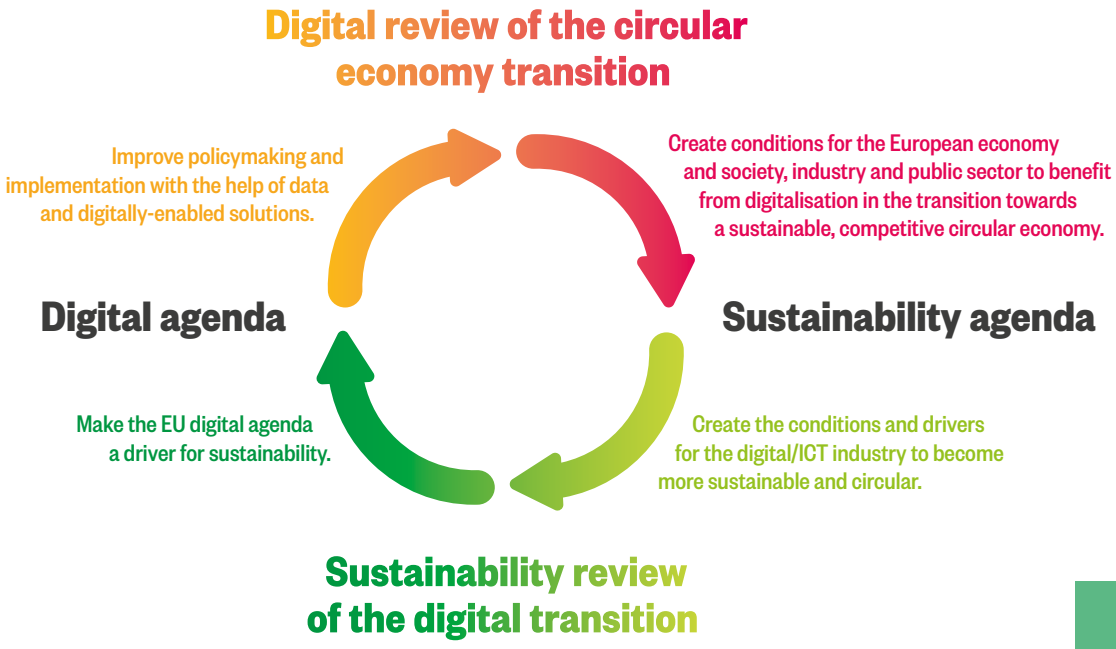
- Improve policymaking and implementation with the help of data and digitally-enabled solutions, to create a sustainable CE at the EU, national and subnational levels. Digitally-enabled solutions can be used to monitor compliance; improve market surveillance; ensure law enforcement; and improve instruments like EPR, ecodesign and PP, and their effectiveness.

- Create conditions for European economy and society, industry and the public sector to benefit from digitalisation in the transition towards a sustainable CE. This can be done by ensuring that in the follow-up to the Green Deal proposal – including in the CE, industrial, climate and environmental initiatives –, data and digitally-enabled solutions are put forward as enablers for greater sustainability. Awareness raising, education and training will also be needed to help citizens, consumers and businesses to adjust and contribute to the transition.

2. A sustainability review of the digital transition

- Create the conditions and drivers for the digital/ICT industry to become more sustainable and circular. This should entail reducing the negative externalities of data centres, ICT hardware (e.g. mobile phones) and software (e.g. AI, blockchain) on the environment, climate and natural resources (e.g. via ecodesign), for instance.

- Make the EU digital agenda a driver for sustainability. This entails ensuring, for example, that digital and data-related legislation on the free flow of data and data protection contribute to achieving a climate-neutral, sustainable CE. Moreover, the solutions themselves (including AI, blockchain and IoT-enabled solutions) must be developed and deployed for the same purpose. EU investments in digitalisation must be aligned with these efforts.



Key recommendations for the EU institutions

It is in the EU's interest to ensure that the ongoing digital transformation contributes to achieving its sustainability objectives.

1. DEFINE A VISION AND ACT ACCORDINGLY

1.1. Set a goal to make the EU a global leader in utilising data and digitally-enabled solutions in achieving a sustainable CE.

1.2. Define a vision for achieving a digital CE where the value of products and materials is maintained for as long as possible and resources are used sustainably with the help of digitalisation. This should entail maximising the value of data, and developing and deploying sustainable digitally-enabled solutions to improve products, services, production (e.g. design) and consumption patterns.

The vision must align with the SDGs and EU's climate commitments under the Paris Agreement – to become climate-neutral by 2050 – while contributing to the creation of a more innovative, competitive and socially-cohesive Europe. The transition must happen within the limits of our planet while creating added value for the European economy and society and the conditions for European industry to lead the transition. The implementation of the Green Deal, including new CE, industrial action, environmental policy and digital agenda initiatives, should reflect this vision.

1.3. Tap into the synergies between the digital and circular agendas by carrying out **a digital review of the CE transition and a sustainability review of the digital transition.**

2. USE GOVERNANCE, POLICIES AND REGULATION TO PROVIDE A FRAMEWORK FOR ACTION

2.1. Review the required data and indicators for achieving a (digital) CE and update the monitoring framework for CE as well as the digital, consumer conditions and Single Market scoreboards accordingly.

2.2. Develop a joint data space for a CE that incentivises and enables **fair access to and sharing of data/information**.

► Ensure that under the revised Directive on open data and reuse of public sector information, **public data** that is pertinent for the transition to a CE is free and accessible without compromising data privacy interests. Encourage public administrations to provide businesses with practical examples of how data can be made available and shared while respecting GDPR and IPRs.

► Create an EU framework for a free flow of **non-personal data** that enhances the availability and access to data needed to achieve a sustainable CE and encourages innovative circular business models.

► Develop **guidelines for the tracking** of products, materials and substances across value chains while using lessons learned. They should be made feasible, with a set of minimum criteria for sharing data. They should balance between safeguarding companies' commercial and strategic information and providing, for example, consumers and waste operators access to needed information on a product.

► In the short term, 'coalitions of the willing' in the private sector should be encouraged to improve information sharing on the principle of freedom of contract (i.e. parties agree on the terms and conditions). By 2030, the long-term aim must be to establish **a standardised EU system for information sharing** across value chains that ensures both 'data sharing' and 'data protection' in B2B and B2C markets (via e.g. blockchain-enabled solutions). This could serve as a basis for the development of electronic product passports.

2.3. Explore how data and digitally-enabled solutions could be used, on a case-by-case basis to improve **EPR** schemes. The aim should be to foster trust and the sharing of relevant information between stakeholders on materials and products to enable their sustainable use, reuse, repair and recycling, and minimise their environmental and climate footprints.

2.4. Ensure that **ecodesign** rules and principles contribute towards and benefit from a (digital) transition to a (digital) CE. Building on systemic assessments, the Commission should explore the possibilities of integrating digital tools (e.g. tags) into products to support information sharing in the value chain. Based on existing scientific evidence, it should consider the introduction of new product requirements and guidelines – including for new product categories on a case-by-case basis (e.g. ICT) – which support

the design of sustainable circular products.

2.5. The upcoming review of the **e-Commerce** Directive must support a transition to a sustainable CE. Some of the major points to consider include enabling trade in secondary raw materials and used products, providing access to repair services and enforcing compliance with the EPR rules.

2.6. Reduce barriers that hinder the development and deployment of **digitally-enabled services** and new circular business models (e.g. 'servitisation') that can foster dematerialisation. Issues to consider are standards, service fees, geo-blocking, procurement and taxation rules.

2.7. Facilitate the **PP** of digitally-enabled circular solutions. The rules should not favour goods over (digital) services. Lifecycle costs and environmental and social sustainability impacts should be considered.

2.8. Facilitate legal **waste shipments** within the EU and put an end to illegal ones with the help of digitally-enabled solutions (e.g. finalise the harmonised electronic notification procedure).

3. USE ECONOMIC INSTRUMENTS TO ENCOURAGE AND ENABLE THE TRANSITION

3.1.Consolidate the EU's financial tools, including those under the 2021-2027 MFF, to support the development and deployment of innovative digitally-enabled solutions for the CE. EIB financing, the IPCEI framework and ETS Innovation Fund should be used to leverage further private and national funding.

► EU investments in existing and emerging digitally-enabled solutions should be made **conditional** and contribute to sustainability and circularity goals. The aim should be to make digital/ICT industry more sustainable while using the solutions to accelerate change towards a sustainable CE.

► Invest in **digital infrastructure** for connectivity and Internet coverage, as well as cybersecurity measures to ensure that businesses and consumers are safely connected and benefit from digitally-enabled solutions for a CE, both within and outside of urban areas.

► As the EU implements its industrial, CE and digital strategies, it must create the conditions for **a sustainable industrial transition**, helping the industry to reduce its environmentaland/or climate footprints and develop and deploy solutions for a sustainable digital CE.

► Support the **public sector**'s application of digitally-enabled solutions (e.g. robotics, asset tracking) to improve resource and waste management and reduce waste.

► Ensure that citizens, workers and SMEs have the necessary **digital skills** to contribute to the transition by building on existing initiatives (e.g. New Skills Agenda for Europe). The CF should especially be used to address the growing digital gap in Europe.

3.2. Create a market for existing and emerging digitally-enabled solutions for the CE.

► Promote **PP** as an investment and innovation tool at the EU, national and subnational levels.

► Explore and share good practices on **taxation and other fiscal incentives**.

4. STRENGTHEN PARTNERSHIPS AND EMPOWER CITIZENS

4.1. Use existing **stakeholder platforms** to increase the awareness of member states, subnational authorities, academia and businesses on the interlinkages between digitalisation and the CE. Use them to convene intelligence and facilitate the scaling up of existing solutions. Showcase

good practices within the private (e.g. improving design, business models and industrial symbiosis with digitally-enabled solutions) and public sectors (e.g. using PP and tax incentives to encourage development and deployment of innovative solutions). Encourage businesses to exchange on required standards and means to improve information/data sharing.

4.2. Increase **citizens' and consumers' trust** in new digitally-enabled solutions. Engage with them on the benefits of data exchange, and using digitally-enabled solutions for the environment/CE, and safeguarding ePrivacy.

4.3. Use **global fora** (e.g. WTO, OECD) to showcase political leadership and promote global collaboration in the (digital) transition to a (digital) CE:

► Adopt a set of **global ethical and sustainability guidelines** for emerging technologies like AI. Europe's global approach should build upon the work of the AI HLEG.

► Establish **international norms for sharing information** across global value chains, building upon existing international standards and databases.

Annexes

ANNEX I: LIST OF THE EPC DIGITAL ROADMAP FOR A CIRCULAR ECONOMY TASK FORCE MEETINGS IN 2017-2019

20 November 2017
Launch event of the project "The circular economy and digitalisation – setting the scene"

6 February 2018
Workshop "Building knowledge on processes and materials – The role of digitalisation"

20 April 2018
Workshop "Creating partnerships – the role of digitalisation"

26 June 2018
Workshop "Developing innovative business models for circular economy – the role of digitalisation"

19 September 2018
Workshop "Textiles, food systems and plastics: Digitalisation as an enabler for the Circular Economy"

19 October 2018
Workshop "Transition towards a digital circular economy: the case of remanufacturing"

23 November 2018
Workshop "Addressing the key barriers to a circular economy: information transfer"

7 February 2019
Workshop "Digitalised circular economy: the role of public procurement"

28 March 2019
Workshop "The policy framework for action: what should be done to facilitate transition to a digitalized circular economy?"

9 July 2019
Workshop "The circular economy – closing the loop through digitalisation"

ANNEX II: LIST OF SPEAKERS AT EPC DIGITAL ROADMAP FOR A CIRCULAR ECONOMY TASK FORCE MEETINGS IN 2017-2019

Salla Ahonen, *Senior Adviser, Confederation of Finnish Industries*

Stéphane Arditi, *Policy Manager for Circular Economy, Products and Waste, European Environmental Bureau*

Ikaterini Argyrou, *Assistant Professor, Center Entrepreneurship, Governance & Stewardship, Nyenrode Business University*

Anna Athanasopoulou, *Head of Unit, Tourism, Emerging and Creative Industries, DG Grow, European Commission*

Martin Bailey, *Head of Unit Digital Single Market, DG for Communications Networks, Content and Technology, European Commission*

Marie-Paul Benassi, *Acting Director for Consumers, DG Justice and Consumers, European Commission*

Madeleine Bergrahm, *Nordic Sustainability Manager & EU Sustainable Public Procurement, HP*

Sten-Erik Björling, *CEO, Enviro Data*

Pierre Blanc, *Key Accounts Innovation Manager, TagItSmart*

Leon de Graaf, *Adviser for environment and climate, BusinessEurope*

Bruno de Oliveira Alves, *Policy Officer, Digital Single Market, DG Communications Networks, Content and Technology, European Commission*

Maarten Depypere, *Engineer, iFixit*

Tommaso di Vico, *Open Innovation Junior Manager, Cariplo Factory*

Hans-Christian Eberl, *Policy Officer, Circular Economy and Biobased Systems, DG Research and Innovation, European Commission*

Mathias Falkenberg, *EU Environment and Waste Policy Advisor, BDE Bundesverband der Deutschen Entsorgungs-, Wasser- und Rohstoffwirtschaft e. V.*

Shameek Ghosh, *Founder, TrusTrace*

Susanna Gionfra, *Policy Analyst, Institute for European Environmental Policy*

Jonna Haeggblom, *Head of Product, Circular.fashion*

Peter Hyldgaard, *CEO, Rezycl*

Ilias Iakovidis, *Adviser for Societal challenges, DG Communications Networks, Content and Technology, European Commission*

Jean-François Junger, *Deputy Head of Unit, eGovernment and Trust, Directorate-General for Communications Networks, Content and Technology, European Commission*

Harri Kalimo, *Jean Monnet Professor, Institute for European Studies (VUB)*

Krista Keller, *Statistical Researcher, Statistics Netherlands (CBS)*

Johan Kerver, *CEO and CTO, FiliGrade Watermarks*

Karin Kilian, *Policy Officer, Directorate-General for Environment, European Commission*

Kristi Klaas, *Counsellor for Environmental Affairs, Permanent Representation of Estonia to the EU*

Salla Koivusalo, *Senior Advisor on Public Procurement, City of Vantaa*

Tineke Lambooy, *Professor of Corporate Law, Nyenrode Business University*

Pascal Leroy, *Secretary General, WEEE Forum*

Sigrid Linher, *Director Energy & Environment, Orgalim – Europe's Technology Industries*

Ado Lõhmus, *Deputy Secretary General, Ministry of the Environment of Estonia*

Aurore Maillet, *Member of Cabinet of the European Commissioner for Maritime Affairs and Fisheries, European Commission*

Cristina Martinez, *Deputy Head of Unit, Smart Mobility and Living, DG CNECT, European Commission*

Jyri Maunuksela, *Senior Researcher, LUKE*

Philippe Micheaux Naudet, *Deputy Secretary General, Senior Project Manager, ACR+*

Maximilian Müller, *Project Manager EU and International Affairs, VDI ZRE*

William Neale, *Adviser for Circular Economy and Green Growth, DG Environment, European Commission*

Jussi Nikander, *Senior Scientist, Natural Resources Institute Finland*

Boštjan Okorn, *Material Efficiency and Ecodesign Expert, European Consumer Voice in Standardisation (ANEC)*

Kjeld Olesen, *ICT Working Group Leader, European Regions Research and Innovation Network*

Wilfried Oppermann, *Head of Environmental Product related protection, Siemens AG*

John Ortiz, *World Wide Head of Product Stewardship, HP*

Rien Otto, *Founder, DutchAwearness*

Romain Pardo, *Policy Analyst, IEEP*

David Parker, *Associate Consultant, European Remanufacturing Council*

David Peck, *Associate Professor, Delft University of Technology*

Fulvia Raffaelli, *Head of Unit Clean Technologies and Products, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, European Commission*

Mathieu Rama, *Policy Officer, RREUSE*

Mike Rasenberg, *Head of Unit, Computational Assessment & Dissemination, European Chemicals Agency*

Mesbah Sabur, *Founder, Circularise*

Sira Saccani, *Director, Sustainable Production Systems, EIT Climate-KIC*

Kestutis Sadauskas, *Director for Circular Economy & Green Growth, DG Environment, European Commission*

Hugo Maria Schally, *Head of Unit Sustainable Production, Products and Consumption, Directorate General for the Environment, European Commission*

Gaurav Sharma, *Director for Circular Business Models, Schneider Electric*

Brian Smits, *Technical Account Manager, Circularise*

Nikita Stampa, *Head of Unit, Innovative and E-procurement, DG Internal Market, Industry, Entrepreneurship and SMEs, European Commission*

Thea Lyng Thomsen, *Development consultant, GreenLab Skive*

Jürgen Tiedje, *Head of Unit, Advanced Manufacturing Systems & Biotechnologies, DG Research and Innovation, European Commission*

Paul Timmers, *Senior Adviser to EPC on digital transformation and cybersecurity, European Policy Centre*

Marko Turpeinen, *Director, Aalto University*

Karel Van Acker, *Sustainable Metals Processing and Recycling, KU Leuven*

Myrthe van der Plas, *Manager, PwC*

Rob van Kranenburg, *Founder, Internet of Things Council*

Vesa Vanhanen, *Deputy Head of Unit for Digitisation of the Single Market, DG Grow, European Commission*

Barend Verachtert, *Head of Unit, Agri-food chain, DG Research, European Commission*

Helen Versluys, *Expert for Environment, Agoria*

Edward Vingwe, *PhD Fellow, Aalborg University*

Wayne Visser, *Chair in Sustainable Transformation, Antwerp Management School,*

Carsten Wachholz, *Senior Policy Officer for Resource Conservation and Product Policy, European Environment Bureau*

Adrian Wain, *Sustainability Lead for UL EHS Sustainability, UL*

Iseult Ward, *Co-founder and CEO, Food Cloud*

Henning Wilts, *Head of research unit circular economy, Wuppertal Institut*

Pēteris Zilgalvis, *Head of Unit Start-ups and Innovation, Directorate-General for Communications Networks, Content and Technology, European Commission*

Lorenzo Zullo, *Co-Founder & Managing Director, Chemycal*

ANNEX III: LIST OF PARTICIPATING ORGANISATIONS AT EPC DIGITAL ROADMAP FOR A CIRCULAR ECONOMY TASK FORCE MEETINGS IN 2017-2019

Aalborg University
Aalto University
ABB
Accountancy Europe
ACR+
Agoria
Agra Europe
Amazon Europe Core SARL
American Chamber of Commerce to the European Union
ANEC
Antwerp Management School
APCO Worldwide
Association of German Chambers of Commerce and Industry (DIHK e.V.)
Aula Europe
Aurubis AG
BASF SE
BDE Federal Association of the German Waste Management Industry
BT
Burson Cohn & Wolfe (BCW)
BusinessEurope
Cambre Associates
Cariplo Factory
CCI Paris Île-de-France
Cefic
Central Denmark EU Office
Central Denmark Region - Region Midtjylland
Central Sweden European Office
CEOC International
CEPI
Chambres de Commerce et d'Industrie de Paris/Ile-de-France auprès de l'UE
Chemycal
Circular.Fashion
Circularise
City of Vantaa
COMECE
Confederation of Danish Industry (DI)
Confederation of Finnish Industries (EK)
Confederation of Norwegian Enterprise
Delft University of Technology
Dell
DIGITALEUROPE
Dutch aWEARness
economiesuisse - Swiss Business Federation
EIT Climate-KIC
Enviro Data
EPPA
EU SWITCH to Green Facility
EUROCHAMBRES
EUROCITIES
Eurodiaconia
Eurometaux
European Automobile Manufacturers Association (ACEA)
European Bank for Reconstruction and Development (EBRD)
European Chemicals Agency
European Climate Foundation
European Commission
European Committee of the Regions
European Economic and Social Commitee
European Enviornmental Bureau (EEB)
European Environment Agency (EEA)
European External Action Service (EEAS)
European Long-Term Investors Association
European Organization for Packaging and the Environment (EUROPEN)
European Parliament
European Regions Research and Innovation Network
European Remanufacturing Council
European Resource Efficiency Knowledge Centre
Federation of the German Waste, Water and Raw Materials Management Industry (BDE)
FiliGrade B.V.
FleishmanHillard
Fondazione Cariplo
Food Cloud
Foreign Economic Relations Board (DEIK)
FuelsEurope
GE
German Electrical and Electronic Manufacturers´ Association
Government of Catalonia Delegation to the EU
GPlus Europe
Grayling
GreenLab Skive
Helsinki EU Office
Hewlett-Packard (HP inc.)
Hong Kong Economic and Trade Office
Housing Europe
IBM
iFixit
IKEA Group
Institute for European Environmental Policy (IEEP)
Institute for European Studies (VUB)
Internet of Things Council

Japan External Trade Organization
Johnson & Johnson
King Baudouin Foundation
Konrad-Adenauer-Stiftung
Kreab
KU Leuven
LighthouseEurope
Lombardy Region Government EU Office
Metsä Group
MFA-Austria
Mid-Norway European Office
Miltton Brussels
Ministry of the Environment of Estonia
Ministry of the Environment of the Republic of Estonia
Mission of Bosnia and Herzegovina to the EU
Mission of Brazil to the EU
Mission of Brazil to the European Union
Mission of Canada to EU
Mission of Canada to the EU
Mission of Canada to the European Union
Mission of Japan to the European Union
Mission of Montenegro to the EU
Mission of Norway to the EU
Mission of Norway to the European Union
Mission of Switzerland to the European Union
Mission of the People's Republic of China to the European Union
Mission of the Republic of Serbia to the EU
Mission of Ukraine to the EU
Mitsui
Mitsui & CO. BENELUX S.A./N.V.
MSEO
Natural Resources Institute Finland (LUKE)
Nokia
North Sweden European Office
Nyenrode Business University
Oakdene Hollins
Office of the Northern Ireland Executive in Brussels (ONIEB)
Orgalim – Europe's Technology Industries
Oslo Region European Office
Permanent Mission of Montenegro to the EU
Permanent Representation of Estonia to the EU
Permanent Representation of Finland to the EU
Permanent Representation of Hungary to the EU
Permanent Representation of the Republic of Cyprus to the European Union
Permanent Representation of the Republic of Poland to the European Union
POLITICO
Province of Limburg
PwC
Quebec General Delegation in Brussels
Refugee Greenspace Initiative
Representation of the Free State of Bavaria to the European Union
Rezycl
Royal DSM
Royal Thai Embassy to Belgium and Luxembourg / Mission of Thailand to the European Union
RREUSE
Salix Advisory SPRL
Schneider Electric
Scotland Europa
Siemens AG
Siemens Healthcare
Ss Cyril and Methodius University - Skopje
Starch Europe
Statistics Netherlands (CBS)
Suez
TagItSmart
Tampere Region EU Office
The Alliance for Beverage Cartons and the Environment (ACE)
The International Federation of Inspection Agencies (IFIA)
TrusTrace
Turkish Industry & Business Association (TÜSIAD)
TURKU-Southwest Finland European Office
UL
United States Mission to the European Union
University of Applied Sciences Darmstadt
VDI ZRE
VDMA
Vodafone
Vrije Universiteit Brussel
WEEE Forum
Welsh Government EU Office
West Finland European Office
Wuppertal Institut
Zealand Denmark EU Office
Zero Waste Europe
ZVEI - Zentralverband Elektrotechnik- und Elektronikindustrie e. V.

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The European Policy Centre (EPC) is an independent, not-for-profit think tank dedicated to fostering European integration through analysis and debate, supporting and challenging European decision-makers at all levels to make informed decisions based on sound evidence and analysis, and providing a platform for engaging partners, stakeholders and citizens in EU policymaking and in the debate about the future of Europe.

The EPC is grateful to its main supporters that enable its five thematic programmes to provide insight in EU policies and develop practical prescriptions.

The King Baudouin Foundation's mission is to contribute to a better society. It promotes change-makers and innovators that serve the public interest and increase social cohesion throughout Europe. In 2002, it established a strategic partnership with the EPC to set the stage for an informed debate about the future of Europe with a wide range of stakeholders. The foundation's sustained support allows the EPC to fulfil its vision while preserving its independence.

The EPC has been awarded an annual operating grant for the period 2018-20 from the Europe for Citizens programme, funded from the EU budget, along with other similar think tanks and civil society organisations. The EPC contributes to the aims of the programme through activities designed to promote citizens' understanding of the EU policymaking process and their involvement in the European public policy debate, as well as through its work on the future of Europe.

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The EU is currently engaged in two transformations that could change our economy and society for the better. If managed well, and in unison, the circular economy and the digital revolution could help the EU address its greatest challenge: to build a sustainable, green economy that is competitive on the global stage.

Digitalisation will not automatically lead to greater sustainability. Nor is the inclusion of cutting-edge technologies in the circular economy a given. But with the right encouragement and incentives from the EU, data and digitally-enabled solutions can accelerate and boost the transition to a sustainable circular economy. They can enhance connectivity and information sharing; make business models, products and processes more circular; and empower citizens and consumers to contribute to the transition. They can be used to improve different segments of the circular economy, including design, production, consumption, reuse, repair, remanufacturing, and overall waste management and recycling.

Combining the circular and digital agendas carries enormous potential. It would be a shame to waste it.

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