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Responsible digital transformation – the bridge between digital and circular economy policies

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Introduction

European industry is facing technological, socio-political and climate change challenges. The transition to climate neutrality is the most urgent challenge of our times and calls for bold and courageous actions for and by industry. Digitalisation is the other key imperative, to remain competitive, creative and ensure Europe's technological sovereignty. To remain at the forefront of technological and social leadership, it is important to strengthen the connections among our digital and green policy objectives.

In September 2018, the European Commission issued a long-term strategy for climate action which calls for net-zero greenhouse gas emissions by 2050 and makes an unprecedented link between the energy and industrial transition. The European Green Deal sets out this European commitment to tackle climate and environmental-related challenges. In addition, the ninth Sustainable Development Goal is to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.

On the one hand, governments in Europe are increasingly committing themselves to clean growth and launching circular economy action plans. On the other hand, the question remains to what extent they take into account the opportunities presented by digital technologies, as well as if and how the impacts of digital policy measures and Industry 4.0 initiatives are assessed against climate goals.

In this context, the objective of this analysis has been to revisit the question of how to create responsible digital transformation models by:

- reviewing some of the most recent national Industry 4.0, digital and circular economy policies and instruments in the EU from an environmental/digital perspective, and
- bringing examples of policy initiatives where advanced and digital technologies are promoted to deliver solutions to pressing environmental problems and the climate crisis and promote good practices.

This study is based on comprehensive desk research and a range of interviews with national policymakers and other relevant stakeholders.

Section 1

1. The twin policy challenges of our times

The fourth industrial revolution is driven by digital and advanced technological developments that will radically transform industrial value chains, business models, production facilities and society. **Digitalisation has both positive and negative consequences for the environment** and the climate.

On the one hand, **advanced digital technologies can lead to more efficient and flexible products** (that replace less resource-efficient technologies) **and circular economy processes** (optimising resource sharing, circulation and longevity). Policy initiatives can be instrumental here to reap all the potential positive benefits. The European Green Deal and the European digital strategy package set out several measures to maximise the impact of policies addressing climate change through artificial intelligence, 5G, cloud and edge computing, and the Internet of Things[1].

On the other hand, **if not properly implemented, the positive effects of digitalisation** on reducing energy consumption, material use and greenhouse gas emissions **can be offset by a drastic increase of electricity and water consumption** by data centres and telecom networks, the production of dangerous waste, or unsustainable mining of rare earth metals.

1.1 European context

The **European Green Deal** launched a concerted strategy for a climate-neutral, resource-efficient and competitive economy. One of the main building blocks of the European Green Deal is the Circular Economy Action Plan, adopted by the European Commission in March 2020 with the aim of accelerating transformational change, while building on circular economy actions implemented since 2015.

The other twin challenge is related to Europe's digital future, where the EU and its Member States are seeking to create the necessary framework for spreading trustworthy technology and providing businesses with competitive advantages enhanced by new digital skills and competences. Responding to this challenge are the **European Digital Strategy, the European Data Strategy** and the White Paper on **Artificial Intelligence** (AI) launched in February 2020. Both strategy packages aim to create actions that bridge digital and green objectives.

The **European Circular Economy Action Plan** includes several actions that address the negative effects of digital transformation:

- The upcoming **'Circular Electronics Initiative'** will mobilise existing and new instruments to promote longer product lifetimes and put in place regulatory measures for electronics and ICT – including mobile phones, tablets and laptops – under the Ecodesign Directive so that devices are designed for energy efficiency, durability, reparability, upgradability, maintenance, reuse and recycling.
- The revision of EU legislation on **batteries**, packaging, end-of-life vehicles, and hazardous substances in electronic equipment will be proposed with a view to preventing waste, increasing recycled content, promoting safer and cleaner waste streams, and ensuring high-quality recycling.
- The **European data space for smart circular applications** is expected to provide the architecture and governance system for product passports, resource mapping and consumer information. Particular attention will be given to sectors such as the built environment, packaging, textiles, electronics, ICT and plastics.

The White Paper on Artificial Intelligence[2] suggests that the environmental impact of AI systems needs to be duly considered throughout their lifecycle and across the entire supply chain, e.g. as regards resource use for the training of algorithms and the storage of data. The digital package has several concrete initiatives:

[1] European Green Deal, European Commission, 2019. https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

[2] https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

- **Data and AI systems can serve to combat environmental emergencies** and to tackle climate change. AI systems can examine resource usage and energy consumption and be trained to make choices that are positive for the environment.
- **The 'GreenData4All' initiative is expected to** support the transition to a greener and carbon-neutral economy and reduce administrative burden.
- **Data centres and telecommunications** will need to become more energy efficient, reuse waste energy and use more renewable energy sources. They can and should become climate neutral by 2030.
- **Destination Earth** is an initiative to develop a high-precision digital model of Earth that would improve Europe's environmental prediction and crisis management capabilities.

1.2 Positive and negative impacts of digital technologies on the environment

Digital technologies are considered to be an important opportunity to strengthen productivity and resilience of businesses, but also reinforce sustainability and more efficient industrial systems. In particular, artificial intelligence is seen as potentially revolutionising the ecological transition.

Digitalisation can be a strong enabler for decarbonisation in all sectors of the economy. Digital technologies can support environmental policies such as waste reduction and recycling and contribute to sustainable transport solutions, energy systems and climate-neutral communities. If digitalisation accelerates green products or processes, they will become more attractive and will tend to substitute other, less sustainable activities.

Digital transformation, however, is energy-greedy and the demand for electricity is expected to increase significantly, especially as a consequence of wireless internet networks, consumer electronic devices and data centres[3]. Digitalisation measures have their own ecological and carbon footprint, where digital technologies are not only energy intensive but need specific materials for electronics, computing and storage. This growing demand for electricity and raw materials to fuel digital transformation will need to be generated without emitting new greenhouse gases or adding unsustainable pressure on existing resources in order to be aligned with the Sustainable Development Goals.

In this respect, rebound effects of digitalisation (the many indirect economic, social and environmental effects of digitalisation, which turn efficiency gains into increased resource consumption) are still not sufficiently considered in most climate protection studies and policies[4] and are not sufficiently reflected upon in digital agendas[5]. For instance, increasing Internet connectivity in everyday life fosters new, or otherwise more energy-intensive forms of demand that counterbalance energy savings[6].

Some of the positive impacts of use of digital technologies on the environment include the following:

Efficiency improvements: Smart energy infrastructure based on the Internet of Things can optimise energy consumption and help avoid unplanned downtime, e.g. adapting street lighting to real requirements. Big data enables a much more accurate, local and efficient organisation of processes and systems. An example of efficiency gains is the digitally supported injection moulding machine that reacts on material fluctuations and can improve the manufacture of recycled plastics. Smart cities, factories and smart mobility will also result in a much more efficient use of raw materials and energy. Smart homes optimise energy consumption, food-sharing apps reduce food waste and intelligent transport systems guide traffic through cities with fewer emissions.

Monitoring energy consumption and material flows: Digitalisation enables remote monitoring of air and water pollution, deforestation, energy and material consumption. With the help of ICT and data, information about the actual composition of a product can be made easily available, fostering reuse. Artificial Intelligence, Big data and IoT can analyse real-time data and predict performance, which enables monitoring of the quality and safety status of materials during transportation, tracking the supply chain end-to-end and identification and response to any bottlenecks. In addition, there is potential for the application of such technologies in the control of invasive species or in the early detection of fires or floods. Data collection is made possible by more and more sensors that collect data and transmit it in real time. AI-based robotic systems can speed up and improve the dismantling of waste. Digital technologies can track the journeys made by products, components

[3] Morley et al (2018). Digitalisation, energy and data demand: The impact of Internet trafficonoverall and peak electricity consumption
[4] Wuppertal Institut (2012). Der Rebound-Effekt Uber die unerwünschten Folgen der erwünschten Energieeffizienz Von Tilman Santarius
[5] Coroama and Mattern (2019). Digital rebound - why digitalisation will not redeem us our environmental sins
[6] Røpke, I. (2012). The unsustainable directionality of innovation – the example of the broadband transition

and materials and ensure the resulting data is securely accessible.

Enhanced decision-making: Artificial intelligence can strengthen climate predictions, enable smarter decision-making for decarbonising industries from buildings to transport, and work out how to allocate renewable energy. Machine learning can monitor, treat and find a solution to changes in temperatures. They can synthesise and interpolate different datasets within a framework allowing interrogation by users and near real-time ingestion of new data. AI can also provide new insights into many complex climate simulations and support climate modelling.

Eco-friendly mobility: Electric and autonomous vehicles on land, air and water have the potential to improve traffic flows and reduce pollution, which will benefit the environment and health. The fifth generation of wireless systems (5G) means everything can be connected, from machines and buildings to everyday objects. Self-driving cars, for instance, can also bring about societal benefits, such as better inclusion of the elderly or people with disabilities[7].

Sharing economy: Digital platforms, internet and blockchain are important pillars of the sharing economy, which links people with each other and enables them to share and exchange things that are not in use anymore or can be loaned for some time to be used by someone else without having to buy a new one.

Precision farming: Precision agriculture refers to a management concept focusing on observation, measurement and responses to inter- and intra-variability in crops, fields and animals[8]. Data, sensor technologies and drones can help manage food resources and face extreme climate conditions.

E-commerce: E-commerce can be more energy efficient than traditional retail, notably by reducing resource use and emissions associated with the associated manufacturing and delivering processes. For instance, when the goods to be delivered are digital, or can be digitalised (such as music, movies, or books), their delivery can also take place digitally (via Internet streaming), without a physical substrate such as a DVD, CD, or paper. Similarly, online grocery orders with subsequent home delivery can reduce CO_2 emissions compared to individual grocery shopping.

Nevertheless, e-commerce also has its negative side. Home deliveries of goods purchased online by trucks may generate a net increase in overall energy consumption and emissions levels in urban areas, where, in the traditional model, customers usually do not drive to the shops but walk or take public transport. This effect is confirmed for the ordering of books and may be even more prominent in the case of apparel, where customers often order more models and several sizes of each, and then take advantage of return deliveries.

Negative impacts are particularly related to energy needs and e-waste

Energy need: Data storage, data processing and AI algorithms consume immense energy. Data infrastructure, as the key building block of the digitalised world, accounts for approximately 2% of global electricity consumption[9]. The environmental footprint of the industrial sector is significant, estimated at 5-9% of the world's total electricity use[10]. Although electronic devices are getting more and more energy-efficient, data production and internet traffic have been growing exponentially in recent years. Blockchain technology, which processes a lot of data and needs lot of computing power, demands a lot of energy resources. PwC estimated that the servers that run bitcoin's software require a minimum of 2.55 gigawatts power, which amounts to energy consumption of 22 terawatt-hours (TWh) per year—almost the same as Ireland[11]. Online content stored in data centres also requires a lot of electricity and online videos alone generate as much greenhouse gas emissions as entire countries[12]. Online video represents nearly 60% of world data traffic[13]. The ultimate question for the future will be if further efficiency improvements will outweigh or not the growing new data demand growth[14].

Demand for critical raw materials: The need for critical raw materials in digital products is significant. Since environmental regulations on the mining of these raw materials are not well enforced, this can lead to unsustainable extraction methods and environmental degradation[15]. Furthermore, mining can also involve human rights abuses, with particular reference to cobalt mining, a key component in lithium-ion batteries

[7] C. D. Harper, C. T. Hendrickson, S. Mangones, and C. Samaras, "Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions

[8] EIP-AGRI Focus Group (2015). Precision Farming, Final report

9 IEA (2018). World Energy Outlook

10 IEA (2017). Digitalisation and Energy

[11] https://www.economist.com/the-economist-explains/2018/07/09/why-bitcoin-uses-so-much-energy

[12] The Shift Project (2019)

[13] Sandvine (2018). The Global Internet - Phenomena Report

[14] IEA (2017). Digitalisation and Energy

[15] Maffey, G., H. Homans, K. Banks, and K. Arts. 2015. Digital technology and human development: A charter for nature conservation.

for smart phones. Some electronic devices also require extremely dangerous and harmful chemicals such as cadmium, lead and mercury in their production.

E-waste: The growing waste of discarded electrical and electronic equipment represents a hazard for the environment and our health. More effort is needed to reuse and recycle devices and reduce the amount of toxic and non-biodegradable materials used in them and thrown away. A further issue of concern is hardware and software obsolescence, which additionally increases material consumption. According to a United Nations study, 40 million metric tonnes of e-waste was discarded in 2014 (UNU-IAS)[16], of which 7 million metric tonnes were from the United States and 6 million from China.

[16] https://i.unu.edu/media/unu.edu/news/52624/UNU-1stGlobal-E-Waste-Monitor-2014-small.pdf

Section 2

2. Coupling digital and green policy objectives – national strategies

National governments across EU Member States have made important steps to highlight environmental objectives and carbon-neutrality targets in their most recent national industrial strategies. However, **sustainability** considerations have been **integrated** only **to a limited extent** into **digital transformation policies** and Industry 4.0 initiatives. More references can be found about the potential of digital technologies within national circular economy strategies.

Circular economy and digital policies **go in parallel rather than being explicitly connected** although there are interesting initiatives and a growing understanding of the interlinkages between them. In several countries the issue is that even if the industrial strategy aims to be climate friendly, it is often constrained by the needs of priority sectors which are both energy intensive and use carbon in their raw materials. In terms of governance, while several Member States have already developed a new institutional set-up allowing better coordination across different policy areas, further work has to be done in creating synergies between the digital and circular economies.

The areas where digital and sustainability are most often coupled relate to **energy efficiency, resource efficiency and smart cities** including smart mobility. The use of artificial intelligence, blockchain and sensors appears among the referenced opportunities which can help monitoring, trace origins and secure quality and efficiency.

Despite the European initiatives, there is a need for more actions at national and regional level as well. There is still often a lack of common narrative for the digital and green transitions[17] due to the fact that the institutions responsible for each area are not yet sufficiently connected and actions launched under each pillar do not suffciently communicate to each other. Not just policymakers but also companies work rather in silos drawing a wall between digital and the circular economy. Hence, there is a missed opportunity for building positive synergies.

A recent French white paper on digital and the environment[18] (2018) highlighted the fact that still too few environmental organisations and stakeholders understand the potential of digital technology, while the promoters of the digital transformation do not make enough effort to think about the environmental implications of digital. In order to make the two objectives converge, the actors would need to develop shared strategies and agendas that can reduce the negative environmental impacts of digital technologies and promote the potential of the positive ones. In the following we present examples of national policy approaches across the EU that advance linkages between digital and green policy agendas.

2.1 National policy approaches with active policy agendas to couple green and digital

Some countries have been active in formulating policy objectives and policy agendas that promote a responsible and sustainable digital transformation.

Finland has the objective of becoming carbon neutral by 2035[19]. The Digital Finland Framework[20] prepared by the Finnish government formulated a specific goal for a *sustainable digital transformation* in Finland. This framework combines the following perspectives:

1) Digital innovation capitalising on the benefits of platform economy and the transformation of the spearhead industry sectors,
2) Support for sustainable digital transformation,

[17] Eco-innovation Observatory, Eco-innovation in France, EIO Country Profile, 2018-2019
[18] https://www.wwf.fr/sites/default/files/doc-2018-03/180319_livre_blanc_numerique_environnement.pdf
[19] Finland Integrated Energy and Climate Plan http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161977/TEM_2019_66.pdf
[20] Digital Finland Framework – Framework for turning digital transformation to solutions to grand challenges https://www.businessfinland.fi/496a6f/globalassets/julkaisut/digital-finland-framework.pdf

3) Response to global megatrends and sustainable development goals.

The Digital Finland Framework highlights the importance of intelligent and clean energy, climate neutral industrial processes and smart mobility services. Finland recognises the need for sustainable, resource-efficient solutions and the promotion of the circular economy. The policy strategy is to combine the material and process strengths in Finland with digital capabilities and support the circular economy through AI, the platform economy and digital design. With recent advances in smart energy, electricity costs for data centres remain relatively low and Finland allows the selling of recovered heat from data centres[21].

Digitalisation is considered a cross-cutting topic and treated as such in particular in the domains of bioenergy, waste-to-value, smart grids, energy storage and smart buildings.

The **German** Ministry of Economic Affairs supports the development of more energy efficient and climate-friendly production processes and incentivises efforts towards climate change mitigation and industrial growth[22]. Germany is also aiming to reduce carbon emissions in electricity generation, heating and industrial companies by boosting renewable energy, energy efficiency and more climate-friendly production processes.

The Action Plan called 'Natural.Digital.Sustainable'[23] launched by the German Federal Ministry of Education and Research (BMBF) aims to lay the foundation for responsible and sustainable digitalisation. It includes education for competences for a sustainable, digital future.

A new initiative of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is the development of an **Environmental Digital Agenda**. The agenda at the moment presents 10 theses[24]:

- Make full use of the potential of digitalisation to support climate action
- Digital monitoring to promote the enforcement of environmental law
- Artificial intelligence to benefit people and the environment
- Environmental information to be easily accessible, freely available, valid and transparent
- Digitalisation to put clear limits on energy and resource consumption
- Digitalisation should create closed product cycles and make business more accountable to ensure the economic transformation is sustainable
- Digitalisation to promote sustainable consumption and mobility, and to raise awareness of the environmental impacts of our actions
- Digitalisation to be driven by sustainability-oriented research
- Digitalisation to be based on a strong civil society, broad participation, and good digital and environmental education
- Digitalisation in which today's new forms of work and collaboration are reflected in organisational cultures.

The agenda will be further refined during the German EU Council Presidency in the second half of 2020.

In the **Netherlands**, the Digital Strategy[25] focuses on preparing the country for the digital future. One of the goals of the strategy is to develop a flexible energy system and make the energy supply more sustainable to fight climate challenge. This is expected to be achieved thanks to intelligent energy networks, allowing a more efficient use of existing infrastructure and new market models. According to this digital strategy, digitalisation helps increase food safety and reduce the environmental impact of agriculture.

Three sustainability objectives are highlighted:

- Smart and sustainable mobility
- Sustainable and safe food supply
- A flexible energy system.

According to the Dutch Circular Economy Strategy, digital platforms and developments such as blockchain make a sharing economy possible. Further digitalisation and the development of big data will enable a much more accurate, local and efficient organisation of processes and systems. This is

[21] https://www.businessfinland.fi/en/do-business-with-finland/explore-finland/ict-digitalization/data-centers/
[22] https://www.bmwi.de/Redaktion/EN/Dossier/modern-industry-policy.html
[23] "Natürlich.Digital.Nachhaltig" – Ein Aktionsplan des BMBF, https://www.bmbf.de/upload_filestore/pub/Natuerlich_Digital_Nachhaltig.pdf
[24] Get the environment into those Algorithms! – The BMU's key points for a digital policy agenda for the environment. https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Nachhaltige_Entwicklung/eckpunktepapier_digitalisierung_en_bf.pdf
[25] https://www.government.nl/topics/enterprise-and-innovation/documents/reports/2018/06/01/dutch-digitalisation-strategy

demonstrated, for instance, by 'smart cities, industry, and mobility' developments, resulting in a much more efficient use of raw materials and energy[26].

At a regional level, Groningen launched a specific policy agenda to connect digitalisation and green chemical industry by increasing energy efficiency, efficient production and encrypted processes. With the help of digital technologies, it aspires to reach up to 30% power savings[27].

2.2 Fostering bottom-up initiatives

Other countries address the positive impacts of digitalisation on climate and the environment through their circular economy strategies or through bottom-up initiatives.

Sweden has committed to make the country fossil-fuel free by 2045 and put in place several measures and funding schemes to decarbonise its industry and businesses. In the 'Smart Industry – a strategy for new industrialisation for Sweden'[28], sustainable production (resource efficiency, environmental considerations) is chosen as one of the four focus areas. The following actions have been put forward:

- Development or improvement of technologies, goods and services to reduce emissions, use of harmful substances and use of energy, and increase resource efficiency, reusability and recyclability
- Explore the potential of new digital technologies to transit to a fossil free and circular economy
- Encourage circular business models
- Ensure that regulations and other mechanisms promote resource efficiency, environmentally friendly production and a sustainable supply of raw materials.

In 2020, the Swedish government will launch four new innovation partnerships to help meet a range of societal challenges, where one will foster the digital transformation of businesses and another one concerns climate change and the circular economy. Cross-cutting working groups are expected to help bridge these two initiatives. The partnership between public actors, business and academia will create innovative solutions that strengthen competitiveness and contribute to sustainable development.

The Swedish approach follows a bottom-up process in the question of coupling digital objectives with green ones. Government initiatives build upon and aim to amplify these local and regional endeavours in fields such as mobility, smart cities, sustainable mining and mechanics. There are several industry and civil society initiatives that prove to be important examples to follow.

The Committee for Technological Innovation and Ethics (Komet) was established by the Swedish Government in 2018 with the objective of reducing uncertainty around existing regulations and creating the conditions to accelerate the use of the new technologies that enable the fourth industrial revolution.

Figure 1: Addressing the sustainable development goals through the Committee for technological innovation and ethics in Sweden

Source: Committee for technological innovation and ethics, Anna Friden presentation, Drive Sweden Forum, September 2019

Recently, the Swedish Energy Agency prepared a plan to use artificial intelligence to deliver solutions to the power sector transformation towards climate neutrality. Other enabling technologies that are strongly built upon include utility-scale batteries, Internet of Things and big data.

In **Austria** energy and resource efficiency are one of the strategic objectives set out in the industrial policy agenda 2016-2020. The Digital

[26] A Circular Economy in the Netherlands by 2050, https://www.government.nl/topics/circular-economy/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050
[27] Provinzie Groningen: The promising connection Digitalisation and sustainable energy in the province Groningen
[28] Smart Industry – a strategy for new industrialisation for Sweden, https://www.government.se/498615/contentassets/3be3b6421c034b038dae4a7ad75f2f54/nist_statsformat_160420_eng_webb.pdf

Strategy has not outlined any specific objective related to the environment, nevertheless, the Austrian Circularity Gap report highlights a specific measure to incorporate digital technology into the circular solutions, such as blockchains and material passports, to trace origins, win and secure trust in the quality of materials[29].

France has included policy measures that tackle climate change and the protection of the environment in its industrial policies. The goal is that all companies will be carbon neutral by 2050. In addition, the 2015 Energy Transition Law for Green Growth, most notably article 173, has strengthened mandatory carbon disclosure for listed companies and has introduced carbon reporting for institutional investors. Listed companies have to include in their annual report information on: financial risks related to the effects of climate change; explanation of measures taken by the company to reduce its effects; the consequences of climate change on the activities of the company and of the use of goods and services produced by the company.

This reporting is additional to the compulsory reporting on the social and environmental consequences of the activities of the company[30].

The **Spanish** Government presented its guidelines for the new 'Spanish Industrial Policy 2030'[31] in February 2019. The ecological transition is identified as a main challenge for the industry together with digitalisation. This new strategy defines as the second of its five key pillars to "Reconcile the progress of the industry with the sustainability and decarbonisation objectives of the economy". The main energy cost of Spanish industries is expected to increase, this is why the predictability, stability and competitiveness of electricity prices is essential in order to facilitate sustainable industrial activity. The decarbonisation of the energy system will meet this expectation. Until it becomes a reality, the evolution of the energy cost of the industry must be monitored.

Sustainability is defined as one of the 10 axes of industrial policy action. The activities proposed under this axis include the following:

- Regulatory development of the Statute for Electro-intensive Consumers
- Normative development of so-called 'closed distribution networks'
- Implement support measures for high efficiency cogeneration associated with production
- Make a transparent evaluation and monitoring of the evolution of the regulated costs of the electrical and gas systems
- Boosting energy efficiency in industry and the development of technologies and innovations in this field for each industrial subsector
- Strengthen electrical interconnections with Europe.

The Spanish 'Industria Conectada 4.0' Strategy was approved in 2015 and does not contain any explicit objective related to climate neutrality, but in all industrial policies climate neutrality is included as a horizontal objective.

The Spanish Circular Economy Action Plan refers to digital technologies as an opportunity to make a leap in the capacity of production means and to increase both the flexibility of the productive process and the efficiency in the use of resources such as space, energy, raw materials and time. In addition, it recommends linking the concepts of Industry 4.0 and circular economy, and incorporating requirements related to the circular economy in assessing applications for financial support under the 'Connected industry initiative'.

The coordination of digital and circular economy related initiatives is carried out by different working groups and inter-ministerial and inter-administrative committees, such as the Inter-ministerial Committee on Circular Economy and the Inter-autonomic Working Group on Circular Economy. Another example is the recently created 'Secretary of State for Digitalisation and Artificial Intelligence', which is part of the Ministry of Economic Affairs and Digital Transformation but will also collaborate with the Ministry of the Environment, where one of the objectives will be to develop and promote digital measures that help in solving environmental problems. A working group has also been created on sustainability, decarbonisation in industry and alternative technologies within the framework of the Sectorial Conference of

[29] The Circularity Gap Report Austria: Closing the Circularity Gap in Austria https://www.ara.at/fileadmin/user_upload/Downloads/Circularity_Gap_Report/CGR_Austria_Endversion.pdf

[30] French Energy Transition Law: Global Investor Briefing, https://www.unepfi.org/fileadmin/documents/PRI-FrenchEnergyTransitionLaw.pdf

[31] Directrices Generales de la Nueva Politica Industrial Española 2030, https://www.mincotur.gob.es/es-es/gabineteprensa/notasprensa/2019/documents/docu%20directrices%20generales%20de%20la%20pol%C3%ADtica%20industrial%20española.pdf

Industry, in which the Ministry of Industry, Commerce and Tourism and the competent bodies of the autonomous regions participate.

2.3 Industrial strategies with green investments

Countries such as the Czech Republic, Greece and Italy dedicate importance to green investments in their industrial strategies.

In **Italy**, discussions on green industry have started relatively recently. In 2017, the Italian Ministry of Economic Development launched the Industry 4.0 National Plan, which aimed at supporting industrial change through measures to promote investments in innovation, technology and skills development. The Plan is now called 'Transizione 4.0', which represents the new national industrial policy programme for the years 2020-2022. The plan dedicates greater attention to innovation and green investments. Among its objectives, Transition 4.0 aims to increasingly incentivise the circular economy and IT systems. In addition, resources for research and innovation 4.0 include budget allocation to research and development projects in 'Digital Agenda' and 'Sustainable Industry'.

In 2019, the Italian government and parliament published the Budget Law 2020, which presents a greater focus on environmental objectives. For instance, the Budget Law includes the establishment of a plan for public investments for the development of an Italian Green New Deal, through the creation of a fund of €4.24 bn for the years 2020-2023. Part of the fund will be dedicated to interventions aimed at the reduction of greenhouse gas emissions.

In addition, Italy has proposed some forward-looking measures which focus on sustainable innovation. The Italian Ministry for technological innovation and digitalisation has developed the 'National Strategy for the technological innovation and digitalisation of Italy 2025'. The strategy presents three key challenges to address, building on the UN Sustainable Development Goals (SDGs):

- Digitalisation of society
- Innovation of the country
- Sustainable and ethical development.

In **Greece**, the government presented 'Greece: a growth strategy for the future'[32] in 2018, where one of the objectives is to green the economy. Greening the economy will not only foster growth, investment, creation of jobs and SMEs, but will also reduce carbon footprints and emissions, improve resource efficiency, the reuse of secondary materials, innovation and investment in new technologies, the development of new skills and the use of talent, knowledge and research at home, and the strengthening of the social economy. The measures presented include the development of the circular economy, waste management and recycling, and encouragement of business involvement in sustainable practices. The strategy also considered how tax alleviation regimes could be put in place for companies' investments in frontline environmental and climate-friendly R&I and technology.

The **Czech Republic** has approved a cross-sectorial strategy called the Digital Czech Republic that addressed the effects of digitisation on the economy and society. The strategy highlights the positive effect and contribution of digitalisation in reducing the use of paper and waste (cars, offices, furniture, warehouses, etc). The increased use of digital technologies is expected to increase the related electricity consumption. However, a decrease in other areas, such as more efficient ways of providing services or a reduction in services provided in traditional ways, is also expected as a consequence of digitalisation. When it comes to Industry 4.0, the Czech strategy also recognises the importance of resource-efficient, energy and environment-related legislation for industry and industrial transformation. It also mentions the importance of paying attention to potential failures of systems that may cause a negative impact on human health and the environment.

[32] Greece: a growth strategy for the future, http://www.mindev.gov.gr/wp-content/uploads/2018/09/Growth-Strategy.pdf

Figure 2: Review of examples of national digital and circular economy policies (not exhaustive)

	Industrial strategy	Digital strategy	Circular economy strategy	Policy measures
Austria	Energy efficiency		Track and optimise resource use and strengthen connections between supply-chain actors through digital, online platforms and technologies.	
Czechia	Reuse of waste			
Denmark		Smart City solutions and role of data		Digital circular options and data
Finland	Sustainable economic growth	Intelligent energy, climate neutral industrial processes and smart mobility		Database to enhance the circulation of materials
France	Digitalisation of mobility services	Smart cities Ecological mobility New materials Green chemistry	Enabling networking, access to information and data for citizens, support for decision-making and the production of new services	
Germany	Energy transition			Environmental Digital Agenda
Italy	Resource efficiency			Technologies for Living Environments Borghi di futuro
Netherlands	Resource efficiency and raw materials	Flexible energy systems	Blockchain and the sharing economy, smart cities, industry and mobility	Energy optimisation Precision farming
Spain	Ecological transition Boosting energy efficiency		Using digital technologies to increase the flexibility of productive processes and resource efficiency	Innovation projects Cluster policy (eg. Basque Aclima cluster)
Sweden	Renewable material, energy, sustainable mobility		Resource efficiency	AI for energy Green data centres

Source: Technopolis Group

Section 3

3. Policy measures at national, regional and city level

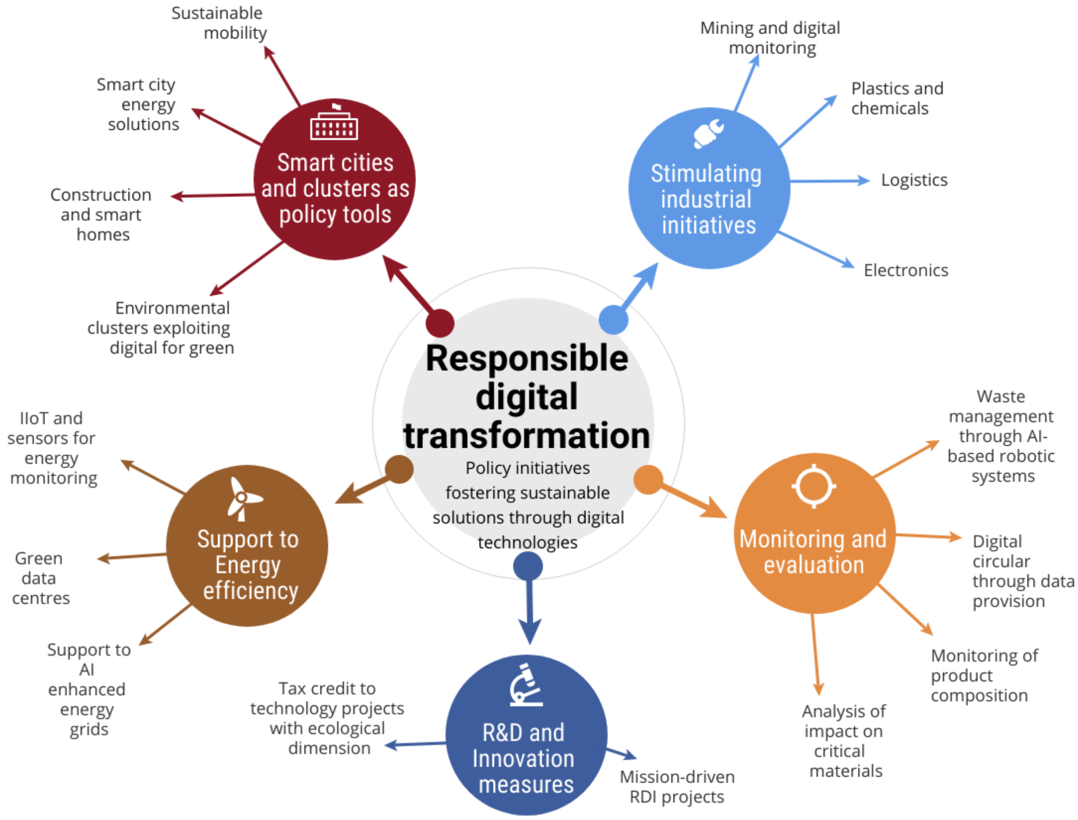
Currently, **there are a very lilited number of policy measures** that aim explicitly at fostering the use of digital technologies to solve climate or environment-related challenges. The most common policy initiatives target **energy, resource efficiency and mobility**.

Digital solutions to environmental problems have been supported through various R&D and innovation programmes, although not as an explicit objective of these policy measures. Several countries also use the concept of smart cities, clusters and local ecosystems to trigger positive linkages. Regulatory initiatives related to digital transformation of society and the environment have also been launched. In several countries, we find interesting voluntary initiatives by local and industrial stakeholders.

In general, it is not yet on countries' policy agendas to commission studies or launch a thorough reflection on the **impact of digital transformation, digital factories or any digital measures on the environment and climate,** accounting for the rebound effects, or the positive and negative consequences.

In this section we review policy measures especially at national level but also regional and local level which aim to support the circular economy, the environment and the climate, enabled by digital technologies (see Figure 3).

Figure 3: Types of responsible digital transformation policy measures



Source: Technopolis Group, 2020

3.1 Research and innovation programmes fostering responsible digitalisation

Austria: COMET Competence Centres

The Austrian national programme COMET[33] (Competence Centres for Excellent Technologies) is a technology policy initiative that aims to focus existing and develop new competences by collaborating with international researchers, scientific partners and companies. Although there are no dedicated centres to couple digital technologies with the circular economy, several supported centres and projects currently do so. For instance, the COMET Competence Centre for Recycling and Recovery of Waste 4.0 (ReWaste4.0) – located in Steiermark – is a long-term oriented, innovative and cooperative project fostering waste management and new Industry 4.0 approaches based on digital networking, communication between waste quality and plant performance and enhanced by robotics technology. The alpS Centre for Climate Change Adaptation encourages future role models for a competitive, sustainable and energy-optimised alpine tourism, based on snow management modelling driven by big data, development of an energy management system, and a concept for e-mobility. The AdaptInfra project supported the development of remote sensing and monitoring of inaccessible slopes in mountain regions with the help of drone-based surveying.

Spain: R&D and innovation projects

In Spain, the link between digital technologies and sustainability is addressed through the selection of research and innovation projects for support. The Centre for Industrial Technological Development (CDTI)[34] supports industrial R&D projects focused on the fight against climate change, energy efficiency, circular economy and sustainability. Another instrument, called Cervera Transfer Projects, supports individual R&D projects by companies collaborating with National Technology Centres and focusing on technologies defined as priorities. Some of the priority technologies respond directly to the problems of sustainability, such as eco-innovation and energy transition, and others will represent an important contribution to it (advanced materials, intelligent manufacturing, deep learning and artificial intelligence). Projects must be contracted to the state-level Technological Centres to perform certain activities. The costs financed include personnel expenses, instruments and material, contractual research, technical knowledge and patents acquired among others.

Italy: Cross-Tech Hub

The Cross-Tech Hub Italia[35] aims to create and develop technological hubs across industries through public-private partnerships in coordination with related ministries. The main technologies will be AI, cybersecurity and 5G, and the main sectors will be autonomous and sustainable mobility, robotics, and the 'made-in-Italy' sectors (manufacturing, tourism, food, fashion, etc.).

The 2020 Budget Law introduced a tax credit for R&D, innovation and design, with the objective of stimulating investments in these areas and sustaining 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 digital innovation, which amounts to 10% of eligible expenses with maximum annual amount of €1.5 m.

SBIR pre-commercial public procurement competition in the Netherlands

The Dutch Ministry of Economic Affairs organised a competition for blockchain applications in the framework of the Small Business Innovation Research Programme SBIR[36] in 2017. The sum of €500,000 was made available for the development of blockchain solutions to sustainability challenges such as energy. The competition boosted the development of blockchain and provided businesses with the opportunity to grow.

3.2 Energy solutions

Sweden, Germany, France: green data centres through sustainable energy

In a new initiative in Sweden, data centres have been transformed according to the circular economy model as interviewees highlighted. Data centres are the most important control centres of the Internet. Industrial Internet, mobile-connected objects, Internet of Things, health applications and 5G will lead to a huge number of end devices and an enormous

[33] https://www.ffg.at/en/comet-competence-centers-excellent-technologies
[34] https://www.cdti.es/

[35]https://innovazione.gov.it/assets/docs/MID_Book_2025.pdf
[36] https://business.gov.nl/subsidy/small-business-innovation-research/

increase in traffic volume. Current data centres feature huge computing power, massive storage capacities and very high performance, based on centrally stored and processed data. The energy used is growing along with the amount of data stored, processed and communicated.

In Germany, a programme for climate protection in relation to data centres has been launched. This programme is intended to support local authorities in investing and optimising data centres. These measures can include, for example, the future use of free cooling, heat-flow management, or possibilities for waste heat utilisation. The investments will also be used to retrofit or improve hardware components such as servers, cooling systems and emergency power supplies, as well as to carry out energy monitoring. The implementation of these measures is a prerequisite for the certification of data centres with the 'Blue Angel' label. The programme can also be used to finance staff training[37].

In France, the Natixis bank's data centre in Marne-La-Vallée supplies water at 55 °C to heating systems in an area undergoing urban development, as well as to the local Val d'Europe water sports centre. The Stimergie company has developed a system which allows the recovery of 1 MWh of heat per server per year, which represents 60% of the heat generated, i.e. the servers' energy consumption is reduced by more than half. The company has signed several contracts to install this system elsewhere in France, including at a block of 40 flats in Nantes and the swimming pool at La Butte aux Cailles in the 13th arrondissement (metropolitan district) in Paris[38].

Eureka SENDATE data centres

Data centres need sustainable, cost-effective and efficient solutions to power them, and the excess heat from data centres needs to be reused to power homes, cities and the economy. Research institutes in Sweden are working on repurposing the heat generated from data centres into greenhouses in order to extend the growing season. Sweden is also involved in a pan-European project called SENDATE[39], which is a cluster project in the framework of EUREKA funded by Germany, France, Finland and Sweden. The goal of the SENDATE research programme is to provide a secure, flexible and low latency distributed data center approach to support new application scenarios. Similarly, the Code of Conduct for Data Centres, an initiative led by the Joint Research Centre of the European Commission, aims to improve the energy efficiency of data centres. The European Commission will support a wider business deployment of this initiative, including consideration of commercialising the scheme to increase adoption.

Smart Energy Finland

The Smart Energy Programme[40] Finland is organised by Business Finland and particularly focusses on technological and digital solutions to energy generation and consumption, along with related innovation. To boost the overall economy's innovative edge in this domain, a total of €100 m in funds has been and will be made available to companies between 2017 and 2021. The programme does not only focus on the value chain of energy systems and smart buildings but highlights the specific role of IoT, AI and digitalisation as horizontal cross-cutting issues[41].

German Recycling Management Act and the Digital Agenda

As part of the German Digital Agenda, a 'duty of care' for retailers has been introduced as part of the Recycling Management Act. The aim of this is to conserve resources. Due to the constant emergence of new retailers and providers in online shopping, there are also more and more returns where the goods are not reused after being returned. Goods worth several billion euro are destroyed every year[42].

3.3 Regional ecosystems, smart cities, clusters

Smart cities

Smart city initiatives are increasingly wide-spread and provide one of the popular solutions to align digital and green policy objectives. Smart mobility and smart energy grids all rely on digital technologies such as automation, the Internet of Things and machine learning that make current city practices more sustainable and ultimately improve citizens' quality of life. For instance, among many others, France, Denmark and Finland have set themselves the

[37] https://www.ptj.de/projektfoerderung/nationale-klimaschutzinitiative/kommunalrichtlinie/rechenzentren
[38] Villani et al (2018). For a meaningful artificial intelligence: towards a french and european strategy
[39] https://www.celticnext.eu/project-sendate/
[40] https://www.businessfinland.fi/en/for-finnish-customers/services/programs/smart-energy-finland/
[41] Eco-innovation observatory
[42] Eco-innovation Observatory Country profile Germany 2018-2019

goal of being a reference for smart cities and have included this objective in their most recent digital agendas.

Italy: regional and local ecosystems for technologies and the environment

The Technologies for Living Environment Cluster[43] aims to develop technologies and solutions which impact mainly two key aspects of the Italian and European societies and economies: the aging population and requirements for energy and safety in living environments. Europe, just like other developed world regions, is undergoing a demographic transition that is bound to radically transform the way in which the living environments of our society are structured, whether houses, working environments or public environments. However, an ageing population implies not only challenges but also opportunities for citizens, social and health systems, industry and the European market.

Germany: digital services for people living in sparsely populated areas

In Rhineland-Palatinate, the Land's (regional government) Ministry of Internal Affairs and Sports, and the Fraunhofer Institute for Experimental Software Engineering, are implementing a project to digitise the supply of goods, communication, mobility and e-government with a focus on digital solutions for people living in sparsely populated areas. An example of the measures implemented is a local online marketplace (BestellBar) and a mobile app based on a voluntary delivery service (LieferBar) where volunteers deliver parcels to customers who live on the routes along which they travel, thereby earning credits to be used in other parts of the system; and a local news portal (DorfNews) and mobile app (DorfFunk), which enable the municipalities to inform residents quickly and automatically, integrating existing news sources from the web and social media[44].

Spain: Basque Environmental Cluster and Environment 4.0

Aclima[45], the Basque Environmental Cluster has committed itself to the Basque Environment 4.0 strategic areas and to exploring the opportunities offered by the Internet of Things, big data, robotics, artificial intelligence, etc. The positive potential impacts of digital technologies are seen in resource efficiency, risk management, monitoring and management of biodiversity and sustainable cities. Drones play an increasing role in fields and farming. In combination with monitoring through different types of sensors, predictive models and a judicious interpretation of the data, agriculture's accuracy, speed, reliability, safety at work and energy efficiency can be improved, minimising environmental impacts. The manufacturing and construction industries can also take advantage of new technologies to improve efficiency in the consumption of raw materials, water and energy, and in the control of their environmental impacts and the health of the surrounding society. New technologies have also started to improve the management and protection of the most sensitive natural areas and their biodiversity. In addition, the management of drinking water and sanitation networks in cities can be improved by data and digital technologies.

3.4 Smart mobility

Spain: electric vehicles

Electric vehicle technology is being significantly promoted by a range of aid programmes, as well as the coordination and development of a National Framework of Action for alternative fuels along with their reports and follow-up. Initiatives include collaboration with third countries such as with the Chinese business platform for the EV100 electric vehicle. Strategic documents, such as the Comprehensive Strategy to support the automotive sector, lay the foundation for the transformation of the sector towards new sustainable mobility

Finland: Mobility as a Service solutions

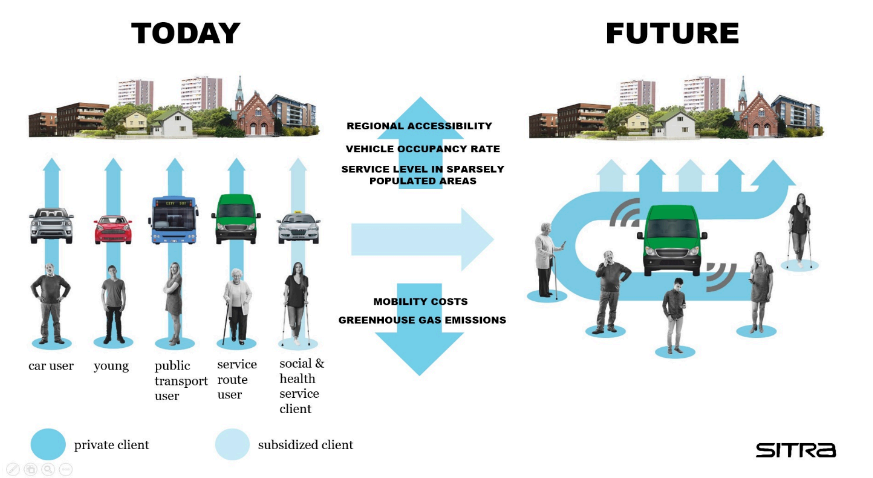
New technologies, innovative Mobility as a Service (MaaS) solutions[46], and close cooperation between the public and the private sector may serve as a springboard for the development of services. This cooperative project is a result of a funding call for project proposals on regional mobility organised by Sitra during the first half of 2018. Four companies are working together on creating a digital platform, based on the requirements set by the practical challenges and needs of three

[43] https://www.researchitaly.it/en/national-technology-clusters/technologies-for-living-environments/
[44] Sources: https://www.digitale-doerfer.de; https://enrd.ec.europa.eu/sites/enrd/files/tg_smart-villages_casestudy_de.pdf.
[45] https://aclima.eus/en/
[46] https://futuremobilityfinland.fi/cases/maas-global-mobility-as-a-service/

different pilot regions. At the same time, cooperation between the public and the private sector is promoted. The project will thus create preconditions and lay the foundation for a cost-effective service model that can also be introduced in other regions. The platform is based on open technical interfaces, which enables its introduction elsewhere in Finland and abroad.

3.5 Monitoring resource consumption

Figure 4: Mobility as a Service (MaaS) in Finland



Denmark: supporting digital circular options by commercial use of data

Technological developments in the digital field, and opportunities for developing new business models, move faster and faster. The increased use of digital sensors, and Internet of Things solutions that can measure material consumption, quality and quantity, have resulted in the constant generation of massive amounts of data related to different material flows. These data represent potentially valuable information for enterprises, since data can contribute to transparency about which materials are found in concrete products and buildings, where they are found, and which substances they contain. Data may also work as a driver of innovation in terms of developing new solutions and services that contribute to an optimisation of material flows. For instance, it is possible to reduce transport costs, and thus increase the economic profit from recycling, if the waste bin can tell the waste collector when it needs to be emptied.

Finland: data to enhance circulation of materials

Currently, there is no precise data on the quantity, quality and composition of the materials used in the human-made environment, ranging in scale from buildings to cities and beyond. To enhance the reuse of materials, there should be more information available on the composition, total amounts and geographical locations of materials in use or available for recycling. The Finnish National Waste Plan to 2023[47] aims for a shift from recycling to a circular economy. The plan is based on the Waste Act, and it also sets goals concerning construction and demolition waste. Among other things, it aims to reduce the amount of waste from the construction sector, enhance the use of construction and demolition waste as reusable materials and improve the precision and accuracy of statistical data on construction and demolition waste. In collaboration with Sitra, the Ministry of the Environment has set out to explore the possibility of establishing a building database. A preliminary study on the matter was carried out in 2019 in partnership with the Finnish Environment Institute, VTT Technical Research Centre of Finland Ltd. and the University of Tampere. Based on the study, an information service on materials will be developed, enabling the management of the quantity and location of materials in use or available for recycling.

3.6 Fostering voluntary industrial initiatives

Interviewees highlighted the importance of working together with industry and foster the emergence of industrial and local initiatives that use digital technologies to solve environmental challenges.

[47] https://www.ym.fi/en-US/The_environment/Waste/The_National_Waste_Plan

Estonia: AI-enhanced forestry

Estonian forest management companies use forestry software to conveniently manage forests, manage forest resources and plan various types of forest operations. Digital technologies support forestry in various aspects. AI/ML-based software can manage maintenance, evaluate forest health or organise logging work, optimise truck routes or track the logging process[48].

Sweden: sustainable mining

One example of a voluntary industrial initiative is sustainable mining in Sweden. LKAB, ABB, Epiroc, Combitech and Volvo Group joined forces with the goal of setting a new world standard for sustainable mining[49]. The sustainable mine of the future requires new control systems, new and developed mining equipment, and complex and efficient management systems to meet future demands on a sustainable industry. After 2030, LKAB is scheduled be ready to mine iron ore deeper in the mines in Kiruna and Malmberget, to ensure long-term competitiveness. This presupposes that decisions will be made in the mid-2020s for one of Sweden's largest industrial investments ever.

Slovenia: digital solutions for more sustainable farming

Slovenia has made recent progress in supporting sustainable agriculture by using digital technologies that can enable in particular smart farming or food traceability. Agricultural companies and farms have been introducing more and more digital solutions for sustainable farming[50].

Spain: plastics, chemicals and steel

In Spain, voluntary initiatives by industrial sectors are also considered as important, such as in the plastics sector (Plastics 2030, Plastics Europe[51]), the chemical sector (SusChem) or the paper sector. Other sectors have developed examples of circularity, such as the steel sector, which has demonstrated steel production from 90% scrap steel, or glass manufacturing.

[48] https://estoniantimber.ee/best-practices/digital-revolution-in-the-estonian-forestry-and-wood-industry/
[49] https://www.lkab.com/en/about-lkab/technological-and-process-development/research-collaborations/new-world-standard-for-sustainable-mining/
[50] Eco-innovation Observatory Country profile Slovenia 2018-2019
[51] https://www.plasticseurope.org/en/newsroom/press-releases/archive-press-releases-2018/plastics-2030-voluntary-commitment

Appendix A: Interviews

Table 1: List of interviews conducted during the preparation of the report

Country	Organisation
Czech Republic	ENVIROS, s.r.o
Finland	Business Finland
Germany	VDI Verein Deutscher Ingenieure e.v.
Italy	Ministry of Economic Development
Spain	Subdirectorate General for Emissions Trading and Flexibility Mechanisms, Spanish Office of Climate Change (OECC), Ministry for Ecological Transition
Sweden	VINNOVA

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. The project provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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