# Eco-Innovation and Digitalisation

## Case studies, environmental and policy lessons from EU Member States for the EU Green Deal and the Circular Economy

EIO Biennial report

2020

# Eco-Innovation Observatory

The Eco-Innovation Observatory functions as a platform for the structured collection and analysis of an extensive range of eco-innovation and circular economy information, gathered from across the European Union and key economic regions around the globe, providing a much-needed integrated information source on eco-innovation for companies and innovation service providers, as well as providing a solid decision-making basis for policy development.

The Observatory approaches eco-innovation as a persuasive phenomenon present in all economic sectors and therefore relevant for all types of innovation, defining eco-innovation as follows:
"Eco-innovation is any innovation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle".

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# Eco-Innovation Observatory

## Biennial report 2020

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**Acknowledgments**

We would like to express our gratitude to the country experts for their work effort in the preparation of the country reports and the collection of good practice examples and policies for the biennial report. In addition, we would like to recognise the contributions of the experts from the national authorities and ministries for their feedback and helpful comments on the EIO country reports.

The authors would especially like to thank Ms Malgorzata Kicia for her valuable comments and the review of this report.

**A note to readers**

Any views or opinions expressed in this report are solely those of the authors and do not necessarily reflect the position of the European Union. A number of companies are presented as illustrative examples of eco-innovation in this report. The EIO does not endorse these companies and is not an exhaustive source of information on innovation at the company level.

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# Preface: The series of EIO reports

The Eco-Innovation Observatory (EIO) has been monitoring developments across the EU since 2009. It has developed an online database[1] and contributes to the European Commission Eco-Innovation online presence[2], a series of regularly updated country reports, and annual/biennial reports focusing on specific thematic issues and highlighting key trends. In this sense, the EIO has helped to build a conceptual basis and a shared understanding of what eco-innovation is and why and how it should be supported by policy interventions, businesses and consumers.

The earlier reports of the Eco-Innovation Observatory (EIO 2011, EIO 2012, EIO 2013, EIO 2014, EIO 2016, EIO 2018) introduced and exemplified the concept of eco-innovation and analysed findings of the EU Member States' eco-innovation performances based on a targeted indicator system. They also reflected on emerging trends and developments in the European Member States in the context of resource efficiency and, based on the rapidly expanding pool of good practice examples of the European countries, undertook foresight assessments on the future orientation of eco-innovation.

Each EIO annual or biennial report (AR) has a special thematic focus: the first AR (EIO 2011) specified the role of material resources and resource efficiency for eco-innovation, the second AR (EIO 2012) focused on business opportunities of eco-innovation, the third AR (EIO 2013) on the issue of how different stakeholders can contribute to building a green economy, and the fourth AR (EIO 2014) focused on how a transition to a circular economy could be enabled. The 2016, then biennial report of the Eco-Innovation Observatory discussed the role of policies for eco-innovation in the circular economy transition. It looked at the framework conditions fostered by European policies and how the circular economy concept has been embedded in the current policy contexts at the European and national level. It also discussed the bottom-up and top-down circular economy challenges. The 2018 report focused on the contribution of product eco-innovation towards a circular economy transition in the EU. Besides providing good practices and trends of product eco-innovations, it especially drew on sustainable product policy experiences in Member States.

This report focuses on **digital eco-innovation for a circular economy transition within the EU**. The aim of the study is to provide an overview of trends in technological digital eco-innovations and illustrate those by good technology and policy practices that can further drive the circular economy, as well as innovation to make digital products, hardware and infrastructures more sustainable in Member States. The overarching objective is to draw lessons for EU level policies.

The report is intended for EU and national policy-makers, researchers, NGOs, other stakeholders from the private sector and consumers.

Key questions for each chapter include:

- Chapter 1: Introduction – What does eco-innovation mean in the context of digitalisation for the circular economy? How can it be defined?
- Chapter 2: What is the state of the eco-innovation and circular economy developments within the EU?

[1] http://www.eco-innovation.eu/

[2] www.ec.europa.eu/environment/ecoap/_en

- Chapter 3: Digitalisation in the EU within the framework of the Circular Economy and Green Deal: What are new approaches, solutions, practices, policies and instruments? Which case studies and examples illustrate eco-innovative technical and digital solutions?
- Chapter 4: Which digitalisation policies and instruments are implemented at the national level of the EU Member States?
- Chapter 5: Which adverse effects of digitalisation must be taken into account?
- Chapter 6: What are some of the implications of the Covid-19 pandemic for digitalisation?
- Chapter 7: What are the key findings and policy messages?

The information compiled in this report builds on the information collected for 28 country profiles and conducted complementary research. It will also discuss and assess analytical findings on the environmental pros and cons of the digital transformation and its processes. A specific chapter 2 highlights new findings and trends regarding eco-innovation performance in Member States (based on the 2019 Eco-Innovation Scoreboard). A special chapter 6 provides some reflections on the implications of the Covid-19 pandemic for digitalisation trends and options for eco-innovative solutions.

# Executive summary

## Digital eco-innovation as a means to reach a circular economy in Europe

This report focuses on **digital eco-innovation for a circular economy transition within the EU**. The study provides an overview of trends in technological digital eco-innovations and illustrates those by good technology and policy practices that can further drive the circular economy, as well as innovation to make digital products, hardware and infrastructures more sustainable in Member States.

Digitalisation is taking place at a fast pace in all European countries. The Covid-19 pandemic is also accelerating digitalisation at many levels. Digitalisation is transforming the economies, societies, forms of communication, jobs and the necessary skills for the workplace and everyday life. The great challenges resulting from this are addressed by a number of newly launched European policies that have strong links to digitalisation and for a transformation towards an innovative and sustainable society.

In 2019, the European Commission adopted the European Green Deal (European Commission, 2019c), a long-term strategy for a sustainable Europe. The New Circular Economy Action Plan (European Commission, 2020c), the Biodiversity Strategy for 2030 (European Commission, 2020g) and the planned Zero Pollution Action Plan[3] are three important initiatives under the Green Deal. The vision is a digitalised and a sustainable society. The various strategies and action plans therefore draw up a large portfolio of measures, instruments and milestones that are always linked to digital technologies. At best these are eco-innovative and sustainable; they ought to contribute to improving living conditions in Europe.

This report considers digitalisation a major opportunity to accelerate the transition to a circular Europe, which, however, should not create new avoidable short- or longer-term environmental pressures or shift problems. The EIO defines digital eco-innovation as:

> *"an innovative application of digital technologies that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances, including GHGs, across the whole life-cycle of products, services or systems."*

## Eco-innovation performance of countries

Analyses of the EU Eco-Innovation Index show a high variance among European countries regarding their eco-innovation performance. Top performing countries have been traditionally strong in securing R&D personnel, in producing academic publications and patents, as well as in fostering eco-industries that helped them to create value added and provide green jobs. Most of these countries also perform well in the indicator related to the value of green early stage investments, potentially pointing to more eco-innovative start-ups in future markets, and thereby further strengthening their relative eco-innovation performance in coming years.

In contrast, countries with low investments in eco-innovative research and innovative start-ups tend to also perform less well in other categories of the index. This relationship between poor performance in inputs and poor performance in outputs and outcomes is especially evident in the group of 11 countries classified as 'countries catching up in eco-innovation'. These results suggest that increasing deficit areas

[3] https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_en

of, for example, R&D spending in low performing countries could help to trigger more eco-innovative activities on the ground. Individual country profiles developed by the EIO project and available online provide more analysis of country-level performance and pinpoint areas for improvement, as well as highlighting examples of good practices.

## Key findings

- Digitalisation is not about a single technology; rather, it is about the emergence of highly interconnected systems and business models enabled and scaled up by digital applications.
- Digitalisation as a systemic enabling process has enormous potential to boost the circular economy and contribute to the sustainability transition. On the other hand, as one of the drivers of growth of production and consumption globally, digitalisation is also a challenge for environmental and social sustainability.
- The scope and speed of the digital transformation varies across European countries, sectors, organisations and places. For example, less than a fifth of companies in the EU are highly digitised, leaning toward much greater levels of uptake in large enterprises as opposed to SMEs. The provision of digital public services is increasing across Member States, with 64% of EU citizens using online public services in 2018.
- Many Member States are increasingly making the link between digital technologies and eco-innovation to achieve circular economy and sustainability objectives. However, there are still a number of national digital strategies which do not impose any sustainability objectives. Policy framework conditions are also often fragmented with respect to support and diffusion of digital innovation.
- Despite progress in waste management and recycling across the EU, circularity rates remain relatively low. Digitalisation can help to minimise waste, enable more efficient processes in companies, promote longer product life cycles and reduce transaction costs through significantly improved information. There is an enormous spectrum of possible applications to scale-up and mainstream eco-innovations toward a sustainable circular economy. Some key examples of potential applications include:
    - the monitoring and measuring of pollutants, substances, resources, and material flows and conflict minerals;
    - digitalising energy supply, infrastructures and markets;
    - the creation of digital passports and transparent supply chains of products;
    - smart traffic systems and digitalised traffic management and retail logistics;
    - better product information for consumers on food, electronic goods, repair, and reusability;
    - genetic and phenotypical mapping of the natural world, including e.g. monitoring deforestation, assessing the state of natural ecosystems, and disaster prediction.
- Digitalisation will not automatically lead to greater sustainability. Currently, the development has been characterised as rather ambivalent as far as sustainability is concerned. Possible adverse effects of the digital transformation could include:

- direct ecological impacts, e.g. emissions and resource use related to the extraction of materials, production, use and disposal of digital devices, in particular considering metals, rare earths and plastics;
- indirect ecological effects, e.g. rebound effects related to the acceleration or amplification of consumption of other goods and services;
- potential health impacts, e.g. uncertain health effects of electromagnetic fields and radiation;
- adverse economic and social effects, e.g. related to the deep transformative potential that could be used to disempower, disrupt und undermine traditional institutions and structures.

- Covid-19 has revealed weaknesses of the present unsustainable European lifestyles and at the same time pushed the significance and development of digital technologies enormously. The insights gained in this period must serve as a starting point for the advancement of a digital circular economy.
- The report features 85 eco-innovation emerging good practice examples (e.g. in business) and 68 policy examples related to digitalisation and/or circular economy gathered in the 2020 EIO country profiles. A selection of good practices is highlighted in boxes throughout this report as well as in the Annex, noting that outstanding good practices were sourced from across the EU, also in those countries with average or low performance at a country-wide level in the overarching EIO Index.

## Policy messages

- Digitalisation is the key driver of innovation processes for production and consumption systems all over Europe – it is not only a key challenge for environmental and social sustainability, but above all an opportunity.
- Digitalisation can help achieve the vision and targets of the European Green Deal. Public investments in digital innovation and infrastructures need to be linked directly with wider social and environmental missions and embed stringent environmental criteria.
- Digital eco-innovation could become an effective tool to address challenges and accelerate sustainability transitions, especially in the most resource and energy intensive sectors, i.e. food, feed and agriculture; mobility and traffic management; and housing and construction. Policy makers could target digital eco-innovation in these areas to accelerate the European Green Deal.
- But achieving a circular economy will require system eco-innovation that looks beyond individual sectors, conventional supply chains or single types of actors (e.g. food system rather than only food production; mobility rather than transport); it requires assessing resource interlinkages ('the nexus'). Digitalisation can play a key role in making innovation more collaborative, transparent, cross-sectoral and data-driven.
- Policy instruments and institutional arrangements must be flexible and agile to take into account market and social implications of digitalisation. Potential rebound and adverse effects of digital technologies should be anticipated, continuously assessed and countered by policy mixes.
- To encourage wider diffusion as well as scaling-up of promising digital eco-innovations, an EU policy mix needs to become coherent across governance levels, in particular as regards framework conditions and research and innovation funding.

# 1 Introduction – Digital eco-innovation for the circular economy

Eco-innovation has been an important strategic concept in the European policy for more than ten years now. A successful spread of eco-innovation concepts and business models, institutional structures, technologies and policies, however, meets the challenge that material flows and emissions continue to be at a high level and the circularity rates are rather low.

The environmental and sustainability policy has not yet succeeded in achieving a sufficiently strong reduction in environmental pollution, an increase of material circularity rates, a halt to the loss of biodiversity and a decrease of material throughput. The debate on how to achieve the necessary consensual goals in both the scientific and political spheres continues. Particularly controversial is the question of the relevance of economic development or economic growth for achieving environmental policy goals, which appears in a new light due to the Covid-19 pandemic.

Following the last Eco-Innovation reports in 2016 (Circular Economy Policies) (EIO, 2016) and 2018 (Product Policies) (EIO, 2018), there seems to be a continuing strong trend towards developing circular economy strategies and programmes at the national scale, or at least in integrating circular economy elements into the framework of resource efficiency strategies, which reveals a strong dynamic in this policy area. Concepts, drafts or related programmes are being worked on in most European countries (EEA, 2020).

However, a study of research and innovation investments in the circular economy context[4] shows that the research and innovation flows of funds are mainly directed towards technology and process optimization, and the most favoured sector is the manufacturing and water sector (Bahn-Walkowiak et al., 2019). In terms of Technology Readiness Levels, the programmes are overwhelmingly field pilot or market introduction, and single point interventions, thus leaving much room for better coordination and up-scaling (Vrancken et al., 2019).

*"Looking at the objectives and key performance indicators, the results do not really provide a consistent strategic idea of a European circular economy approach. The different member states and regions seem to follow different and sometimes even contradictive strategies. And although the member states and regions have of course very different potentials and framework conditions for transformations towards a circular economy, the differences […] seem to rather highlight the need for a more consistent European R&I strategy on CE than a smart specialisation strategy"* (Bahn-Walkowiak et al., 2019).

Besides "[i]ntegrating circularity principles into business innovation processes" this must also address consumer behaviour and design of products and services (EEA, 2019a) and it "will require fundamental transitions in core production-consumption systems such as those meeting European demand for food, energy, mobility and housing. Such transitions will necessarily entail "profound changes in dominant institutions, practices, technologies, policies, lifestyles and thinking" (EEA, 2019b) (Geels et al., 2019).

Several recent studies convey a picture of distance-to-target and show that efforts for a Circular Economy have to be scaled up enormously. At the European level, the circularity rate was estimated between 10-15% in 2014 (Mayer et al., 2019), at the global level it is considered 9.1% (de Wit et al., 2018). Some authors find that "recycling was surprisingly low, considering the fact that the EU-28 has strict waste regulations, elaborate waste collection and recovery systems, and high material category-specific recovery rates that range from 25% for biomass to 70% for metals" (Mayer et al., 2019). Other authors point to the problem that a major parts of all material flows are used "to manufacture or operate stocks", hence withdrawing materials from potential recycling processes (Haas et al., 2020). Eurostat states a circularity rate of material use of 11.2 % in 2017, showing a minor increase by three percentage points up from 2004 (Eurostat, 2020).

[4] http://cicerone-h2020.eu/context/

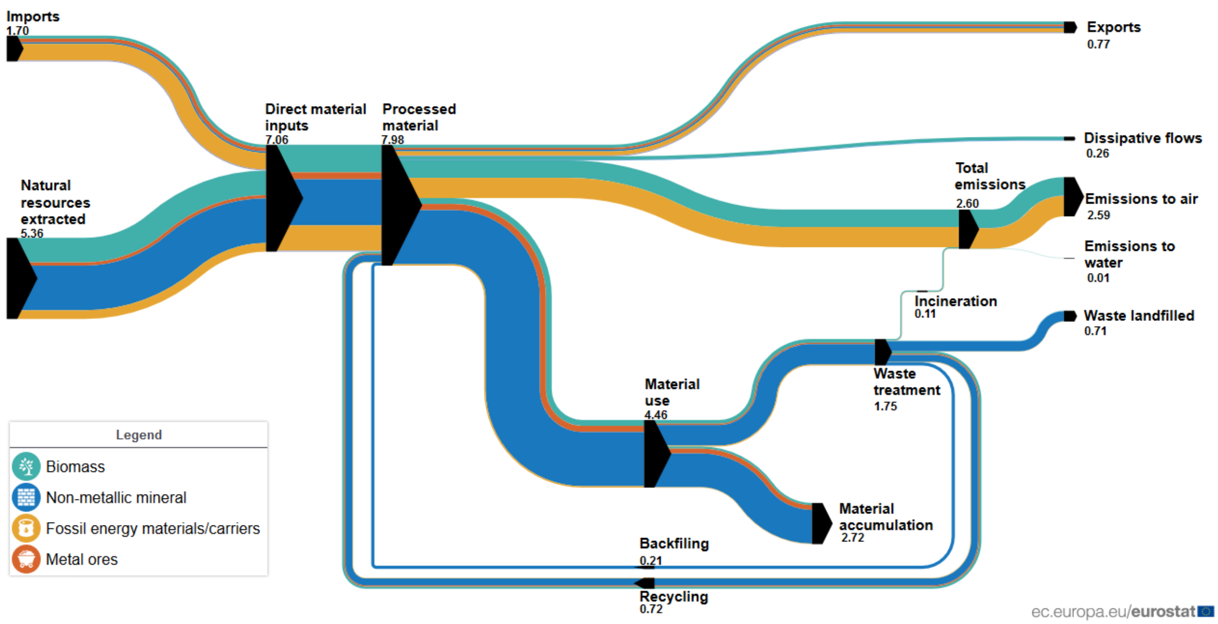


***Figure 1: Material flows in Europe, 2017, billion tonnes per year (Gt/year); Source: (Eurostat, 2020)***

Important steps to respond to the sustainability challenges have now been taken with the release of the European Green Deal[5], a blueprint for Europe's sustainable and digital transformation. All initiatives, including the Circular Economy Action Plan[6] are consequently and systematically taking up the potentials for sustainability through digitalisation. This strategic realignment is also intended to create the framework for a reorientation of research, investment, innovation, and eco-innovation.

## 1.1 What is digital eco-innovation?

The very first report of the Eco-Innovation Observatory has defined eco-innovation as:

> *"(…) the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle" (EIO, 2010).*

Since that time, the digitalisation has taken up high speed while the circular economy approach has been further advanced and diffused over Europe (Ekins, 2010) (European Commission, 2020c) (European Commission, 2020i) (European Policy Centre, 2020).

In 2015, the first Circular Economy Action Plan (COM(2015)641/2) already highlighted the role of digitalisation and artificial intelligence as an accelerator of energy and resource optimisation. The technologies are considered having the potential to improve information availability in order to support circular business models and responsible consumption choices. The circular digital economy is expected to have a positive net resource impact and address substantial challenges such as unsustainable consumption patterns, short product life-spans and insufficient security of sensitive business data (European Commission, 2015).

[5] See: European Commission. (2019). *The European Green Deal.* https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

[6] See: European Commission. (2020). *Circular Economy Action Plan*. https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

Yet, on-going digitalisation processes have immense material and energy requirements and largely follow the classical ‘linear” economic logic. Broadband subscriptions in the EU, for example, have increased by at least 30% (see Figure 2) and the of population in Europe using the internet has surpassed 80% (see Figure 3), with corresponding energy consumption. More significantly, with the rise of smartphones, Internet use has become ubiquitous and omnipresent.

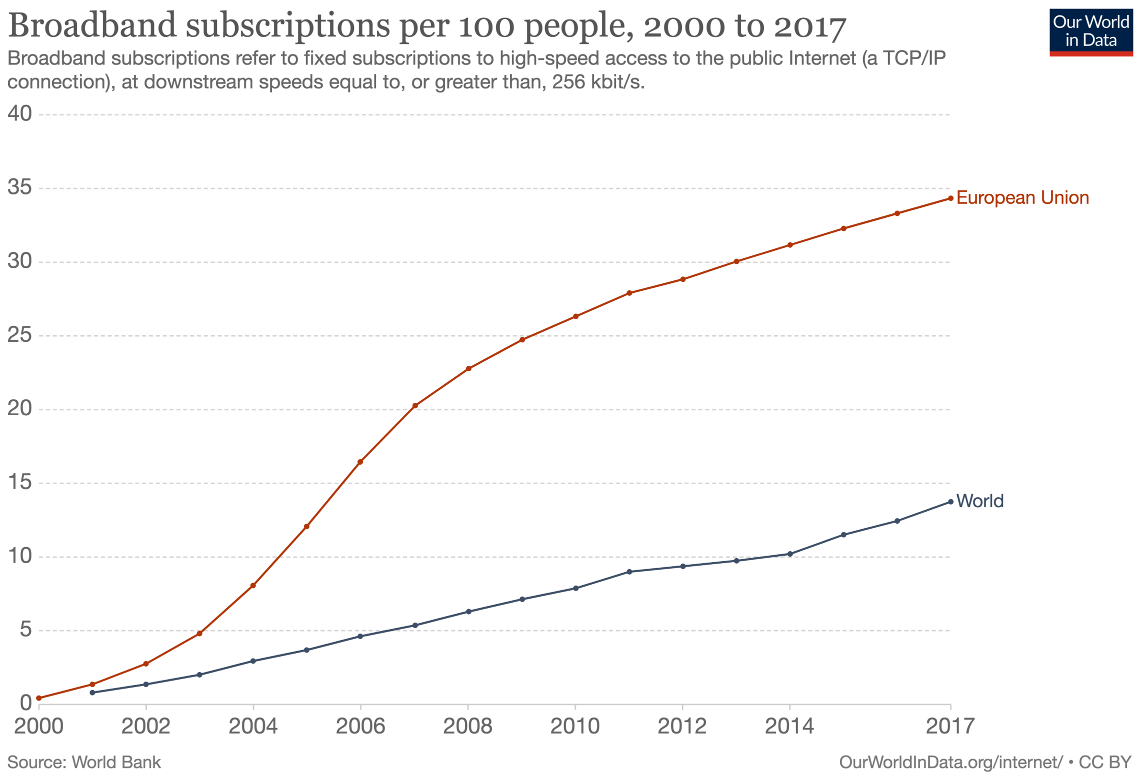


***Figure 2: Broadband subscriptions per 100 people; Source: (Roser et al., 2015)***

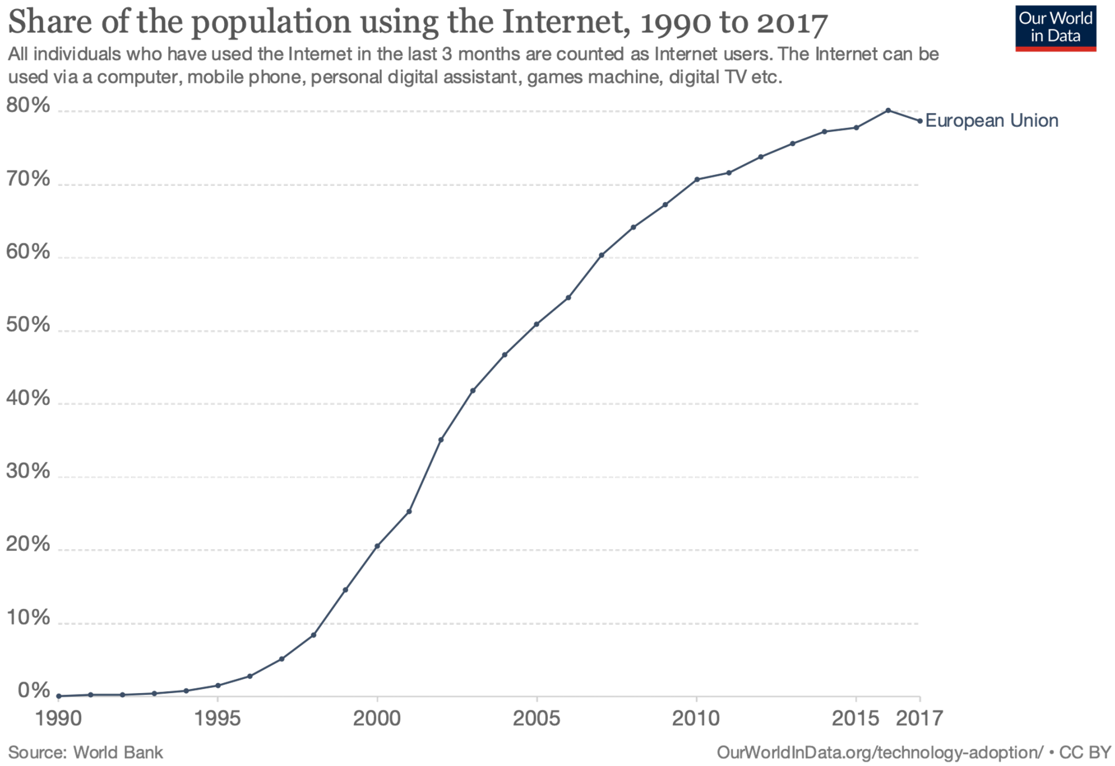


*Figure 3: Share of population using the internet; Source: (Ritchie, 2017)*

The most effective transition to a circular economy will therefore not only use digital technologies for increasing the circularity of 'traditional' sectors but also circularise the technology sector itself. The means of solving one problem often create new problems which then call for new means. With the corresponding need for reflexivity in mind, the following report will look at European policy and practices in terms of which innovation paths European countries are taking to achieve the goals of the circular economy and sustainability.

The state-of-the art and the distance-to-target, which are reflected in the low circularity rates today and the mixed picture along most environmental policy fields, need to be kept in mind (EEA, 2019b). In addition, the aim of climate neutrality has to receive attention (European Commission, 2019c), p. 5, (Ellen MacArthur Foundation, 2019). Eco-innovation for climate neutrality, as called for in the Green Deal, could be defined as the introduction of a solution that – besides reducing the use of natural resources (including materials, energy, water and land) and decreasing the release of harmful substances – contribute to the reduction of GHG emissions along the whole life-cycle.

In this sense, the definition of digital eco-innovation in the tradition of former eco-innovation reports shall be advanced as follows:

> *"Digital eco-innovation is an innovative application of digital technologies that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances, including GHG, across the whole life-cycle of products, services or systems."*

## 1.2 What is the potential of digitalisation to foster a circular economy transition?

Digital technologies are thought to have enormous potential for contributing to the circular economy transition. Digitalisation is yet not simply the diffusion of a single technology; rather, it is the emergence of a highly interconnected system and networking process in itself. It represents the convergence and interplay of many fields, such as computer science, engineering, informatics, mathematics, biotechnology, nanotechnology, and manufacturing. To reap the potential benefits of digitalisation it will require continued developments across all these domains as well as in other disciplines, the social sciences foremost among them (TWI - The World in 2050 Initiative, 2019).

As described by the OECD and others, four pervasive trends characterise innovation in the digital age:

1. **Data is** becoming a **key input for innovation** (Von der Leyen, 2019).
2. **Innovation activities** increasingly **focus on** the development of **services** enabled by digital technologies.
3. **Innovation cycles are accelerating**, with virtual simulation, 3D printing and other digital technologies providing opportunities for more experimentation and versioning[7].
4. **Innovation is** becoming **more collaborative**, given the growing complexity of and interdisciplinary needs for digital innovation (OECD, 2019); (OECD, 2020).

Eco-innovation is an indispensable component for a transition to a circular economy. In the course of this process, the entire industrial system and product and consumption patterns will have to be transformed. (Jesus et al., 2018). The following digital technologies are likely to be most important in this transformation from today's perspective.

[7] For example, supporting re-industrialisation, place-based industries and 'fablabs' for start-ups and SMEs.

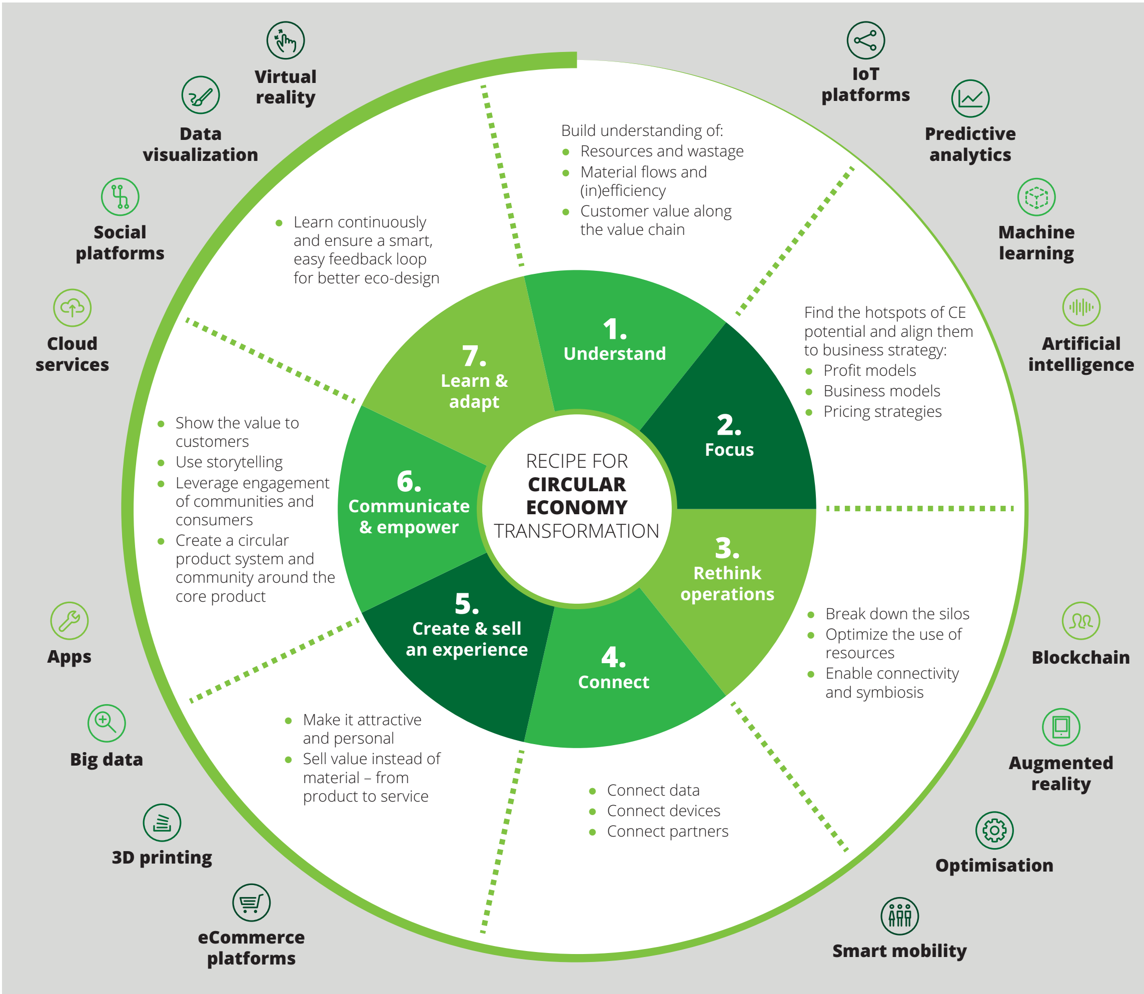


*Figure 4: Recipe for Circular Economy Transformation (by digital approaches); Source: (Deloitte, 2018).*[8]

Impacts of the digital transformation differ significantly, however, – both among and within sectors – in three main respects.

1. The **scope of opportunities for innovation** in products, processes and business models that digital technologies offer differs among sectors.
2. Sectors need **different types of data for innovation**, and so the challenges faced for their exploitation differ.
3. The **conditions for digital technology adoption and diffusion** also vary, for instance due to differences in capabilities to take up those technologies and the level of maturity of sector-specific digital technology applications (OECD, 2019).

The Circularity Gap Report provides indications as to which of the resource-intensive sectors could particularly benefit from a development towards a circular economy and also indicates which of the strategies would benefit significantly from the incorporation of digital technologies (de Wit et al., 2018).

[8] https://www2.deloitte.com/content/dam/Deloitte/fi/Documents/risk/Circular%20goes%20digital.pdf


*Figure 5: Circular economy strategies and their potential; Source: (de Wit et al., 2018), p. 29.*

Following the logic of this report displayed in the figure above, the areas of food waste, regenerative energies and reuse in particular have the greatest relevance for the circular economy, as does design in the context of living and building. Furthermore, the business models in the field of mobility need to be rearranged, as well as the preservation of what has already been produced is seen as an important potential in many areas.

Digitalisation is ubiquitous and most innovation processes will be connected to it either way. It is therefore necessary to focus on key areas where digitalisation has particularly important impacts or potentials in terms of eco-innovation.

## 1.3 The relations of the digital circular economy to biodiversity

Standardisation is an important prerequisite for working towards a circular use of the outputs of human production (the technosphere) (Zalasiewicz et al., 2017). For instance, heterogeneous plastic waste streams often result in lower quality recycled materials and contaminants make food-related applications problematic (Marie Kampmann Eriksen, 2019). Tramp elements in recycled steel prevent higher value applications (Rankin, 2011).

In contrast, diversity is an important condition for the resilience and richness of the biosphere, a characteristic of the ‘web of life’. Circular economy strategies focus on establishing two circular loops: a socio-economic loop where waste materials are recycled as secondary material inputs and an ecological loop where renewable biomass circulates (Mayer et al., 2019). There is a tension between standardisation within a circular ‘ecological’ loop and tolerance for and fostering of diversity outside the loop. Overcoming this tension will ultimately help to preserve biodiversity, increase resilience and generate greater insight from natural biological processes. Ideally, digitalisation can be steered towards enhancing standardisation in the technosphere and the preservation and recovery of diversity in the biosphere.

Homogenisation was the great feat of the Fordist and Taylorist epoch, allowing to reap the benefits of economies of scale. Its agricultural expression were large monocultures and the intensive use of pesticides and fertilisers (Rudy et al., 2008). Digitalisation brings increased capacities for automatized agricultural monitoring, analytics and subtle interventions with the potential to enable a working of the soil that can handle greater diversity and even thrive on it.

Ideally, digitalisation, artificial intelligence and better sensoring should help to enable an agriculture that better adapts to and incorporates biodiversity. In the field, this could take the form of analytically enhanced utilisation of complementarities between species and greater tolerance for ecological diversity enabled by more precise monitoring and intervention methods. Such advances in monitoring, analytics and deployment should ideally be accompanied by an up-skilling of farmers in order to not only improve the knowledge codified into hard- and software but also that of the people involved.

In contrast, in the factory, better sensoring and the deployment of advanced synthetic biology, ‘white biotech’, can help to accept more diverse inputs to create the homogenous, standardised and marketable intermediate products that allow circularities at scale.

Achieving the circular economy requires harnessing the potential of the bioeconomy. Agriculture, chemicals, dairy, food, forestry, pulp and paper, and waste management are among the traditional sectors making up the bioeconomy (OECD, 2020, p. 144). Digitalisation is bound to transform some of these sectors as it is boosting data processing capacities in genome sequencing, biology and biotechnology (OECD, 2020, p. 143). The development of bio-based technologies is crucial for the generation of renewable feedstocks for the circular economy with the potential to replace fossil-based production (OECD, 2020, p. 144).

Digitalisation helps to generate ever more data about biological processes and also provides enhanced computational tools for analysing this data. In conjunction with automation, robotics and machine learning, experimental and prototyping cycles can be dramatically accelerated (OECD, 2020, p. 144). This helps to speed up development cycles for both synthetic biology as well as the identification and purposeful use of naturally occurring compounds (OECD, 2020, p. 144). These fields produce compounds and processes for the field of green chemistry which seeks to minimise the use and generation of hazardous substances.

Digitalisation also accelerates the genetic and phenotypical mapping of the natural world and thereby boosts the discovery of natural biological materials and processes. It allows to assemble vast databases of biological materials and calculate their theoretical biochemical reactions (OECD, 2020, p. 147). Increasingly powerful computer systems for DNA sequencing and synthesis dramatically lower the costs for such activities. More knowledge about natural entities and processes has the potential to inform the production of bio-based materials, how to keep them in circular loops and how to optimally break them down before their release into the biosphere. Digitalisation, if wisely used, can help to close material loops and preserve biodiversity.

# 2 Eco-Innovation Index and trends

The Eco-Innovation Index, developed by the Eco-Innovation Observatory, is a tool to assess and illustrate eco-innovation performance across EU countries. The index illustrates the performance of all 28 EU Member States. By promoting a holistic view on economic, environmental and social performance, the Eco-Innovation Index complements other measurement approaches of innovativeness of countries such as the EU Innovation Scoreboard. The different aspects of eco-innovation are captured by the index through 16 indicators grouped into five thematic areas:

(1) *Eco-innovation inputs* comprising investments (financial or human resources) which aim at triggering eco-innovation activities.
(2) *Eco-innovation activities*, illustrating to what extent companies in a specific country are active in eco-innovation.
(3) *Eco-innovation outputs*, quantifying the outputs of eco-innovation activities in terms of patents, academic literature and media contributions.
(4) *Resource efficiency outcomes*, putting eco-innovation performance in the context of a country's resource (material, energy, water) efficiency and GHG emission intensity.
(5) *Socio-economic outcomes*, illustrating to what extent eco-innovation performance generates positive outcomes for social aspects (employment) and economic aspects (value added to an economy, exports).

The index illustrates the performance of individual Member States compared to the EU average. By doing so, strengths and weaknesses of single countries in terms of their eco-innovation performance can be distinguished. The composite index is scaled to a reference value by setting the EU average at a value of 100. Thus, countries with higher values than the EU average obtain a score higher than 100 and countries with lower values achieve less, depending on the deviation from the EU average. Countries achieving a score beyond 115 are grouped as 'eco-innovation (EI) leaders', while a score between 85 and 115 represents 'average eco-innovation (EI) performers'. Countries scoring lower than 85 are addressed as 'countries catching up in eco-innovation (EI)'. For more information about the calculation methodology, see the technical note for EcoI Index 2019[9].

Taking into consideration the availability of more recent data and new data sources, the Eco-Innovation Index is continuously adapted and improved. Replacements of underlying data sources and changes in the country scores for the respective indicators may limit the direct comparability of the index results over time.

## 2.1 Key trends of the EU Eco-Innovation Index 2019

In the 2019 version of the Eco-Innovation Index, Luxembourg leads the ranking of all EU countries, with an aggregated score of 165. Denmark, Finland and Sweden follow with respective scores of 146, 145 and 143. The 'eco-innovation leaders' grouping is completed by Austria, Germany and the UK. Ten Member States obtained scores around the EU average of 100 and were therefore labelled as 'average eco-innovation performers'. The aggregated eco-innovation scores in this group range from 112 (Italy) to 85 (Belgium). The last group is composed of eleven countries that are 'catching-up with eco-innovation' and their aggregated scores range from 82 (Lithuania) to 34 (Cyprus). Except for Greece, all countries in this last group are Member States that joined the European Union in or after 2004.

[9] Available for download at https://ec.europa.eu/environment/ecoap/indicators/index_en

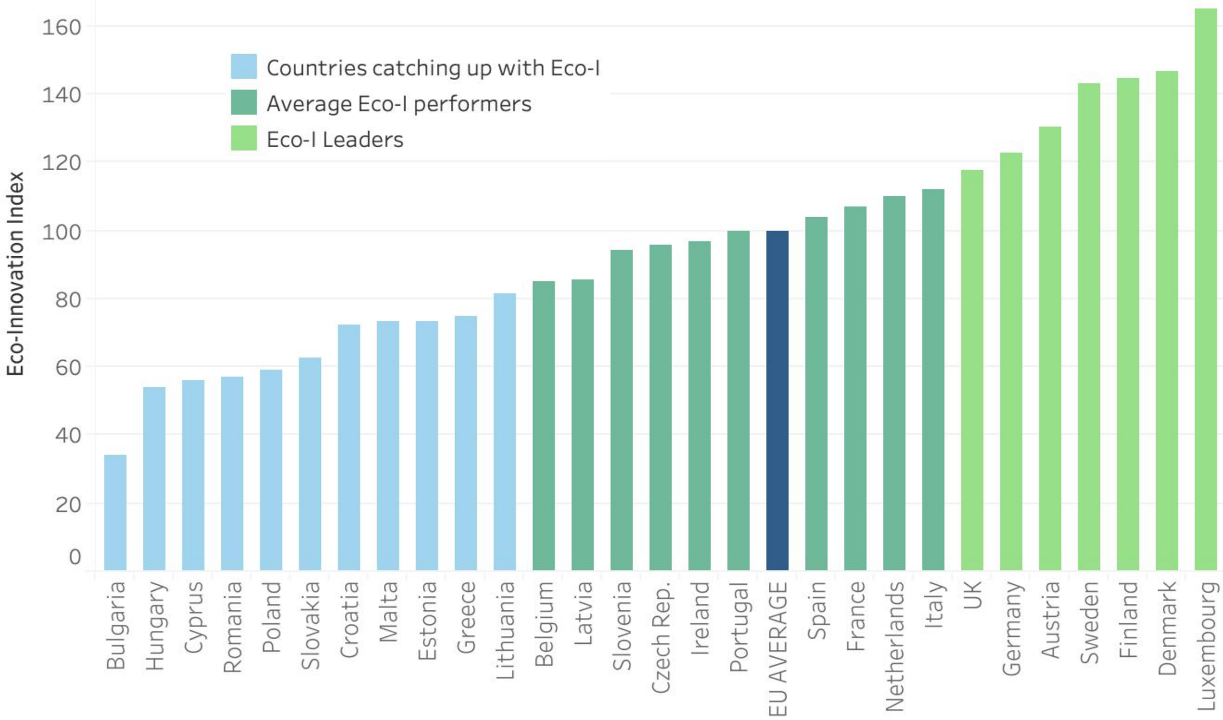


***Figure 6: Eco-Innovation Index 2019***

Compared to the 2015-2018 editions of the Eco-Innovation Index, most countries remained in their respective country cluster. For example, the traditional top-performing countries such as Denmark, Germany, Finland, Luxembourg and Sweden have consistently ranked high in the index 2019, completed by Austria and the UK. However, as it was the case in the previous years, some changes in ranking took place among the EI leaders. Luxembourg reaffirmed its 1st position that it had already in 2016 but Germany fell from the 2nd position to the 6th. More importantly, in 2019, the group of eco-innovation leaders was joined by the United Kingdom who has been improving its performance to a score of 118, corresponding to the 7th position. Similarly, in the two other eco-innovation categories (average EI performers and countries catching up in EI), only minor changes in the group compositions can be observed. The Member States that were considered as catching-up countries in the last Eco-Innovation Index all remained in this category, except for Belgium and Latvia that became average eco-innovation performers. The catching-up countries were joined by Croatia and Lithuania which, although they had improved their performance in 2018, regressed from average EI performers to the bottom category.

While this aggregated index provides a general overview of the overall eco-innovation performance and the geographical structure across the EU, it does not allow to identify strong or weak areas for the various Member States. Therefore, Figure 7 illustrates the scores of the five sub-indices in the Eco-Innovation Index. The colours cover a range from light green (high scores) to dark turquoise (average scores) to light blue (low scores). In order to illustrate the diversity across the EU countries, the minimum and maximum scores as well as the overall score range are indicated for each of the five components, and also for the aggregated index.

| | | Eco-innovation inputs | Eco-innovation activities | Eco-innovation outputs | Resource efficiency outcomes | Socio-economic outcomes | Eco-Innovation Index |
|---|---|---|---|---|---|---|---|
| EI leaders | Luxembourg | 154 | 104 | 184 | 199 | 191 | 165 |
| | Denmark | 130 | 94 | 188 | 161 | 172 | 146 |
| | Finland | 142 | 103 | 251 | 48 | 191 | 145 |
| | Sweden | 180 | 156 | 165 | 119 | 91 | 143 |
| | Austria | 85 | 105 | 153 | 127 | 183 | 130 |
| | Germany | 172 | 84 | 127 | 111 | 136 | 123 |
| | UK | 108 | 112 | 82 | 192 | 92 | 118 |
| Average Eco-I performers | Italy | 69 | 108 | 102 | 178 | 103 | 112 |
| | Netherlands | 134 | 86 | 118 | 128 | 86 | 110 |
| | France | 127 | 109 | 98 | 114 | 83 | 107 |
| | Spain | 71 | 139 | 122 | 114 | 62 | 104 |
| | Portugal | 55 | 135 | 98 | 100 | 100 | 100 |
| | Ireland | 76 | 119 | 61 | 185 | 38 | 97 |
| | Czech Rep. | 82 | 156 | 49 | 59 | 120 | 96 |
| | Slovenia | 106 | 98 | 107 | 73 | 95 | 94 |
| | Latvia | 32 | 68 | 104 | 95 | 132 | 86 |
| | Belgium | 91 | 89 | 94 | 118 | 36 | 85 |
| Countries catching up with E-I | Lithuania | 72 | 67 | 52 | 100 | 112 | 82 |
| | Greece | 79 | 63 | 147 | 53 | 48 | 75 |
| | Estonia | 106 | 60 | 46 | 0 | 175 | 73 |
| | Malta | 9 | 60 | 65 | 198 | 2 | 73 |
| | Croatia | 46 | 99 | 44 | 89 | 67 | 72 |
| | Slovakia | 26 | 95 | 37 | 84 | 52 | 62 |
| | Poland | 45 | 60 | 70 | 32 | 94 | 59 |
| | Romania | 21 | 46 | 37 | 81 | 93 | 57 |
| | Cyprus | 1 | 64 | 108 | 68 | 38 | 56 |
| | Hungary | 48 | 82 | 9 | 65 | 50 | 54 |
| | Bulgaria | 23 | 65 | 19 | 4 | 56 | 34 |
| | *Minimum* | *1* | *46* | *9* | *0* | *2* | *34* |
| | *Maximum* | *180* | *156* | *251* | *199* | *191* | *165* |
| | *Range* | *179* | *110* | *242* | *199* | *189* | *131* |

***Figure 7: Scores in the five components of the Eco-Innovation Index 2019, by country***

The performance regarding ***eco-innovation inputs***[10] was above the EU average for the majority of the top-performing countries, with the exception of Austria. As in previous versions of the index, the indicator of 'green early stage investments', calculated as the total of the time period 2016 to 2019, diverged widely between the EU Member States. For three EU Member countries (Cyprus, Czech Republic and Malta), no investment at all was reported by the primary data source (Cleantech). Luxembourg was by far the leading

[10] Indicators in the sub-index of eco-innovation inputs: 1.1. Governments environmental and energy R&D appropriations and outlays; 1.2. Total R&D personnel and researchers; 1.3. Total value of green early stage investments.

country in the observed period, with 458 US$ per capita. In terms of 'governmental R&D appropriations and outlays in the areas of environment and energy', Germany was leading with 0.08% of GDP, while Denmark had the highest number R&D personnel and researchers (2.5% of total employment). Finally, regarding the component of eco-innovation inputs, all countries at the lower end of the performance spectrum had scores below the EU average, with the exception of Estonia (106).

In the second component of ***eco-innovation activities***[11], leading countries scored slightly above the EU average, except for Denmark and Germany that scored below, and Sweden that was ranked 1st in this index component with a score of 156.  With the identical sub-index score of 156, Czech Republic shares this 1st position, despite belonging to the average performers' category. Similarly, Spain and Portugal displayed good performance regarding eco-innovation activities. Czech Republic performed well due to the highest score in ISO registrations, Spain due to high levels of implementation of resource efficiency actions among SMEs, and Portugal due the latter, as well as the best performance in the implementation of sustainable products among SMEs. Also in this component, all countries catching up in eco-innovation had a performance below the EU average.

High performance regarding ***eco-innovation outputs***[12] was found in most countries of the group of eco-innovation leaders, with the exception of the UK. With a component score of 251, Finland led the ranking, as it displayed the best or second-best performance in the three indicators of this component. For eco-innovation related patents, Germany was the leader, with 53 patents per million habitants. Denmark, Luxembourg and Sweden also had top-scores in this third component. On the other side of the spectrum, Greece had a high performance (147) despite being on 19th place in the overall composite index. This was mainly determined by the high score of eco-innovation media coverage. Of all EU Member States, Hungary had the lowest performance regarding eco-innovation patents (0.5 patents per million inhabitants in 2016), resulting in the lowest sub-index score.

In the component of ***resource efficiency outcomes***[13], scores across all EU Member States were more evenly distributed. This relates to a fact already observed in evaluations of earlier versions of the index, i.e. that some high-performing eco-innovation countries are characterised by comparatively high values of per capita resource use as well as GHG emissions. For example, Finland, ranking 4th in the overall index, has a remarkably low score of 48 in this component. This results from its high levels of material and energy use, caused by the comparatively high importance of resource-intensive industries. On the other hand, the second top-performing country for the resource efficiency outcomes dimension is Malta which ranks 26th on the overall composite index, only slightly surpassed by Luxembourg. Malta's results can be explained by the high level of energy productivity and low GHG emissions intensity in the country. The United Kingdom, Italy and Ireland also scored well in this dimension. The lowest index scores are observed for Estonia (0) and Bulgaria (4), as in 2018.

Performance is also mixed across the three country groups with regard to the fifth component ***socio-economic outcomes***[14]. Both high and low performing countries are found in each of the groups. For example, one of the top-performing countries in this dimension is Estonia with a score of 175, which however has an overall ranking of 20th. This results from high percentages of employment and turnover in eco-industries and circular economy in the country. On the other hand, consistently with the results of 2018, Sweden received scores below the EU average, while Luxembourg and Denmark have significantly

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[11] Indicators in the sub-index of eco-innovation activities: 2.1. Implementation of resource efficiency actions among SMEs; 2.2. Implementation of sustainable products among SMEs; 2.3. ISO 14001 registered organisations.

[12] Indicators in the sub-index of eco-innovation outputs: 3.1. Eco-innovation related patents; 3.2. Eco-innovation related academic publications; 3.3. Eco-innovation related media coverage.

[13] Indicators in the sub-index of resource efficiency outcomes: 4.1. Material productivity; 4.2. Water productivity; 4.3. Energy productivity; 4.4. GHG emissions intensity.

[14] Indicators in the sub-index of socio-economic outcomes: 5.1. Exports of products from eco-industries; 5.2. Employment in environmental protection and resource management activities; 5.3. Value-added in environmental protection and resource management activities.

improved their score. For both these latter countries this is due to their performance in employment in environmental protection and resource management, which are the two best ones. With regard to exports of products from eco-industries, the leader is Germany, closely followed by Luxembourg, while Cyprus is lagging behind. Possible explanation to the trends in the socio-economic outcomes indicators is that in the eastern European countries there is a bigger sector of repair, refurbishment of goods which to a larger extent is focused on repair of cars, machinery, transportation means which are often older than the one seen in the economically more advances Member States.

## 2.2 European eco-innovation performance from a global perspective

The Global Eco-Innovation Index, which is built upon the same methodological principle as the European index, illustrates the eco-innovation performance across a large number of countries worldwide.[15] The index 2019 comprises 130 countries covering industrialised countries, emerging economies and developing countries. Figure 8 illustrates the results of the 2019 Global Index in the form of a world map.

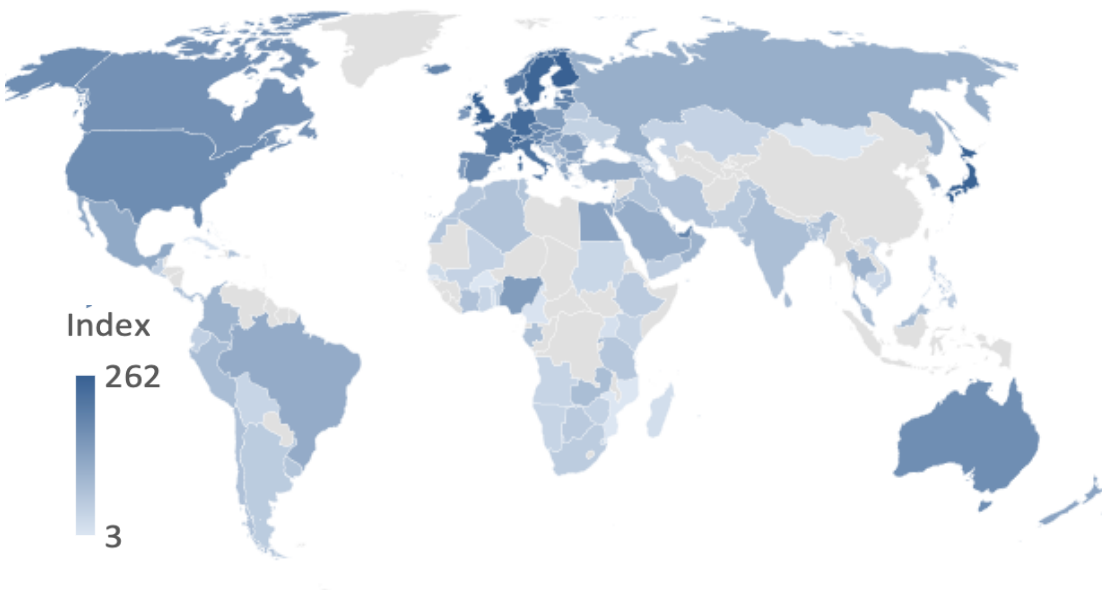


***Figure 8: Global Eco-Innovation Index 2019***

As the country average has also been set to 100, the spectrum of the Global Eco-Innovation Index ranged from 3 (scored by Burkina Faso) to 262 (scored by United Kingdom). Every EU Member state achieved a score above the global average (between 125 to 262), while 15 EU countries were in the top 20 eco-innovation leaders group. Switzerland (2nd), Japan (4th), Norway (11th), and Iceland (18th) were the remaining non-EU leading countries in this top 20. The major emerging economies were ranked closely to the world average. The BRICS countries such as China (score of 129), Brazil (score of 116), Russia (score of 109) achieved scores above the average, while India (79) and South Africa (53) were below that average. The countries Burkina Faso, Mozambique, Mongolia, Cameroon and Cuba achieved scores lower than 10, and thus, represented countries with the lowest eco-innovation performance.

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[15] The Global Eco-Innovation Index consists of 14 indicators from 12 different data sources, most of which are similar to those used in the index 2019 for the EU-28. Main differences are the absence of the R&D human capital indicator, and use of the ORBIS data (https://orbis.bvdinfo.com) for estimation of indicators such as share of companies involved in eco-industry activities, employments on those companies and revenue generated by these companies.

## 2.3 Policy implications

Analyses of the EU Eco-Innovation Index showed a high variance among European countries regarding their eco-innovation performances. All the ‘eco-innovation leaders’ have been traditionally strong in securing R&D personnel, in producing academic publications and patents, as well as in fostering eco-industries that helped them to create value added to their economy and green jobs in these industries. Most of the leaders have become especially prominent in attracting the green investments to their eco-innovative start-ups. However, their attentions should be drawn to material productivity and promotion of resource efficiency actions in their SMEs and larger companies, as well as to improving the energy productivity in countries like Finland and Sweden.

In the case of the ‘average eco-innovation performers’ one can note their good performance in eco-innovation activities. This indicator is associated with the eco-innovative efforts of their companies. Low performance, however, is especially evident in indicators related to investments in eco-innovative research and innovative start-ups. Indeed a poor performance in inputs tends to reflects an average performance in other categories of the index. This relationship between inputs and other categories of the Index is also seen in the country group ‘catching up in eco-innovation’. Implications may be drawn in particular regarding the need to improve R&D funding toward eco-innovation.

By extending the view of eco-innovation activities from EU Member states to a larger number of countries around the world, it can be seen that, in general, EU Member States continue to hold leading positions regarding their eco-innovation performance. This may be due to the increasing efforts of the European Commission to promote sustainability-oriented polices addressing climate change, circular economy and eco-innovation. This points to the opportunity for Member States to take advantage of a frontrunner position in the pursuit of new lead markets, in particular with respect to maintaining a competitive edge in the transition to a circular economy.

# 3 Digitalisation within Europe in the context of Circular Economy and Green Deal

## 3.1 Trends: Some spotlights

Digitalisation is taking place at a fast pace in all European countries. It is transforming the economies, societies, forms of communication, jobs and the necessary skills for the workplace and everyday life (EPC, 2020). Human beings themselves will be changed by the digital revolution (WBGU, 2019).

The European Union is strongly committed to promote and invest in digitalisation in Europe. The Commission has proposed the creation of a Digital Europe programme which brings direct investment of 9.2 billion € for the deployment of innovative digital technologies in five key areas: supercomputing, AI, cyber security, advanced digital skills, and ensuring a wide use of these digital technologies across the economy and society. Moreover, almost 15% of the total proposed 2021-27 Multiannual Financial Framework (MFF) has been allocated to innovation and digitalisation (Sabbati & Sapala, 2020). This commitment is reasoned by the expected benefits of digital technologies.

Nevertheless, the European Commission is aware that "digital technologies, as advanced as they may be, are just a tool. They cannot solve all of our problems. Yet they are making things possible which were unthinkable a generation ago" (European Commission, 2020h).

The process to create a Europe fit for the digital age is "a complex puzzle with many interconnected pieces; as with any puzzle, the whole picture cannot be seen without putting all the pieces together" (European Commission, 2020b). Besides, the international role of Europe cannot be neglected. Europe aims to become a global role model for the digital economy, by supporting developing economies in going digital, and developing digital standards and promoting them internationally (European Commission, 2020b).

The scope and speed of the digital transformation varies across European countries, sectors, organisations and places. Some indicators can be used to spotlight the state of the art in European countries. Firstly, the **Digital Adoption Index** calculated by (The World Bank, 2016) is a worldwide index that measures countries' digital adoption across three dimensions of the economy: people, government, and business (see Figure 9).

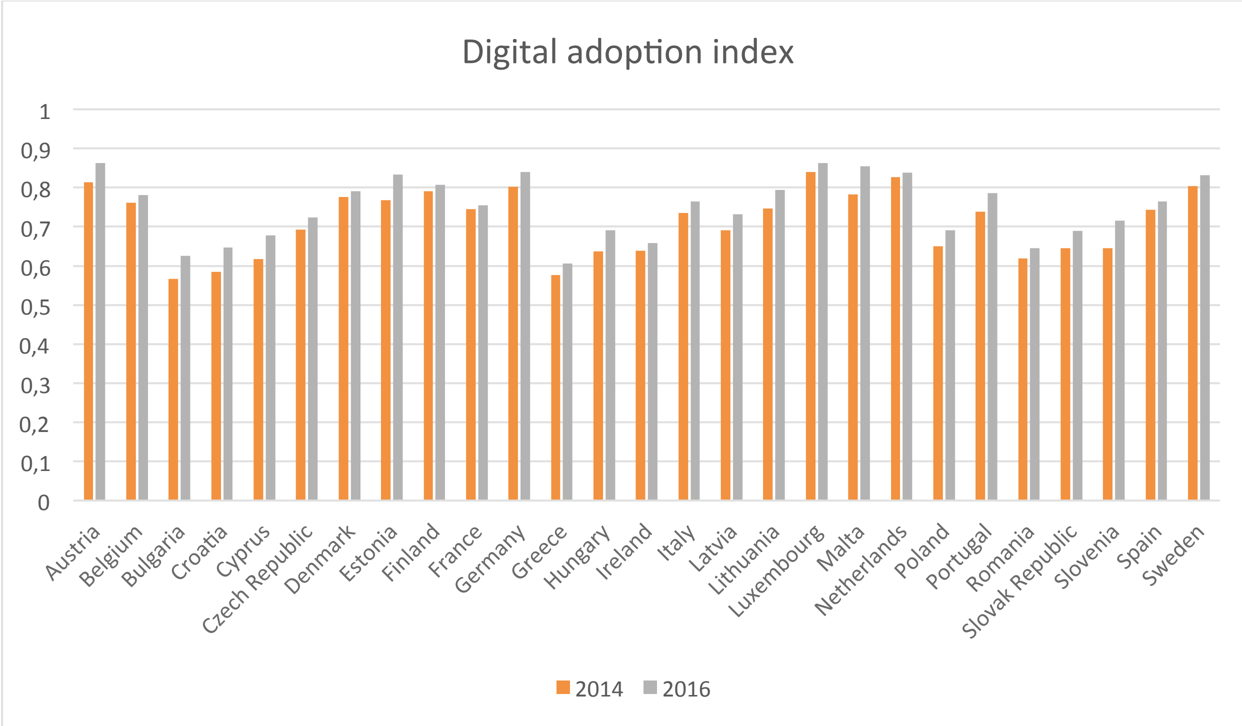



*Figure 9: Digital Adoption Index in European Countries, in 2014 and 2016. Source: (The World Bank, 2016).*

The index shows a positive trend, as it is increasing in all the EU countries, but there are differences among EU Member States.

Looking at the private sector, the Digital Intensity Index (DII), a micro-based index that measures the availability at firm level of twelve various digital technologies, shows that less than a fifth of companies in the EU-28 are highly digitised, but the situation across countries is varying, ranging from 50% of the companies, e.g. in Finland and Denmark, to only 10%, e.g. in Bulgaria, Greece and Latvia. The digitalisation of economic sectors is progressing at different pace, depending on the specific needs and starting points (European Commission, 2019b).

Figure 10 shows the **adoption of digital technologies by European companies**, as percentage of small-medium and large enterprises. Large enterprises have a bigger rate of adoption for all the technologies. ERP and social media are the two most common technologies, both among small-medium and large companies.

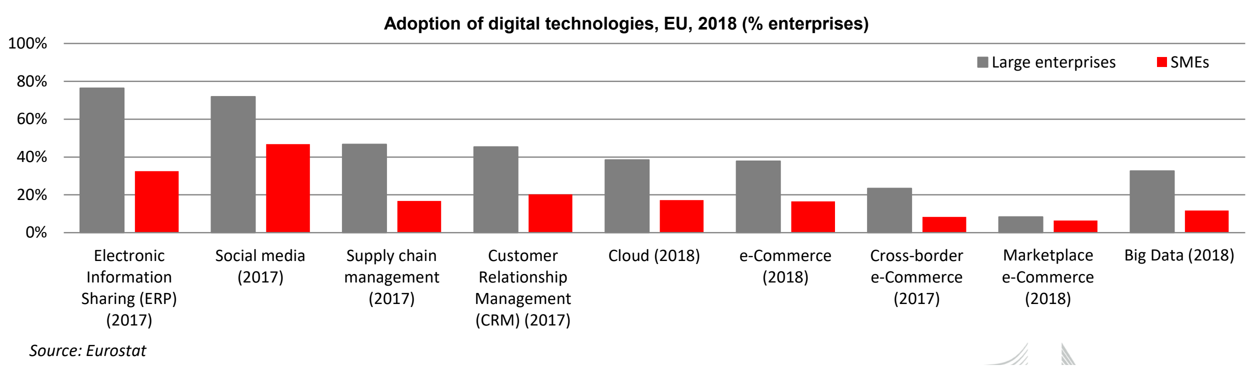



*Figure 10: Adoption of digital technologies by European enterprises. Source: (European Commission, 2019b), p.8.*

Focusing on the public sector, Figure 11 shows the **digital public services dimension** (which consists of eight indicators) of European countries. The demand side of digital public services is progressing, as 64%

of EU citizens used public services online in 2018, compared to 60% in 2014 (European Commission, 2019a). The provision of government online services is progressing, with several Member States recording strong improvements. In addition, the provision of **digital public services for businesses** is improving, having increased by more than 25 % in the last 5 years (European Commission, 2019a).

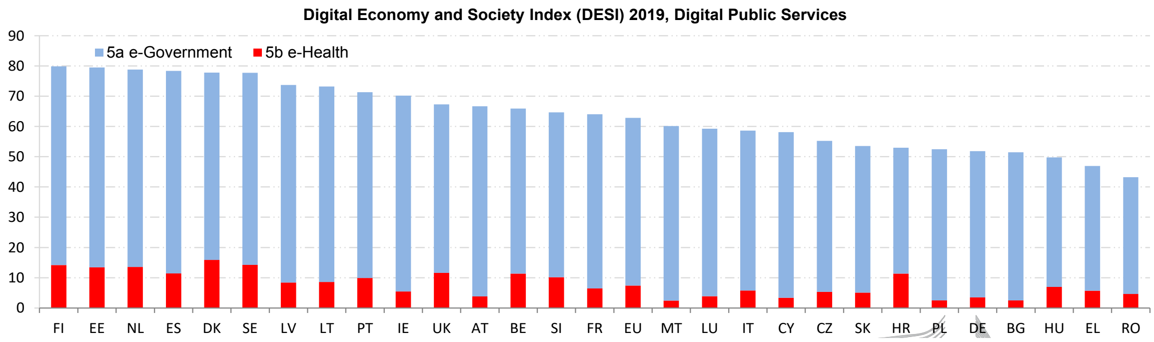



*Figure 11: Digital Public Services indicator in European Countries. Source: (European Commission, 2019a), p.3*

Figure 12 shows the **e-government users** in 2018 (% of internet users needed to submit filled forms to public authorities over the Internet in the last 12 months). However, the digital divide in capabilities is still high, as citizen use of e-government depends highly on income. Policies are fundamental to guarantee the digitalisation does not aggravate inequalities among citizens.

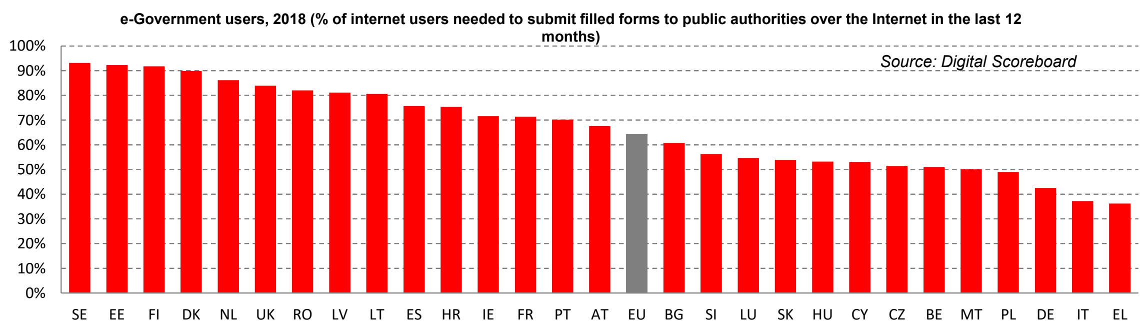



*Figure 12: E-government users in European Countries. Source: (European Commission, 2019a), p.4*

## 3.2 Digital potentials addressed in EU policies

A number of newly launched European policies has strong links to digitalisation while striving for a transformation towards an innovative and sustainable society. In 2019 and early 2020, the European Commission released the **European Green Deal** (European Commission, 2019c), and its initiatives: the New **Circular Economy Action Plan** (European Commission, 2020c), the **Biodiversity Strategy for 2030** (European Commission, 2020g) and it is planned to release a **Zero Pollution Action Plan**. Further important strategies are the New Industrial Strategy (European Commission, 2020d) and the SME Strategy for a sustainable and digital Europe (European Commission, 2020e). In all those policies digital technologies are explicitly or implicitly addressed in the context of the main focus, associated with the expectations that the desired transformation process will be massively fostered by and with digital technologies (European Commission, 2020i).

The following chapter strives to give an overview of these links and relations while looking at what the EU Member States have reported on eco-innovation and digitalisation in their Eco-innovation country profiles

2020[16]. This way, insights will be gained to what extent the European member states are already involved in this process.

### 3.2.1 European Green Deal

The European Green Deal was presented by the European Commission under Ursula von der Leyen on 11 December 2019 with the overall and ambitious objective to reduce the net emissions of greenhouse gases in the European Union to zero by 2050, thus making the continent the first to become climate neutral. The Green Deal has eight pillars comprising manifold strategic measures and approaches over the most resource and emissions-intensive sectors such as energy, mobility, building and food. A large number of goals, prospective instruments, steps and milestones are formulated touching on diverse innovation paths and technologies. The character of the total of about 70 measures is very different, ranging from proposals and declarations of intent to funding programmes to draft laws.

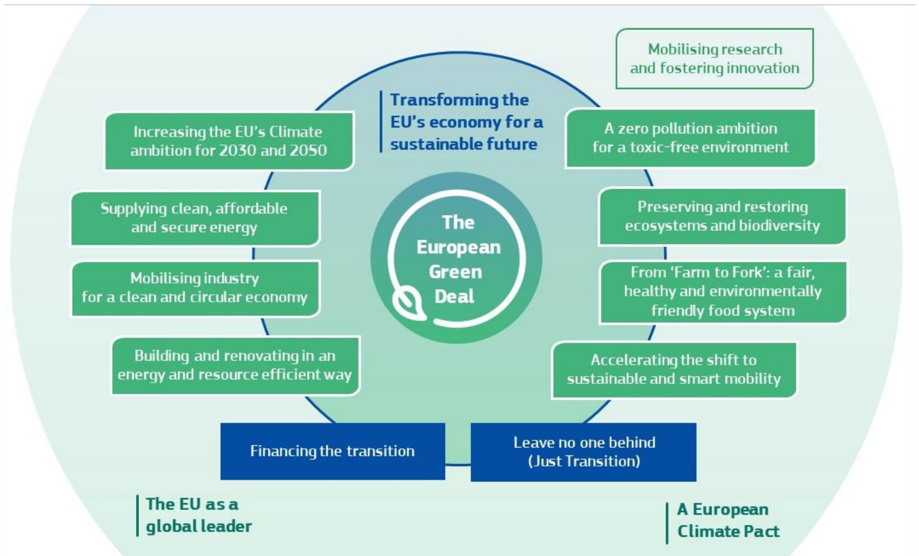



*Figure 13: The European Green Deal and its main pillars; Source: (European Commission, 2019c), p. 3*

According to the European Commission, innovation is one of the policy levers that the Green Deal will consistently use, together with regulation and standardisation, investment, national reforms, dialogue with social partners and international cooperation. Given the level of ambition and the novelty of the proposed measures, "new technologies, sustainable solutions and disruptive innovation are critical to achieve the objectives of the European Green Deal" (European Commission, 2019c). However, the term eco-innovation is not used in the document.

Effective transformative policies are needed in many sectors across the economy, i.e. industry, production and consumption, transport, food and agriculture, construction, as well as for large-scale infrastructures, or in the context of taxation and social benefits in order to deliver the Green New Deal. Within this context, "the EU should also promote and invest in the necessary digital transformation and tools as these are essential enablers of the changes" (European Commission, 2019c). That calls for the exploration of "measures to ensure that digital technologies such as artificial intelligence, 5G, cloud and edge computing and the internet of things can accelerate and maximise the impact of policies to deal with climate change

[16] The recent country profiles comprise the following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Spain, Slovakia, Slovenia and UK. They have been published on: https://ec.europa.eu/environment/ecoap/country_profiles_en

and protect the environment" (European Commission, 2019c). Worth to note is the Just Transition Mechanism, a financial mechanism that aims to secure a structural change in those regions that are prospectively most strongly affected by such a transition.

Attention is also put on the sustainability of the digital sector itself (from broadband networks to data centres and ICT devices), which shall move towards energy efficiency and circularity (e.g. transparency on the environmental impact of electronic communication services; 'take-back' schemes to incentivise the return of devices such as mobile phones, tablets and chargers; diversifying supply from secondary sources).

The analysis of the Communication reveals digital technologies as fundamental to achieve the specific objectives announced in the eight pillars:

1. Develop a power sector based on renewable sources, complemented by the rapid phasing out of coal and decarbonising gas, but at the same time, providing a secure and affordable energy supply for consumers and businesses. For this to happen, it is essential to ensure that the European **energy market is fully integrated, interconnected and digitalised**, while respecting technological neutrality.
2. Enable the transition to climate neutrality in the energy sector, through **smart infrastructure**, such as smart grids;
3. Improve the availability of information on the characteristics of products sold in the EU; for instance, an **electronic product passport** could supply information on a product's origin, composition, repair and dismantling possibilities, and end of life handling;
4. Enable the **distance (to target) monitoring** of air and water pollution; this might also contribute to the monitoring of air quality plans, helping local authorities achieve cleaner air;
5. Enable the **monitoring and optimise** how energy and natural resources are used;
6. Increase digitalisation and **climate-proofing of the building stock**;
7. Develop **smart traffic management systems**;
8. Provide **better information** on **food**, such as where it comes from, the nutritional value, and its environmental footprint;
9. **Predict and manage environmental disasters**. In particular, the Commission wants to develop a very high precision digital model (a 'digital twin') of the Earth, thanks to the "Destination Earth" initiative. This aims to radically improve Europe's ability to predict extreme weather patterns, gauge the impact of climate change and manage natural and environmental disasters, which is defined as a priority.
10. **Engage with the public** on climate action;
11. Enable the **use of accessible and interoperable data in evidence-based decision-making**, expanding the ability to understand and tackle environmental challenges. For this purpose, digital infrastructure (e.g. supercomputers, cloud, ultra-fast networks) and artificial intelligence solutions are fundamental.

The following table summarises the Green Deal's interfaces to digitalisation, the technologies targeted and also indicates which countries provide an eco-innovation practice example of such technologies (as far as reported in the country reports).

*Table 1: The EU Green Deal and its interfaces to digitalisation*

| EU Policy | Interfaces to digitalisation | Targeted Technologies | Case Studies from EU MSs |
|---|---|---|---|
| The European Green Deal | Climate change | - Disaster prediction | Bee2Fire Detection (Portugal) |
| | Energy system | - Digitalised energy market<br>- Smart infrastructures (smart grids) | Aqualoop (Cyprus)<br>Prognosis (Poland) |
| | Value chains and circular economy | - Electronic product passports | The Circular Dataset Initiative (Luxembourg) |
| | Zero Pollution | - Distance monitoring of air and water pollution<br>- Artificial intelligence<br>- Cloud and edge computing | ESAQIRQ (Malta)<br>URADMonitor (Romania) |
| | Building and renovation | - Climate-proofing of building stock | The Edge building - computer with a roof (Netherlands) |
| | Mobility | - Smart traffic management systems | The Belfast Glider (United Kingdom)<br>ŠKODA AUTO DigiLab (Czech Republic)<br>TracksOnTheMap (Hungary)<br>Urban Air (Romania) |
| | Food | - Digitalised consumer information (nutritional value, environmental footprint) | Yuka, mobile application to scan food labels (France) |
| | Research & innovation | - Engage with the public on climate action in virtual spaces, AI solutions, clouds | GeoChallenge (Belgium)<br>ArboSmart (Croatia)<br>Nuritas (Belgium)<br>Timbeter (Estonia)<br>Sensoneo (Slovakia) |

As the table above shows, there are several good practices and digital solutions that have been identified in the Member States fitting with the main objectives of the European Green Deal, its interfaces to digitalisation, and its targeted technologies. Three examples of such technologies and digital solutions are illustrated in the boxes below.

***Box 1: Good practice example – The Circular Dataset Initiative (Luxembourg)***

**Circular Dataset Initiative**

In line with the EU Green Deal's objectives and the interfaces to digitalisation cited in Table 1, notably in connection to value chains and circular economy, the Circularity Dataset Initiative aims to develop an industry standard at the European level to provide a framework for circularity data on products throughout the whole value chain, from raw materials to finished products, from their use phases up to eventual re-use and recycling.

At the moment, it is difficult to obtain reliable data on the circular properties of different products as there is no standardised reporting on these aspects. Issues linked to confidentiality may arise, because of conflicts between the need for transparency to determine the actual circularity of the product and the requirement to protect sensitive manufacturing data.

Luxembourg's Circularity Dataset Initiative's aim is fourfold:

- Fill the gap which currently exists on circular economy data;
- Save costs for manufacturers by increasing data exchange efficiency across supply chains and by developing a widely recognised industry standard (which would replace the multiple formats which may be required of manufacturers to account for product circular economy characteristics);
- Improve data sharing on circular economy across supply chains;

- Maintain the integrity of data to ensure it is reliable.

The pilot project, launched at the national scale in Luxembourg, is part of the efforts conducted to support companies in transitioning towards a circular economy. Since its inception in 2018 by the Ministry of the Economy of Luxembourg, more than 50 companies from 12 different European countries have joined the Circularity Dataset Initiative, including industry leaders. Notable participants include IKEA, Saint-Gobain, Tarkett and ArcelorMittal. The theoretical proof of concept was developed for two product categories linked to construction materials and fast-moving consumer goods. The Circularity Dataset Initiative was presented during a press conference in December 2019 and gained a lot of momentum in 2020, with strong interest from the European Commission and from an increasing number of companies, platforms and associations joining the project.

The dataset will take the form of a "Product Circularity Data Sheet" (PCDS), an internationally accepted dataset template, which will list relevant circular information in standardised and auditable statements, allowing product circularity evaluations. Managing the PCDS may call for new technologies such as blockchain or artificial intelligence, to ensure traceability for instance.

**Keywords:** Circularity, product passports, evaluation, audit

**Sources:**

Ministry of Economy. November 2019. *Circularity Dataset Initiative - Luxembourg leads European Circularity Dataset Initiative.* Available at: https://meco.gouvernement.lu/fr/le-ministere/domaines-activite/ecotechnologies/circularity-dataset-initiative.html

European Union. November 2019. *Luxembourg launched "Circularity Dataset Initiative" supported by major international industry leaders.* Available at: https://circulareconomy.europa.eu/platform/en/strategies/luxembourg-launches-circularity-dataset-initiative-supported-major-international-industry-leaders

Positive Impakt. *Circularity Datasets standardization – Phase 1.* Available at: http://positiveimpakt.eu/portfolio/circularity-datasets-standardization-phase-1/

In line with the EU Green Deal's targeted policy area of "Building and renovating", the need for a cleaner construction sector in the EU is apparent. While building renovation is essential as buildings account for 40% of energy consumed and many buildings are not sufficiently isolated to be efficient in energy use, new buildings must be proactive in terms of energy efficiency. The case study provided in the box below presents The Edge, a Dutch office building located in Amsterdam, which was fully designed and constructed as a "smart building", illustrating the transition into the digital age while achieving highest possible levels of sustainability.

***Box 2: Good practice example – The Edge building, a computer with a roof* (Netherlands)***

**The Edge, Amsterdam**

Completed in 2015, the Edge Building located in Amsterdam has been internationally considered as the greenest and smartest building for a number of years, and described as a "computer with a roof". It is equipped with several tens of thousands of sensors which send user-generated data for analysis and modelling to better inform and manage building system operation. The construction of this building is fully aligned with the EU Green Deal's policy area of "Building and renovating", with ambitions towards integrating the circular economy in the design of buildings and increasing the use of digitalisation in construction and renovation.

The Edge's atrium: the heart of the building (source: Inhabitat)

Its environmental features are various: the roof and the building's south facade have the largest surface of photovoltaic panels among European office building, and energy for heating and cooling is provided through an aquifer thermal energy storage system. A heat-pump is applied to this storage system and significantly increases its efficiency.

One of The Edge's key features is its innovative and digitally based lighting system, an ethernet-powered LED lighting system integrated with over 30,000 sensors. The sensors allow the system to constantly meet lighting needs in relation to occupancy, movement, outside lighting levels, humidity and temperature, while adjusting energy use. Around 6,000 luminaires are installed in the building, and every second luminaire is equipped with additional multi-sensors which allow the detection of movement, light, infrared and temperature.

This lighting system was co-developed with the company Philips, and is entirely computer controllable. The system is estimated to reduce energy consumption associated with lighting by 50% compared to conventional lighting.

Overall, the Edge uses approximately 70% less electricity than regular office buildings. Since its completion, it has won several BREEAM (Building Research Establishment Environmental Assessment Method) awards, and the Urban Land Institute (ULI)'s Global Award for Excellence. The Edge represents a flagship example of a successful energy-efficient building, fulfilling the EU Green Deal's objective of increasing the energy performance of buildings.

**Keywords:** Construction, digital solutions, energy performance

**Sources:**

BREEAM. *The Edge, Amsterdam*.
Available at: https://www.breeam.com/case-studies/offices/the-edge-amsterdam/

Centre for Digital Built Britain. 2018. *The Edge Amsterdam – showcasing an exemplary IoT building.*
Available at: https://www.cdbb.cam.ac.uk/news/2018CaseTheEdge

*Note: Not reported as part of the country report.

Another resource and emissions intensive sector focused in the Green Deal is mobility – in particular individual mobility. Emissions are either growing or stable at a high level in many European countries while accounting for 25% of the overall greenhouse gas emissions. Public transport is one indispensable element for a transition to sustainability, albeit its relation to a circular economy is not all that clear at first sight. Multimodal digital freight systems, interconnected smart transport and traffic management systems should certainly contribute to a prospective reduction of individual mobility and a too large European vehicle fleet by supporting smart and easy to handle ticket systems and multimodal transportation.

***Box 3: Good practice example – The Belfast Glider* (United Kingdom)***

**Belfast Glider**

Operational since 2018, the Belfast Glider, the city's bus transit system, provides Belfast residents with an attractive alternative to the use of private cars, countering the Belfast average car occupancy of 1.2 people per car. The Glider network offers a number of key advantages which help manage traffic throughout the city, including:

- 25% reduction in public transport journey times;
- Improvement in journey time reliability;
- Improved passenger safety and security - both on the vehicles and at halts.


Belfast Glider (Source: Focus Transport)

The Glider network was constructed at a cost of approximately €100m, among which €17 million was provided by European funding from the European Regional Development Fund, through the Investment for Growth and Jobs Programme for Northern Ireland 2014-2020. The Glider operates a fleet of 18-metre long buses, which offer services such as free WI-FI, USB charging facilities, CCTV to ensure safety, but most importantly real-time visual and audible information on traffic updates, contributing to efficient traffic management.

The Glider's off-board ticketing system has a keen focus on integration, flexibility and convenience. Consumer preference towards mobile phone ticketing convinced Glider to introduce new ticketing systems and Translink, the company operating the Glider, is planning on implementing contactless payment cards on buses, e-purse payments, ticket vending machines and validators available at every halt and online ticket purchase options. These new options aim to facilitate transport and ensure speedier boarding and journey times, contributing to more efficient traffic management. In addition to their advantages for traffic management, Glider buses have diesel hybrid electrical engines which emit low levels of pollution and noise.

This example shows the importance of efficient public transport systems as the City Council's Belfast Agenda sets out bold ambitions in terms of attractiveness for residents, job creation and tourism. The Glider is a prime example of how the city aims to achieve these ambitions, while contributing to the EU Green Deal's objectives in terms of sustainable and smart mobility.

**Keywords:** Smart mobility, traffic management, public transport

**Sources:**

Translink. *Glider, The effortless and smooth way to travel.* Available at: https://www.translink.co.uk/usingtranslink/introducingglider

Eltis. October 2018. *Glider, Belfast's new BRT system turned operational.* Available at: https://www.eltis.org/discover/news/glider-belfasts-new-brt-system-turned-operational

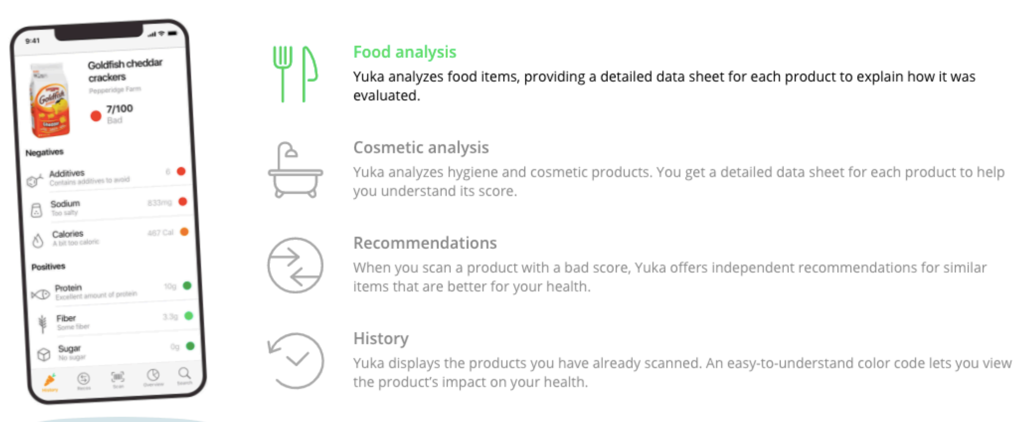
*Note: Not reported as part of the country report.

Not least, in line with the EU Green Deal's objectives on food, digitalised consumer information applications have emerged in several EU Member States. In France, the mobile application Yuka scans and analyses product labels to provide information on their nutritional value, and orients consumers in making healthier choices.

*Box 4: Good practice example – Yuka, the mobile application which scans food labels (France)*

**Yuka, mobile application which scans food labels**

The mobile application Yuka was launched in January 2017, with the objective of helping consumers make healthier diet choices, and making manufacturers improve the nutritional quality of their products. The app enables users to scan the barcodes of food and personal care products and provides them with information on the products' impacts on human health. This service is line with the EU Green Deal's Farm to Fork objective's concerning food labelling as a solution to empower consumers to choose healthy and sustainable diets.




Presentation of the Yuka application (Source: Yuka)

Yuka provides a rating out of 100 for food products as well as detailed information explaining the analysis associated with each product. Food product scores are based on three criteria:

- **Nutritional quality,** which represents 60% of the score. The calculation method is based on the Nutri-Score method, created by the French Public Health Agency. The methodology considers calories, sugar, salt, saturated fats, protein, fibre, and share of fruits and vegetables in the products.
- The **presence of additives,** which represents 30% of the score. Benchmarks are based on scientific research and recommendations from scientific institutions (EFSA, ANSES, IARC) as well as from numerous independent studies. A risk level is associated with each additive: risk-free (green dot), limited risk (yellow dot), moderate risk (orange dot), or high risk (red dot).
- The **organic dimension,** which represents 10% of the score: Products which carry the European organic label (Euro-leaf) are included.

Yuka uses a database containing information on over 1 million food products and 500,000 cosmetic products. More than 800 new products are added daily to the database. Originally, the app relied on the Open Food Facts database, an open and collaborative database which uses the same model as Wikipedia. Yuka created its own database in 2018 to implement advanced systems to monitor and verify data. Launched in France, the app is now available in five other EU countries: Belgium, Ireland, Luxembourg, Spain and the UK, as well as in Switzerland and North America. Its business model relies on two sources of funding: a paying version of the app, which provides additional features: search bar, offline mode and unlimited product history; and a nutrition program which offers a 10-week program with information on the basis of healthy diets and access to recipes and tips from nutritionists.

Yuka hence provides digitalised consumer information on the nutritional value of food products, in line with the objectives of the EU Farm to Fork strategy, a corner stone of the EU Green Deal, by making sure Europeans get healthy, affordable and sustainable food. While the application is a very good solution to give consumers access to this information, a mandatory label on food products, such as the existing Nutri-Score method applied in France since 2017 (later adopted in Belgium in 2019 and foreseen in other Member States), would be a more concrete way to provide consumers with immediate information on the nutritional quality of the food products they purchase. This is another key objective of the Farm to Fork strategy, as the Commission set out to "propose mandatory harmonised front-of�pack nutrition labelling and develop a sustainable food labelling framework that covers the nutritional, climate, environmental and social aspects of food products". This objective could also provide an opportunity for more finely-grained assessment of nutritional content/value of food which cannot carry labels for practical reasons (e.g. fresh fruit or vegetables), at which point labels could be inspired by Yuka's model and propose QR codes to scan directly on supermarket stalls.

**Keywords:** Digitalised consumer information, health, nutrition, mobile app
**Source:** *Yuka, Official website.* Available at: https://yuka.io/en/app/

### 3.2.2 Circular Economy Action Plan 2020

The New Circular Economy Action Plan (COM(2020) 98) which was released in early 2020 announces to make a decisive contribution towards climate-neutrality by 2050, as called for in the Green Deal. The new plan emphasises that achieving a climate-neutral circular economy requires the full mobilisation of the industry and that actions have to be taken within the next five years. The role of digitalisation as an accelerator for the transformation is clearly stressed and an integration of both the digital and circular economy agenda is pursued (European Commission, 2020c).

> The document states that *"Building on the single market and the potential of digital technologies, the circular economy can strengthen the EU's industrial base and foster business creation and entrepreneurship among SMEs. Innovative models based on a closer relationship with customers, mass customisation, the sharing and collaborative economy, and powered by digital technologies […] will not only accelerate circularity but also the dematerialisation of our economy and make Europe less dependent on primary materials"* (European Commission, 2020c).

However, as pointed out by a recent study on the potentials of actions of the 2020 CEAP, the focus has been mainly on supply side and production measures in the past (i.e. the foregoing CEAP 2015) and this is also striking in the new CEAP.

Scanning through the new circular economy action plan and analysing its transformation strategies, various interfaces with digitalisation can be identified providing potential areas for digital technologies.

As a part of the action plan, a sustainable product policy legislative initiative will be proposed, which will widen the **Eco-design Directive** beyond energy-related products with the overall aim to make products fit for a climate-neutral and resource-efficient circular economy. Recent eco-design has shown the technical limits and difficulties of looking solely at the energy efficiency of standalone devices. Digitalisation can be a key enabler of a systems approach by using smart controls in systems ('intelligent efficiency'). Furthermore, machine learning algorithms can ensure a more in-depth data interpretation that provides manufacturers with insights of a product's use, performance or environmental condition but do consume significant amounts of energy at the same time (García-Martín et al., 2019).

The action plan also announces incentives to **product-as-a-service** and other business models in which producers keep the ownership. As these can be supported by online platforms and apps, IoT (internet of things)-led services play a core role here. A digitalised product-as-a-service system enables services based on data generated insights, it enables consumers to continuously use the latest software but also a replacement of hardware at its end of life.

Another emphasis is led on **product information and solutions** such as digital passports, tagging and watermarks. This digital passport, for example, is an application solution that allows companies to assess their alignment with best practices towards the origin of products, Corporate Social Reporting, product compliance with international standards, and legal compliance.

***Box 5: Good practice example – Sustainabill - supply chain platform (Germany)***

**sustainabill - A Platform for supply chain sustainability insights**

The sustainabill cloud platform offers a number of services and technological solutions to help companies identifying risks in their supply chains and improve the supply chain's sustainability. The tool is applicable to industry and products and enhances visibility, helps to achieve traceability and essentially increases transparency.

Using new and various digitised application-oriented tools (e.g. supply chain visualisation, mulit-tier visibility, risk heat maps, supply chain mapping & traceability) the supply cloud platform offers solutions contributing to a circular economy, to sustainable sourcing, social compliance and human rights, decrease of climate emissions, and better audit and certification management in industries for textiles, minerals, food and others. The social impact start-up also offers webinars and further information material.

**Keywords:** supply chain management, traceability, supply chain transparency
**Contact**: https://sustainabill.de ; sustainabill GmbH, 50670 Cologne, Germany


**Source:** sustainabill 2020

Further potential is seen on the application of a **new sustainable production framework**, and with regard to that, the establishment of a European Dataspace for Smart Circular Applications[17] as a driver of applications and services including product passports, resource mapping and consumer information. Here, the smart use of data can have a transformative effect on all sectors. With regard to the European Dataspace it will be important to make sure that a minimum standardisation is advanced but that there remains room for experimentation.

**Waste management plays** a major role when it comes to circular economy. The action plan points out that 'improvements in waste management are relevant to make it fit for circular economy and the digital age'. The collection of waste and recycling data will enable adjustment of measures and the adaptation of policy executions to increase their effectiveness. Waste collection and separation programs are largely digitised already, while different types of sensors in vehicles, bins, software platforms and mobile apps already provide important benefits. The cloud-based technology has the capability to collect real-time data, and thereby, help to better target recycling efforts. Digital technologies can 'track the journey of products, components and materials and make the resulting data securely accessible'. Tagging of product at the material level has the potential to drastically improve the understanding of a materials provenance, its way through the economy and the problems and pitfalls involved in integrating it into circular flows.

***Box 6: Cutting edge technology – DNA tagging of materials***

**DNA tagging of materials**

DNA tagging of materials promises drastically increased traceability.

Applied DNA Sciences is a U.S. company offering a service where materials, e.g. cotton, are marked with a unique molecular tag and can be tested throughout the supply chain to verify the presence of the tag. The Fraunhofer Institute for Applied Polymer Research (Fraunhofer IAP) in Potsdam-Golm, Germany, has also developed a method using tomato DNA-based permanent taggants to prevent counterfeiting in silicone

[17] *"Establish a common European data space for smart circular applications making available the most relevant data for enabling circular value creation along supply chains. A particular focus will be concentrated at the outset on the sectors targeted by the Circular Economy Action Plan, such as the built environment, packaging, textiles, electronics, ICT and plastics. Digital 'product passports' will be developed, that will provide information on a product's origin, durability, composition, reuse, repair and dismantling possibilities, and end-of-life handling"* (https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf)

breast implants (Additives for Polymers, 2018). This technology does not only have potential for preventing counterfeit but also for tracking the circulation of transformation of materials throughout the economy, allowing to improve sorting, recycling and lesson drawing for the circular economy.

**Keywords:** DNA tagging, supply chain, traceability, verification
**Sources:** https://adnas.com / https://perma.cc/J9FH-SMQA

Furthermore, a green transition requires the financing of sustainable production and consumption patterns. The establishment of the **Circular Economy Finance Support Platform**, for example, can be improved by digitisation measures. Fintech can help disclosure of environmental data by companies and help increasing financial inclusion. Potential applications can cover supply chain traceability to ensure sustainability throughout the supply chain. As digitalisation connects data, devices and decisions, real-time data can be created about an item´s location, condition and availability, and thus, ease access to products and services that makes processes more effective.

*Box 7: Experimental technology – Everledger makes the electric battery supply chain transparent*

**Everledger makes the electric battery supply chain transparent**

Whether batteries can be successfully integrated into the circular economy is a crucial factor for the sustainability of the transition towards electric vehicles. The UK-based company Everledger is developing a passport for vehicle and portable electronics batteries in order to ensure optimal management and responsible recovery at end-of-life.
The passport transactions are automatically verified via a blockchain platform and Internet of Things (IoT) technologies, which facilitates data exchanges among the different stakeholders. Currently, the technology is tested in two pilot projects. Better lifecycle data also promises to enable a smooth repurposing of vehicle batteries for energy storage.

This project is particularly interesting with regard to the European Commission’s (2019c, p. 9) aim to “ensure a safe, circular and sustainable battery value chain for all batteries”.

**Keywords:** Blockchain, IoT, batteries, e-vehicles, energy storage
**Source:** www.everledger.io

As the Commission seeks to advance a sustainable product policy legislative initiative in order to make products with for, inter alia, the circular economy (European Commission, 2020c, p. 6), the role of digitally enhanced contaminant assessment with radically reduced costs become an important enabler of circularity. This is in line with the Commission’s ambition to “develop methodologies to minimise the presence of substances that pose problems to health or the environment in recycled materials and articles made thereof”.

Trust in recycled plastics, for instance, can be damaged if contaminants are found in recycled products. For example, hazardous chemicals (e.g. toxic flame retardants) have found their way into many black plastic products via the recycling of electronic waste (Turner, 2018). While regulation is an important pillar for preventing such ‘toxic circularity’, better digitally-enabled contaminant detection can also increase consumer safety and help to assure that consumers can trust the products of a circular economy.

Particularly in the case of plastic, a combination of precise monitoring of waste flows as well as contaminant screening will be important in order to avoid problems that might arise from any mandatory requirements for recycled content, as envisaged by the Commission (European Commission, 2020c, p. 12). Machine learning can help to better analyse spectroscopic data and thereby improve contaminant detection, as shown in the case of soil (Sun et al., 2019).

Sensors involving a biological component/organisms – such as DNA probes, antibodies, enzymes, or cell receptors – (biosensors) permit to detect contaminants at a low concentration in drinking water, food, and soil (Singh et al., 2020). They have become an important alternative to conventional methods for contaminant detections, such as chromatography (chemical separation of substances) and spectroscopy, which tend to be expensive and dependent on expert labour. Bio- and nanotechnologies are important contributors to the development of advanced biosensors (Kanellis, 2018). Further digitalisation and robotisation can help to speed up biosensor development cycles and could potentially lead to a range of low-cost biosensors, which could help to 'detoxify' the circular economy.

***Box 8: Experimental technology – Biosensor detects pollutants on fruit and vegetables***

**Biosensor made in Valencia detects pollutants on fruit and vegetables**

Researchers from the Ainia Technology Centre in Valencia, Spain, have developed an optical biosensor that allows to screen fruits and vegetables for pesticide residues in a way that is easier, cheaper and faster than using traditional tests. Experts in biochemistry and electronics collaborated in the creation of this optical biosensor, which registers changes in the properties of light arising from the interaction of contaminants with antibodies. The biosensors reduces the price of contaminant testing and could therefore contribute to more frequent testing and increased consumer safety. The EU's European Regional Development Fund contributed the lion's share of the project budget.

**Keywords:** biosensors, contaminants, food
**Source:** https://perma.cc/Z9PD-X823

Finally, digital technologies will also be required referring to the monitoring progress. European Commission will update the **Monitoring Framework for the Circular Economy** and implement new indicators relying on European statistics (European Commission, 2020c, p. 23).

The following table summarises the above, shows the CEAP's 2020 interfaces to digitalisation, the technologies targeted by the CEAP and, thirdly, which countries already use such technology (as far as reported in the country reports).

*Table 2: The CEAP 2020 and its interfaces to digitalisation*

| EU Policy | Interfaces to digitalisation | Targeted Technologies | Case Studies from EU MSs |
|---|---|---|---|
| **Circular Economy Action Plan 2020** | Eco-design | - Smart controls 'intelligent efficiency'<br>- Machine learning algorithms | Timbeter (Estonia)<br>EcoBox SBR-Q (Slovenia)<br>Aqualoop (Cyprus) |
| | Product-as-a-Service | - IoT (internet of things)-led services | Bee2Fire Detection (Portugal) |
| | Product information | - Block chain<br>- Artificial intelligence models | (digital passports, tagging and watermarks)<br>Everledger (UK)<br>Sustainabill (Germany) |
| | New sustainable production framework / European Dataspace for Smart Circular Applications | - Smart data use | Cirkeltips (Belgium)<br>Circular Dataset Initiative (Luxembourg)<br>Green-Effective Perfomance Calculator (Poland)<br>CYRKL Platform (Czech Republic) |
| | Waste Management | - Cloud-based technologies | FoodCloud (Ireland)<br>Elwis (Slovakia)<br>EntoGreen (Portugal)<br>Anaergia's OREX (Cyprus) |
| | Circular Economy Finance Support Platform | - Fintech<br>- Block chain | FIRESPOL (Croatia) |
| | Monitoring Framework | - Horizon 2020 and Copernicus data<br>- Data-based new indicators and metrics | eAgronom (Estonia)<br>Sensoneo (Slovakia) |

The examples show that digitalisation can help to minimise waste, enable more efficient processes in companies, promote a longer product life cycles and reduce transaction costs through significantly improved information. Material cycles can be closed or be slowed down by increased resource efficiency. Numerous technological challenges remain however unresolved and knowledge gaps exist have to overcome for the implementation of business models a circular economy using digital technology (Antikainen et al., 2018).

### 3.2.3 Biodiversity Strategy 2030

The Biodiversity Strategy 2030 was released in May 2020 in the middle of and under the impression of the COVID-19 pandemic. Therefore, not only the importance of green areas and ecosystems for recreation areas is strongly emphasised in the strategy but investing in nature protection and restoration is also considered a means to economically recover from the COVID-19 crisis. The Biodiversity Strategy states to protect at least 30% of the land and 30% of the sea within the EU. One third of protected areas, representing 10% of EU land and 10% of EU sea, should furthermore be strictly protected. As farmers play a vital role in preserving biodiversity, the document underlines the importance of **working together with farmers to support and incentivise the transition to fully sustainable practices**. Incentives can be set towards precision farming and digitally optimised farming (European Commission, 2020g).

Precision farming is an agricultural concept involving new production and management methods that make intensive use of data. Smart electronics, sensor technologies and application methods can be used to optimise production processes and growth conditions, including devices for sensor-assisted soil assessment or the monitoring of free-ranging animals. Digital farming is based on precision farming and includes the use of web-based data platforms and big data analyses. Furthermore, the Internet of Things (IoT) can be used in agriculture comprising sensors, drones, robots and cameras. The availability of real-time data and information then allows farmers to identify and manage potential problems in a timely manner and simplify sustainable farming practices (European Commission, 2020g).

Smart and precision agriculture should ideally be put to the service of enabling polycultures (Gilles Dryancour, 2017) which allow radically reduced chemical inputs and greater biodiversity (Eurostat, 2019). Ecological intensification is a knowledge-intensive process that seeks to use land, water, biodiversity and nutrients in a way that is efficient, regenerative, and minimises negative impacts (FAO, n.d.). Up skilling and the increased leverage of robotics and sensors help to address the greater labour and knowledge intensity of ecologically intensified polycultures.

***Box 9: Good practice example – NIK implements precision farming (Bulgaria)****

**NIK implements precision farming in Bulgaria**

Bulgaria's agricultural sector is characterised by large-scale exploitations that are usually rented by their owners to farmers. Both the size of properties, and the financial support provided by the EU create favourable conditions for the adoption of precision farming. To answer the demand for these technologies, a number of local providers have flourished. NIK is one such providers, working in partnership with foreign technology leaders from the EU and Northern America.

Since 2002, they equip large-scale farms with a wide array of technics and services:

- precision farming equipment (e.g. GPS devices, weather stations, precision plantings' precision sowing systems, Precision Processing systems, self-propelled vehicles etc.)
- agro-management software (e.g. enabling a better use of farm vehicles through automation)
- integrated agronomic services (e.g. satellite monitoring of crop development, soil mapping, weather data, etc.

While their focus is mostly on productivity and improving the daily work of farmers, their offer enables the adoption of eco-innovations which might improve the state of the environment in Bulgaria's farming regions. For example, precision farming technics can reduce the use of pesticides and fertilisers; automated vehicles can save fuel; and they also promote circularity by selling both second-hand machines and spare parts to repair vehicles.

They have received multiple prizes for their achievements in bringing digital technologies to Bulgarian farmers.

**Keywords:** precision farming, agriculture, automation, earth observation, second-hand equipment
**Sources:**
Van Es, H., Woodard, J. (2017) Innovation in Agriculture and Food Systems in the Digital Age, in *The Global Innovation Index 2017,* https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2017-chapter4.pdf
NIK company website: https://nik.bg/en/about-us/

*Note: Not reported as part of the country report.

The biodiversity strategy also foresees the protection of soil fertility, the reduction of soil erosion and the increase of soil organic matter by adopting **sustainable soil management practices**. This compiles the identification of contaminated soil sites and the improvement of soil quality monitoring. Various new technologies can be applied here: The Digital Soil Mapping (DSM) approach, for instance, creates spatial soil information based on geographic information system (GIS) or global positioning system (GPS). It thereby utilises quantitative inference models to generate predictions of soil classes in a database. Satellite technologies can be applied additionally to measure and visualise soil moisture, texture or nutrient content (European Commission, 2020g).

***Box 10: Good practice example – Naïo: Weeding robots to reduce herbicides use* (France)***

**Naïo Technologies: Weeding robots to reduce herbicides use**

Before herbicides became a widespread technic, manual weeding was the only way to avoid the proliferation of undesired plants within cultures, occupying the space of crops and sometimes attracting pest. The task was labour intensive: it was repetitive, tiring, and demanded many hands. Herbicides helped to address this issue and resulted in higher productivity for farmers. However, their impact on the local environment has render their widespread use controversial, and tightly regulated, especially in organic farming.

Naïo Technologies was born out of a discussion between an asparagus productor, who was struggling to find workers to help with vegetable picking, and a PhD student in robotic. Within a few years, a start-up was launched, following by its first weeding robot, Oz. With the help of a camera and dedicated sensors, map memorisation, GPS guidance, and a four-hour battery, the robot can weed a 10-hectare field for a highly competitive price (€2 per hectare, without the help of any chemical product. In 2017, the company released two new robots: Dino, aiming at large-scale vegetable farms, and Ted, designed for vineyard weeding. The robots benefit from longer lasting batteries

Founded in near Toulouse, in the south-west of France, the company started with a strong local element, although it now aims to expand to international markets. The entrepreneurs benefited from the regional entrepreneurial ecosystem for training and ideas, and the robots were assembled by local subcontractors.
The company claims that a majority of their clients are organic farmers looking for an alternative to chemical weedkillers and tedious labour. To ensure the robots ecodesign, the company is currently conducting a life-cycle analysis.

The start-up proved successful, and in 2016, after five years of existence, the company of almost 20 employees claimed €350,000 of sales turnover and attracted €3 millions of investment.

**Keywords:** precision farming, herbicides, robotic, sustainable agriculture
**Sources:**
Naïo Technologies company website: https://www.naio-technologies.com/en/
Galeron, F. (2016) Naio Technologies: Qui sont les créateurs du robot des champs? *La Tribune*, 2 March

2016, http://mouves.org/Mouves2015/wp-content/uploads/2016/03/02032015-La-tribune-Naio-Technologie-citation-Naoile.pdf

©Naïo Technologies

*Note: Not reported as part of the country report.

As forests play a core role for biodiversity, the document addresses the need for a **mapping and monitoring of EU´s remaining primary and old-growth forests**. This process can be accelerated through electronic forest management based on new digital technologies. Forests can, for example, be monitored by apps (e.g. the Forest Watcher mobile app, which is the alert system of Global Forest Watch), which cover functions such as deforestation monitoring and fire alerts. Furthermore, algorithms based on Artificial Intelligence (AI) can be used for global data processing of forests presenting a comprehensive monitoring approach.

*Box 11: Good practice example – OpenForests* (Germany)*

| |
|---|
| ***OpenForests, satellite imagery for forest mapping and monitoring***<br><br>OpenForests was founded in 2011 in Germany. The company develops integrated information management systems for forestry, agroforestry and conservation projects, with the aim to support sustainable landscape management. They work with a combination of satellite, drone and field data, that is then analysed through a web-based forest information management software. The software is customized for each client, who can then use it to store maps, inventory data, management measures and budget planning.<br><br>The company's goal is to build, for each case, an entire information chain. One important element of to create platforms to share information: it enables cooperation between a network of stakeholders for the conservation of the specific forest. Providing transparent communication tools is key to ensure the support and engagement of local communities, helping people to reconnect with their local ecosystem.<br><br>**Keywords:** forestry, satellite imagery, landscape<br>**Sources:** Company website: https://openforests.com/project-all/ |

*Note: Not reported as part of the country report.

Those case studies from EU Member States illustrate how precision farming technologies can be used to improve agricultural productivity while preserving the environment.

Another crucial point with regard to forests is the **protection and restoration of forest ecosystems**. Start-ups already use new technologies such as machine learning for timber measurement or data management. Block chain and supply chain mapping are additionally used to enhance the transparency of the timber markets and space technologies to track the wood supply chains. Also forest fires can be prevented by digital solutions combining satellite images and artificial intelligence. In order to gain a better picture of the health of European forests, the Commission will work with other data providers to further develop the Forest Information System for Europe and link all EU forest-data web-platforms. This will help produce up-to-date assessments regarding the condition of European forests.

Finally, regarding the need of restoring **freshwater ecosystems and the natural functions of rivers,** virtual watersheds can be built that illustrate the effects of real-world events within a computer simulation resulting in databases and maps (European Commission, 2020g).

*Table 3: The Biodiversity 2030 Strategy and its interfaces to digitalisation*

| EU policy | Interfaces to digitalisation | Targeted Technologies | Case Studies from EU MSs |
|---|---|---|---|
| **Biodiversity Strategy 2030** | Working together with farmers to support and incentivise the transition to fully sustainable practices | - Smart electronics<br>- Sensor technologies<br>- Application methods<br>- Web-based data platforms<br>- Big data analyses<br>- Internet of things | Naïo Technologies (France)<br>NIK (Bulgaria)<br>eAgronom (Estonia) |
| | Sustainable soil management practices | - Digital Soil Mapping (DSM)<br>- Satellite technologies | no information |
| | Mapping and monitoring remaining primary and old-growth forests | - Mobile applications<br>- Artificial Intelligence | OpenForest (Germany)<br>Timbeter (Estonia) |
| | Protection and restoration of forest ecosystems | - Machine learning<br>- Block chain<br>- Space technologies<br>- Satellite images | OpenForest (Germany)<br>Timbeter (Estonia) |
| | Restore freshwater ecosystems and the natural functions of rivers | - Virtual watersheds | no information |

### 3.2.4 Zero Pollution ambition

The European Green Deal addresses the elimination of pollution as one of its top priorities. It aims at both protecting citizens' health and restoring ecosystems. The Zero Pollution ambition was first outlined in the Political Guidelines of the then-candidate Von der Leyen, and in the European Green Deal:

- **Clean water**: This objective is directly linked to the biodiversity strategy and Farm to Fork strategy: biodiversity in lakes, rivers and wetlands is to be preserved, while the agricultural reforms should reduce pollution from excess nutrients.
- **Clean air:** The strategy will include a review of air quality standards in line with the World Health Organization guidelines. It will also support local authorities in achieving cleaner air.
- **Industry**: Pollution from large industrial installations will be addressed. The strategy will aim at improving the prevention of industrial accidents.
- **Chemicals:** A new chemicals strategy is under preparation. It will be strongly oriented towards "sustainability for a toxic-free environment". As part of this work, the development of sustainable alternatives will be supported, with the aim of combining better health protection and increased global competitiveness. Rules on assessment of substances launched on the market are to be improved. Hazardous chemicals, pesticides and endocrine disrupters would be targeted.

The European Commission published a roadmap for an EU Zero-pollution action plan in October 2020[18]. Four key areas were included:

1. Implementation and enforcement – how public authorities, businesses and citizens can use EU rules on pollution more effectively
2. Existing legislation related to health and environment

[18] https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_en

3. Monitoring and governance of pollution prevention and reduction policies – how monitoring and governance can be strengthened both at EU and international level

**4. Societal change – exploring digital solutions and other means to drive the shift to more sustainable solutions in our society**

The interfaces to digitalisation in this field are:

- Monitoring of urban waste streams for micro plastics and chemicals, including pharmaceuticals
- Air quality monitoring
- Prevention and monitoring of industrial pollution (incl. accidents)
- Prevention / control of hazardous chemicals

The initiative is currently in the public consultation phase. The adoption of the roadmap with a possibly changed content is planned for 2021.

*Table 4: Zero Pollution Approach and its interfaces to digitalisation*

| **EU policy** | **Interfaces to digitalisation** | **Case Studies from EU MSs** |
|---|---|---|
| **Zero Pollution** | Monitoring of waste streams | Clean Sea Solutions' autonomous robot and modular floating dock collect marine plastic waste and prevent the inflow of plastic to the open sea. |
| | Air quality monitoring | ESAQIRQ (Malta) |
| | Prevention and monitoring of industrial pollution | Smart water treatment solution expands water reuse in the oil and gas industry |
| | Prevention/ control of hazardous chemicals | Tools to help consumers detect toxic substances and make informed choices – ToxFox |

A good practice example from Malta is shown in the box below.

*Box 12: Good practice example – ESAIRQ Project - Environmental Sensors for Air Quality (Malta)*

**ESAIRQ Project - Environmental Sensors for Air Quality**

The university of Malta is part of a consortium of twenty-six businesses and academic research organizations from six different EU countries involved in the ESAIRQ research project that aims to develop innovative sensor technologies for indoor air quality monitoring. In particular, it seeks to increase the selectivity of sensors to particle matter and to enhance detection of polluting organic and inorganic matter within gas mixtures arising indoors that influence the ambience in indoor spaces and have an impact on health. These sensors will be developed at an affordable cost, with potential future applications in manufacturing. The project runs from 2018 to 2021 and the university's participation is supported by co-funding from Malta Enterprise through the Eureka network.

As part of the research collaboration, the university of Malta is designing and implementing a wireless sensor network for indoor air quality monitoring in the ICT building. The building has no windows and the internal climatic conditions including temperature, ventilation and humidity are regulated by a building management system (BMS). In order to increase energy efficiency, air is recycled by the ventilation system and blended with fresh air to ensure optimal air quality. The air quality monitoring Wireless Sensor Network will provide data input into the BMS. Data collected from a system of sensors will be transmitted via Ethernet or Wi-Fi to a cloud-based web service for storage and big data analysis. In 2018-2019, a prototype sensor node was installed in the building that provides live values on environmental parameters including temperature and relative humidity, as well as on gas-sensing parameters such as levels of carbon dioxide, particulate matter and volatile organic compounds.

**Keywords:** air quality; cloud computing; sensor technology

**Sources:** https://www.um.edu.mt/projects/esairq/; https://www.project-esairq.com/

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## 3.3 Implications for the European Green Deal Debate

The Commission's "European strategy for data" aims to "create a single European data space" (European Commission, 2020b) and intends to support the establishment of nine common European data spaces, one of which will be dedicated to the European Green Deal. It aims to harness data in support of action on biodiversity, climate change, circular economy, deforestation, compliance assurance, and zero pollution (European Commission, 2020b).

The European Green Deal foresees investments in nature-based solutions as a climate change adaptation strategy (European Commission, 2019c). It also appreciates how digitalisation "presents new opportunities for distance monitoring of air and water pollution" (European Commission, 2019c, p. 9). In addition to bridging distances and connectivity, digitalisation and robotisation can also be harnessed to speed up the development of biosensors, which can improve contaminant and nutrient detection, but also of sensors more generally, which can help to better obtain a more holistic understanding of how best to integrate nature-based solutions at the interface of biodiverse habitats and food and biomass production.

The European dataspace could usefully be aligned with a range of existing initiatives, for instance, the DNA mapping of Europe's biodiversity, the Earth BioGenome Project. The Project aims to "sequence, catalog and characterize the genomes of all of Earth's eukaryotic biodiversity over a period of ten years".[19]. There is a joint direction of preserving **biological diversity and** improving means for **a circular economy**. Ideally, a circular economy helps to preserve the biosphere and the biosphere provides information and elements on how to increase the circularity of the technosphere. For example, some microbes have evolved to feed on synthetic polymers and thereby break them down. The design of multi-enzyme systems has the potential to eventually depolymerise mixed polymer wastes and thereby contribute to a circular economy (Knott et al., 2020). In order to tackle plastic pollution, this process could be accelerated by further investigating such mechanisms. Detailed and big data about bacterial biodiversity and the enzymes produced could contribute to identifying promising candidates for combinations, directed evolution and synthetic biology.

A better mapping of genetic information will ideally be integrated with profound investigations of eco-system dynamics, which can boost the potential of nature-based solutions, e.g. by realising the potential of releasing decomposed waste streams back into ecosystems in a way that is not harmful to biodiversity and ecosystem services.

An example for an existing initiative from the area of compliance assurance that could be integrated in the European data space is the KOTOKAS information system engaged and overseen by the Estonian National Environmental Board. It aims to centralise environmental permit applications, processing, declaring environmental fees and filling annual reports (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

As the Commission (European Commission, 2020b) seeks to "[e]stablish a common European data space for smart circular applications making available the most relevant data for enabling circular value creation along supply chains" and envisages the development of **digital product passports** that inform about "a

[19] https://www.earthbiogenome.org/

product's origin, durability, composition, reuse, repair and dismantling possibilities, and end-of-life handling". It seems opportune to tap into synergies with existing initiatives such as Everledger (UK), the Circular Economy Initiative for ENEL Suppliers Engagement and the Circular Dataset Initiative (Luxembourg) (see **Fehler! Verweisquelle konnte nicht gefunden werden.**) and achieve both minimum standards and interoperability but also maintain openness to new eco-innovative solutions (European Commission, 2020b).

Apps such as Yuka (see above) can increase their value if governments offer regular voluntary testing of groceries and other products, the results of which can then be communicated via QR codes associated with specific batches of products. Companies could also be offered to provide information on other metrics, such as carbon and water footprint, which are less directly relevant to consumer health. By adopting solely providing a service which may be taken up voluntarily, potential resistance to mandatory transparency measures can be reduced while the political and technical conditions for an eventual adoption of mandatory measures can be improved.

By providing more detailed data on pesticide use and nutrient content, the rather dichotomous distinction between organic and non-organic products could become dramatically more nuanced and the consumer value of organic products better comprehensible and apparent. Such data will also help policy makers to stronger link policies with impacts on consumer health, biodiversity and soil fertility. A voluntary testing regime could also over time be aligned with the European Organisational Environmental Footprint (OEF) and Product Environmental Footprint (PEF) initiatives, both being developed under the Circular Economy Action Plan[20] as an important tool to verify green indications made by businesses.

Apps and QR codes could similarly provide voluntarily supplied information on the presence of endocrine-disrupting substances in other products. Demand reduction for such products would help to protect biodiversity and improve human health, potentially making people more resilient against infectious diseases (such as Covid-19). EU support for increased regular testing of nutrient content and environmental pollutants could boost the market for biosensors (see e.g. Box 8 on a biosensor detecting pollutants on fruit and vegetables) and analytics as well as further promote European leadership in consumer confidence in its products. Eventually, greater knowledge of how contaminants are regionally distributed and brought in contact with specific groups would help to inform policy making and planning.

While there could be industry resistance against the overt regulation of certain substances, the nourishing of a stronger industry lobbying for the wider use of sensors detecting contaminants would be a boon to efforts at increasing transparency and creating consciousness about pollution and how to minimise it.

Europe has a strong potential to maintain, expand on and benefit from its lead market role in the transition to a circular economy. However, many of the competitive benefits in knowledge intensive sectors may ultimately be appropriated through Silicon Valley. The Commission can seek to counter this through an active strategy of software creation and knowledge diffusion. The European data space for smart circular applications should take into account and productively engage existing platforms where the coder community hosts and develops open source software, such as GitHub and SourceForge (Klug & Bagrow, 2016). In parallel, European source-code-hosting facilities should be strengthened and gain visibility. The Commission should also encourage the publication of open source software in open access journals. In this way, the research and development work financed by the Commission can best be appropriated by the data science community. The Commission may also consider the development of online tutorials, mirroring or piggybacking onto commercial offers such as DataCamp, to facilitate training in complex circular economy applications (see e.g. Box 13 on the open source circular economy software: *pycirk*).

[20] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12511-Environmental-claims-based-on-environmental-footprint-methods

*Box 13: Good practice example – Open source circular economy software: pycirk (Netherlands)*

**Open source circular economy software: *pycirk***

Pycirk is a package for the data science and research computing programming language Python to *model Circular Economy policy and technological interventions in Environmentally Extended Input-Output Analysis. The package is open source and can be modified by other researchers and programmers* (Donati et al., 2020).

**Keywords:** software, circular economy, open source
**Source:** *https://pypi.org/project/pycirk/*

The tagging of packaging will help to realise the Green Deal's ambition to "ensure that all packaging in the EU market is reusable or recyclable in an economically viable manner by 2030" (European Commission, 2019c) by going beyond the targeting of production facilities or market entry and permitting the tracing the various destinations and degradation states of packaging materials, which is important for the evaluation and re-adjustment of circular packaging policies.

The Commission also intends to **pilot a data strategy** to realise its 'zero pollution' ambition, both in the natural environment and concerning hazardous substances in consumer products (European Commission, 2020b). In this context, not only accessing available data but also generating new and more extensive data and better analytics of these is important. This is where the development of novel sensors and machine learning applications come in to play (e.g. Aquaspark (Slovenia) or Sennseo (Slovakia). Such considerations may ideally find its way into the Commission's zero pollution action plan for air, water and soil scheduled for 2021.

As the European Commission (European Commission, 2020b) seeks to "strengthen provisions on monitoring , modelling and air quality plans to help local authorities achieve cleaner air", it may usefully experiment more with the diffusion of low cost air quality measurement devices and applications to enable citizens to better hold local governments to account (European Commission, 2020f). Such an initiative may then also be extended to water quality and other monitoring. This is another application for improved sensor systems, increasing the potential benefits from their further development.

The European Green Deal foresees that under the condition of persistent differences in the level of decarbonisation ambitions between the EU and other major players, "the Commission will propose a carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage" (European Commission, 2019c). **Border carbon adjustment mechanisms** seek to level the carbon price applied to domestic and foreign products at the border. Such a measure would need to be in compliance with World Trade Organization rules and should therefore not discriminate against importers. A relatively simple way of implementing such a border carbon adjustment would be to rely on benchmarks based on best available technologies (Grubb et al., 2014). Producers who outperform those benchmarks could be asked to present verified Product Carbon Footprints or Environmental Product Declarations which could make them eligible for a discount (Jordan & Bleischwitz, 2020). Such labels would be important to differentiate lower or zero carbon products, such as the envisaged zero carbon steel (European Commission, 2019c, p. 8).

The adoption of **embodied carbon standards** for buildings and cars (European Political Strategy Centre, 2016) could help to establish Environmental Product Declarations (EPDs) and/or Product Footprints as an informational medium across and along supply chains. Improved real-time communication along supply chains could over time help to transform the currently rather static EPDs into dynamically updated information on the environmental footprints of value chains. Circularity data could be integrated into such information flows. EPDs could also be used to communicate the environmental footprint of food products, in line with the Green New Deal's ambitions.

The European Commission (European Commission, 2020c) aims to "widen the Ecodesign Directive beyond energy-related products so as to make the Ecodesign framework applicable to the broadest possible range of products and make it deliver on circularity". An extended **Eco-Design Directive** could potentially be used to introduce embodied carbon standards for buildings and cars. However, it may also be applied to intermediate products, such as steel. Such measures could complement a carbon price and raise the minimum carbon requirements at the level of products. The informational flows required for such standards could also be used to potentially support border carbon adjustments.

As outlined above, the informational measures necessary to improve products, enable the circular economy and to respond to asymmetrical climate mitigation ambition levels could converge and strengthen each other in synergistic ways. The secure management of informational flows accompanying physical ones can be a prime example of how digitalisation can enable the regulatory framework propelling further eco-innovation.

# 4 Policies and instruments at a national level: EU Member States

The EU is currently facing two transitions that can bring significant environmental, social and economic benefits to our economy, namely **the circular economy transition** and the **digital revolution**. While the interlinkages between these transitions are becoming increasingly clear and can lead to significant benefits, combining the circular economy and digital agendas in countries' policy frameworks is not an automatic process.

Countries in Europe are increasingly recognising the role that digitalisation can play to boost eco-innovation and a sustainable, circular economy. Overall, digitalisation can lead to improvements in the different aspects of a circular economy, whether it's in design, production, consumption or end-of-life treatment. Such recognition is often translated in the integration of the digital dimension in national strategies and policies. More precisely, national digitalisation policies in the EU Member States can be broadly categorised into the following:

- Digitalisation as a key component of national strategies for eco-innovation and/or circular economy
- Digitalisation applied as a policy tool/ instrument towards achieving specific eco-innovation/ circular economy objectives

The Eco-innovation reports on EU Member States have shown that countries are placed at different stages when it comes to digitalisation, with some countries significantly less mature than others. This is due to the novelty of the digital field, in particular in relation to its role in eco-innovation and circular economy. Many countries are still developing strategies and policies directed to boosting the transition to a circular economy, and therefore the integration of digitalisation is considered at different levels of relevance across countries.

## 4.1 Digitalisation as a key component of national strategies for eco-innovation and/or circular economy

Harnessing the potential of digitalisation for a green and circular economy requires the acknowledgement of the benefits of the interrelations between the two agendas into horizontal policies and programmes.

The integration of digitalisation as a key component of national circular economy strategies represents a relatively new approach to policymaking. In fact, many national strategies where the link is made explicit have been developed recently and generally provide a forward-looking approach, the implications of which will become increasingly visible in the near future. At the same time, the success of these approaches will also depend on the continuation of the efforts beyond the strategies' timespans.

Several countries have integrated digitalisation in their national strategies adopted for reaching circular economy and eco-innovation objectives. For instance, the **French Roadmap to a Circular Economy**[21] includes several measures on digitization and digital technologies, recognising their potential contribution to the transition to a circular economy by enabling networking, access to information and data for citizens, and the production of new services. Similarly, supporting the circular economy through data and digitalisation features is one of the six thematic priorities of the **Danish Circular Economy Strategy**[22].

[21] French roadmap to a Circular Economy. Available at: https://www.ecologie.gouv.fr/sites/default/files/FREC%20anglais.pdf

[22] Danish Strategy for Circular Economy. Available at: https://mfvm.dk/publikationer/publikation/pub/hent-fil/publication/strategy-for-circular-economy/

While acknowledging the advantages that digitalisation can bring to the circular economy transition, the Danish government also recognises the issues faced by enterprises to access and use relevant data and is making efforts to further analyse and overcome such obstacles.

Some European countries do not yet present specific national strategies directed to boosting the circular economy. However, they have put in place strategies for reaching environmental and sustainable development objectives more broadly, which often integrate the role of digitalisation as well. An example is given by **Malta's Low Carbon Development Strategy**[23] which aims at the decarbonisation of the country through low-carbon investments in selected sectors. Information and communication technologies (ICT) are earmarked as enablers of resource efficiency, with applications in the building sector, water management, energy and smart grids, as well as mobility.

On the other hand, some Member States have introduced a somewhat different approach to merging the circular and digital agendas in their policy frameworks. In fact, some countries have put in place national digitalisation strategies and policies, where circular economy and eco-innovation increasingly feature as key principles. The **German Environmental Digital Agenda**[24] provides a clear example of such an approach, where digitalisation is steered in an environmentally compatible direction, and the opportunities for environmental protection are emphasised.

In addition to environmental compatibility, the circular economy is especially considered as a key sector for innovation. In Luxembourg, the Ministry of Economy recently integrated the circular economy in the **Luxembourg's Data-driven Innovation Strategy**[25], at the core of several of its planned initiatives for the digitalisation of the country's economic sectors. The **Italian National Strategy for Technological Innovation and Digitalisation**[26] merges three key challenges, namely the digitalisation of society, the innovation of the country, and sustainable and ethical development. For instance, the strategy promotes the use of alternative energy sources and contributes to reducing energy consumption through the development of digital infrastructure and data centres. **Malta's Digital Strategy**[27] includes the creation of demand for environmental services as one of the core principles underpinning the strategy's vision. In particular, the strategy identifies opportunities for ICT to enhance energy efficiency.

Lastly, in some European countries, the interrelations between circular economy and digitalization appear more prominently in their national research and innovation policy strategies. For instance, ICT is identified as a priority research area for the eco-innovation field in **Bulgaria's National Strategy for the Development of Scientific Research**[28]**.** Similarly, the **Slovenia Smart Specialisation Strategy**[29] identified three priority pillars for its implementation in the country, namely digitalization, circularity, and industry 4.0. The first two pillars indicate a growing integration of the circular economy and digital agendas in the fields of research, development and innovation.

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23 Malta's Low Carbon Development Strategy. Available at: https://meae.gov.mt/en/Public_Consultations/MSDEC/Documents/MSDEC%20LCDS%20Vision.PDF

24 German Digital Policy Agenda for the Environment. Available at: https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/broschure_digital_agenda_eng_bf.pdf

25 The data-driven innovation strategy for the development of a trusted and sustainable economy in Luxembourg. Available at: https://gouvernement.lu/dam-assets/fr/publications/rapport-etude-analyse/minist-economie/The-Data-driven-Innovation-Strategy.pdf

26 National Strategy for the technological innovation and digitalisation of the country. Available at: https://innovazione.gov.it/assets/docs/MID_Book_2025.pdf

27 National Digital Strategy 2014-2020. Available at: https://economy.gov.mt/en/ministry/The-Parliamentary-Secretary/Documents/Digital%20Malta%202014%20-%202020%20(2).pdf

28 National strategy for development of scientific research in the republic of Bulgaria 2017 – 2030. Available at: https://epluse.ceec.bg/wp-content/uploads/2018/09/20171112-06.pdf

29 Smart Specialisation Strategy of the Republic of Slovenia. Available at: https://www.sbra.be/sites/default/files/Smart%20Specialisation%20Strategy%20of%20Rep%20of%20Slovenia.pdf

## 4.2 Policy instruments promoting digitalisation towards achieving specific eco-innovation, circular economy, or sustainability objectives

In addition to integrating digitalisation and circular economy as key components of overarching national strategies, Member States may choose to implement diverse policy instruments which promote digitalisation as a tool to achieve specific eco-innovation, circular economy or sustainability objectives. There is a wide range of policy instruments which can be adopted in order to promote digitalisation, as data and digitally enabled applications can make significant contributions towards a circular economy.

***Box 14: Good practice example – Roadmap for the Circular Economy (France)***

**Roadmap for the Circular Economy (France)**

The roadmap lists a set of 50 measures aimed at the operational implementation by all stakeholders (citizens, local authorities, companies, administrations, associations) of the transition to be made to move from a linear "make, consume, throw away" economic model to a circular model that will integrate the entire life cycle of products, from their eco-design to waste management, including their consumption while limiting waste. The roadmap includes several measures on digitization and digital technologies, as these represent an opportunity for the transition to a circular economy, especially by enabling networking, access to information and data for citizens, support to decision-making and the production of new services.

Digital technology is regarded at the service of the circular economy in order to achieve the objectives to reduce natural resource use, the amount of non-hazardous waste, greenhouse gas emissions and others.

**Keywords:** Circular Economy, transition
**Website:** https://circulareconomy.europa.eu/platform/sites/default/files/frec-anglais.pdf
**Source:** Anti-Waste and Circular Economy Act (2020):
https://www.legifrance.gouv.fr/eli/loi/2020/2/10/TREP1902395L/jo/texte

In some cases, Member States use fiscal incentives to promote circular economy or sustainability objectives in the context of innovation. For instance, the **2020 Italian Budget Law**[30] introduced a tax credit for R&D, innovation and design, with the objective of stimulating investments and maintaining the competitiveness of Italian firms. In particular, technological innovation activities with ecological transition or a digital innovation objective may benefit from the tax credit, stimulating the innovation in these two fields. Further, the **Finish Smart Energy Programme**[31], managed by Business Finland focuses on technological and digital solutions for innovation in the fields of energy generation and consumption. Amongst other topics, the programme focuses on the entire value chain of energy systems, smart buildings, IoT, AI and digitalisation. A total of €100 million in funds will be made available to companies between 2017-2021 to boost competitiveness in these sectors. These two examples illustrate how Member States can promote the development of digital technologies and innovation hence achieving sustainability objectives through fiscal incentives.

While supporters of digitalisation frequently emphasise its potential to solve environmental problems, there are still grey areas on whether positive environmental impacts can outweigh the negative ones, in terms of GHG emissions, resource depletion, water, land use and biodiversity impacts associated with digital technologies. Some Member States, for example the United Kingdom, have developed policy to integrate circular economy notions in ICT technologies, to contribute to a greener usage of digital

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30 Ministry of Economy and Finances. Less taxes and more focus on the environment and welfare: the 2020 Budget Law. Available at: https://www.mef.gov.it/en/focus/Less-taxes-and-more-focus-on-the-environment-and-welfare-the-2020-Budget-Law-00001/

31 Business Finland. Smart Energy Finland. Available at: https://www.businessfinland.fi/en/for-finnish-customers/services/programs/smart-energy-finland/

technologies. For instance, the **UK's "Greening Government Sustainable Technology Strategy to 2020"** defines the government's ICT green commitments and adoption of efficient and sustainable practices[32]. The strategy also aims to raise awareness on the sustainability impacts of online services. While this strategy targets UK departments and supporting agencies, Defra also published a corporate report entitled **"Sustainability in information and communication technology (ICT): A Defra guide"** to help businesses create a greener and more sustainable future through ICT[33]. Defra's Digital, Data and Technology Services directorate also launched a **Joint Sustainable Information and Communication Technologies (ICT) Group**, consisting of multinational organisations from ICT supply chains, to share, promote and implement sustainable best practices for more sustainable ICT choices[34]. Through these various actions, Member States promote a greener use of digital technologies, contributing to circular economy and sustainability objectives.

***Box 15: Good practice example – Digital Policy Agenda for the Environment (Germany)***

**Digital Policy Agenda for the Environment (Germany)**

The German Federal Environment Ministry presented in early 2020 the Environmental Digital Agenda, which is a strategic package of 70 measures aiming to organise the digital transformation climate-friendly, use it for prosperity and competitiveness, social justice and support an intact environment.

The aim is both to steer digitalisation in an environmentally compatible direction and to use the opportunities offered for environmental protection. The BMU worked out the agenda within a broad participation process of around 200 experts. The Digital Agenda is the first strategy in Europe that consistently combines digitisation and environmental protection.

- Reduce the ecological footprint of digitisation and protect human health
- Digitalisation as a driver for a social-ecological transformation
- Using digital technologies for environmental governance, participation and engagement, and more effective administration, decision-making and enforcement (Environmental Policy 4.0)
- Advance innovation against the background of environmental policy needs, close research gaps and exploit systemic innovation potentials.

**Keywords:** Digital transformation, social-ecological innovation, environmental policy
**Website:** https://www.bmu.de/digitalagenda/

Meanwhile, other Member States adopt policies promoting the use of digitalisation to achieve sustainability objectives in the context of specific sectors. For instance, the **Czech Action Plan for the Future of the Automotive Industry** sets out objectives for the industry, highlighting the need to reduce the environmental impact of both the production and operation of motor vehicles. The action plan deals with electromobility, autonomous vehicles and digitalisation, with a number of proposed measures which relate to the infrastructure for emission-free vehicles, automated controls, high-speed internet, digital and mobile services and research and development for the automotive industry. This example illustrates the use of digital technologies in specific sectors, as a key tool to reach circular economy or sustainability goals.

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[32] Defra. Policy paper - The greening government: sustainable technology strategy 2020 - sustainable technology for sustainable government. Available at: https://www.gov.uk/government/publications/greening-government-sustainable-technology-strategy-2020/the-greening-government-sustainable-technology-strategy-2020-sustainable-technology-for-sustainable-government

[33] Defra. October 2019. Sustainability in information and communication technology (ICT): a Defra guide. Available at: https://www.gov.uk/government/publications/sustainability-in-information-and-communication-technology-ict-a-defra-guide

[34] Defra. October 2019. Helping businesses create a greener, more sustainable future through ICT. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/840765/defra-industry-guide-ict-sustainability.pdf

## 4.3 Conclusions

As seen in the sections above, many Member States are increasingly making the link between digital technologies and their potential to achieve eco-innovation, circular economy and sustainability objectives. However, there are still a number of overarching national digital strategies which do not impose any objectives in relation to sustainability. The **Belgian Digital Wallonia Strategy**[35] for instance sets the directions for Wallonia to seize the socio-economic opportunities of the digital transformation, but makes no link to eco-innovation, circular economy or sustainability issues. The same can be said of the **Estonian National Agenda 2020** for Estonia, and its **Digital Agenda**[36] outlines whose main goals focus on the development of information society and the increase of cyber security, and of the **UK's Digital Strategy**[37], which do not include measures on environmental sustainability.

These examples illustrate the differences between EU Member States when it comes to making the link between digitalisation, eco-innovation and the circular economy. The potential for combining objectives between digitalisation and eco-innovation remains to be seized by some Member States, though the previous sections have shown that others are well on their way in interlinking the objectives of the circular economy transition and the digital revolution.

35 Digital Wallonia. Digital Strategy (2019-2024). Available at: https://www.digitalwallonia.be/en/digital-strategy

36 Ministry of Economic Affairs and Communications. Digital Agenda 2020 for Estonia. Available at: https://www.mkm.ee/sites/default/files/digital_agenda_2020_estonia_engf.pdf

37 UK Digital Strategy. Available at: https://www.gov.uk/government/publications/uk-digital-strategy

# 5 Possible adverse effects of the digital transformation

The digital revolution will have a large role to play in deliberately and constructively supporting sustainable development as, for example, embodied in the **Sustainable Development Goals**[38]. Therefore, digital technologies should support prosperity, social inclusion, environmental sustainability, and inclusive governance (TWI - The World in 2050 Initiative, 2019). However, digitalisation will not automatically lead to greater sustainability. Currently, it has to be seen as an ambivalent development as far as sustainability is concerned, including both supporting and harmful effects (Ramesohl & Berg, 2019). This chapter will concentrate on the risks stemming from digitalisation. In this, it will focus on current or potential threats to the environment and only briefly addresses economic and social problems digitalisation may cause.

Adverse effects of digitalisation can be categorised into (Sühlmann-Faul & Rammler, 2019):

- direct ecological impact (e.g. emissions and resource use),
- indirect ecological effects (e.g. rebound effects),
- potential health impacts, and
- adverse economic and social effects.

The following sections describe these effects in the order listed above.

## 5.1 Direct ecological impact of digitalisation

Direct effects of digitalisation refer to adverse environmental impact caused by the production, use and disposal of devices. They can hence be traced along a product's/technology's lifecycle and refer to resource use for production (and maintenance) purposes, energy consumption, and emissions caused by production, use and disposal of digital appliances.

The **production of digital appliances** involves numerous, often problematic materials, specifically comprising a wide range of metals including rare earths (see Table 5), and plastics. This fact causes problems in several areas. First of all, many of these materials are themselves produced under problematic circumstances causing heavy burdens on the environment in their production phase and may also involve hostile working conditions amounting to slave work in developing countries and including unsafe mining in the most extreme instances (Pilgrim et al., 2017). Secondly, in some appliances, due to faulty design as well as application in very small and mixed amounts, metals used may not lend themselves to effective recycling processes at the end of the lifecycle. Hence, many materials are lost in the disposal process. Sovacool et al. (2020) also emphasise the need to make mining and metal processing at the beginning of the life-cycle more efficient and resilient, identifying key sustainability challenges for e.g. cobalt, copper, lithium, cadmium, and rare earth elements (REEs).

[38] The Sustainable Development Goals (SDGs), which were agreed upon at the Rio+20 Conference in 2012, are the relevant political objectives of the United Nations (UN) in the context of economically, socially and ecologically sustainable development. The total of 17 targets and 169 sub-targets were introduced on 1 January 2016 and are to be achieved within the period of 15 years, i.e. by 2030. They have been signed by 193 UN member states (UN 2016; https://www.un.org/sustainabledevelopment/ ).

***Table 5: Demand of future technologies by metals. Source: (Pilgrim et al., 2017), p. 18.***

| metal | Demand of future technologies (in metric tons) | | Demand for metal at the ratio of worldwide production | | End-of-Life recycling rate (as percentage) |
|---|---|---|---|---|---|
| | 2013 | 2035 | 2013 | 2035 | |
| Lithium | 610 | 110,000 | 0.0 | 3.9 | < 1 |
| Heavy REM | 2,000 | 7,400 | 0.9 | 3.1 | < 1 |
| Light REM | 29,000 | 64,000 | 0.8 | 1.7 | < 1 |
| Tantalum | 500 | 2,100 | 0.4 | 1.6 | < 1 |
| Cobalt | 5,000 | 120,000 | 0.0 | 0.9 | > 50 |
| Germanium | 60 | 120 | 0.4 | 0.8 | < 1 |
| Platinum | 0 | 110 | 0.0 | 0.6 | > 50 |
| Tin | 180,000 | 150,000 | 0.6 | 0.5 | > 50 |
| Palladium | 20 | 100 | 0.1 | 0.5 | > 50 |
| Indium | 230 | 360 | 0.3 | 0.5 | < 1 |
| Gallium | 90 | 130 | 0.3 | 0.4 | < 1 |
| Silver | 5,800 | 8,300 | 0.2 | 0.3 | > 50 |
| Copper | 120,000 | 300,000 | 0.0 | 0.3 | > 50 |

**Disposal of digital appliances** then poses another important problem. Electronic Waste (often referred to or subsumed under WEEE – Waste of Electrical and Electronic Equipment) has become a large waste stream that is expected to rise continuously. In the EU, the WEEE-waste stream amounted to 9 Million tonnes in 2005 and is expected to reach 12 Million tonnes in 2020[39]. *"Electrical and electronic equipment continues to be one of the fastest growing waste streams in the EU, with current annual growth rates of 2%. It is estimated that less than 40% of electronic waste is recycled in the EU20"* (European Commission, 2020c, p. 10). While not all appliances listed under WEEE are to be seen as digital equipment such as computers and smart phones outright, it is important to understand that many more contemporary goods are equipped with digital equipment. Semi-conductors ("chips"), RFID-tags, sensors, etc. are part of or attached to a vast array of goods including but not limited to toys cars, heaters, furniture, lighting, coffee machines and packaging. This effectively indicates the ubiquity digitalisation has already reached in our everyday life. If not handled properly, WEEE can pose high risks to environment and health (ibid.). Unfortunately, a considerable amount of WEEE in the EU is exported – sometimes under false pretence – and then treated inadequately in non-EU countries, e.g. in Agbogbloshie, Ghana (Blacksmith Institute, 2013) or in Dandora, Kenya[40]. In these cases, the appliances are often burned in the open to extract copper. Other materials, metals and plastics, are lost and leak into the environment.

The EU is aware of these problems and issued several directives to account for WEEE. They most notably include the "Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment" (WEEE Directive, 2012), which was consecutively updated and changed since its first issuance, and the "Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment" also known as "RoHS-directive"(RoHS Directive, 2011). "Take-back" schemes – helping to promote circular economy values -- were a key result of such Directives.

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[39] Waste Electrical & Electronic Equipment (WEEE), https://ec.europa.eu/environment/waste/weee/index_en.htm, 21.8.2020

[40] ISWA - Onyari, J., *2017. Special Report for #closedumpsites: Kenya's Dandora Dumpsite - a Health and Environmental Tragedy.* ISWA. Available at: https://www.iswa.org/home/news/news-detail/article/special-report-for-closedumpsites-kenyas-dandora-dumpsite-a-health-and-environmental-tragedy/109/, 21.8.2020

Energy consumption of digital appliances of all sorts has become another major issue regarding environmental effects of digitalisation. According to Jones (2018) internet traffic developed from about 2 Terabyte in 1987 to about 1.1 Zetabyte in 2017. This corresponds with the fact that an exponentially increasing number of devices are in some way linked to the internet and/or are employed with ICT.

Therefore, Jones (2018) shows that ICT, and networks and data centres specifically, will cause a substantial increase in energy demand effectively showing an exponential development as well. Currently, ICT-related energy consumption dependent on source lies between 5% of total energy consumption. According to Jones (ibid.), this is projected to increase to about 21% in 2030. Likewise, BMU (2020) projects an annual ICT-related energy increase by about 9%. While this projection – like any other – has to be seen with caution due to the uncertainties inherent to all such forecasts, the ubiquity of digitalisation already has massive effects. The share of GHG-emissions caused by digital technologies has grown from 2.5% to 3.6% from 2013 to 2017, with streaming services becoming a central cause (Ferreboeuf et al., 2019). However, in this regard it is not the single act of streaming a video in itself that poses a problem, but the large amounts of data that is streamed globally by literally billions of users every day that aggregates to high energy and infrastructure demand. This illustrates the importance of scale associated with so many instances of digitalisation. Summing up, it is easy to spot that the direct effects of digitalisation on the environment cannot be neglected. While measures are already being taken both by policy and the providers of technologies and services as well, large efforts will still be required considering the expectation of further growth in the utilisation of digital technologies.

Today, the ICT sector accounts for 5-9% of electricity use and more than 2% of global greenhouse gas emissions (GHG). If uncontrolled, the ICT footprint could increase to 14% of global emissions by 2040 (European Commission, 2020i). A recent report (The Shift Project, 2019) has estimated that the percentage share of global GHG emissions resulting from digital technologies will rise from 2.5% in 2013 to 4% in 2020 and 8% in 2025, primarily due to increases in energy consumption over this period. However, it has been shown that if new, highly efficient technologies can be used to substitute existing low-efficiency technologies, then the carbon and energy and cost savings could be significant (Grubler et al., 2018). However, the high innovation frequency of the digital economy and planned obsolescence of digital end devices also need governance to avoid the continuous increase in global electrical demand and electronic waste.

## 5.2 Indirect ecological effects

“... *the transformation brought about by digital technology will be profound positive ones. We‘re heading into an era that won‘t just be different; it will be better, because we‘ll be able to increase both variety and the volume of our consumption*“ (Brynjolfsson & McAfee, 2016, p. 10).

This quotation from MIT researchers Erik Brynjolfsson and Andrew McAfee perfectly illustrates part of the challenges brought forth by digital information. In contrast to the previous section, digital appliances are not only a concern themselves, but the functions and opportunities provided by ICT and internet-based commerce (e-commerce) that create a negative environmental impact enabled through digitalisation (Kahlenborn et al., 2018). So, while digital technologies can be applied to decrease resource and energy use in production and consumption – effectively creating an increase in resource, energy and thus, economic efficiency – these gains can be overcompensated e.g. by acceleration or amplification effects in the consumption of other goods and services. In this instance, digitally enabled consumption results in rebound effects (Santarius, 2012) (Lange & Santarius, 2018).

Another point in case is the infrastructure required by ICT and digitalisation. High-speed internet and mobile devices have already led to the emergence and erection of a large infrastructure spanning from mobile communication networks over ground-based fiber-optic networks to (swarms of) satellites for space-based communication infrastructure. Arguably, this infrastructure itself requires massive amounts of resources both in production and construction (Malmodin & Lundén, 2018, p.13). In the same regard, the increased energy use of ICT may, in some instances, also require the erection of new energy infrastructure, including new power plants (Danilak, 2017), resulting in further resource and energy requirements.

A further issue that relates to both direct and indirect effects of digitalisation concerns obsolescence, induced by digital technologies and the speed of their development – both in hardware and software. In terms of software, the development of new operating systems or new versions of existing ones can exclude the use of older equipment either, because it is not technologically apt to process the new software, or, because it is wilfully excluded by the software's developers, which for example can be specifically observed in mobile communication. In this latter case the motivation of the producers lies in stimulating purchases of novel equipment. Notably, such instances of obsolescence, especially through software, not only occur in private end-consumer settings but also regard investment goods such as machinery, a point that often goes unheeded, but creates specific pressure for less technology-savvy SMEs, and hampers the transition towards a circular model.

## 5.3 Potential health impacts

There has been a long and continuously evolving societal debate over the health impacts of digital devices – in particular regarding the use of mobile communication devices linked to radiofrequency and electromagnetic fields. Amidst the Covid-19 pandemic and the imminent roll-out of 5G, the public debate on the radiation associated with mobile communication has been highly charged and polarised. The rise of conspiracy theories linking 5G technology to the spread of the coronavirus has coincided with the torching of mobile phone masts in 10 European countries. On the other hand, scientific inquiry (e.g. into impacts on the environment) has also been downplayed or purposefully misconstrued. Amidst this high stakes environment continued research and evidence-based discussion is critical.

To-date, it seems no major studies have determined a clear causal link between e.g. mobile phone usage and brain tumors[41] or skin cancer[42], but that clinical tests have not been able to completely eliminate uncertainty about the health impacts of cell phone use (Schmidt 2018). France, for example, has banned WIFI in institutions catering to children under the age of six, namely nurseries, schools, kindergartens and childcare centres. In addition, in primary school WIFI may only be enabled when currently in use (The Connexion, 2015). Public Health England (PHE) acknowledges uncertainties about the health effect of radio waves and therefore discourages the "excessive use of mobile phones by children".

Over the years the European Commission (n.d.) has funded many research projects on the potential health effects of electromagnetic fields. Digitalisation has an enormous potential to generate important information on the relation between a range of potential health hazards and actual health outcomes, be they from naturally occurring or man-made radiation or chemicals. Any further rollout of mobile

[41] The largest study examining the relation between mobile phone usage and brain tumors, Interphone, surveyed more than 5,000 patients who had been diagnosed with one of these tumors between 2000 and 2004. The International Agency for Research on Cancer (IARC) report on the Interphone study summarises the results as not having found a statistically significant increase for glioma, meningioma, and acoustic neuroma as resulting from mobile phone usage 'overall'. However, individuals who had accumulated more than 1640 hours of mobile phone call time showed a higher risk. At the same time, the report warns that a causal interpretation is not warranted due to biases and errors. In particular, the Interphone study notes "implausible values of reported use" among those with more than 1640 hours of accumulated mobile phone, as well as a lack of linear effects (The INTERPHONE Study Group, 2010; Wild, 2011).

[42] A large Danish cohort study found "no association between tumours of the central nervous system or brain and long term (≥10 years) use of mobile phones" (Frei et al., 2011). Based on the same cohort study Poulsen et al (Poulsen et al., 2013) also found "no support for a relationship between mobile phone use and skin cancer". However, the Danish cohort study only divides the population into subscribers and non-subscribers of mobile phones and does not take into account the overall call time. It thus does not shine a light on particular risks potentially associated with heavy use, as suggested by the Interphone study. Therefore, small to moderate risk increase for particularly heavy users or for longer exposure periods cannot be ruled out (Frei et al., 2011).

communication should be accompanied by increased data collection and analysis to monitor the relationship between wireless technologies and health impacts (Miller et al., 2019). Further research could also help to adjust the course of technological investment at an early stage and to avoid over investment into e.g. riskier frequencies or device types, should those be the case.

The early detection of problems could help to design 'softer' technologies that reduce health and environmental risks while still advancing innovation. But also a number of further health impacts can play a role in the context of digitalisation and would deserve further investigation: psychological effects, e.g. through the use of virtual spaces and online games but also through increasing remote or tele-working and virtual communication without personal contact, orthopaedic impacts due to lack of movement, effects on vision, hearing, etc. In the Green Deal, this is not a specific topic.

## 5.4 Adverse economic and social effects and systemic risks

Given the concentration of this report on matters concerning ecology, this area will not be discussed in-depth. However, it is obvious that digitalisation has vast implications both on the economy (global, EU and national) and on societies at every level from families and private households over schooling to social cohesion and the way democracy (and other forms of government) is practiced. Focusing on potentially adverse effects in this chapter, the following list compiled by WBGU[43] (WBGU, 2019, p. 293) is instructive:

- "*the disempowerment of the individual, threats to privacy and an undermining of the digitalized public sphere through digitally empowered authoritarianism and totalitarianism,*
- *an undermining of democracy and deliberation by normatively and institutionally non-embedded, automated decision-making or decision-making support,*
- *dominance by companies that can elude government control, driven by further data-based power concentration,*
- *disruption of labour markets by the comprehensive automation of data-driven activities and the danger that human labour will become increasingly irrelevant to the economy,*
- *a deeper division of global society as a result of limited access to, and use of, digital potential, mainly by wealthy minorities in the global society,*
- *abuse of the mechanization of humanity on the basis of human-enhancement philosophies and methods."*[44]

It is obvious that almost each point mentioned justifies deep and intricate discussion and research, which cannot be conducted here. The list just serves to show how deep the transformation caused by digitalisation is, and that strong negative economic and social consequences may ensue if they are not actively managed. Further important points not included here are cyber-crime and cyber warfare, which are very real threats to individuals, companies, economies and societies (Gimpel & Schmied, 2019). They also have an environmental impact, e.g. when digital attacks destroy infrastructure such as power plants and cause leakage of harmful substances.

[43] German Advisory Council on Global Change.

[44] The list also includes environmental risks which have been omitted here because they have been treated in the previous sections of the chapter.

# 6 Covid-19 pandemic implications for digitalisation

Corona has “exposed a number of vulnerabilities in the EU and its Member States” (European Commission, 2020a) and triggered an unprecedented digitalisation push with manifold positive and negative environmental, societal and economic impacts.

The power of data is most essential also in the **health** sector (European Commission, 2020c). Besides being a tool to combat the pandemic through warning apps on smart phones, digitalisation and health data can help, for example, to make pervasive inequalities in terms of exposure to environmental pollution more visible, and how these relate to the susceptibility to Covid-19[45]. While the link to CE is not apparent at first sight, stronger hygienic rules and the increased need for and use of medical equipment do bring up a number of circular economy and new waste issues.

Some common metabolism-disrupting chemicals, to which humans become routinely exposed, can affect the ability of human bodies to regulate their energy balance, potentially leading to weight gain and obesity, which in many European countries has become a major health problem (Nadal et al., 2017). Environmental-related diseases such as type II diabetes and metabolic syndrome share pathogenic mechanisms at the molecular level with coronavirus and make more susceptible to Covid-19. A deep reduction in pollutant emissions in our environment would be an important step to alleviate the immune deficiency that makes people particularly susceptible to viral outbreaks (Tsatsakis et al., 2020, p. 19).

Biosensors have a range of applications, amongst them the detection of environmental contaminants as well as of pathogens, such as viruses (S. Singh et al., 2020). After the development of a biosensor for the detection of severe acute respiratory syndrome (SARS-CoV-1), now there are also efforts to develop biosensors for the detection of the coronavirus responsible for SARS-CoV-2 (Perry, 2020). Machine learning can help to improve the reliability and reproducibility of such biosensors (Cui & Zhou, 2020). Harnessing digitalisation for the development of better biosensors holds potential for both addressing public health challenges in the form of pathogens and environmental contaminants that lead to people becoming more susceptible to such pathogens, and the development of a circular economy and biodiversity-friendly agriculture with the potential to close industrial loops and reduce the release of contaminants into the environment.

**Online trade -** Online transactions have increased tremendously compared to the previous years. The majority of consumers shows increasing interest in regional and local consumption options, but there is a lack of corresponding offers. At the same time, major corporations have immensely benefitted from the situation while e.g. regional outlets and local stores have suffered. Traffic and packaging volumes increase due to growing online trade and clearly point to a stronger need for smart logistics, reusable packaging systems, and a stronger focus on regional food.

**Mobility and traffic** - Due to the Covid 19 containment measures a strong decrease in business trips and commuter travelling could be observed: The COVID-19 lockdown has shown the potential for traffic reduction through home offices and virtualisation of business contacts; but - at the same time - public transport suffered enormously because it was used less due to the hygienic concerns of the users. This also calls for smart traffic systems under new framework conditions, as well as explorations into new patterns of work and their implications for the circular economy.

As soon as the containment measures came into effect, the digitalisation drive led to 10-20 % more **data volume**, driven by video conferencing and streaming, and to a correspondingly higher utilisation of the communications infrastructure (especially in the fixed network) (Loose-Müller et al., 2020).

[45] For example, https://theintercept.com/2020/06/26/coronavirus-toxic-chemicals-pfas-bpa/

In almost all examples it will depend strongly on whether the environmentally relieving digitalisation impacts can be sustained while those developments leading to a stronger negative net impact can be stopped. The use of digital solutions for work, shopping and leisure and the underlying infrastructures have increased significantly in a short period of time, and it has significantly increased the number of people who use them and fostered the long-term growth trend of the sector. Thus, the environmental, climate and circular economy significance of this field of action is enormously growing.

As part of the economic recovery and crisis management and the Green Deal, there is an opportunity to consistently implement measures to strengthen digital infrastructures for energy and resource efficiency, the reduction of energy consumption through better utilisation as well as a sustainable energy supply through renewable energies of data centres and communication networks (Loose-Müller et al., 2020) (SYSTEMIQ et al., 2020).

# 7 Key findings and policy messages

## 7.1 Brief summary

The report followed a three-thronged approach to data collection and analysis. First, it built on inputs developed in previous work packages within the Eco-innovation Observatory project, namely investigating and updating the Eco-innovation Index: The aim was to highlight key eco-innovation country developments, including especially the Eco-Innovation scoreboard.

In a second step, recent European Policies (i.e. European Green Deal, Circular Economy Action Plan and Biodiversity Strategy, and Zero Pollution ambition) were inspected to identify interfaces and synergies with digitalisation trends and developments. 28 country profiles contributed to this report by feeding in good practices at the business and policy level to with view to the technology requirements formulated in respective EU policies. This was also done to get an impression of the state-of-technologies in countries.

The country profiles from 27 EU Member States plus United Kingdom were used as a basis to gain first insights on the state-of-the art of the digitalisation for a Circular Economy. The involved countries presented in total 85 eco-innovation good practice examples and 68 policy examples with relations to digitalisation and/ or circular economy. A part of these addresses both action areas as practices fostering a digital circular economy, a selection of which can be found in the Annex.

Visionary and smart digital eco-innovation as good practices with a potential to be diffused over Europe – as envisaged in the EU policies – are reported in a limited number. Niche innovations can be found in many countries, but their potential is unclear at present and could not be assessed within the scope of this report (but calls for further research). The policy framework conditions are often fragmentary with respect to support and diffusion.

## 7.2 Main policy messages and conclusions

- Digitalisation is the key driver of innovation processes for production and consumption systems all over Europe, – it is not only a key challenge but above all an opportunity.
- However, technology cannot replace politics: unconditional trust in technology leads one to think that all technological progress is “good” and “automatically” leads to the transformation and improvement, or environmental relief. This may not be the case and must be observed.
- The climate-neutral circular economy, as called for in the Green Deal, will have to transform basic industries where the central technological challenge is optimising the use of materials and energy.
- Digitalisation technologies can help to achieve this core target but will require extensive technology and infrastructure investments in the right channels – innovation without eco-innovation criteria is not useful.
- Policy instruments have to be flexible enough to take account of the accelerated dynamics of markets resulting from digitalisation and the systemic shortening of innovation cycles, rebound effects must be monitored and channelled.
- A concentration on the most resource- and energy intensive sectors is required in the context of digitalisation and the corresponding technologies; food, feed & agriculture, mobility & traffic management, housing and construction (EEA, 2019b). Currently, the virtual and digital developments are motivated by technology options more subject to free market conditions than other sectors (such as the game sector, communication, retail).

- Going beyond isolated sectors, circularity needs to be recognised as the property of a system, not only of a product (Adams et al., 2016); (Ceschin & Gaziulusoy, 2016); (Konietzko et al., 2020). From this perspective, achieving circularity also requires system-level innovation and sector coupling.
- However, “As long as primary raw materials are cheaper than reused goods or secondary raw materials, policy interventions to deliver a more circular economy will have little impact” (Pantzar & Suljada, 2020).
- Many technologies illustrated in the practice examples have the character of niche innovations with a potential for scaling up. Whether they will be able to reach wider and cross-country diffusion depends on many criteria: e.g. whether they receive support for further spreading, be able to cross the death valley, are congruent to superior policies etc. Here, coherence of policy action across levels highly relevant.
- Lifestyles, consumer behaviours and social values only play a minor role in the Green Deal. These are, however, integral to the success of a circular economy transition. How and whether digitalisation and more sufficient lifestyles have to go hand in hand, and where the potential pitfalls for discord lay, is an area in need of further research.
- The debate around the Green New Deal has recently developed into a wide-ranging debate about green stimulus and Covid-19 economic stimulus measures programmes. Some authors criticise that the Green Deal itself bears the inherent contradiction that also "green growth" or a decoupled growth calls for the economy to continue to grow, neglecting the problem that the growth of financial flows, the production of goods and services and the acceleration of both are traditionally main drivers of environmental destruction (e.g. Schepelmann & Fischedick, 2020) (Mastini et al., 2021). Eco-innovation pathways leading to more sufficient lifestyles should have a stronger role in the Green Deal and deserve more research and investigation.

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# ANNEX

*Table 6: Selection of digital technology examples from country profiles*

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| **Aqualoop** | Water/ Energy | Water temperature regulator connected to Wi-Fi | Aqualoop is a system designed to equip household with a water temperature regulator, connected to home Wi-Fi, with a weekly scheduling to make sure that people always have hot water when they need it. It allows the control of the immersion heater in place of a traditional switch, providing information on how much hot water users have. This process is enhanced by the digitalization of the hot water control: the mobile application Aqualoop gives users the opportunity to control the time, intensity and temperature of water flow.<br>Keywords: Energy efficiency, digitalization, water control<br>Link: http://www.hotwatercontrol.com/en/index.html<br>Contact: info@hotwatercontrol.com | **Cyprus** |
| **ArboSmart** | Green Infra-structure | Software as a service | The Zagreb start-up ArboSmart Technologies has designed an innovative smart system ArboSMART Cloud intended for the management of green infrastructure, of trees as well as other greenery in urban and peri-urban areas. ArboSmart is the first global solution of its kind, built as SaaS (software-as-a-service) that requires no additional user investment nor hidden costs.<br>Link: https://www.arbosmart.com/Index | **Croatia** |
| **Bee2Fire Detection** | Fire Detection | Surveillance system through visual recognition AI | Compta Emerging Business is a software and IoT solutions manufacturer working for the global market in areas such as smart cities, energy efficiency and logistics. In 2018, Compta Emerging Business launched one of its flagship products – the Bee2FireDetection. This product is a surveillance system that automatically detects fires in early stages in distances up to 15 km and assist in decision-making processes, enabling rapid response and support in firefighting operation efforts. Bee2FireDetection uses Visual Recognition AI on captured images from surveillance cameras and other data sources to enable real time forest fire detection and to estimate the fire propagation over the terrain and recommends where to act first. This solution demonstrates the potential of using AI to address forest fires which constitute one of the biggest threats to the natural capital in countries such as Portugal.<br>Digitalization \| Artificial Intelligence \| Fire Prevention<br>Website: www.ceb-solutions.com/products/bee2firedetection/ | **Portugal** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| **Circular Dataset Initiative** | Products | Product circularity data Sharing | The objective of the Circularity Dataset Initiative is to develop an industry standard at European level which provides a regulated framework for circular data on products throughout the whole value chain, from raw materials to finished products, from the use phase to recycling.<br><br>Currently, it is difficult to obtain reliable data on the circular properties of different products, notably as there is no standardized reporting. Issues linked to confidentiality may arise because of conflicts between the need for transparency to determine the actual circularity of the product and the will to protect sensitive manufacturing data from the industry.<br><br>Luxembourg's Circularity Dataset Initiative will help manufacturers and other stakeholders save costs by increasing data exchange efficiency across supply chains. The project aims at developing an internationally accepted dataset template that can be used by any manufacturer, regardless of his position in the supply chain.<br><br>Since its inception, more than 50 companies from 12 different European countries including industry leaders have joined the Circularity Dataset Initiative. After a series of webinars, a physical meeting brought all actors of the initiative together to finalize the theoretical proof of concept, which was developed for two product categories linked to construction materials and fast-moving consumer goods. The dataset will take the form of a "Product Circularity Data Sheet" (PCDS), which will list relevant circular information in standardized and auditable statements, allowing product circularity evaluations. Managing the PCDS may call for new technologies such as blockchain or artificial intelligence.<br><br>Keywords: Circularity, evaluation, audit<br><br>Link: https://meco.gouvernement.lu/fr/le-ministere/domaines-activite/ecotechnologies/circularity-dataset-initiative.html | **Luxembourg** |
| **Circular Economy Initiative for ENEL Suppliers Engagement** | Energy | Data sharing through IT tool | The Circular Economy Initiative for ENEL Suppliers Engagement was launched by the Italian energy company ENEL in 2018. The objective of the initiative is to improve the sustainability of the supply chain, its efficiency and circularity. The suppliers, 200 in total, can insert their data through an IT tool to determine the circular economy index of their company as well as targets and benchmarks for improvement.<br><br>The initiative is based on the adoption of an Environmental Product Declaration, to calculate and assess the environmental impacts of products and services of ENEL suppliers throughout the entire life-cycle. Declarations of this kind already exist and are made on a voluntary basis.<br><br>The initiative is expected to lead to changes in design, innovation and cost savings.<br><br>Keywords: Circularity, sustainable supply chain<br><br>Websites:<br><br>• https://www.enel.com/stories/a/2020/01/enel-procurement-sustainability-sustainable-supply-chain | **Italy** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| | | | • https://circulareconomy.europa.eu/platform/en/good-practices/getting-suppliers-involved-better-assess-circularity-throughout-value-chain-project-enel | |
| **Cirkeltips** | Waste | Data sharing on waste management performance of companies | In 2017, the tool "cirkeltips" was launched. This tool gives information to companies about the amount of waste they produce and how it is treated (based on information available in government databanks), making it possible to benchmark their waste management performance towards the average in their branch. Based on this data, the tool generates advice on how to better treat waste or avoid it. Companies are also invited to exchange good practices with other companies via this tool. Specifically, these are the things you can do:<br>• Analyse your annual waste data<br>• Tailor-made tips for your company on waste and material management<br>• Practical, sustainable and financially interesting<br>Keywords: Open data, waste treatment sustainability, digitization<br>Link: https://www.cirkeltips.be/home.xhtml | **Belgium** |
| **Cyrkl** | Secondary Raw Materials | Digital market of secondary raw materials | Cyrkl is a young and innovative technology company and business partner for more than 500 companies not only in the Czech Republic. The Cyrkl represents a platform for a digital marketplace that connects the supply and demand of secondary raw materials and facilitates finding new high-value reuse options for materials or waste products for various companies. Cyrkl developed a digital database tool that uses machine learning and the knowledge of waste experts to find the best possible use for individual materials. The company supports digitization and ensures transparency and assistance in connecting individual parties.<br>The whole solution works similarly to the Uber platform. Thanks to automatic data analytics, it is connected to a business partner with whom they can already agree on specific requirements. On this digital market, waste as well as by-products of production and all types of recycles can be traded. The team of waste experts helps to determine whether the material is suitable and to whom it is optimal to hand it to in accordance with the law. Thanks to the first trades of the company, hundreds of tons of materials did not travel to landfills.<br>Keywords: Digitisation, digital market, secondary raw materials, waste, recycling, circular economy<br>Link: https://www.cyrkl.com | **Czech Republic** |
| **eAgronom** | Agriculture | Web and mobile platform | Founded by the son of a farmer and an experienced software developer, eAgronom offers digital solutions that cater the needs of farmers and simplify daily and seasonal farm exercises, thereby taking their businesses to the digital age. The Estonian start-up's services, which can be accessed via web and mobile platforms, enable farmers to manage their entire farm, exchange information with and instruct employees, and oversee fields in real time. Specifically, eAgronom supports farmers to make more efficient, cost-saving and environmentally friendly decisions which mitigate their respective risks and give them better planning capacities. The company's customer base lists | **Estonia** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| | | | cases in which farmers have saved tens of thousands of euros by using this software. eAgronom, which was founded in 2016, has already entered several international markets and continues to expand in terms of both, company size and geographic coverage.<br><br>Keywords: Farming, planning, agriculture, software<br><br>Website: https://eagronom.com/en/ | |
| **EcoBox SBR-Q** | Wastewater | Smart remote control monitoring technology and data transfer | Roto has developed the EcoBox SBR-Q treatment plant which is supported by smart remote control monitoring technology and equipped with a system for transferring and converting data from the waste water treatment plant EcoBox to a smart device. Telemetric performance monitoring reduces operating and servicing costs, enables timely ordering of services, quick access to technical documentation and easy switching between day-to-day and holiday mode of operation. The owner of a sewage treatment plant can monitor its performance on a smart device on a phone or tablet application and does not have to physically interfere with the sewage treatment plant. Thus, maintenance costs are reduced and the lifespan of a treatment plant is extended. The wastewater treatment plant can be installed in four hours.<br><br>The Eco Box SBR-Q municipal wastewater treatment plant achieves high purification effects and provides reduced power consumption through a computer-controlled wastewater treatment system. The control system, together with the compressor unit, operates almost inaudibly and odour-free and is not sensitive to temperature fluctuations in the environment.<br><br>In 2019, the Eco Box SBR-Q municipal wastewater treatment plant received a National gold medal for innovation by the Chamber of Commerce and Industry of Slovenia.<br><br>Keywords: Wastewater treatment plant, computer-controlled, Eco box, Roto<br><br>Websites:<br>• ROTO products selected among the most environmentally friendly in 2019, available at: https://rotoeco.eu/en/roto-products-selected-among-most-environmentally-friendly-2019<br>• To je slovenska čistilna naprava, ki jo podpira pametna tehnologija, available at: https://oe.finance.si/8954313/To-je-slovenska-cistilna-naprava-ki-jo-podpira-pametna-tehnologija | **Slovenia** |
| **Eljoy Bikes** | Mobility | E-Bike rental | Eljoy Bikes (Varna, Bulgaria) started making bicycles over 5 years ago. The company is export-oriented and its mission revolves around clean environment, faster commuting, safer batteries and ease of use. The frames are hand-painted, the batteries as well as the bicycles are hand-assembled. The company is also part of the Cleantech Bulgaria and Climate-KIC Accelerator Program.<br><br>Eljoy Bikes was selected during the Sofia Urban Challenge Phase I open innovation competition as the start-up that provided the most appropriate solution for tackling Bulgaria's capital air pollution challenge. The e-bike rental system | **Bulgaria** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| | | | for Sofia has been launched. Eljoy Bikes is one of the partners in a system with Sofia Municipality, Cleantech Bulgaria, Climate-KIC, EMB – e-mountain bike, ElDrive, etc.<br><br>Keywords: Electrical bikes, green mobility, eco innovation, e-bikes<br><br>Link: https://www.eljoybikes.com/ | |
| **Elwis** | Waste Manageme nt | Data collection through QR code or RFID chip | Elwis offer an evidence system of waste management within particular municipalities. It offers detailed information on waste management up to a household level. It combines a software solution with practical data collection. Each household and waste type is marked with an original identifier - QR code or RFID chip. This data is scanned into the software system and is possible to be analysed within a user-friendly application. The company offers training to municipality employees with information campaigns for local inhabitants as well as with data evaluation. Based on information obtained through ELWIS smart waste evidence system, municipalities can, with the assistance of JRK, design bonus schemes for households with better waste separation results.<br><br>Keywords: Waste management, smart evidence system, waste separation<br><br>Link: https://moderneodpady.sk/ | **Slovakia** |
| **ESAQIRQ** | Air Quality | Environmental sensors for air quality | The university of Malta is part of a consortium of twenty-six businesses and academic research organizations from six different EU countries involved in the ESAIRQ research project that aims to develop innovative sensor technologies for indoor air quality monitoring. In particular, it seeks to increase the selectivity of sensors to particle matter and to enhance detection of polluting organic and inorganic matter within gas mixtures arising indoors that influence the ambience in indoor spaces and have an impact on health. These sensors will be developed at an affordable cost, with potential future applications in manufacturing. The project runs from 2018 to 2021 and the university's participation is supported by co-funding from Malta Enterprise through the Eureka network.<br><br>As part of the research collaboration, the university of Malta is designing and implementing a wireless sensor network for indoor air quality monitoring in the ICT building. The building has no windows and the internal climatic conditions including temperature, ventilation and humidity are regulated by a building management system (BMS). In order to increase energy efficiency, air is recycled by the ventilation system and blended with fresh air to ensure optimal air quality. The air quality monitoring Wireless Sensor Network will provide data input into the BMS. Data collected from a system of sensors will be transmitted via Ethernet or Wi-Fi to a cloud-based web service for storage and big data analysis. In 2018-2019, a prototype sensor node was installed in the building that provides live values on environmental parameters including temperature and relative humidity, as well as on gas-sensing parameters such as levels of carbon dioxide, particulate matter and volatile organic compounds.<br><br>Keywords: Air quality; cloud computing; sensor technology<br><br>Websites: https://www.um.edu.mt/projects/esairq/; https://www.project-esairq.com/ | **Malta** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| **Everledger** | Product Traceability | Blockchain service | "A Battery Passport is a digital identity that connects the battery and its critical parts to the internet, so it can be managed on a blockchain platform. The platform supports exchange of data among authorised life cycle stakeholders to support a sustainable value chain for electric vehicle and portable electronics batteries." https://www.everledger.io/batteries-life-cycle-management/ | **UK** |
| **FoodCloud** | Food Waste | Matchmaking app | FoodCloud is a platform that enables supermarkets to donate their surplus food products to local charities and community groups across Ireland. It diverts fresh food from landfills, reducing food waste, and helps address the issue of food poverty in the country (a situation experienced by 8,7% of the population in 2017).<br><br>The platform operates via a mobile app that enables both sides to notify their needs and offer, replicating a model that is now widely used. It also provides reporting and other supports to ensure traceability of products, and the management of food redistribution at national and international scale.<br><br>FoodCloud was awarded a Green Technology Award in 2019 from the Irish Green Awards and had previously been the winner of both Net Visionary Awards – Best Use of Technology for Social Good, and Digital Agenda Impact Award in 2017.<br><br>Keywords: Food waste, social impact, digital platform<br><br>Website: https://food.cloud/<br><br>Green Awards 2019: https://www.greenawards.ie/2019-winners | **Ireland** |
| **GeoChallenge** | | Geographical information | The SPW, in partnership with various public and private players and with the support of the Agence du Numérique, is launching the first edition of a programme for the digital exploitation of Walloon geographical information: the GeoChallenge. Objective: to develop concrete solutions that meet the expectations of citizens and Wallonia. Wallonia wishes to encourage the development of innovative services and solutions based on the use and enhancement of Walloon geographical information, in particular to:<br>• promote and facilitate the use of environmentally friendly modes of transport<br>• facilitate and encourage the discovery of the natural heritage of Wallonia<br>• support the implementation and facilitate the accommodation of entrepreneurs<br>• improve the quality of life<br><br>Link: https://www.digitalwallonia.be/fr/publications/geochallenge | **Belgium** |
| **Greece Costa Nostrum** | Sustainable Beaches | Tool and mobile app to guarantee the sustainable | Costa Nostrum provides a certification standard for sustainable management and development of the Mediterranean beaches. It is a "tool" that can objectively guarantee the sustainable development of the Mediterranean beaches, | **Greece** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| | | development of beaches | primarily by defending the environment, contributing to the financial development of the region around sustainable Costa Nostrum® beaches and by ensuring social cohesion and prosperity of the citizens of the region.<br>The innovation of the certification standard Costa Nostrum – Sustainable Beaches rests on the fact that it is based on a sum of indexes - criteria which ensure the actual, all-aspect (economic, social and environmental) sustainable development of beaches.<br>This certification ensures that there is a good environmental waste management, protection of local marine and terrestrial biodiversity and protection of natural resources.<br>In order to digitalise the call for action, Costa Nostrum has developed a mobile application to follow the clean-up of beaches.<br>Keywords: Environmental protection of oceans, waste management, biodiversity conservation, digitalization<br>Website: www.costanostrum.org/en/mobile-app/ | |
| **Green-Effective Performance Calculator** | Products and Packaging | Digital marketing solutions | Werner & Mertz Professional presents a new tool to support the development of circular economics, nominated for the RAI Interclean Innovation Award at Amsterdam.<br>Green-Effective Performance Calculator™ is a digital marketing solution for sustainable businesses. It transforms products designed according to the principles of circular economics into a business advantage, certifying in a personalized way the savings of green cleaning products, oil, plastics and carbon dioxide. More recently, it was awarded a Plastics Recycling Award Europe 2018 for the best recycled commercial product.<br>• Digital transformation, sustainable business advantage, green cleaning product<br>• Immo Sander, Head of Packaging Development at Werner & Mertz. | **Poland** |
| **HUBBIG** | Logistics | Digital platform | HUBBIG is an innovative digital platform connecting ship operators, airlines, road hauliers, freight forwarders and NVOCC ('Non-Vessel Owning Common Carrier') agents, the so-called logisticians, with importers and exporters.<br>Link: https://hubbig.com/ | **Croatia** |
| **KOTOKAS** | Adminis-tration | Information system | KOTOKAS is an information system engaged and overseen by the National Environmental Board that aims to centralise environmental permit applications, processing, declaring environmental fees and filling annual reports. In other words, KOTKAS is designed to a be a “one-stop-shop” for all administrative matters concerning the environment and its economic use. KOTKAS thereby also improves the maintenance, usage and availability of gathered information, potentially opens up the door for further data analysis and data-based processes, ultimately benefitting the environment, economy and society alike. The information system allows users to not only apply for permits and environmental charge declarations but also have access to statistics on environmental use as well as self-monitoring information related to permits. | **Estonia** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| | | | Keywords*:* Textiles, gelatine, leather production, livestock industry<br><br>Website*:* https://kotkas.envir.ee/<br><br>Contact*:* Alar Valdmann, alar.valdmann@keskkonnaamet.ee | |
| **Monitoring Water Consumption and Leakage** | Water | Data management and information system | Water scarcity and pressures on Malta's natural ground water resources arising from increased public water demand have prompted a strategy aimed at optimising the efficiency in the use of water resources through a number of focused water demand management measures. Upgrades to the automated meter management system in 2017 have resulted in the elaboration of improved data analytics for monitoring and real-time decision-making (REWS, 2018b). The data intelligence assists the Water Services Corporation in determining water consumption profiles and seasonal water use data that reflect the customer's needs and water usage. The data analytics also serve as a diagnostic tool for detecting billing as well as water consumption anomalies.<br><br>The Water Services Corporation piloted an innovative technology in a number of districts in Malta and the sister island of Gozo in 2018-19. This involved the installation of a series of data loggers in the water network system that relay information to the central Control Room about the water flow, relating this flow with the water pressure. The technology highlights aberrations in water signals that may be linked to water leakage or theft of water and the locations where this is occurring.<br><br>Keywords: water management; conservation; data intelligence systems<br><br>Website: http://www.wsc.com.mt/eradicating-water-theft/ | **Malta** |
| **Nuritas** | Bio-technology | AI and genomics | Nuritas is a Dublin-based bio-technology start-up that uses artificial intelligence and genomics to identify and use natural bioactive peptides that can enhance functional and health foods. These peptides can be derived from hydrolysed proteins that are broken down or synthesised. For example, the first product developed by Nuritas for BASF, PeptAIde, is derived from brown rice. This combination of digital and bio-engineering technologies has been praised as the kind of eco-innovation needed to address societal challenges (from healthy diets to developing alternative protein meals) while creating local jobs.<br><br>Nuritas has received funding from Enterprise Ireland, the European Commission and the European Investment Bank, notably to scale up development of new therapeutics in areas of interest including anti-aging, anti-inflammatory and diabetes treatment.<br><br>Keywords**:** Bio-technology, artificial intelligence, health, plant-based diets<br><br>Source: Government of Ireland (2019) Bioeconomy Implementation Group: First Progress Report https://www.dccae.gov.ie/documents/Bioeconomy_Implementation_Group-First_Progress_Report.pdf<br><br>Website: www.nuritas.com | **Ireland** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| **Prognosis** | Energy | Wireless technology for remote energy meter reading system | Pronosis's remote energy meter reading system uses wireless technology to provide customers with up-to-date, exhaustive data from their meters in the form of easy-to-read charts and reports. They can view these reports and monitor their energy consumption 24 hours a day via an online application accessible from any web browser and portable devices.<br>The system sends customers immediate E-Mail or SMS alerts regarding optimal tariffs and enables them to adjust their contracted electricity capacity to avoid fines for exceeding it.<br>Prognosis offers comprehensive energy management diagnostics and audits and can quickly pinpoint the most energy-intensive aspects of an organisation's activity. This can support customers in making upgrades to their electricity infrastructure, leading to further savings of up to 15%.<br>Finally, as well as benefiting customers, the technology has allowed Prognosis to achieve sales revenues of over approximately EUR 330 000 (PLN 1.4 million) and create seven full-time equivalent jobs.<br>EU funding supported its creation and helped prognosis implement a business model to commercialise the product and related services on domestic and international markets.<br>Keywords: Digitalization, energy efficiency, cost reduction<br>Website: https://ec.europa.eu/regional_policy/en/projects/poland/innovative-polish-software-optimises-energy-management | **Poland** |
| **Qubiqo** | Water and Sewage | Data-capture, visualization and analytics platform to monitor water and sewer networks | Qubiqo is a Bulgaria based engineering company that provides comprehensive solutions for monitoring of water and sewer networks. The simple philosophy of the company is that the higher the number of monitoring points the better the understanding of network operators. To achieve this, Qubiqo has developed QDATA – a data capture, visualization and analytics platform that is typically facilitated by deploying its own data loggers. Equally important, QDATA seamlessly integrates data from water meters, pressure and level sensors and other devices that water utilities inevitably already have on the ground.<br>In essence, Qubiqo provides a bridge between physical and digital infrastructure to facilitate utilities' understanding of network performance. Market-wise, the company is focused on Eastern Europe with numerous projects and utility partnerships in Bulgaria, North Macedonia, Kosovo and other countries.<br>Qubiqo's toolbox is a prerequisite for efficient network operations and non-revenue water reduction but also investment planning and improved customer service.<br>Keywords: Water networks, monitoring, data<br>Link: https://qubiqo.com/en/q-scada-analytics/ | **Bulgaria** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| **Sensoneo** | Waste Manage-ment | Smart sensors for waste monitoring through global system for IoT or mobile communication | Sensoneo presents an integrated waste management solution. It combines unique ultrasonic Smart Sensors that monitor waste in real-time using global system for internet of things or mobile communication with sophisticated software (Smart Analytics, Smart Route Planning and Smart Management system) providing cities and businesses with data-driven decision-making and optimization of waste collection routes, frequencies and vehicle loads, resulting in overall waste collection cost reduction by at least 30% and carbon emission reduction up to 60% in cities. SENSONEO produces two types of ultrasonic sensors that are able to monitor any type of waste in bins of various types and sizes. They are robust, shock and short resistant. The company also offers a citizen app which informs people about waste levels in all monitored bins and enables them to find the nearest available empty bin.<br><br>Keywords: Waste management, smart sensors, data-driven decisions<br><br>Website: https://sensoneo.com/ | **Slovakia** |
| **SKODA AUTO DigiLab** | Urban Mobility | Digital innovation lab for urban mobility | ŠKODA AUTO is consistently optimising the ecological footprint of its cars – from the extraction of the raw materials required to the end of their life cycle based on its 'GreenFuture' strategy. Now, the manufacturer has taken another important leap forward: since the start of 2020, ŠKODA has recycled 100% of all waste produced during manufacturing and usually disposed of in landfills, either materially or thermally. This is an important step towards even greater, all-embracing recycling efforts and a clear commitment to strengthening the circular economy.<br><br>In 2019, the era of eMobility had begun for the ŠKODA brand. It started with an electric version of the CITIGO model and the SUPERB model with a plug-in hybrid drive. ŠKODA is consistently continuing to also implement its strategy in digitization. The ŠKODA AUTO DigiLab is an innovation lab located in Prague, Czech Republic, which focuses on the next stage of mobility, connectivity, and digitalization. ŠKODA strives to be the Simply Clever company providing the best mobility solutions. It aims to bring digital, connected, safer, greener and smarter cars, mobility products and services to everyone. ŠKODA AUTO DigiLab presents on-site solutions for urban mobility. Citymove will help users to decide whether to leave the car at home. It allows to choose between public transport, a shared bicycle, and a taxi (or a car for a ride), and thus creates a smart mix of mobility. Users can choose, book, and pay for suitable means of transport and get the most convenient and fastest route just by finger touch. The application can be downloaded immediately for free. In the initial phase, it will combine the offers of the Transport Company of the Capital City of Prague (DPP),f free e-bike sharing and Liftago's carpooling service and will later integrate other transport platforms.<br><br>Keywords: eMobility, digitalisation, waste, resource and material efficient use, circular economy<br><br>Link: https://skodaautodigilab.com/ | **Czech Republic** |
| **Timbeter** | Timber | Digital timber measurement through machine learning and AI | Timbeter is a digital timber measurement solution that uses machine learning technology and artificial intelligence for accurate log detection. Being a forest-tech company with locations across the world, Timbeter's aim is to eradicate illegal logging and improve timber supply for both log buyers and sellers, using a unique algorithm. The software allows different actors in the timber-producing industry to share measurements with contractors and | **Estonia** |

| Title | Sector | Technology/Tool | Description | Country |
|---|---|---|---|---|
| | | | clients, store and manage logs, reduce the costs of log inventory, transfer data across devices and instances, integrate data into existing workflow processes and measure log count, diameter and density in less than 3 minutes.<br><br>Keywords: Timber, log measurement, data exchange<br><br>Website: http://www.timbeter.com/<br><br>Contact: info@timbeter.com | |
| **Too Good To Go** | Food Waste | App | In France, 10 million tons of food go to waste every year which amounts to EUR 16 billion. On average, this means that one individual wastes 29 kilos of food per year, i.e. one meal per week.<br><br>To reduce food waste and, thus, its environmental and economic impacts, Too Good To Go was created in 2016. It is an app connecting consumers with restaurants, supermarkets, bakeries, etc. with unsold food. Consumers can buy "food baskets" for a discount price using the geo-tracking feature.<br><br>In 2019, 10 million food baskets were bought on the app, amounting to 250,000 tons of CO2 saved. Besides, the number of food baskets bought in 2019 was 2.5 times the number of food baskets bought in 2018. According to an internal survey, 90% of the content of the food basket is eaten by the consumers.<br><br>The success of Too Good To Go can be explained by several elements:<br>• In 2016, the Garot Act obliged distributors to reduce food waste – which made them more prone to adhere to the idea of the app;<br>• The increasing interest for eco-friendly habits that can be adopted easily: the app is used in 15 countries (Europe and USA);<br>• The support and recognition from institutional actors, from their peers in the environmental sector, the food sector but also in the digital sector.<br><br>Keywords: Food waste, app, food baskets, geo-tracking<br><br>Website: https://toogoodtogo.org/en | **France** |
| **TracksOnTheMap** | Transport | IT tool | Heavy duty vehicles produce about a quarter of $CO_2$ emissions from road transport in the EU and some 6% of the EU's total greenhouse gas emission. Providing a simple-to-use IT tool which logistics professionals need and can cut their cost through the following: empty runs, freight rates, claims, dispatching time, resources and carbon footprint.<br><br>Keywords: Transportation, freight transport, IT tool, logistics<br><br>Website: https://trucksonthemap.com/ | **Hungary** |

*Table 7: Selection of digital policy examples from country profiles*

| Country | Policy of relevance to digitalisation | Description | Digital-environment link |
|---|---|---|---|
| **Belgium** | **Digital Wallonia strategy** | On December 6th, 2018, the Walloon Government validated the update of the Digital Wallonia strategy for 2019-2024. It sets the framework defining the directions that Wallonia will have to take to seize the socio-economic opportunities of the digital transformation for a period of 5 years. This is an integrated strategy covering the different relevant dimensions: territorial connectivity, 4.0 digital economy and industry, 4.0 administration and digital skills. It has a total budget of € 503 million, financed through the ordinary regional budgets, the 4.0 Marshall Plan and the ERDF. | |
| **Bulgaria** | **National strategy for development of scientific research in Bulgaria 2017 – 2030: Better Science for a Better Bulgaria** | In October 2016, Bulgaria adopted the strategy 'Better Science for a Better Bulgaria – Vision for a research policy strategy in support of society and economy'. The following priority research areas are of relevance to eco-innovation: mechatronics, clean technology and new energy and energy efficient technologies; health and quality of life, green and eco-technologies, biotechnologies, eco-foods, purification and waste technologies; environmental protection; utilisation of raw materials and bio-resources; environmental monitoring; materials and nanotechnology; and ICT. | ✓+ |
| **Bulgaria** | **National Digital Bulgaria 2025: programme and roadmap** | The programme builds upon the Digital Bulgaria 2015 and aims to introduce digital solutions in different sectors of the economy: for citizens and businesses. It addresses issues such as building the common digital market; improvement of compatibility and standards; enhancing security; improving access to broadband internet; stimulating computer literacy; etc. The Ministry of Transport, ICT and Communication coordinates the implementation of the programme. Other relevant strategic document in the sector include: National Reform Programme 2020; National Strategy for the Development of Broadband Internet 2012-2020; Strategy for the Development of E-government 2014-2020; National Cyber Security Strategy Bulgaria 2020.<br><br>In addition to the programme, Bulgaria has adopted a **Digital Roadmap 2025**. The roadmap comprises of five priorities: better access to digital networks and services; development of dynamic and innovative digital economy; improvement of digital competencies and skills; quality electronic services to business, citizens and e-government; cyber security. | |
| **Bulgaria** | **Innovation Strategy for Smart Specialisation (ISSS), 2014 – 2020** | Goal 2 of the Innovation Strategy for Smart Specialisation of the Republic of Bulgaria 2014-2020[46] is "support for accelerated uptake of technologies, methods, etc., for improvement of the resource efficiency and the application of ICT in enterprises". Priority activities include the promotion of innovation for resource efficiency in the water sector (reuse and recycling of water, water and wastewater treatment, including resource recovery; and intelligent | ✓+ |

46 http://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=948

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | | monitoring systems) and in waste sector (waste prevention, collection, recycling and recovery; introduction of high-tech information and communication systems for reporting quantities of waste collected).<br><br>Cleantech is one of the priority areas in the strategy. 'Innovation for resource efficiency' is a horizontal topic of the Strategy. The Strategy also includes the objective for Bulgaria to move from the group of "modest innovators" to the "moderate innovators" group by 2020. | |
| **Bulgaria** | **Operational Programme for Science and Education for Smart Growth, 2014-2020** | OP Science and Education for Smart Growth (OP SESG) is managed by the Ministry of Education and Science (MES) with a total budget of BGN 1.37 billion. **Four Centres of Excellence** have been funded**:** Universities for Science and IT in the e-society; Informatics and ICT; Cultural Heritage BG; and Mechatronics and clean technologies. The last one is relevant in the area of eco-innovation.<br><br>An additional **nine Centres of Competence** have been launched. The ones relevant for eco-innovation are:<br>• Clean technologies for a sustainable environment - water, waste, energy for a circular economy (Clean & Circle);<br>• Intelligent mechatronic, eco- and energy-saving systems and technologies (SMEEST);<br>• HITMOBIL - Technologies and systems for generation, storage and consumption of clean energy;<br>• Sustainable utilization of bio-resources and waste from medicinal and aromatic plants for innovative bioactive products;<br>• Digitization of the economy in a Big Data environment | ✓+ |
| **Croatia** | **Strategic Plan of the Ministry of Economy, Entrepreneurship and Craft (2019-2021)** | This strategic document was published in March 2018 and lays out the main strategic goals with regards to strengthening Croatian economic growth. Tax reduction and reduction of administrative costs for the business sector, increasing the competitiveness of the economy by stimulating investment and innovation, and strengthening the competitiveness of Croatia's trade activities within the EU's internal market remain the three most important goals of the 2019-2021 strategy document. This includes tax unburdening of business sector by 30% compared to administrative cost in 2017 by 2020 as well as removing a number of barriers to market competition. Furthermore, it also includes digitalisation of Croatian industries, entrepreneurship and an innovative environment that attracts foreign and domestic investments, as well as more incentives and advisory for SME's, etc. This plan aims in general to improve innovation, investment in R&D, entrepreneurship infrastructure and trainings. | |
| **Cyprus** | **Establishment of deputy Ministry for Research Innovation and Digital Governance** | The project named "**Innovate Cyprus**" then established a national council of Research and Innovation, and a deputy Ministry for Research Innovation and Digital Governance, providing funding of EUR 60 million. | |
| **Czech republic** | **Action Plan for the Future of the Automotive Industry in the Czech** | The Ministry of Industry and Trade, in cooperation with other ministries, representatives of the automotive industry, energy companies and other interested parties, prepared the **Action Plan for the Future of the Automotive Industry in the Czech Republic -"Czech Automotive Industry 2025".** In addition to industrial production, the shape of the economy will increasingly be affected by the services, digital technologies, and the pressure to reduce the | ✓+ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | **Republic -"Czech Automotive Industry 2025** | environmental impact on both the production and operation of motor vehicles. These changes pose important questions for the automotive industry, which is one of the main pillars of the Czech national economy and can offer future opportunities to reduce the impact on the environment.<br><br>**The action plan** deals with **electromobility, autonomous vehicles and digitalization**. The plan had proposed 25 measures that relate to the infrastructure for **emission-free vehicles, standardization and legal aspects of automated controls, high-speed internet, digital and mobile services and research and development for the automotive industry**. In order to achieve the objectives of the action plan, it will be necessary to adapt the relevant subsidy titles to support science, research, and innovation and to ensure change in the education system. | |
| **Czech Republic** | **Digital Czechia** | Digitalisation became one of the top priorities of the new government in 2018. To this end, a new **programme Digital Czechia** was introduced in October 2018 encompassing three strategies to digitalise the country, one of which overlaps with Industry 4.0, the previous strategy for the digitalisation of Czech industry that was established in 2016. Furthermore, the implementation plans of the Digital Czechia programme were introduced and approved by the Czech government in mid-April 2019. At the beginning of 2019, an umbrella document titled the **Innovation Strategy of the Czech Republic 2019-2030 (Czech Republic: The Country for the Future)** was introduced and additional sectoral or thematic documents are foreseen to be adopted throughout 2019, such as **the Action Plan of Autonomous Driving.** | |
| **Denmark** | **Strategy for Circular Economy** | In September **2018** the Danish Government launched the **Strategy for Circular Economy** (Ministry of Environment and Food of Denmark, 2018). The strategy is a follow-up on the 27 recommendations that the Advisory Board for Circular Economy presented in June 2017 (see previous eco-innovation report) and covers the period 2018-2022. It is also closely related to the Utilities Strategy that the Danish government launched in September 2016 promoting, among others, better utilisation of waste (Danish Ministry of Climate, Energy and Utilities, 2016). The strategy is also contributing to realise the Danish government's plan of action for the 17 UN Global Goals.<br><br>To support the transition to a more circular economy the Danish Government has allocated DKK 116 million **Es ist eine ungültige Quelle angegeben.** that will 15 initiatives across six thematic areas:<br>1) **Strengthen enterprises** as a driving force for circular transition.<br>2) Support circular economy through **data and digitalisation.**<br>3) Promote circular economy through **design.**<br>4) Change **consumption patterns** through circular economy.<br>5) Create a proper **functioning market for waste and recycled raw materials**.<br>6) Get more value out of **buildings and biomass**.<br><br>There are three sectors that the Danish Government finds have particular circular economy potential: 1) **the food sector**; 2) the **industry**; and 3) the **building and construction sector**. | ✓✓++ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | | The second area on **data and digitalisation** includes one (#4) initiative - "Supporting digital circular options by commercial use of data and challenges". The Danish Government The strategy does not state any specific circular economy strategy linked to digitalisation, but mentions the 'Government Strategy for Denmark's digital growth' (see below). Finally, it is not yet decided that there will be a follow up of the strategy after 2022 | |
| **Denmark** | **Strategy for Denmark's Digital Growth** | In January 2018, the Danish government presented the new 'Digital Growth Strategy'. The strategy consists of 38 initiatives, and have been allocated EUR 134 million from 2018 to 2025 and EUR 10 million onwards per year (Ministry of the Environment, 2018). The seven main initiatives include: 1) Digital Hub Denmark; 2) SME: Digital; 3) The Technology Pact; 4) Strengthened Computational Thinking in Elementary School; 5) Data as a Driver of Growth; 6) Agile Regulation for New Business Models; 7) Strengthened Cyber Security in Companies.<br>While the strategy does not explicitly mention circular economy or eco-innovation, it is linked to the fourth imitative 'Supporting digital circular options by commercial use of data and challenges' under the Danish Governments' Strategy on Circular Economy.<br>Website: https://eng.em.dk/media/10566/digital-growth-strategy-report-uk-web-2.pdf | ✓+ |
| **Denmark** | **Erhvervsfremme i Danmark 2020-2023** | The Danish Executive Board for Business Development and Growth has developed a strategy, *Erhvervsfremme i Danmark 2020-2023* (Danmarks Erhvervsfremmebestyrelse, 2020) that sets the framework for the efforts of the Danish Business Promotion Board in the coming years. The strategy presents six areas as driving forces for Danish growth and development: **Skilled labour and social inclusion**; **Entrepreneurship**; ***Green transition and circular economy***; **Innovation**; **Digitization and automation**; and **Internationalization.** The strategy also identifies the 13 strongest and most promising business areas for Denmark which includes **environmental technology**, **energy technology** and **digital technology**. | + |
| **Estonia** | **National Agenda 2020 for Estonia** | As a cross-cutting issue, Estonia updated its **National Agenda 2020 for Estonia** in 2018. The rationale underlying this agenda is to provide a secure, well-performing and reliable infrastructure based on which further digitalisation can proceed. Some of the expected main benefitting areas concern the competitiveness of the economy, social wellbeing and effectiveness of public governance. More particularly, the Digital Agenda outlines several goals in the two major focal areas of *development of information society* and *increasing cyber security*. Some of these goals entail *raising the capability of the public sector for using data analytics and research, adopting artificial intelligence applications,* or *accelerating innovation in the fields of e-governance and cyber security* (Government of the Repubic of Estonia, 2018). | |
| **Estonia** | **National Agenda 2020 for Estonia** | As a cross-cutting issue, Estonia updated its **National Agenda 2020 for Estonia** in 2018. The rationale underlying this agenda is to provide a secure, well-performing and reliable infrastructure based on which further digitalisation can proceed. Some of the main areas expected to benefit concern the competitiveness of the economy, social wellbeing and effectiveness of public governance. More particularly, the Digital Agenda outlines several goals in the two major | |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | | focal areas of *development of information society* and *increasing cyber security*. Some of these goals entail *raising the capability of the public sector for using data analytics and research, adopting artificial intelligence applications,* or *accelerating innovation in the fields of e-governance and cyber security.* | |
| **Estonia** | **National Transport Development Plan 2014-2020** | Another relevant strategy that is of major importance in the context of eco-innovation in Estonia can be found in the **National Transport Development Plan 2014-2020**, which directly targets all issues surrounding the transportation system in the Baltic nation. The government currently reviews and amends the strategy, which is expected to be updated and rolled-out in 2021. Particularly in Estonia, transport is considered within the context of spatial planning, greenhouse gas emissions, technological development and new, digitally based forms of mobility | |
| **Estonia** | **Entrepreneurship Growth Strategy and RDI Strategy** | Entrepreneurship Growth Strategy and RDI Strategy clearly formulate three focus sectors to be paid attention to: *i) ICT and supporting sectors (e.g. automation and robotics, software development), ii) health technologies and services (e.g. biotechnology, e-health)* and *iii) resource efficiency (e.g. material science, knowledge-based construction)*. The field of RDI moreover opens up an interesting path of investigation by focussing on **research commercialisation** and the general process from innovation to mainstreaming. In this respect, Estonia shows room for improvement. Even though most academic spin-off companies are usually founded in the fields of biotechnology (33%), ICT (16%) and health (11%), and therefore in sectors relevant to eco-innovation, commercialisation skills are often poor and efforts, more often than not, nipped in the bud as neither the national RDI strategy nor Intellectual Property regulations pave the way for commercialisation activities | ✓+ |
| **Finland** | **Digital Infrastructure Strategy 2025** | According to this strategy, "digital infrastructure promotes competitiveness and wellbeing by enabling the utilisation of, for example, data economy and artificial intelligence in both the private and public services." The strategy also particularly elaborates on how it aims to support research and innovation and refers to a number of "of public sector-coordinated or publicly funded research and development projects under way related to digital infrastructure and digital services" (Ministry of Transport and Communications, 2019). | |
| **Finland** | **Smart Energy Programme Finland** | The Smart Energy Programme Finland is organised by Business Finland and particularly focuses on technological and digital solutions to energy generation and consumption and their innovation. To boost the overall economy's innovative edge in this domain, a total of €100 million in funds has been / will be made available to companies between 2017-2021. More specifically, the programme focuses – amongst other – on the entire value chain of energy systems, smart buildings as well as IoT, AI and digitalisation as horizontal cross-cutting issues. In fact, digitalisation is given highest attention to and claimed to be taken full advantage of. The programme ultimately aspires to boost companies' growth, motivate the formation of start-ups, build up test platforms and attract international investment in Finland, for instance.<br><br>Keywords: *renewable energy, energy transitions, smart energy*<br><br>Website: https://www.businessfinland.fi/en/for-finnish-customers/services/programs/smart-energy-finland/ | ✓+ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | | *<u>Contact</u>: Helena Saren, helena.saren@businessfinland.fi* | |
| **Finland** | **Bioeconomy strategy** | The **Bioeconomy strategy**, which has already been addressed in earlier stages of this report, represents a crucial political advance to boost eco-innovation in its entirety. Several goals have been formulated, which are – amongst others – rooted in the desire to gain *i) new business opportunities from the bioeconomy, ii) a coherent policy environment, iii) a strong competitive operating environment and competence base,* as well as *iv) a boost of the digital society through spatial data* (Bioeconomy Finland, 2018). | ✓+ |
| **France** | **Roadmap for the Circular Economy** | The roadmap lists a set of 50 measures aimed at the operational implementation by all stakeholders (citizens, local authorities, companies, administrations, associations) of the transition to be made to move from a linear "make, consume, throw away" economic model to a circular model that will integrate the entire life cycle of products, from their eco-design to waste management, including their consumption while limiting waste. The roadmap includes several measures on digitization and digital technologies, as these represent an opportunity for the transition to a circular economy, especially by enabling networking, access to information and data for citizens, support to decision-making and the production of new services.<br><br>Digital technology is regarded at the service of the circular economy in order to achieve the objectives to reduce natural resource use, the amount of non-hazardous waste, greenhouse gas emissions and others.<br><br><u>Keywords:</u> Circular Economy, transition,<br><br><u>Website:</u> https://circulareconomy.europa.eu/platform/sites/default/files/frec-anglais.pdf | ✓✓++ |
| **Germany** | **Digital Policy Agenda for the Environment** | The German Federal Environment Ministry presented in early 2020 the Environmental Digital Agenda, which is a strategic package of 70 measures aiming to organise the digital transformation climate-friendly, use it for prosperity and competitiveness, social justice and support an intact environment.<br><br>The aim is both to steer digitalisation in an environmentally compatible direction and to use the opportunities offered for environmental protection. The BMU worked out the agenda within a broad participation process of around 200 experts. The Digital Agenda is the first strategy in Europe that consistently combines digitisation and environmental protection.<br><br>• Reduce the ecological footprint of digitisation and protect human health<br>• Digitalisation as a driver for a social-ecological transformation<br>• Using digital technologies for environmental governance, participation and engagement, and more effective administration, decision-making and enforcement (Environmental Policy 4.0)<br>• Advance innovation against the background of environmental policy needs, close research gaps and exploit systemic innovation potentials.<br><br><u>Keywords:</u> Digital transformation, social-ecological innovation, environmental policy | ✓✓++ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | | Website: https://www.bmu.de/digitalagenda/ | |
| **Greece** | **Establishment of new Ministry of Digital Governance** | The government has set digitalisation as one of its strategic priorities, as a new Ministry of Digital Governance was established in 2019. The COVID-19 pandemic triggered several digital initiatives to address the challenges and barriers of this health crisis and this has accelerated the pace of digital transformation. | |
| **Hungary** | **Digital Success Programme** | In 2016, the **Digital Success Programme** was launched in Hungary as a framework for different initiatives fostering the shift to a digital economy and society. Under the Digital Economy, such programmes as **Industry 4.0**, the **Digital Workforce Programme** or the **Digital Agriculture Strategy** have been put in place. The **Digital Start-up Strategy of Hungary**, drawn up as part of the programme, formulates the government's vision for Hungarian digital enterprises up to 2020.<br>In parallel with the start-up strategy, various other strategic documents have been drawn up within the framework of the Digital Success Programme, several of which have links with the start-up ecosystem, such as the **Digital Education Strategy of Hungary** and **Digital Export Development Strategy of Hungary**. Hungary's financial technology strategy, the **FinTech Strategy**, was approved in July 2019. | |
| **Italy** | **National Strategy for the technological innovation and digitalisation of the country** | The strategy was developed by the Italian Ministry for technological innovation and digitalisation. It builds on the UN SDGs and focuses on three key challenges: the digitalisation of society; the innovation of the country; the sustainable and ethical development of society. The strategy defines a structural transformation process for the country. It aims to introduce and apply technology and innovation in cities and small centres to improve the quality of life. By developing digital infrastructure and data centres, it promotes the use of alternative energy sources and contributes to reducing energy consumption. In addition, the strategy wants to ensure and maintain the economic, social and environmental sustainability of all innovations. | ✓✓++ |
| **Italy** | **Transition 4.0 Plan** | Transizione 4.0 is the new national industrial policy plan for the years 2020-2022, following the Industria 4.0 Plan. The current plan presents greater emphasis on green investments, circular economy and innovation and it includes budget allocation to research and development projects in "Digital Agenda" and "Sustainable Industry". | ✓✓++ |
| **Italy** | **tax credit for R&D, innovation and design** | The 2020 Budget Law introduced a **tax credit for R&D, innovation and design**, with the objective of stimulating investments in these areas and sustainaining the competitiveness of Italian firms. The activities for technological innovation aim to create and improve products and production processes. In particular, a tax credit is applied to technological innovation activities aimed at reaching an ecological transition or a digital innovation which amounts to 10% of eligible expenses with maximum annual amount of EUR 1.5 million. | ✓+ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| **Luxembourg** | **Data-driven Innovation Strategy** | In 2019, the Ministry of the Economy integrated Circular Economy in its "**Data-driven Innovation Strategy**", identifying this sector as key for innovation in the future[47]. The strategy outlines the government's vision for digitalising economic sectors, and is the continuation of the previous "Digital Initiative" Research and Innovation Smart Specialisation Strategy (RIS3), dating from December 2017.<br><br>The Data-driven Innovation Strategy outlines four key policy initiatives to be implemented in the five years following the plan, among which several integrate circular economy:<br>• Circular test market<br>• Data hub<br>• Finance<br>• Performance economy ecosystem | ✓✓++ |
| **Luxembourg** | **Artificial Intelligence: a strategic vision for Luxembourg** | https://digital-luxembourg.public.lu/sites/default/files/2019-05/AI_EN_1.pdf | ✓+ |
| **Luxembourg** | **Digital Luxembourg** | Since 2014 with the "Digital Luxembourg" initiative, the Luxembourgish government strives to place digitalisation at the heart of its policies. Circular economy and digitalisation are strongly interrelated in the government strategy. ICT technologies are considered as a tool to increase efficiency towards a more sustainable way of production. For instance, the government published its Research and Innovation Smart Specialisation Strategy (RIS3) in 2017, as a toolbox to anticipate the incoming changes. Consequently, the Prime Minister, Xavier Bettel, enacted the creation of the Ministry of Digitalisation in 2018. | ✓+ |
| **Malta** | **Digital Malta** | One of 10 core principles underpinning the implementation of the 'Digital Malta'[48] vision is that of creating demand for environmental services through the implementation and application of ICT. In particular, Malta's Digital Strategy (2014-2020) identifies opportunities for ICT to enhance energy efficiency. Malta has developed wide access to broadband networks and e-services that could potentially facilitate dematerialisation of products and services. In 2017, 95% of enterprise had broadband access and the use of the internet for e-commerce activities increased by 1% in 2018 compared to the previous year (NSO, 2019c). The government offers a wide array of e-services and an estimated 56.8% of total internet users availed themselves of e-government services in 2018 (NSO, 2019c). However, harnessing the potential of ICTs for a green economy will require the integration of ICT-enabled green innovation into relevant horizontal policies and programs, including identifying synergies with the smart specialisation strategy. | ✓✓++ |

[47] Government of the Grand Duchy of Luxembourg, May 2019, The data-driven innovation strategy for the development of a trusted and sustainable economy in Luxembourg. Available at: https://gouvernement.lu/en/publications/rapport-etude-analyse/minist-economie/intelligence-artificielle/data-driven-innovation.html

[48] https://digitalmalta.org.mt/en/Pages/Strategy/Digital-Malta-Vision.aspx

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| **Malta** | **Low Carbon Development Strategy** | In order to pursue GHG emissions reductions, low carbon investments are being prioritised in the following key areas of action identified in the Low Carbon Development Strategy document: energy, transport, waste, agriculture, water, enterprise, tourism, information and communication technologies (ICT), infrastructure (planning and monitoring of existence infrastructure), finance and expert knowledge. Focussing on ICT, a number of areas of application for decarbonisation have been identified that include water resources management; energy management and smart energy grids; mobility; and smart logistics. In particular, ICT is earmarked as an enabler of resource efficiency in buildings, (the latter being one of the areas for smart specialisation) as it offers a number of opportunities for greening. The Low Carbon Development strategy aims to promote public-private partnership models to support research and innovation aimed at assessing and optimise energy demands throughout a building's life cycle. An innovative aspect for Malta being proposed is the establishment of B2B business models involving the energy utility, communication operators and building management companies. | ✓✓++ |
| **Portugal** | **Digitalisation of waste tracking** | Before 2018, all waste tracking notes (own translation from *Guias de Acompanhamento de Resíduos*) were physical, i.e., these had to be bought and filled every time a waste transfer took place. Following a long discussion and technical development process, in January 1st 2018, the Portuguese Environmental Agency made available the necessary infrastructure for waste generators and managers to emit the electronic waste tracking notes (eGAR), enabling the dematerialization of the whole waste transfer process.<br><br>Besides saving resources and simplifying the process for the parties involved, the eGAR have enabled a significant improvement in the reliability of the waste statistics in Portugal, decreasing the risk of human error and possible misconduct. Authorities can check in real-time if a waste transfer has been inserted in the tracking platform or compare observed with reported quantities. | ✓+ |
| **Slovakia** | **Implementation Plan of the Research and Innovation Strategy for Smart Specialisation** | The **Implementation Plan of the Research and Innovation Strategy for Smart Specialisation** of the Slovak Republic, adopted in 2017 sets new responsibilities to further smart specialisation of the country, such as appointing a clear entity responsible for the strategy or setting up a clear mechanism for the monitoring of activities. It set the focus on 5 smart specialisation domains, namely vehicles for the 21st century, industry for the 21st century, digital Slovakia and creative industry, population health and medical technology and healthy food and environment. | ✓+ |
| **Slovakia** | **2030 Digital Transformation Strategy for Slovakia** | **2030 Digital Transformation Strategy for Slovakia** (approved by Government Decree 206/2019) envisions that by 2030, Slovakia will become a modern country with innovative and ecological industry built on a knowledge-based and data economy, with effective public administration ensuring smart use of the territory and infrastructure and with information society whose citizens use their potential at full and live high-quality and secure lives in the digital era. **The first action plan for the digital transformation of Slovakia 2019-2022** presents priorities for the upcoming years. The first is to support the digital transformation of schools and improve the preparedness for the labour market through the acquisition of digital skills and competencies for the digital era. The second priority is to set the bases for a modern, digital and data economy as well as for the digital transformation of the wider economy. It is | ✓+ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
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| | | followed by the priority to improve the capacity of public administration to utilize data for the benefit of the citizens. Last but not least it aims to support the development of artificial intelligence. | |
| **Slovenia** | **Development Strategy for the Information Society & Next-Generation Broadband Network Development Plan to 2020** | In March 2016 the Development Strategy for the Information Society until 2020 and the Next-Generation Broadband Network Development Plan to 2020 were adopted. They stress, that "an accessible and quality broadband infrastructure is a crucial factor in addressing the economic, social and environmental challenges, contributing substantially to the economic and general development of the modern digital society" (Next-Generation Broadband Network Development Plan to 2020, 2016, p. 5). However, circular economy is not specifically addressed by them. | ✓+ |
| **Slovenia** | **Smart Specialisation Strategy** | In September 2015 the Smart Specialisation Strategy of the Republic of Slovenia (S4, 2015) was adopted. It was a precondition for using EU structural funds in the field of research, development and innovation, and it aimed to i) strengthen the competitiveness of the economy by enhancing its innovation capacity, ii) diversify existing industries and service activities, and iii) boost growth of new and fast-growing industries and enterprises (S4, 2015, p. 5).<br>In identifying S4 priority areas of application great emphasis was given to strong empirical bases which resulted in 3 priority pillars and 9 areas of application, i.e. (S4, 2015):<br>1) DIGITAL / Healthy working and living environment (areas of application: Smart cities and communities; Smart buildings and homes, including wood chain);<br>2) CIRCULAR / Natural and traditional resources for the future (areas of application: Networks for the transition to circular economy; Sustainable food production; Sustainable tourism);<br>3) "(S)INDUSTRY 4.0" (areas of application: Factories of the future; Health – medicine; Mobility; Development of materials as end-products). | ✓✓++ |
| **UK** | **Greening Government Sustainable Technology Strategy to 2020** | In December 2018, Defra published the UK's "Greening Government Sustainable Technology Strategy to 2020". This strategy defines the government's information and communication technologies (ICT) green commitments and their adoption of efficient and sustainable practices. A first strategy was published in 2011, and was considered as the building blocks of the 2020 strategy, as it is now in operation in 14 contributing government departments.<br>The 2020 strategy describes how modern digital tools can bring central government staff to work effectively together within departments and with customers, to achieve savings on office space, energy, paper, and travel through the use of best practices. The strategy also aims to raise awareness on the sustainability impacts of online services: these impacts are little known by users, due to the proliferation of digital technology and data services and the globalisation of service supply.<br>The 2020 Greening Government Commitments programme outlines the UK government's commitment to delivering sustainable operations and procurement by 2020. The Sustainable Technology Strategy addresses three key challenges, namely: | ✓✓++ |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
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| | | • Describing how the government best procures and exploits information and communications technology for sustainable outcomes;<br>• Outlining the Sustainable ICT response to departmental transformation programmes, plans, commitments and wider government imperatives;<br>• Providing a guiding view of how the government can meet the sustainability challenges and opportunities provided by digital technologies and digitalization.<br><br>The strategy's main outcome is to create: "*A resilient digital and technology ecosystem, fully utilised by digital citizens, delivering a net gain for the environment and society through reduced impacts and measurable benefits*."<br><br>Among the main department commitments, UK departments and supporting agencies will:<br><br>• Quantify and report on their e-waste and energy and carbon footprint of the digital and technology services used and their sustainability impacts;<br>• Seek e-waste targets of zero to landfill by 2020;<br>• Adopt an "e-conferencing facility first" approach/policy to meetings, seeking to positively impact reduction of journeys with a target of 40% reduction.<br><br>Keywords: ICT, technology, sustainable, digital<br><br>Websites: https://www.gov.uk/government/publications/greening-government-sustainable-technology-strategy-2020/the-greening-government-sustainable-technology-strategy-2020-sustainable-technology-for-sustainable-government<br><br>https://Defradigital.blog.gov.uk/2018/12/10/introducing-the-government-wide-sustainability-strategy/<br><br>https://www.computerweekly.com/news/252454625/Defra-unveils-Green-government-tech-vision | |
| **UK** | **Industrial Strategy** | The UK government also published its **Industrial Strategy** in November 2017, with the overarching aim to boost productivity and earning power. The strategy focuses on five key foundations for productivity: ideas, people, infrastructure, business environment and places. It defines four grand challenges: AI and the digital economy, the future of mobility, clean growth, and the ageing society.<br><br>One year after the publication of the Industrial Strategy, the government issued a paper "Forging our future: Industrial Strategy - the story so far" to present the results of the strategy one year in. The Industrial strategy drives innovations through the government's Industrial Challenge Fund, in collaboration with Innovate UK and UKRI. As of December 2018, £652 million had been delivered in funding support, with the objective of reaching £4.7 billion over 4 years after the deployment of the Strategy. | ✓+ |
| **UK** | **Digital Strategy** | The United Kingdom also published its Digital Strategy in March 2017, with the goal of developing a world-leading digital economy in the United Kingdom. It has seven strands, including connectivity, skills and inclusion, digital | |

| Country | Policy of relevance to digitalisation | Description | Digital-environ-ment link |
|---|---|---|---|
| | | government, data economy. None of the key foundations of the digital strategy however includes measures on environmental sustainability. | |
| **UK** | **Sustainability in information and communication technology (ICT): A Defra guide** | Defra published a corporate report entitled "Sustainability in information and communication technology (ICT): A Defra guide" in 2019. This report applies the UN's SDGs, its Guiding Principles on Business and Human Rights and its Environment guidance on chemicals and waste, as well as the UK Government's 25 Year Environment Plan. It aims to help businesses create a greener and more sustainable future through ICT, by providing:<br>• An overview of the key sustainability challenges and opportunities for circular economy, sustainable procurement, ecological footprints and ISO (International Organisation for Standards); and<br>• Guidance on best practices, such as the key steps that are expected of organisations to help them integrate sustainable ICT into supply chains, systems and ways of working[49].<br>In 2018, Defra's Digital, Data and Technology Services directorate has already launched a Joint Sustainable Information and Communication Technologies (ICT) Group, consisting of multinational organisations from ICT supply chains, to share, promote and implement sustainable best practices. The publication of the guide results from the work of this group, which brings together the latest best practice guidance promoting more sustainable ICT choices. | ✓✓++ |

*Table 8: List of country examples for digital technology solutions and policies (by countries)**

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **Austria** | Secontrade - The Platform for safe raw material trade | RepaNet Re-Use- and repair network | beeanco - an innovative online market for sustainable goods and services | | Master Plan Environmental Technology (MUT) | Goodbye shopping bags (Pfiat di Sackerl) | | |
| **Belgium** | GeoChallenge | Compost in City – Recyclo | | | "Cirkeltips": A government-led initiative to enhance waste management | Good Food Strategy: Towards a sustainable food system | New plastics training center | |
| **Bulgaria** | Ecologica: recycling of WEEE | Qubico: monitoring of water and sewer networks for saving water | Biomyc: Bio-based sustainable packaging | LAM-ON: biodegradable laminating film for print and packaging | Ordinance on construction waste management and use of construction and demolition | | | |
| **Croatia** | Project of waste-water collection, drainage and treatment in the area of the island of Krk | Delt Papir d.o.o. paper awarded with EU Ecolabel | Six Valamar Campsites Hold the Prestigious EU Ecolabel for Tourist Accommodation | Saponia d.d. acquired the EU Ecolabel | Food Waste Prevention Centre – FWAPC is Civil Society Organization (CSO) / Non-Governmental Organisation (NGO) in Zagreb | Co-financing the purchase of energy efficient vehicles | Project FIRESPOL - Financial Instruments in Renewable Energy Projects | |
| **Cyprus** | Anaergia's - OREX™ system that extracts organic waste from MSW | Aqualoop - equips households with a water temperature regulator connected to home WiFi | | | A knowledge Alliance in Eco-innovation Entrepreneurship to Boost SMEs Competitiveness (MSEecoMP): 2017-2019 | | | |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **Czech Republic** | CYRKL Platform - Digital market of secondary raw materials | DigiLab presents on-site solutions for urban mobility SKODA Auto | | | Czech Circular Hotspot - Czech Invest | State Programme of Environmental Education and Consultancy 2016–2025 | OP EIC – Operational Programme Enterprise for Innovation and Competitiveness | |
| **Denmark** | Animal Feed 4.0 - intelligent feed production | Power-to-X is key to achieving substantial CO2 reductions | Rainwater for washing machines and toilets cut water consumption by 40 per cent | | Strategy for Circular Economy | Danish Eco-Innovation Program (MUDP): Strategy 2020-2023 | Energiforskning.dk - Energy and Climate funding platform | Grøn Projektbank – Green project data base |
| **Estonia** | Cleantech ForEst | Timbeter - a digital timber measurement solution with machine learning technology and artificial intelligence to accurate log detection | eAgronom - digital solutions for farmers | Gelatex - eco-friendly, non-toxic textile that provides a sound and durable alternative to leather | Energy Data Access Conference | Circular Economy Conference | | |
| **Finland** | Solar Foods - “food out of thin air” by using air, water and electricity | Teraloop - alternative model to electrochemical batteries | | | European Days for Sustainable Circular Economy 2019, Helsinki | Smart Energy Programme | | |
| **France** | Too Good to Go - app connecting consumers with restaurants, supermarkets, bakeries, etc. that have unsold food | Ecodair - refurbishing professional computer equipment for resale with a warranty | | | French Tech - a governmental label awarded to metropolitan clusters recognised for their startup ecosystem | French Impact - create a favorable environment to scale up local innovations that have proven their effectiveness into national solutions | | |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **Germany** | National Biodiversity Monitoring Centre - knowledge about the state of biodiversity | Sustainbill Cloud Platform - helps companies identifying risks in their supply chains and improve the supply chain's sustainability | An online platform for construction materials - Restado | Remondis Lippewerk - Center for an industrial circular economy | Environmental Digital Agenda | Programme for promotion of climate protection in data centres - support local authorities in investing and optimising data centres | Resource efficient circular economy - innovative product cycles (ReziProk) | Export initiative Environmental Technologies |
| **Greece** | Kafireas (solar parks and wind farms | Costa Nostrum - Certification Standard for sustainable management and development of Mediterranean beaches | | | Business Innovation Greece | The "Great Walk of Athens" initiative | | |
| **Hungary** | CleenUp - a service for car fleet operators, including an eco-friendly washing and cleaning system | TrucksOnTheMap - IT tool to cut empty runs, freight rates, complaints, dispatch times, resources and their carbon footprint. | Water Retainer - an organic, liquid soil conditioner increases soil humidity management | | The Smart City Vision of Budapest | Start-up incubation for a more innovative, environmentally friendly agriculture | | |
| **Ireland** | Minimising the impact of Ireland's data centres | The Causeway project to support use of biogas in the transportation sector | Nuritas - a biotechnology start-up using AI and genomics to identify and use natural bioactive peptides that can enhance functional and health foods | FoodCloud - a platform enabling supermarkets to donate their surplus food products to local charities and community groups | Green Government Initiative to roll out GPP | National Bioeconomy Campus: ICT-Biochain (digital innovation hub), and the AgriChemWhey flagship initiative; a second integrated biorefinery, specifically for the conversion of dairy side streams to | Rediscovery - National Centre for Circular Econmy - | |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | high value bio-based chemicals | | |
| **Italy** | Catalyst Group - a start-up that has developed a new, all-circular construction system | RiceRes project – Valorising waste from rice production | GIDA water purification plant | | Circular Economy Initiative for ENEL Suppliers Engagement | CONAI - a diversification system for plastic packaging in its extended producer responsibility scheme | | |
| **Latvia** | Alternative Plants produces natural active ingredients for cosmetic products | PolyLabs - a chemical production company, clients are companies in the polyurethane industry | | | Circular Economy Strategy | Procurement action plan for sustainable catering | | |
| **Lithuania** | Project “Man rūpi rytojus” supporting businesses, policy-makers and citizens through evidence-based research on sustainability, circular economy | Auga Group - largest vertically-integrated organic food companies investing in sustainable farming practices | Ecococon - development of eco-friendly housing through innovative use of ecological materials | | National science programme “Agro-, forest and water ecosystem sustainability” | Towards a Sustainable Lithuania: Integrating Sustainable Development Goals into National Strategic Documents | | |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **Luxembourg** | HPC (High Performance Computing) MeluXina to boost CE by enabling companies to expand their calculations capacities | EcoBox - a refundable lunchbox | | | Circularity Dataset Initiative - develop an industry standard at European level for circular data on products throughout the whole value chain | CleanTech Cluster | | |
| **Malta** | 3DMicroGrid project - the first campus-wide smart micro-grid ‘living laboratory’ as a training and research facility | Monitoring and real-time decision-making for water consumption and leakage using Data Management and Information Systems | ESAIRQ Project - Environmental Sensors for Air Quality | FLASC: Floating Liquid Piston Accumulator Using Seawater Under Compression | Resource Recovery and Recycling Agency | ‘WATER Be the Change’ Campaign | Net Zero Impact Utility | |
| **Netherlands** | Swapfiets - for a fixed monthly fee, users get a bike that always works | Bedzzzy - an innovative mattress, using both new techniques and a new, circular, business model | The circular kitchen - easily changed modules | | “Versnellingshuis Nederland Circulair” (Accelerator for circularity - look for iconic circular projects and hand out the ‘Circular Awards’ | CIRCO - a program of the Top Sector Creative Industry, focused on circular design | | |
| **Poland** | Green-Effective Performance Calculator™ - a digital marketing solution for sustainable businesses | Prognosis’s remote energy meter reading system uses wireless technology to provide customers with up-to-date, exhaustive data from their meters in the form of easy-to-read charts and reports. | A sustainable and circular fashion industry | | Financial instrument for circularity: ING Bank Slaski | | | |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **Portugal** | Goma - brand of eco-friendly tiles | Bee2FireDetection - a surveillance system that automatically detects fires in early stages in distances up to 15km | EntoGreen - bio-based technologies to recycle nutrients from agricultural and food waste and reintroducing them in the food chain; biomimicry to address waste production and the need for more efficient nutrient sources | | eGAR - real-time waste tracking notes | Regional agendas for the circular economy | | |
| **Romania** | URADMonitor - a worldwide network of automated monitors, providing a first line detection and warning system against the harmful chemical and physical factors in the environment | Urban Air - an app that bundles all shared mobility solutions at one place (operating in 60 cities) | | | RETRACE - promote the adoption of Systemic Design as a method in designing regional and local policies, supporting them in their transitions towards a Circular Economy | Alba Iulia smart city | | |
| **Spain** | cleanSpot - a smartphone application helping to find recycling centers | Newfert project - recovery of nutrients from organic waste to produce fertilizers | | | REPSOL, Circular Economy Strategy | R&D Strategy in Artificial Intelligence | Circular Bioeconomy Strategy | Estrategia de Economía Circular de Castilla - La Mancha |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **Slovakia** | Sensoneo - combines unique ultrasonic Smart Sensors that monitor waste in real-time using global system for internet of things or mobile communication with sophisticated software (Smart Analytics, Smart Route Planning and Smart Management system) | ELWIS - Smart Waste Evidence System for municipalities, waste type is marked with an original identifier - QR code or RFID chip. This data is scanned into the software system. | | | Greener Slovakia - Strategy of Environmental Policy until 2030 | Circular Slovakia Platform | Action Plan for the Transformation of the Upper Nitra Coal Mining Region | |
| **Slovenia** | Domel motor - a worldwide novelty, as it achieves 96% efficiency using standard sheet metal, ferrite magnets and low material utilization | EcoBox SBR-Q treatment plant, supported by smart remote control monitoring technology and equipped with a system for transferring and converting data from the waste water treatment plant | Iskraemeco's Fair Meter project - focus is raw materials, their origin, labour standards and the promotion of higher industry standards | Aquaspark – Advanced Water Purification Technology - a fully autonomous system which provides high-quality drinking water system by physically removing pathogens, particulates, and turbidity from virtually any water source | EcoLexLife: Raising awareness on Environmental Liability Directive in Slovenia | Decarbonising Slovenia: A Deep Demonstration of a Circular, Regenerative and Low-Carbon Economy | The Danube goes circular | |

| Country | Practice 1 | Practice 2 | Practice 3 | Practice 4 | Policy 1 | Policy 2 | Policy 3 | Policy 4 |
|---|---|---|---|---|---|---|---|---|
| **UK** | Saturn Bioponics is an agri-catalyst programme - It developed a technology involving 3D hydroponic towers, the Saturn towers, which allows to grow food while using less resources and achieving higher productivity than traditional soil farming | Water companies innovating in natural capital investment solutions | Building information modelling (BIM) - an approach adopted by the UK government in response to difficulties in the construction sector | | Greening Government Sustainable Technology Strategy to 2020 | London's Environment Strategy | The Saltire Tidal Energy Challenge Fund | |

* Note: Some countries reported more than 4 practice or 4 policy examples. Please refer to the country profiles of the countries.

# About the Eco-Innovation Observatory (EIO)

The Eco-Innovation Observatory (EIO) is the initiative financed by the European Commission's Directorate-General for the Environment. The Observatory is developing an integrated information source and a series of analyses on eco-innovation trends and markets, targeting business, innovation service providers, policy makers as well as researchers and analysts.

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