Environmental Protection Agency

Rialtas na hÉireann
Government of Ireland

CIRCULAR INSIGHTS SERIES

ROLE OF IRELAND'S DIGITAL SECTOR IN ACCELERATING THE TRANSITION TO A CIRCULAR ECONOMY

ENVIRONMENTAL PROTECTION AGENCY

The EPA is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

Regulation: *Implementing regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.*

Knowledge: *Providing high quality, targeted and timely environmental data, information and assessment to inform decision making.*

Advocacy: *Working with others to advocate for a clean, productive and well protected environment and for sustainable environmental practices.*

Our responsibilities include:

Licensing

- Large-scale industrial, waste and petrol storage activities;
- Urban waste water discharges;
- The contained use and controlled release of Genetically Modified Organisms;
- Sources of ionising radiation;
- Greenhouse gas emissions from industry and aviation through the EU Emissions Trading Scheme.

National Environmental Enforcement

- Audit and inspection of EPA licensed facilities;
- Drive the implementation of best practice in regulated activities and facilities;
- Oversee local authority responsibilities for environmental protection;
- Regulate the quality of public drinking water and enforce urban waste water discharge authorisations;
- Assess and report on public and private drinking water quality;
- Coordinate a network of public service organisations to support action against environmental crime;
- Prosecute those who flout environmental law and damage the environment.

Waste Management and Chemicals in the Environment

- Implement and enforce waste regulations including national enforcement issues;
- Prepare and publish national waste statistics and the National Hazardous Waste Management Plan;
- Develop and implement the National Waste Prevention Programme;
- Implement and report on legislation on the control of chemicals in the environment.

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- Engage with national and regional governance and operational structures to implement the Water Framework Directive;
- Monitor, assess and report on the quality of rivers, lakes, transitional and coastal waters, bathing waters and groundwaters, and measurement of water levels and river flows.

Climate Science & Climate Change

- Publish Ireland's greenhouse gas emission inventories and projections;
- Provide the Secretariat to the Climate Change Advisory Council and support to the National Dialogue on Climate Action;
- Support National, EU and UN Climate Science and Policy development activities.

Environmental Monitoring & Assessment

- Design and implement national environmental monitoring systems: technology, data management, analysis and forecasting;
- Produce the State of Ireland's Environment and Indicator Reports;
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- Oversee the implementation of the Environmental Noise Directive;
- Assess the impact of proposed plans and programmes on the Irish environment.
- Environmental Research and Development
- Coordinate and fund national environmental research activity to identify pressures, inform policy and provide solutions;
- Collaborate with national and EU environmental research activity.

Radiological Protection

- Monitoring radiation levels and assess public exposure to ionising radiation and electromagnetic fields;
- Assist in developing national plans for emergencies arising from nuclear accidents;
- Monitor developments abroad relating to nuclear installations and radiological safety;
- Provide, or oversee the provision of, specialist radiation protection services.

Guidance, Awareness Raising, and Accessible Information

- Provide independent evidence-based reporting, advice and guidance to Government, industry and the public on environmental and radiological protection topics;
- Promote the link between health and wellbeing, the economy and a clean environment;
- Promote environmental awareness including supporting behaviours for resource efficiency and climate transition;
- Promote radon testing in homes and workplaces and encourage remediation where necessary.

Partnership and networking

- Work with international and national agencies, regional and local authorities, non-governmental organisations, representative bodies and government departments to deliver environmental and radiological protection, research coordination and science-based decision making.

Management and structure of the EPA

The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

- Office of Environmental Sustainability
- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

The EPA is assisted by advisory committees who meet regularly to discuss issues of concern and provide advice to the Board.

Circular Insights

Role of Ireland's Digital Sector in Accelerating the Transition to a Circular Economy

ENVIRONMENTAL PROTECTION AGENCY

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Foreword

The Environmental Protection Agency (EPA)'s *Circular Economy Programme* is supporting the Whole of Government Circular Economy Strategy. The overall approach of the Circular Economy Programme, which incorporates the National Waste Prevention Programme, is to influence behavioural change, support sustainable choices and inform policy towards the implementation of a circular economy.

One of the pillars of the Circular Economy Programme is Advocacy, Insights, Data and Coordination. The Circular Economy Programme is commissioning a series of *Circular Insights* studies on emerging and priority topics to build evidence and fill knowledge gaps to support circular economy policy. Through analysis of data, literature review, stakeholder interviews, and assessment of best and emerging practices, it is intended that these studies will offer insights relevant to policy makers, business and other circular economy practitioners and contribute to national discussions on circular economy.

This *Circular Insights* study has been carried out by KPMG under contract to the EPA.

Glossary[1 2 3 4]

Artificial Intelligence (AI)	a machine's capability to perform tasks which would normally require human intelligence
Big data (analytics)	large datasets that can be used to analyse and reveal patterns, trends and associations
Blockchain	distributed ledger that can be used to record and share information securely and enable online transactions
Dematerialisation	is delivering the same product or service using a percentage or none of the mass or material types.
Digitalisation	growing applications of digital technologies across the economy
Digital solutions	applications of digital technologies to enable a transition from a linear to a circular system or economic model
Digital Twins	digital replicas of something that exists in the physical world, like a good, a process or a service
End-of-life handling	is how a material, component or product is treated (e.g. incinerated , recycled, repaired) at the end of the material, component or product's life cycle.
Internet of Things (IoT)	everyday physical objects or devices connected to the Internet, and which can identify themselves to other objects. IoT can be used e.g. to predict when machines need maintenance or to micromanage energy usage
Longevity	focusing on keeping resources in use and/or extending material, component, or product lifetime
Machine learning	subpart of AI, whereby a machine is trained to use large amounts of data and algorithms to find connections and perform tasks
Product as a service (PAAS)	selling the service provided by the product rather than the product itself
Renewability	refers to moving to systems that can renew themselves and are not finite
Subtractive manufacturing	controlled machining/material removal processes i.e. removing material from a solid block such as metal or plastic.
3D printing/additive manufacturing	computer processes which join or solidify materials to create a three-dimensional object, often using less material in comparison to traditional manufacturing methods

1 Available at: *DRCE_web.pdf (epc.eu)*

2 Available at: *https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf*

3 Available at: *Dematerialization - Circular Economy Guide (ceguide.org)*

4 Available at: *https://formlabs.com/eu/blog/additive-manufacturing-vs-subtractive-manufacturing/*

Executive summary

The circular economy aims to transition away from the traditional 'take, make, consume and dispose' linear economy to a circular economy which focuses on keeping resources in use and designing out waste, ultimately supporting the climate and wider sustainability agenda.

Digitalisation is identified as a key enabler for accelerating the adoption of a circular economy. Data and digitally-enabled solutions are already being leveraged to improve circularity across economies and there remains significant scope to strengthen this transition globally. Such solutions can optimise value chain management, improve value chain transparency, facilitate dematerialisation and waste-to-resource matching; however, these digital solutions must also be circular by design.

The engagement and research undertaken for this paper has informed the development of a suite of recommended opportunities for the public and private sector to accelerate a digitally-enabled circular economy in Ireland, summarised in the table below.

Opportunities	Action	Description	Relevant stakeholders
Digital solutions to improve circular data management, circular strategy development and iteration, and circular performance monitoring	Integrate digital solutions into operations to provide better management and access of data with a circularity focus	Government bodies and public and private organisations should integrate digital solutions such as Internet of Things and cloud computing into their operating systems to improve data management with a focus on circular thinking and circularity improvements.	• Government bodies • Public institutions • Corporates and SMEs
	Development of iteration and smart feedback loops	Digital solutions should be introduced to enable continuous learning and circular design improvements. Smart feedback loops can facilitate improvements in circular performance measurement enabling organisations to explore the next steps to iterate their design and continue to add value to their business and the system as a whole. Government regulation can drive adaptation and learning at a business level through circularity targets and annual disclosure requirements while using digital technologies to monitor non-movers.	• Government bodies • Public institutions • Corporates and SMEs

Opportunities	Action	Description	Relevant stakeholders
Customer, consumer and citizen circular economy value	Analyse citizen and consumer data to understand behaviour and values	Customers, consumers, and the public are key stakeholders in the transition to a circular economy. Digital enabled solutions, such as data analytics and machine learning, should be used by public and private organisations to analyse citizen and consumer data to understand their behaviour and the effectiveness of policy measures relevant for the circular economy or an organisation's circular economy offering in meeting consumer values.	• Government bodies • Public institutions • Corporates and SMEs
Development of digital engagement platforms	Circular and sustainability-related information should be communicated through digital solutions to drive further insight and understanding	The development of a circular economy may be disruptive, affecting all of society and requiring collaboration and participation between private and public entities, citizens and consumers. Government bodies and businesses should utilise digital platforms to raise awareness around the steps needed to create a circular economy, providing guidance on how consumers and citizen can play their part.	• Government bodies • Corporates and SMEs
	Digital communication and sustainability label(s) standardisation	Develop criteria on the type of information that should be shared on online platforms to avoid confusion and mistrust.	• Government bodies
	Digital communication platforms that are user-friendly and intuitive	Digital platforms need to be user-friendly and intuitive to engage consumers and the public, ensuring information is not lost or hard to find.	• Government bodies • Public institutions • Corporates and SMEs

Opportunities	Action	Description	Relevant stakeholders
Stakeholder partnership and innovation facilitation	Government bodies should promote collaboration and industrial symbiosis development and support circular business innovation increasing awareness on the interlinkages between digitisation and the circular economy.	Government bodies should act as a knowledge broker and provide platforms for joint data and information sharing. These platforms should also be used to increase the awareness among businesses and wider stakeholders on the interlinkages between digitalisation and the circular economy.	• Government bodies • Public institutions
	Private enterprises should engage with peers to further develop networks and work through barriers.	Private enterprises should explore ways to improve information transfer between businesses and develop collaborative data exchange platforms that protect their IP while enabling the transfer of data down value chains.	• Corporates and SMEs
Training on digital skills, data protection and privacy measures	Develop digital skills and knowledge of citizens and workers	Government bodies and public and private organisations should ensure that stakeholders in the digitally-enabled circular economy transition have the necessary skills to contribute most effectively. They should introduce reskilling and upskilling initiatives to adapt to the changing nature of work through digital solutions.	• Government bodies • Public institutions • Corporates and SMEs
	Increase awareness around personal data privacy and the benefits of digital solutions and engagement in data sharing	To maintain and increase trust in the digitally-enabled circular economy, government bodies and organisations should open dialogue channels and inform stakeholders on ways to ensure data privacy and the benefits digital solutions and data sharing can provide.	• Government bodies • Public institutions • Corporates and SMEs

Opportunities	Action	Description	Relevant stakeholders
Data guidelines and standards development for the free flow of data	Development of data access rules or guidelines for data exchange	Data needs to be collected, stored and transferred in a secure manner - protecting intellectual property, trade secrets and personal information to ensure engagement from all stakeholders. Clear rules at a national and international level, regarding who should have access to what data, when and how are necessary to refer to - removing some of the barriers relating to data sharing.	• Government bodies • Public institutions
	Development of guidelines for the free flow of data and minimum criteria for data collection	Government bodies can develop guidelines for the free flow of non-personal data and provide a set of minimum criteria for data collection, what information is needed and the benefits of exchanging information. Government bodies should provide businesses with incentives to engage in exchanging data to ensure information flows easily across the economy.	• Government bodies • Public institutions
Ensure digital solutions are designed and used in line with the aims of a circular economy	Drive circularity within the digital sector	Digital solutions must be designed and used in line with the aims of a circular economy. Digital solutions should be developed considering the principles of dematerialisation, and lifetime extension as well as integrating renewable energy.	• Government bodies • Public institutions • Corporates and SMEs
Addressing regulatory roadblocks for a digitally-enabled circular economy	Update regulation in line with a digitally enabled circular transition	Implement regulatory changes and identify the impacts they will have on both the digital sector and the transition to the circular economy ensuring changes enhance both sectors.	• Government bodies

1. Introduction

The circular economy is a largely untapped €1.8 trillion opportunity[5] and a key instrument to help achieve the Paris Agreement 1.5°C target whilst delivering an estimated 700,000 jobs by 2030[6]. The circular economy aims to move away from the traditional 'take, make, consume and dispose' linear economy and promote longevity and optimal (re)use as well as a focus on reducing the use of raw materials. Improved resource use is critical to achieving our climate ambitions and sustainable development, which is reflected in the growing number of policies, plans and strategies that aim to transition existing linear economies to circular economies.

Digitalisation can be a key enabler and accelerator of the circular economy. Digitalisation refers to the application of digital technologies across the economy[7]. Data and digitally-enabled solutions can be used to improve business models and associated products and services[8]. These solutions help to optimise value chains by improving the efficiency of design, production, distribution, consumption, reuse and other waste prevention, and waste management including recycling. Solutions such as online platforms, digital product passports, Big Data, Artificial Intelligence (AI), Blockchain and the Internet of Things (IoT) are already being used as springboards for companies and individuals to transition to more circular practices and lifestyles. Examples of existing and emerging solutions demonstrating the role digitalisation can play in accelerating a circular economy are provided throughout this paper as case studies to showcase best practice.

Ireland has a relatively strong digital performance in comparison to European countries, ranking 5th on the Digital Economy and Society Index – scoring well for the use of e-commerce by small and medium-sized enterprises (SMEs), digital public services and advanced digital skills. However, basic digital skills are currently lower than the EU average (53% compared to 56% respectively)[9]. This highlights the important role of strengthening basic digital competencies across the nation to ensure individuals are well positioned to grasp the opportunities of the digital economy.

Although digitalisation is not a panacea, if pursued in a sustainable way it can facilitate a more successful transition to a circular economy. However, digital solutions must also be circular in design – utilising the principles of dematerialisation, renewability, longevity, and improved end-of-life handling.

1.1 AIMS AND OBJECTIVES

The overarching aim of this paper is to inform and educate policymakers, businesses, and individuals on the role Ireland's digital sector can play in accelerating our transition to a circular economy. The findings of this study have been informed through engagement with circular economy experts and stakeholders with deep knowledge of the digital sector alongside a targeted desktop-based analysis of policy, leading industry reports, academic literature, and case studies.

This paper provides (1) an overview of the existing policy landscape at a global, European, national, and regional level, see Appendix A, (2) a description of the key barriers the digital sector faces when looking to support and accelerate our transition to a circular economy (3) an analysis of the key digital solutions to drive a circular economy and (4) a suite of opportunities to strengthen the integration of digitally-enabled circular solutions. The stakeholders engaged with as part of this study are listed in Appendix B.

5 Ellen MacArthur Foundation (2015)

6 Available at: *https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN*

7 Available at: *https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf*

8 Available at: *DRCE_web.pdf (epc.eu)*

9 Available at: *https://digital-strategy.ec.europa.eu/en/policies/countries-digitisation-performance*

2. Barriers To A Digital Circular Economy

Although the circular economy is identified as a key instrument to contribute to decarbonisation and to tackle the depletion of resources whilst providing economic opportunities, the global economy is estimated to be less than 10% circular[10]. Great strides have been made to drive a digitally-enabled circular economy, however its lack of penetration into mainstream operations is a result of existing barriers. These barriers must be remediated to transition to a successful circular economy. Common barriers and challenges cited in relation to establishing a digitally-enabled circular economy can be grouped into four key themes: behavioural, regulatory, financial and operational.

- **Behavioural:** Concerns around data privacy from both the private and public sector as well as from individuals can be a major barrier to the proliferation of a digitally-enabled circular economy. Tracking and tracing as well as understanding product make-up can help to improve circularity. However, these solutions in turn raise concerns around privacy, competitive advantage and data security. In relation to data security, the risk of unauthorised access and potential corruption to data can be a challenge to the successful integration of a digitally-enabled circular economy[11] [12]. Several solutions enabled through digitalisation, such as the sharing economy, result in a change in consumption habits and reluctance to adapt to these new mechanisms of consumption whether it be for example a lack of trust or inflexibility can inhibit their success[13]. From a business perspective, the risk of leaking proprietary information to competitors, for example through product passports, is a concern. Companies can be reluctant to share sensitive data due to the risk of losing control of it[14]. In relation to consumers, solutions that integrate IoT connectivity for product tracking also raise concerns around data privacy[15] [16]. These concerns cement the importance of ensuring a secure reputation of service providers in addition to effective privacy protection laws, such as the EU General Data Protection Regulation[17].
- **Regulatory:** Legislation can be outdated and can inhibit organisations from embedding the circular economy into their business. In relation to data and digitally-enabled solutions, regulatory barriers can hinder the free flow of non-personal data – a challenge that can only be addressed whilst ensuring information and data security is maintained.

10 https://www.circularity-gap.world/2022#Intro

11 http://norden.diva-portal.org/smash/get/diva2:1612604/FULLTEXT01.pdf

12 https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848

13 https://www.researchgate.net/publication/336304456_Why_Won't_You_Share_Barriers_to_Participation_in_the_Sharing_Economy_Completed_Research

14 http://norden.diva-portal.org/smash/get/diva2:1612604/FULLTEXT01.pdf

15 https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf

16 https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848

17 https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf

- **Financial:** Transitioning to circular business models requires a rethink of existing practices, investment in new technologies, upskilling employees, new product/service development and a transformation of current value chains. These investments can act as a barrier to uptake in companies with short pay-back periods in place, particularly if the future revenue impact of adopting circular business models is uncertain. In relation to the digital sector, investment in technologies is typically capital intensive, resulting in material upfront investment in hardware e.g. robots and sensors in addition to software[18]. Furthermore, companies that already have made significant capital investments in infrastructure not aligned with the circular economy may be unwilling to transition operations in the short to medium term.
- **Operational:** Adopting circular business models often necessitates a shift in the value chain. Circular business models require improved cooperation and collaboration with suppliers, customers, waste operators etc. which can be difficult for companies with complex supply chains. In addition, a lack of appropriate digital infrastructure (e.g. internet connectivity and cloud services) can act as a barrier for enabling a successful circular economy. In relation to the digital sector, currently there is inadequate digital infrastructure for connectivity (i.e. high-speed broadband, 5G) and cybersecurity in the EU[19]. Understanding the importance of appropriate infrastructure, the Government has set a target to ensure that all households and businesses will be covered by a Gigabit network service no later than 2028, with all populated areas covered by 5G no later than 2030[20].
- **Skills:** As with infrastructure, underdeveloped digital skills can impair effective digitalisation. At a national level, it is estimated that approximately 240,000 people were employed in the 'digitally intensive' sector in 2019[21]. However, the expected rapid acceleration and uptake of digital technologies will necessitate greater upskilling of the workforce and wider society to adapt to the digital revolution. As such, Ireland aims to increase the share of adults with at least basic digital skills to 80% by 2030 (compared to approximately 53% in 2019[22]) and to increase the number of individuals with higher-level digital skills to over 12,400 graduates, apprentices, and trainees by end-2022.[23]

18 *https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf*

19 Available at: *https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848*

20 Available at: *https://www.gov.ie/en/publication/adf42-harnessing-digital-the-digital-ireland-framework/*

21 Available at: *New Digital Strategy an important step in backing Irelands digital future - IBEC*

22 Available at: *https://digital-strategy.ec.europa.eu/en/policies/countries-digitisation-performance*

23 Available at: *https://www.gov.ie/en/publication/adf42-harnessing-digital-the-digital-ireland-framework/*

3. Digital Solutions to Drive a Circular Economy

Given the low level of circularity at a global level today, there remains significant scope for digitalisation to strengthen the transition to a circular economy, through, for example, dematerialisation, information sharing and optimised value chain management. However, progressing digitalisation is not without its challenges. While data and digitally-enabled solutions can improve efficiencies, they can also result in rebound effects leading to an increase in emissions, depletion of critical raw materials and generation of material volumes of e-waste – each of which is discussed later in this paper.

The following section presents an analysis of the outputs from stakeholder engagement and desktop research on the key emerging themes and state of play with respect to digitalisation enabling a more circular economy in addition to key insights and evidence of best practice.

3.1 OPTIMISING VALUE CHAIN MANAGEMENT

Digitalisation can make significant contributions to organisations' value chains and improve the overall operation of businesses. It can facilitate more sustainable design and production processes, extend the lifecycle of products through predictive maintenance or product as a service (PAAS) business models, and encourage the reuse, repair and recycling of these products[24].

The design phase is vital to determine the overall environmental impact of a product throughout its life span. It is estimated that the design phase can influence up to 80% of all-product related environmental impacts[25]. Designing products, components and materials that are sustainable, durable, can be disassembled, reused, repaired and recycled is vital to create a circular economy. Digital solutions such as 3D modelling and AI can offer designers a means to test and refine design suggestions with circular economy principles in mind. Materials can be compared, and structural designs altered virtually to manage the complex nature of balancing a range of environmental impacts, product and component functionality and end-of-life handling requirements that are compatible with a circular economy - ultimately designing out waste and pollution[26] [27]. For example, in the construction sector Building Information Modelling (BIM) is a solution for developing and managing information relating to a construction project over its life-cycle. BIM creates a digital description of the built asset by integrating 3D models and data on product, execution and handover information[28]. It helps to improve the efficiency of design and construction and can be used during the operational phase to manage the asset by providing real-time information about its performance[29].

Business model innovation, moving from manufacturing products to a service offering can reduce the impact on the natural environment, improve product durability, extend product lifespans and drive redesign in supply chains. PAAS business models can be offered in two forms; the products are either (1) offered entirely as a service, where the consumer purchases the result rather than the equipment or (2) services such as maintenance contracts are offered in combination with the product itself enhancing the

24 *The circular economy: Going digital (epc.eu)*

25 *Sustainable Product Policy (europa.eu)*

26 *The circular economy: Going digital (epc.eu)*

27 *New promises AI brings into circular economy accelerated product design: a review on supporting literature | E3S Web of Conferences (e3s-conferences.org)*

28 *https://www.thenbs.com/knowledge/what-is-building-information-modelling-bim*

29 *https://www.thenbs.com/knowledge/what-is-building-information-modelling-bim*

value of the business offering[30] [31]. The service element adds increased value to the product as resources are maximised through reuse, repair and recycling.

Digital solutions such as big data analytics, IoT and cloud computing are all enablers of the product to service business model innovations[32]. IoT sensors transmit valuable data on product usage and condition. These data when tracked and assessed by big data analytics allow service providers to optimise product use and plan for maintenance to maximise the longevity of the products[33] [34]. Digital sharing platforms enabled by cloud computing connect consumers to products without the consumer needing to purchase their own product to service their needs[35]. This sharing of products helps to reduce resource consumption - accelerating more circular practices. For example, the Dutch company Bundles offers a pay-per-use or rental model for home appliances leveraging IoT technologies to facilitate its PAAS offering to track water and energy usage as well as to optimise maintenance[36]. Bundles' business model sells washing cycles rather than washing machines to help consumers reduce cost and extend the lifetime of machines[37]. In terms of sharing assets, FLOOW2[38] is an online business-to-business (B2B) sharing marketplace for organisations to share underutilised assets such as company cars, office space, printing facilities and personnel.

Optimising production and manufacturing can provide economic benefits as well as circular economy improvements. There is a range of examples of industrial manufacturing utilising digital solutions to reduce environmental impacts, resource consumption and waste generated at the production stage. Digital solutions such as 3D printing offer on-demand products and services to consumers to help reduce costs, optimise production and produce inventory when necessary i.e. reducing the generation of surplus stock[39]. Intelligent and connected assets can enable predictive maintenance to allow manufacturers to identify developing issues while prolonging the operating lifespan of the machinery or asset component driving further efficiencies[40]. For example, Adidas and Carbon[41] [42] utilised 3D printing technology to create a 3D printed shoe - Futurecraft 4D. 3D printed shoes utilise less materials and easily recyclable parts. In addition, 10XL is a Dutch manufacturer of products ranging from furniture to boats made from recycled plastic waste. 10XL employs additive and subtractive manufacturing alongside design strategies of durability, disassembly and design for recycling as part of its circular business model[43].

30 *Product services for a resource-efficient and circular economy – a review - ScienceDirect*

31 *Sustainability | Free Full-Text | Circular Economy Business Models with a Focus on Servitization | HTML (mdpi.com)*

32 *Resources | Free Full-Text | Towards Circular Economy in the Household Appliance Industry: An Overview of Cases | HTML (mdpi.com)*

33 *Digital solutions for a circular electronics value chain - ITU Hub*

34 *Sustainability | Free Full-Text | Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies | HTML (mdpi.com)*

35 *Resources | Free Full-Text | Towards Circular Economy in the Household Appliance Industry: An Overview of Cases HTML (mdpi.com)*

36 *Digital solutions for a circular electronics value chain - ITU Hub*

37 *https://www.circle-economy.com/resources/bundles*

38 *https://www.floow2.com/how-does-it-work-en.html*

39 *The circular economy: Going digital (epc.eu)*

40 *Artificial-intelligence-and-the-circular-economy.pdf (mckinsey.com)*

41 *Carbon 3D Print Lattice Innovation — The adidas Story*

42 *The circular economy: Going digital (epc.eu)*

43 *https://www.nweurope.eu/projects/project-search/transform-ce-transforming-single-use-plastic-waste-into-additive-manufacturing-and-intrusion-extrusion-moulding-feedstocks-and-creating-a-new-circular-economy-model-for-nwe/business-case-studies/business-case-study-1-10xl/*

Digitalisation can play a role at the final stage of a product, component or material life-cycle improving the reuse, repair and remanufacturing of products. Products at the end of their life-cycle need to be inspected and treated for any damage sustained throughout their lifespan. Many of these digital solutions are built around AI algorithms to recognise and identify objects using cameras and sensors aiding used product assessment, sorting and disassembly. These technologies speed up the process of inspecting non-uniform products through automated assessment, providing recommendations on whether the product can be reused, resold or recycled to maximise value preservation. AI can also be used to automate the disassembly process altering the equipment based on the condition of the used item[44].

Digital platforms facilitate the reuse of products, components and materials through the sale of second-hand items. Reuse can be supported through after-market service providers utilising AI to manage reverse logistics, screening and testing, and repairing and refurbishing of second-hand products [45] [46]. The fashion industry has a growing number of digital marketplaces to facilitate the resale of used products, for example ThreadUp, Tradesy and Poshmark.[47]

Case studies

- A Californian based engineering firm, *Motivo*, use machine learning to optimise the design and manufacture of integrated circuits by incorporating best practices shortening the time to detect complex chip failures and reducing the waste generated in the manufacturing process through optimised design.
- *Teemill* is an e-commerce company that uses AI to improve sustainability within the fashion industry. Users create an account with Teemill and can design/customise a range of organic, sustainable products. Once a customer places an order, the customised artwork is printed onto the product and it is packaged and shipped by Teemill. When the product is worn-out, it can be returned through the Remill programme where it is remade into new products. Each product has a unique label that customers scan to return.
- *Circos* offers a subscription model for baby clothing (and maternity wear) through an online service platform. Members of Circos pay a monthly fee to access a range of high-quality clothing from different brands delivered to the consumer's door. Clothes are returned when outgrown or no longer needed and are either cleaned and reused or worn-out garments are recycled into something new[47].
- *HP instant Ink* is an ink cartridge replacement service that charges a fee based on the number of pages you print each month, and the printer sends ink level information to HP. When ink levels get low, HP automatically ships replacement cartridges.
- *M-Use* is a pay-per-use model for elevators developed by Mitsubishi. Elevators are fitted with sensors that measure usage and can determine the right type of maintenance required at the right time.
- *Optical sorting equipment:* In September 2021, it was announced that all soft plastics can be accepted in Irish recycling bins having previously been placed in general waste bins. This change was facilitated by the installation of optical sorting equipment at recycling facilities that can identify different polymers, enabling soft plastic to be separated and sorted for recycling. This system analyses the sensor data by AI determining what recycling stream the soft plastic needs to be sorted into.
- Several online trading platforms such as DoneDeal, Adverts, Thriftify, ebay, Facebook marketplace provide an avenue for second-hand goods to be sold and reused.

44 *Artificial Intelligence and the circular economy (ellenmacarthurfoundation.org)*

45 *Artificial Intelligence and the circular economy (ellenmacarthurfoundation.org)*

46 *Artificial-intelligence-and-the-circular-economy.pdf (mckinsey.com)*

47 Available at: *Increasing clothing use through subscription: Circos (ellenmacarthurfoundation.org)*

3.2 VALUE CHAIN TRANSPARENCY

Improving transparency across value chains is crucial for achieving a successful circular economy. Digitalisation can help to strengthen tracking and tracing whilst storing and sharing information securely[48] [49]. For example, digital passports provide information on a product's characteristics such as its origin, durability, composition, reuse, repairability and end-of-life handing, as demonstrated in the PANGAIA and Everledger case studies below. These passports can be efficiently accessed by scanning QR codes, electronic tags and digital watermarks. Digital passports offer several benefits, such as helping manufacturers to understand the environmental footprint of their products, providing end users with improved transparency on a product's impact enabling improved decision making and illustrating product composition for recyclers/waste handlers to facilitate improve end-of-life treatment. The ability of digital passports to improve information flow will facilitate the EU's Sustainable Products Initiative aim of making products placed on the EU market more sustainable[50]. In terms of tracking, developments in connected IoT systems can provide real time asset tracking which facilitates optimised use and maintenance[51]. For example, Swiss coffeemaker Thermoplan uses qiio's IoT solution to remotely monitor its automatic coffee machine usage in real-time, which optimises maintenance as Thermoplan now sends out technicians when actually required[52].

In addition, the safe storage and transfer of reliable information and data is key for facilitating the establishment of safe circular markets[53]. The irreversible or immutable nature of data within Blockchain makes it a very secure distributed ledger improving transparency, providing enhanced monitoring capabilities, and enabling secure transactions[54] [55] [56]. [57]

Case studies

- *Everledger* is working to improve battery lifecycle management and is developing solutions to register, track and transfer these products. Everledger is utilising the latest identification, data capture and blockchain technologies to develop a battery passport and connect batteries to the Everledger blockchain platform. The ability to trace batteries from manufacturing will enable improved life cycle management – with the aim of increasing reuse of batteries and reducing waste generation.[57]
- *TrusTrace* provides a platform built on AI, machine learning, blockchain and bots for supply chain transparency and product traceability in the fashion, food, and retail industries. The solution helps companies to understand the social and environmental impact of their supply chains, which in turn can drive more sustainable sourcing decisions. For example, Swedish retailer Coop used the TrusTrace platform to calculate the sustainability footprint of 10,000 products. Coop customers can scan registered products on an app to better understand and compare their sustainability aspects.

48 Available at: *https://ec.europa.eu/environment/ecoap/sites/default/files/eio5_eco-innovation_and_digitalisation_nov2020.pdf*

49 Available at: *https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf*

50 Available at: *https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-products-initiative*

51 Available at: *https://www3.weforum.org/docs/WEF_Intelligent_Assets_Unlocking_the_Cricular_Economy.pdf*

52 Available at: *https://qiio.com/press-releases/thermoplan-partners-with-qiio-for-iot-coffee-machine-solution/*

53 Available at: *https://www.era-min.eu/sites/default/files/publications/201023_ecera_white_paper_on_digital_circular_economy.pdf*

54 Available at: *https://weee-forum.org/wp-content/uploads/2021/10/Thought-Paper-2021.pdf*

55 Available at: *http://kth.diva-portal.org/smash/get/diva2:1589368/FULLTEXT01.pdf*

56 Available at: *https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848*

57 Available at: *https://everledger.io/the-battery-passport-and-the-future-of-the-auto-industry/*

Case studies

- *PANGAIA*, partnered with EON on their *Horizon Capsule* to print digital passports on care labels so that customers can scan a QR code and learn about the garment's lifecycle impact and care instructions. The company also uses EON's Circular Product Data Protocol to ensure resale, recycling and sorting partners have access to appropriate data to manage products from one lifecycle to another. The Protocol is a global classification system for apparel products in the circular economy that ensures product and material data is communicated in a consistent manner.
- *Circularise* is a supply chain transparency start-up that enables companies to track materials and products and verify their origins, certificates, and carbon footprint on a public blockchain. Circularise helps brand owners and OEMs to make sustainability claims that are backed by trustworthy data and enables manufacturers and suppliers to be recognised for their sustainability efforts. For example, Circularise partnered with Porsche to trace plastics from raw material production to the final car. Car owners can see what car is made of, where parts come from and what impact they have on the environment – traced and validated on a blockchain enabled digital infrastructure created by Circularise.
- *OPTEL's* Intelligent Supply Chain platform provides track and trace technologies linked together in the cloud to facilitate improved decision making and ultimately support supply chain efficiency and sustainability. For example, OPTEL assisted a cocoa processor in achieving 100% responsibly produced cocoa. Using OPTEL's GeoTraceability solution and a physical traceability system, the customer can sell geo traceable cocoa products, proving that the cocoa in their products is responsibly sourced.

3.3 DEMATERIALISATION

Dematerialisation is the movement away from physical items and towards digital items, from atoms to bits, delivering the same product or service using a proportion or none of the original material. The rise of the digital age saw a natural progression in material quantities with smaller products substituting for larger products and the collation of products or functionalities into one. The smartphone sitting in your pocket now houses your Walkman, camera, notebook and phone among many more services is the prime example of how digitalisation enabled material efficiencies that continue today. Furthermore, technological innovation has enabled 'lightweighting' of products. However, the wider implications of dematerialisation must be considered. For example, while smartphones have enabled music, photo and notebook storage, they in turn rely on data storage, software and associated infrastructure and the use of critical raw materials. It is crucial that these solutions are also developed sustainably.[58]

Case studies

- *Fabricant* is a digital fashion house reimagining the fashion industry while reducing its environmental impact. Digital fashion is a visual representation of clothing using 3D software, which helps to reduce the environmental impact of the industry. Fabricant can create digital samples at the design and manufacturing stage which reduces waste generation. A 'digital try-on' allows the customer to try-on the digital item before purchasing the physical item thereby minimising the number of returns. In addition, the virtual try-on experience allows customers to wear digital garments and create social media content which can combat single use items purchased for media generation.
- Before Netflix, the video rental industry operated using material intensive items at brick-and-mortar locations. Netflix has disrupted this by delivering DVDs initially through mail before moving to a fully digital video streaming service - providing TV shows and developing content. The need for physical versions has been removed with customers now streaming online with an added benefit of a reduction in transportation costs and improved convenience adding to customer satisfaction[58].

58 Available at: *Digitization and virtualization - Circular Economy Guide (ceguide.org)*

3.4 MATCHMAKING

A lack of partnerships and collaboration across and between value chains and stakeholders is a key impediment for a successful circular economy. Data and digitally-enabled solutions can facilitate business-to-business (B2B) and business-to-consumer (B2C) partnerships for improved waste-to-resource matching[59]. Understanding opportunities for reverse logistics, industrial symbiosis or remanufacturing across value chains requires knowledge on product condition as well as the existing market situation, which can be facilitated by digital solutions[60]. This matchmaking function helps companies to source high-value reuse options for materials and or products - which can be powered by AI, blockchain and smart contracts[61] and individuals to source excess products to avoid waste generation.

Case studies

- *Excess Materials Exchange* is a digital matching platform that sources reuse options for materials or products. The solution is comprised of four key components: resource passports, tracking and tracing via QR codes and chips to match physical materials to their digital twin the resources passport, valuation, and matchmaking (using AI).
- *FoodCloud* is a social enterprise that aims to divert surplus food from waste. The FoodCloud platform links food retailers with charities and community groups to redistribute excess food. Retailers simply upload a description of the food using an in-store scanner or the FoodCloud smartphone app.
- *Too Good To Go* is world's largest B2C marketplace for surplus food[62]. Using an app that connects consumers with restaurants, bakeries or supermarkets with surplus food, consumers can purchase this excess produce at a discounted price.
- *BE CIRCLE:* is an online platform that supports industrial symbiosis by enabling users to visualise local industrial facilitates (including their materials, water and energy stocks and flows) with the aim to develop synergies[63].

3.5 CIRCULARITY WITHIN THE DIGITAL SECTOR

When progressing digitalisation there is a risk that the roll-out of associated technologies may result in increased consumption and associated environmental impacts. Given the fact that many digital solutions are inherently resource intensive, relying on energy, critical raw materials[64] and water, circular principles must be embedded into their development[65] [66]. At present, Information and Communications Technology (ICT) accounts for approximately 5-9% of total electricity demand, with estimates of an increase to 20% by 2030[67].

59 Available at: *https://www.sciencedirect.com/science/article/pii/S0148296320304987*

60 Available at: *https://ellenmacarthurfoundation.org/artificial-intelligence-and-the-circular-economy*

61 Available at: *https://www.sitra.fi/en/publications/the-winning-recipe-for-a-circular-economy/*

62 Available at: *https://irishtechnews.ie/too-good-to-go-officially-launches-in-ireland/*

63 Available at: *https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848*

64 Critical raw materials are raw materials of high importance to the economy and of high risk associated with their supply. The EU has a list of CRMs which is subject to regular review and update e.g. cobalt, phosphorus and magnesium. For further information see: *https://ec.europa.eu/growth/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en*

65 Available at: *https://www.era-min.eu/sites/default/files/publications/201023_ecera_white_paper_on_digital_circular_economy.pdf*

66 Available at: *https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848*

67 Available at: *https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848*

Electronic products are lasting less time than they used to with IT products often having a short use-phase while the accompanying hardware can have a longer lifetime[68] [69]. In addition, these products are difficult to repair and are not being re-used where possible – with some companies making it difficult to repair their products[70]. These products such as computers and smartphones subsequently become e-waste - the fastest growing waste stream in Europe[71]. E-waste can contain substances of concern such as mercury and lead, resulting in adverse environmental and human health impacts if not managed appropriately. In addition, e-waste contains valuable raw materials such as precious metals, rare earth elements and critical raw materials. Research estimates the value of raw materials in e-waste at US$12.9 billion in Europe[72]. Improved design, with a focus on durability, reusability and reparability is crucial to design out waste and improve resource-use efficiency. Furthermore, there is a need to improve end-of-life management for electronic products. At recycling rates of approximately 40% in Europe[73], there is a need to ramp up collection and recycling rates of these materials from an economic, environmental, and human health perspective. The poor design of IT products historically has contributed to this growing waste stream. Better design of these products is needed to allow for greater repair, refurbishment and reuse.

Ultimately, digitalisation can be a facilitator for the circular economy and should be pursued as a means and not an end. There are a number of emerging solutions looking to improve circularity within the digital economy as summarised in the case studies below. Furthermore, Ireland's new digital strategy[74] aims to address the energy and circular economy challenges from digital technologies to ensure digital technologies are used in a sustainable manner.

Case studies

- Recognising the impact of the sector on carbon emissions, material use and human rights, the *Circular and Fair ICT (CFIT) Pact* is an international procurement-led partnership to promote circularity, fairness and sustainability within the ICT sector. Seven countries have signed the CFIT Pact committing to collaborate on making laptops and smartphones circular and fair through procurement.
- *Vattenfall uses Microsoft Azure IOT* to build and deliver a 24/7 matching solution for Microsoft's Swedish datacentres. The solution enables hourly matching of renewable energy generation with demand 24 hours a day, 365 days a year. Energy produced from renewable sources is measured hourly and consumption is measured by smart meters installed on locations where energy is used. The solution helps Microsoft to improve the accuracy and transparency in its energy usage.
- As part of its ambition to become a zero-waste company by 2030, Microsoft has developed its *Circular Centres programme* to build recycling centres on its data centre campuses to find optimal uses for old servers. Using Microsoft Dynamics 365 Supply Chain Management and Microsoft Power Platform, the reverse supply chain management solution manages warehouse operations such as inventory handling, processing of decommissioned servers and parts harvesting. The Circular Centres model has achieved 83% reuse and 17% recycling of critical parts whilst reducing carbon emissions by 145,000 tCO_2e.

68 Available at: *https://www.era-min.eu/sites/default/files/publications/201023_ecera_white_paper_on_digital_circular_economy.pdf*

69 Available at: *Electronic Waste and the Circular Economy (parliament.uk)*

70 Available at: *https://committees.parliament.uk/publications/3675/documents/35777/default/*

71 Available at: *https://www.ceps.eu/ceps-publications/barriers-and-enablers-for-implementing-circular-economy-business-models/*

72 Available at: *https://www.ceps.eu/ceps-publications/barriers-and-enablers-for-implementing-circular-economy-business-models/*

73 Available at: *https://www.ceps.eu/ceps-publications/barriers-and-enablers-for-implementing-circular-economy-business-models/*

74 Available at: *https://www.gov.ie/en/publication/adf42-harnessing-digital-the-digital-ireland-framework/*

- *Fairphone* is a Dutch company aiming to build a market for ethical and responsibly produced phones. The company focuses on four impact areas: longevity, circularity, sourcing fair materials and good working conditions. Fairphone also raises awareness around the complex supply chains behind electronic products. Fairphone creates modular smartphones that are durable and easily repairable.
- *Closing the Loop* collects scrap mobile phones in Africa for recycling – given that phones get sold on from Europe, the Americas and Asia for low-cost reuse in Africa.
- *Camara*, founded in Dublin, is an international charity that takes in used computer equipment and recycles/remarkets it to fund the purchase of refurbished computers that are shipped to Africa. In Africa, independent social enterprises that are staffed and managed by Camara's local staff prepare the equipment for use and aid schools in installing purpose-built classrooms, as well as provide training for local teachers to enable them to provide digital skills to children.

Overarching areas of focus to accelerate the development of a digitally-enabled circular economy

Government coordination and education are two key overarching areas to encourage the acceleration and adoption of a digitally-enabled circular economy.

3.6 GOVERNMENT COORDINATION

The regulatory environment can either impede or nurture innovation. The digital and circular economy have a symbiotic relationship and as such, management, compliance and regulation need to be developed in consideration of each other to ensure both grow and evolve together. A supportive regulatory environment for circular models can increase capital flow and public awareness while regulatory barriers can hamper scalability for innovative solutions. Ultimately, the right institutional conditions are needed for digitally-enabled circular solutions to succeed[75].

Data privacy concerns are a major challenge for the digital and circular economy. Digitalisation acting as an enabler for the circular economy leads to a vast amount of data generation and sharing. The sharing of this information raises concerns around privacy. Government policy and regulation can address and offset these concerns with regards to digital technologies such as data privacy and security[76].

Ownership and access to data is a developing challenge for digitally-enabled circular business models with buying and collecting the right data becoming time-consuming, resource-intensive and expensive[77]. Guidelines need to be established for the free flow of non-personal data and the development of streamlined and centralised data standards that remove barriers relating to different methods of collecting and disseminating across private and public institutions, regions and countries[78] [79]. These steps once implemented will ensure a common approach to data generation and remove barriers speeding up the time spent, resources used, and costs associated with analysing this information. The enactment of the EU Directive on Open Data and the Re-Use of Public information[80] improved availability of public sector information giving member states minimum requirements on data availability while the proposal

75 *https://www.climate-kic.org/wp content/uploads/2018/08/ClimateKICWhitepaperFinalDigital_compressed.pdf*

76 Available at: *Thought-Paper-2021.pdf (weee-forum.org)*

77 Available at: *ClimateKICWhitepaperFinalDigital_compressed.pdf (climate-kic.org)*

78 Available at: *DRCE.pdf (climate-kic.org)*

79 Available at: *ClimateKICWhitepaperFinalDigital_compressed.pdf (climate-kic.org)*

80 Available at: *DIRECTIVE (EU) 2019/ 1024 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - of 20 June 2019 - on open data and the re-use of public sector information (europa.eu)*

for a European data governance act[81], a key pillar of the European strategy for data, will boost data sharing across sectors and Member States. At a national level, Ireland implemented an Open Data Initiative in 2014 to increase transparency, stimulate new business and improve lives of Irish citizens[82] [83].

The circular economy requires a collaborative and open information sharing ecosystem. As businesses and wider stakeholders need to work in interconnected networks to share information and resources, government bodies also need to have a whole of government approach to the circular economy in relation to setting regulations, business incentives and removing barriers[84] [85]. Current regulations can inhibit the transition as they can be too focused on countering the damaging effects of waste and emissions and less on utilising the value of raw materials. New innovative solutions need to be supported and nurtured by regulation and must accommodate circular economy business models or new digital solutions to encourage the transition to a circular economy.

Case studies

- *Recycl3R*, a Spanish start-up, offers a mobile and web application providing recyclability information to end-users on products/packaging with an integrated reward. Recycl3R has had difficulty in gathering streamlined data on recycling from public institutions (e.g. municipalities' official websites) due to different methods of collection and publication of data. This has resulted in an increase in the time and resources needed to gather and analyse it - affecting scalability both nationally and internationally[86]. The introduction of the EU Directive on Open Data and the Re-Use of Public Sector Information[87] and the development of Ireland's open data technical framework[88] has removed certain hurdles to data sharing within the EU and Ireland, while Ireland's central public sector database, open data portal[89], publishes government data in a way that will make it more accessible implementing Ireland's Open Data Initiative. However, data sharing and processing hurdles remain, particularly in the private sector[90]. Government needs to continue to update and harmonise data standards across industry, working with public and private sectors and at an international level to encourage the development of common data standards to avoid hampering the development of innovative digital solutions.
- *Refurbed*, an online platform offering refurbished consumer electronics through a network of independent refurbishers ran into difficulties with the current WEEE Directive. Refurbed wants to further develop its network of independent refurbishers by establishing a pan-European network. Each time it transports electronic waste across a border it is obliged under the WEEE Directive to provide clear documentation and stating the purpose of refurbishment, the exact amount and type of material which increases the complexing of shipping and network development[91]. At a country level, governments are beginning to look at regulatory barriers to the circular economy in a holistic way, such as the Irish[92] and Dutch[93] Governments in their circular economy strategies, however European and global cooperation is needed.

81 Available at: *European data governance act | Shaping Europe's digital future (europa.eu)*

82 Available at: *Ireland's Open Data Initiative - Observatory of Public Sector Innovation (oecd-opsi.org)*

83 Available at: *Data.gov.ie*

84 Available at: *gov.ie - Whole of Government Circular Economy Strategy 2022 – 2023 'Living More, Using Less' (www.gov.ie)*

85 Available at: *A Circular Economy in the Netherlands by 2050 (europa.eu)*

86 Available at: *ClimateKICWhitepaperFinalDigital_compressed.pdf (climate-kic.org)*

87 Available at: *EUR-Lex - 32019L1024 - EN - EUR-Lex (europa.eu)*

88 Available at: *Open Data Technical Framework - data.gov.ie*

89 Available at: *Data.gov.ie*

90 Available at: *DRCE.pdf (climate-kic.org)*

91 Available at: *ClimateKICWhitepaperFinalDigital_compressed.pdf (climate-kic.org)*

92 Available at: *gov.ie - Whole of Government Circular Economy Strategy 2022 – 2023 'Living More, Using Less' (www.gov.ie)*

93 Available at: *A Circular Economy in the Netherlands by 2050 (europa.eu)*

3.7 EDUCATION, AWARENESS RAISING AND KNOWLEDGE SHARING

To fully leverage the benefits of a digitally-enabled circular economy there is demand for appropriate skills and knowledge. The adoption of digital solutions into circular business models will necessitate a high level of interaction between individuals and technology[94] and so will necessitate a high degree of e-literacy. This is recognised at a national level under (1) Ireland's National Recovery and Resilience Plan (NRRP) 2021[95] which includes an action to address the digital divide and enhance digital skills and (2) Ireland's new digital strategy Harnessing Digital – The Digital Ireland Framework[96], which has a strong focus on strengthening digital skills across the country. As part of this strategy, the Government commits to:

- Provide digital skills through an agile, responsive skills system – ensuring skills policy responses meet the challenges, and realise the opportunity of Ireland's digital transformation; and
- Deliver digital skills for wider society to enable all cohorts of people to engagement with and benefit from digitalisation.

Knowledge and best practice on the circular economy can be shared at an international level – with digital solutions acting as a key enabler for dissemination. The development of digital learning platforms and networks to allow individuals and companies tap into global best practice, knowledge and training in circular economy principles will be vital in the transition away from the linear economy. Furthermore, with the integration of digitally-enabled solutions it is essential stakeholders have trust in these technologies and that the information shared remains secure and private. Informing individuals on how to safeguard ePrivacy is an important aspect of developing circular economy knowledge[97].

Case studies

- *EU Circular Economy Stakeholder Platform* is a joint initiative of the European Commission and the European Economic and Social Committee that brings together stakeholders that are active in the European circular economy. The platform provides a forum for stakeholders to collaborate and share information, expertise, and good practice.
- The *Blue Connection* by Inchainge is a web-based business simulation game to help companies and individuals better understand the opportunities and challenges of adopting circular strategies.
- *CIRCULÉIRE* is Ireland's national platform for circular manufacturing. The platform includes an online open-access knowledge repository of circular economy resources such as case studies, sectoral reports, and policy documents to support industry, entrepreneurs and policy-makers in the transition to a more circular economy.
- *European Resource Efficiency Knowledge Centre* platform helps companies (in particular SMEs), save energy, material, and water costs. It provides tools, information and business opportunities demonstrating how to improve resource efficiency and benefit from circular business models.
- The UN Environment's *International Resource Panel Global Material Flows* Database provides data to help governments and other stakeholders understand and trace the linkages between economic growth and raw material usage.
- *Circular Economy Club* is an international network of the circular economy professionals and organisations that has developed a map of global circular initiatives into the largest open-source database in the circular economy field.
- *Mercato Circilare* is a smartphone app that can be used to search for circular economy products, services and events as well as offering training opportunities. The platform aims to encourage and empower individuals and companies to be more circular.

94 Available at: *https://www.epc.eu/en/publications/The-circular-economy-Going-digital~30c848*

95 Available at: *https://www.gov.ie/en/publication/d4939-national-recovery-and-resilience-plan-2021/*

96 Available at: *https://www.gov.ie/en/publication/adf42-harnessing-digital-the-digital-ireland-framework/*

97 Available at: *pub_9285_drce.pdf (europa.eu)*

4. Insights and Opportunities

The transition to a circular economy is a key facilitator of decarbonisation and improved resource use. Data and digitally-enabled solutions, if developed sustainably, can act as a springboard for accelerating the transition to a circular economy. The importance of achieving a digitally-enabled circular economy is reflected in the growing number of polices and plans at European and national level. As demonstrated throughout this paper, digitalisation can optimise value chain management, transparency, promote and facilitate dematerialisation as well as facilitate waste-to-resource matching. However digital solutions must be developed in line with circular principles to avoid adverse environmental impacts. Both education and government coordination are necessary levers to ensure the successful integration of a digitally-enabled circular economy.

The transition to a digitally-enabled circular economy is currently hampered by behavioural, regulatory, financial and operational barriers. While challenges remain, there has been a suite of plans and policies implemented at an EU and national level to accelerate the shift to a digitally-enabled circular economy, such as Harnessing Digital – The Digital Ireland Framework in addition to the development of Ireland's first national strategy that provides a framework for transitioning to a circular economy – the Whole of Government Circular Economy Strategy. Furthermore, several innovative case studies provided throughout this paper demonstrate the positive steps being undertaken across both the public and private sector to drive a digitally-enabled circular economy. Ultimately, collaboration and cooperation between governments, companies and individuals will be key to share best practice, knowledge and skills to facilitate the roll-out of a successful circular economy.

This section outlines steps that can be taken by companies, public bodies and Government to integrate circular economy principles at organisation, institution or national level and how digital solutions can drive this integration. Throughout these recommendations we outline how they enable connections and collaboration with the wider economy and how policymakers can help to develop a supportive and successful environment to promote digitally-enabled circular innovations.

4.1 DIGITAL SOLUTIONS TO IMPROVE CIRCULAR DATA MANAGEMENT, STRATEGY DEVELOPMENT PERFORMANCE MONITORING

Better management of data and the ability to assess and derive insight from it is a crucial starting point for the development of circular economy innovations. The capacity to collect, interpret and use data underpins the central connection between the digital and circular economy. The collection and better management of data holds the key for system-wide transformation of organisations and the economy, making sense of complex information, identifying areas of action and enabling better decision making[98].

However, data is often used to understand current practices and bring about incremental changes to the existing economic model, rather than transform the model in its entirety. Government bodies, public and private organisations should integrate digital solutions into operating systems to improve insight of operations, data quality and decision making with a focus on circular thinking and circularity improvements. Circular economy-focused methodologies and frameworks that have been developed to help companies, cities and nations measure their circular performance, can aid decision making and report on several circular transition indicators[99]. These methodologies should be used to guide the collection of the required data to provide the insight into the circularity of current operations and

98 *The circular economy: Going digital (epc.eu)*

99 *The circular economy: Going digital (epc.eu)*

measure circular progress. For example, at enterprise level, The Circular Transition Indicators (CTI)[100] is an assessment framework for companies to help measure their circularity. CTI is a good starting point for organisations looking to learn more about the circularity of their business and where to act. While at a city and national level, Ganbatte for cities enables officials and changemakers to establish plans to make cities more circular and sustainable[101].

Time and iteration will be needed to bring about circular changes. The power of digital technologies will aid this iteration and smart feedback loop development which will speed up organisations, cities and nations transition to a circular economy. This information can feed back into circular performance measurement to help drive further understanding of where improvements can be made. Machine learning can be used to acquire and utilise continuously improving input data to make predictions on future trends within organisations or across the economy, stakeholder behaviour and guide design improvements[102] [103]. Government can help guide direction and learning, increase ambition and drive innovation at an organisation level by setting circularity targets, requiring annual reporting and utilising digital solutions (e.g. Copernicus programme uses satellites to monitor atmosphere, marine and land environment changes and are proposed to be used to support environmental reporting and compliance assurance[104] [105]) to monitor compliance with rules. These digital technology feedback systems can also provide the data at a city and national level to find inefficiencies in waste streams, transport systems and public buildings driving circularity.

100 *Circular Transition Indicators v2.0 – Metrics for business, by business - World Business Council for Sustainable Development (WBCSD)*

101 : *Ganbatte Cities | Circular Economy*

102 : *Machine learning approach for a circular economy with waste recycling in smart cities - ScienceDirect*

103 : *Artificial intelligence and the circular economy: AI as a tool to accelerate the transition | McKinsey*

104 *Homepage | Copernicus*

105 *Copernicus for compliance assurance: Interview with Hugo De Groof, DG ENV — Copernicus In Situ Component*

Opportunity	Action	Description	Relevant stakeholders
Digital solutions to improve circular data management, strategy development and performance monitoring	Integrate digital solutions into operations to provide better management and access of data with a circularity focus	Government bodies and public and private organisations should integrate digital solutions such as Internet of Things and cloud computing into their operating systems to improve data management with a focus on circular thinking and circularity improvements	• Government bodies • Public institutions • Corporates and SMEs
	Development of iteration and smart feedback loops	Digital solutions should be introduced to enable continuous learning and circular design improvements. Smart feedback loops can facilitate improvements in circular performance measurement enabling organisations to explore the next steps to iterate their design and continue to add value to their business and the system as a whole. Government regulation can drive adaptation and learning at a business level through circularity targets and annual disclosure requirements while using digital technologies to monitor non-movers.	• Government bodies • Public institutions • Corporates and SMEs

4.2 CIRCULAR ECONOMY VALUES OF CUSTOMERS, CONSUMERS AND CITIZENS

Consumers and the public are key stakeholders in the transition to a circular economy. Understanding their values and how to meet these values is a fundamental element of the transition and development of circular economy strategies. To successfully apply these strategies and innovations to society, such offerings must be adopted and valued by customers, consumers and markets[106] [107]. For both private and public organisations, undertaking customer value and journey mapping and engagement will inform and provide an understanding of the customer's perceived value of their circular business model or innovation ensuring viability through consumer demand and will provide an opportunity for strategy or innovation iteration. Digital solutions, such as data analytics and machine learning should be used by public and private organisations to analyse citizen and consumer data to understand their behaviour and the effectiveness of policy measures relevant for the circular economy or an organisation's circular economy offering in meeting consumer values[108].

106 *Sustainability | Free Full-Text | What Is the Customer Value of the Circular Economy? Cross-Industry Exploration of Diverse Values Perceived by Consumers and Business Customers | HTML (mdpi.com)*

107 *Business Marketing: Understanding What Customers Value (hbr.org)*

108 *Digitalisation – unlocking the potential of the circular economy - Climate-KIC*

Business Marketing: Understand What Customers Value

Opportunity	Action	Description	Relevant stakeholders
Circular Economy Values of Customers, Consumers and Citizens	Analyse citizen and consumer data to understand behaviour and values	Customers, consumers, and the public are key stakeholders in the transition to a circular economy. Digital enabled solutions, such as data analytics and machine learning, should be used by public and private organisations to analyse citizen and consumer data to understand their behaviour and the effectiveness of policy measures relevant for the circular economy or an organisation's circular economy offering in meeting consumer values	• Government bodies • Public institutions • Corporates and SMEs

4.3 DEVELOPMENT OF ENGAGEMENT PLATFORMS

The development of a circular economy will be disruptive, affecting all of society and requiring collaboration and participation between private and public entities, citizens and consumers. Digital engagement platforms can connect businesses to consumers and government bodies to the public and should be utilised to raise awareness around the steps needed to create a circular economy providing guidance on how consumers and citizen can play their part. For example, organisations can use these channels and solutions to educate customers on how to use or how to care for products to maximise their lifetime. Communicating information such as end of life management requirements, environmental impacts or product make-up through QR codes, apps and online platforms will guide consumers and answer any questions they may have, helping them to make sustainable choices and engage with the circular economy. Engaging with consumers helps to create a community around an organisation offering further value to the solution while transparent reporting of accurate information to back up any public claims will be crucial to build and maintain trust and add further credibility to a company's reputation. This will be particularly important with the onset of more rigid and complex Environmental, Social and Governance (ESG) regulations such as the Corporate Sustainability Reporting Directive (CSRD)[109], EU Taxonomy[110] and adherence to waste management regulations[111].

Digital solutions that connect customers to businesses or that interact with the public need to be intuitive, accessible, and user-friendly. If the platform is easy to use it will enable improved stakeholder engagement and getting the right information to individuals[112]. Government can play a further role to ensure standardisation of digital communication, utilising and designating one or a multiple digital labels or communication criteria to educate and guide consumers on choosing sustainable products and services avoiding confusion or losing trust in the information.

109 Available at: *Corporate sustainability reporting | European Commission (europa.eu)*

110 Available at: *EU taxonomy for sustainable activities | European Commission (europa.eu)*

111 Available at: *Waste Framework Directive (europa.eu)*

112 Available at: *Digitalisation – unlocking the potential of the circular economy - Climate-KIC*

Opportunity	Action	Description	Relevant stakeholders
Development of digital engagement platforms	Circular and sustainability-related information should be communicated through digital solutions to drive further insight and understanding	The development of a circular economy may be disruptive, affecting all of society and requiring collaboration and participation between private and public entities, citizens and consumers. Government bodies and businesses should utilise digital platforms to raise awareness around the steps needed to create a circular economy - providing guidance on how consumers and citizen can play their part	• Government bodies • Corporates and SMEs
	Digital communication and sustainability label(s) standardisation	Develop criteria on the type of information that should be shared on online platforms to avoid confusion and mistrust	• Government bodies
	Digital communication platforms that are user-friendly and intuitive	Digital platforms need to be user-friendly and intuitive to engage consumers and the public, ensuring information is not lost or hard to find	• Government bodies • Public institutions • Corporates and SMEs

4.4 STAKEHOLDER PARTNERSHIP AND INNOVATION FACILITATION

Organisations should leverage circularity insights at an inter-organisational level to promote collaboration, partnerships, and industrial symbiosis network development between all stakeholders - moving away from the siloed working environments of the linear economy.

Digital solutions can create B2B linkages required to track the flow of products, components and materials within an organisation's value chain and the wider economy. This data can be used for improved resource management and decision making, such as improving waste-to-resource matching in industrial symbiosis[113] [114] creating an interconnected network such as the national industrial symbiosis program (NISP) piloted in Canada[115], where organisations can match their resource needs to the resource surplus of another - increasing resource efficiency and security[116]. A key benefit for these types of network ecosystems is securing viability through scale. This connection is crucial for Irish companies that can generate greater scale through connections made with organisations and networks in Europe and further afield[117]. The main challenges associated with implementing these network systems includes the management of cross-stakeholder collaboration and the lack of data in terms of visibility of supply and availability within a region. Organisations should explore ways to improve information transfer between businesses and develop collaborative data exchange platforms that protect an organisation's IP while enabling the transfer of data down value chains[118].

113 Available at: *A Collaboration Platform for Enabling Industrial Symbiosis: Application of the Database Engine for Waste-to-Resource Matching - ScienceDirect*

114 Available at: *A Big Data Analytics Approach to Develop Industrial Symbioses in Large Cities - ScienceDirect*

115 Available at: *nispcanadafeasabilitystudy20160725.pdf (wordpress.com)*

116 Available at: *BE CIRCLE | What if industrial ecology was operational for you? (be-circle.com)*

117 Available at: *ClimateKICWhitepaperFinalDigital_compressed.pdf (climate-kic.org)*

118 Available at: *DRCE_web.pdf (epc.eu)*

Government bodies should promote collaboration and industrial symbiosis by acting as a knowledge broker and providing platforms for joint data and information sharing and promote such networks and guidance through awareness campaigns while regulatory compliance and enforcement will help drive further industrial symbiosis[119].

Governments and municipalities have played a role in supporting business innovation relating to the circular economy using stakeholder platforms. For example, Rotterdam Circular is the municipality of Rotterdam's digital platform for start-ups and established entrepreneurs providing information on regulations, taxes and subsidies that relate to circular entrepreneurs while also communicating the value of circular enterprise and provides support for circular aspects of innovation business plans[120]. These platforms should be used to increase awareness among businesses and wider stakeholders on the interlinkage between digitalisation and the circular economy encouraging businesses to collaborate on best practice to improve data and information sharing across value chains and the required standards needed[121].

Digital solutions are already and will continue to play a role in the development of these networks connecting relevant stakeholders, facilitating the sharing of knowledge and resources - ensuring circular innovations reach their full potential[122].

Opportunity	Action	Description	Relevant stakeholders
Stakeholder partnership and innovation facilitation	Government bodies should promote collaboration and industrial symbiosis development and support circular business innovation increasing awareness on the interlinkages between digitisation and the circular economy.	Government bodies should act as a knowledge broker and provide platforms for joint data and information sharing. These platforms should also be used to increase the awareness among businesses and wider stakeholders on the interlinkages between digitalisation and the circular economy	• Government bodies • Public institutions
	Private enterprises should engage with peers to further develop networks and work through barriers	Private enterprises should explore ways to improve information transfer between businesses and develop collaborative data exchange platforms that protect their IP while enabling the transfer of data down value chains	• Corporates and SMEs

119 Available at: *Industrial_Symbiosis (europa.eu)*

120 Available at: *About Rotterdam Circular - Rotterdam Circulair*

121 Available at: *The circular economy: Going digital (epc.eu)*

122 Available at: *The circular economy: Going digital (epc.eu)*

4.5 TRAINING ON DIGITAL SKILLS, DATA PROTECTION AND PRIVACY MEASURES

As discussed previously and throughout this paper, the transition to a digitally-enabled circular economy will require appropriate knowledge and skills of citizens and workers. Government bodies and businesses should ensure that stakeholders in the transition have the necessary digital skills to contribute most effectively. They should introduce reskilling and upskilling initiatives throughout the economy and within organisations to adapt to the changing nature of work resulting from digitalisation. Examples of policy driving digital upskilling in Ireland are discussed on page 20 as part of the NRRP and Ireland's new digital strategy. The Build Digital Project[123] is another good example of a large digital training programme which integrates digital education and training to drive digital transformation in the Irish construction sector. Further improvements could be made to strengthen digital upskilling by implementing regulatory targets and deadlines to accelerate the transition to digital solutions. Such action was undertaken in the UK with the Government requiring all public sector projects to be designed to BIM Level 2[124] which in turn drove industry to upskill in this digital solution.

It is vital that stakeholders trust these new technologies and that the information shared remains secure and private. To maintain and increase trust, government bodies and organisations should open dialogue channels and inform stakeholders on ways to ensure data privacy and the benefits that digital solutions and data sharing can provide[125]. As discussed, digitally-enabled engagement platforms can facilitate this communication and should be developed as appropriate.

Opportunity	Action	Description	Relevant stakeholders
Training on digital skills, data protection and privacy measures	Develop digital skills and knowledge of citizens and workers	Government bodies and public and private organisations should ensure that stakeholders in the digitally-enabled circular economy transition have the necessary skills to contribute most effectively. They should introduce reskilling and upskilling initiatives to adapt to the changing nature of work through digital solutions	• Government bodies • Public institutions • Corporates and SMEs
	Increase awareness around personal data privacy and the benefits of digital solutions and engagement in data sharing	To maintain and increase trust in the digitally-enabled circular economy, government bodies and organisations should open dialogue channels and inform stakeholders on ways to ensure data privacy and the benefits digital solutions and data sharing can provide.	• Government bodies • Public institutions • Corporates and SMEs

123 Available at: *https://www.builddigitalproject.ie/*

124 Available at: *https://www.linesight.com/insights/bim-building-a-solid-foundation/*

125 Available at: *DRCE_web.pdf (epc.eu)*

4.6 DATA GUIDELINES AND STANDARDS DEVELOPMENT

Data privacy, business IP protection and a lack of common data standards for the accurate collection and dissemination of data throughout the economy are limiting factors for organisations to engage fully with a digitally-enabled circular economy. Data needs to be collected, stored and transferred in a secure manner protecting IP, trade secrets and personal information to ensure engagement from all stakeholders. Clear rules at national and international level, regarding who should have access to what data, when and how are necessary for businesses to refer to and will remove some of the barriers relating to data sharing[126]. Identifier systems can enable safe data access and processing by allowing access to specific information regarding a product or material based on access rights to a specific user[127] - important for data stored in digital twins and product passports systems.

To further minimise obstacles in data exchange at national level, Government can develop guidelines or protocols for the free flow of non-personal data and provide a set of minimum criteria for data collection, what information is needed and the benefits of exchanging information[128]. Government should provide businesses with incentives to engage in exchanging data to ensure information flows easily across the economy[129].

Ultimately, data needs to be shared in a standardised form to ensure efficient exchange and processing of relevant data. Common data standards should be set as an agreement within and - preferably - overarching supply chains, inter-sector collaboration and at a national and regional level where necessary[130].

It is important to note that the EU is taking steps to increase the level of data sharing and exchange among organisations and countries within the EU. To address the issue of restrictive flow of non-personal data across European member states the commission enacted the EU Directive on Open Data and the Re-use of Public Sector Information[131] making it easier for a wide re-use and access of public sector and publicly funded information across the Union while also providing guidance on private sector data sharing in a business to government and a business-to-business context[132] [133]. The proposal for regulation of data governance or the Data Governance Act in 2020 aims to make more data available and facilitate data sharing across sectors and EU countries[134], while the establishment of a common European Dataspace for Smart and Circular Applications as outlined in the EU Circular Economy Action Plan[135] will provide the architecture and governance system to drive applications and services to further the transition to the circular economy.

126 Available at: *DRCE_web.pdf (epc.eu)*

127 Available at: *201023_ecera_white_paper_on_digital_circular_economy.pdf (era-min.eu)*

128 Available at: *Digitalisation – unlocking the potential of the circular economy - Climate-KIC*

129 Available at: *DRCE_web.pdf (epc.eu)*

130 Available at: *201023_ecera_white_paper_on_digital_circular_economy.pdf (era-min.eu)*

131 Available at: *DIRECTIVE (EU) 2019/ 1024 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - of 20 June 2019 - on open data and the re-use of public sector information (europa.eu)*

132 Available at: *Communication "Towards a common European data space" | Shaping Europe's digital future (europa.eu)*

133 Available at: *Staff Working Document - Guidance on sharing private sector data in the European data economy | Shaping Europe's digital future (europa.eu)*

134 Available at: *European data governance act | Shaping Europe's digital future (europa.eu)*

135 Available at: *A new Circular Economy Action Plan (europa.eu)*

Opportunity	Action	Description	Relevant stakeholders
Data guidelines and standards development for the free flow of data	Development of data access rules or guidelines for data exchange	Data needs to be collected, stored and transferred in a secure manner - protecting intellectual property, trade secrets and personal information to ensure engagement from all stakeholders. Clear rules at a national and international level, regarding who should have access to what data, when and how are necessary to refer to - removing some of the barriers relating to data sharing	• Government bodies • Public institutions
	Development of guidelines for the free flow of data and minimum criteria for data collection	Government bodies can develop guidelines for the free flow of non-personal data and provide a set of minimum criteria for data collection, what information is needed and the benefits of exchanging information. Government bodies should provide businesses with incentives to engage in exchanging data to ensure information flows easily across the economy	• Government bodies • Public institutions

4.7 ENSURE DIGITAL SOLUTIONS ARE DESIGNED AND USED IN LINE WITH THE AIMS OF A CIRCULAR ECONOMY

While data and digitally-enabled solutions are key enablers of a circular economy, they must also adopt the principles of circularity in their design and use. As discussed, digital solutions can be resource intensive and so must integrate circular principles to ensure their facilitation of a circular economy is not impeded by their own environmental footprint.

Companies and Government have a role to play in scaling up collection and recycling rates of e-waste as well as better promoting dematerialisation, lifetime extension and renewable energy use. Integrating circularity into technology standards could provide a basis for improving the circularity as well as aligning digital infrastructure investment with nations sustainability goals[136].

Examples provided in this paper, such as Fairfone, Microsoft's Circular Centres programme and the Vattenfall Microsoft Azure IoT partnership demonstrate positive steps towards ensuring the accelerated use of data and digitally-enabled solutions are not in conflict with the aims of a circular economy.

136 Available at: *201023_ecera_white_paper_on_digital_circular_economy.pdf (era-min.eu)*

Opportunity	Action	Description	Relevant stakeholders
Ensure digital solutions are designed and used in line with the aims of a circular economy	Drive circularity within the digital sector	Digital solutions must be designed and used in line with the aims of a circular economy. Digital solutions should be developed considering the principles of dematerialisation, and lifetime extension as well as integrating renewable energy	• Government bodies • Public institutions • Corporates and SMEs

Addressing regulatory roadblocks for a digitally-enabled circular economy

Legislation can be outdated and can inhibit organisations from embedding the circular economy into their business. As mentioned throughout this paper, governments can play a pivotal role in the transition towards a digitally-enabled circular economy by implementing innovative and forward-looking regulation. It is vital that any changes to regulation that promote the circular economy also enhance the role the digital sector and its solutions can play in the circular transition. Governments when reviewing current regulation should assess the impact that any changes may have through the lens of the digital sector as well as improvements in circularity. Any changes to regulation need to drive circular innovation rather than hamper it. An in-depth assessment on government interventions for encouraging circular economy activities is provided in a separate study as part of the *Circular Insights* series.

Recommendations	Action	Description	Relevant stakeholders
Addressing regulatory roadblocks for a digitally-enabled circular economy	Update regulation in line with a digitally enabled circular transition	Implement regulatory changes and identify the impacts they will have on both the digital sector and the transition to the circular economy ensuring changes enhance both sectors	• Government bodies

APPENDIX A - POLICY CONTEXT

The ambition to transition to a digitally-enabled circular economy is underpinned by several international, European, national, and regional policies and plans.

GLOBAL

At an international level, there is a drive towards the achievement of deep decarbonisation and wider sustainable development. The Paris Agreement, COP26 outcomes and the United Nations Sustainable Development Goals (UN SDGs) are the key overarching instruments to deliver effective and sustainable change. The shift towards a more circular economy will form an integral part of achieving the ambitious targets of the Paris Agreement, COP26 pledges and UN SDGs.

EUROPEAN

At an EU level, there are several legislative tools and policies that seek to drive a more digitally-enabled circular economy. The Green Deal[137] is the overarching framework for the EU to meet the Paris Agreement target and achieve wider sustainable development. The Green Deal aims to achieve a *"fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net GHG emissions in 2050 and where economic growth is decoupled from resource use"* – these objectives are synonymous with the aims of a circular economy. Digitalisation is a fundamental component of the Green Deal and is identified as a key enabler for reaching its ambition.

The Circular Economy Action Plan[138] (CEAP) adopted in 2020 is one of the main building blocks of the EU Green Deal. The aim of the CEAP is to reduce the EU's consumption footprint and double the circular material use rate in the next decade, whilst boosting economic growth and harnessing the potential of innovation and digitalisation. It is vital in the development of digital infrastructure and assets that entities themselves are built with circular principles in mind. The Circular Electronics Initiative[139] which was announced in conjunction with the CEAP aims to do that. The Initiative promotes longer product lifetimes combatting premature obsolescence and includes the right to repair and an improvement in the collection and treatment of used electronic equipment. Digital technologies for tracking, tracing and mapping of resources will drive efficiencies throughout organisations' value chains ensuring appropriate end-of-life handling.

The EU Industrial Strategy[140] published in 2020 is a key document aiming to ensure that industry can be at the forefront of the new age, seeking to transform industry and ensuring the EU is more competitive globally. The Strategy pins itself at the core, supporting the twin transitions to a green and digital economy. Some key ambitions within the Strategy of relevance to the digital economy are the creation of a more digital single market, transition to a circular economy as well as upskilling and reskilling to retain a qualified workforce in line with the twin transitions[141].

137 Available at: *https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN*

138 Available at: *https://ec.europa.eu/environment/strategy/circular-economy-action-plan_de*

139 Available at: *https://ec.europa.eu/environment/strategy/circular-economy-action-plan_de*

140 Available at: *https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en*

141 Available at: *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0102&from=EN*

As part of the EU's vision *"to pursue digital policies that empower people and businesses to seize a human centred, sustainable and more prosperous digital future"* the Communication 'Digital Compass: The European Way for the Digital Decade'[142] sets out the Commission's digital ambitions for the next decade in the form of four overarching targets: (1) a digitally skilled population and highly skilled digital professionals; (2) secure and sustainable digital infrastructures; (3) digital transformation of businesses; and (4) digitisation of public services. The role of digital solutions and the use of data are noted as key instruments to *"help in the transition to a climate neutral, circular and more resilient economy."*

To limit the risk of greenwashing and improve transparency, the EU adopted the Taxonomy Regulation in 2020.[143] Under this Regulation, the Taxonomy is being established to enhance certainty and support players in the circular economy by providing technical screening criteria for each established environmental objective, including the transition to a circular economy. This Regulation means that businesses will have to show how its products or activities meet defined criteria, such as improved resource use efficiency and maximising recycling. The inclusion of the circular economy highlights its importance as a key environmental objective for the EU Commission.

NATIONAL

At a national level, the Government recognises the importance of the circular economy in achieving its climate ambitions of a 51% reduction in GHG emissions by 2030 and net zero by 2050. Ireland has strengthened its approach to driving a circular economy with recent policy and legislative activity, summarised below.

- Climate Action Plan 2021[144] is the overarching roadmap for achieving Ireland's ambitious climate targets. The Plan includes a dedicated section on the circular economy with 18 actions that aim to support the successful roll-out of a circular economy in Ireland.
- A Waste Action Plan for a Circular Economy[145] is Ireland's roadmap for waste planning and management. Crucially, this Plan moves the focus from traditional waste disposal to look at how we can develop a more circular economy. The digital economy is referenced as a tool to create and recreate value in a circular economy.
- The Whole of Government Circular Economy Strategy[146] (WGCES) is Ireland's first national strategy providing a policy framework for the transition to a circular economy, with an aim to eliminate the barriers of the circular economy transition in Ireland and close the gap between policy and action.
- The Circular Economy Act 2022[147] places the Circular Economy Strategy, and Ireland's commitment to a circular economy, on a clear statutory footing and provide the necessary underpinning for relevant measures. The Act defines the Circular Economy for the first time in Irish domestic law. It incentivises the use of reusable and recyclable alternatives to a range of wasteful single-use disposable packaging and other items. It introduces mandatory segregation of commercial waste, bringing it in line with the household market to support increased recycling rates. integrates the WGCES and Ireland's commitment to the transition to the circular economy into Irish law.

142 Available at: *https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021DC0118*

143 Available at: *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R0852*

144 Available at: *https://www.gov.ie/en/publication/6223e-climate-action-plan-2021/*

145 Available at: *https://www.gov.ie/en/publication/4221c-waste-action-plan-for-a-circular-economy/*

146 Available at: *https://www.gov.ie/en/publication/b542d-whole-of-government-circular-economy-strategy-2022-2023-living-more-using-less/*

147 Available at: *https://www.gov.ie/en/press-release/4546a-landmark-circular-economy-act-signed-into-law/*

- The EPA-led Circular Economy Programme 2021-2027[148], is driving Ireland's move to a circular economy and the programme supports the whole of government Circular Economy Strategy . This national programme incorporates the National Waste Prevention Programme and has a statutory basis under the Circular Economy Act. The EPA's Circular Economy Programme is a driving force for Ireland's move to a circular economy. It supports national-level, strategic programmes to prevent waste and drive the circular economy in Ireland. The vision for the programme is an Ireland where the circular economy ensures that everyone uses less resources and prevents waste to achieve sustainable economic growth.
- Harnessing Digital – The Digital Ireland Framework[149] is Ireland's national digital strategy that focuses on the digital transformation of businesses, digital infrastructure, skills and digitalisation of public services. The Strategy acknowledges that a focus on digital and innovation is vital for achieving our climate targets and includes a workstream to address energy and circular economy challenges from digital solutions.
- Ireland's National Recovery and Resilience Plan[150] is our national plan to contribute to a sustainable, equitable, green and digital recovery effort in the wake of COVID-19.

The WGCES recognises the role that digital solutions can play in accelerating a circular economy. Digital solutions are highlighted as an area for further policy development in the Strategy, either through direct digital provision (e.g. substitution of physical hardcopies with digital copies) or indirect digital provision (e.g. online shopping, e-health provision). The Strategy also references the potential for digital platforms to significantly expand the market for re-used goods. Furthermore, the Waste Action Plan for a Circular Economy has a measure *"to explore the role that Ireland's digital sector can play in accelerating our transition to a circular economy"*[151].

REGIONAL

At a regional level, the drive to decarbonise and improve wider sustainability is reflected in the Regional Assemblies' spatial and economic strategies, with the circular economy and digitalisation included as key enablers to achieve regional objectives. Each of the Regional Assemblies' strategies has a strong emphasis on connectivity as a key growth ambition, whether it be in terms of transport, digital infrastructure, broadband or developing smart regions. This cements the important role that the digital economy will play in future regional economic development.

148 Available at: *https://www.epa.ie/publications/circular-economy/resources/EPA_Circular-Economy-Programme_2021-2027.pdf*

149 Available at: *https://www.gov.ie/en/publication/adf42-harnessing-digital-the-digital-ireland-framework/#*

150 Available at: *https://www.gov.ie/en/publication/2164c-the-national-recovery-and-resilience-plan/*

151 Available at: *https://www.gov.ie/en/publication/4221c-waste-action-plan-for-a-circular-economy/*

APPENDIX B - STAKEHOLDER ENGAGEMENT

Eleven stakeholders were engaged with (10 via interview, 4 via survey) as per the table below. The purpose of these stakeholder interviews and surveys was to gather further insights, beyond what was collated as part of the **targeted desk-based review.**

Stakeholder	Sector	Interview	Survey recipient
Ellen MacArthur Foundation	Charity / Think-tank	Y	N
Circle Economy	Not-for-profit organisation	Y	N
Circuleire	Public-private partnership – circular manufacturing platform	Y	Y
Ibec	Lobby & Business representative group	Y	Y
Department of the Environment, Climate & Communications (DECC)	Government department	Y	N
Irish Green Building Council	Not-for-profit organisation	Y	N
European Environment Agency	EU agency	Y	N
Community Resources Network Ireland	Social Enterprise	Y	Y
Enterprise Ireland	Government agency	Y	N
IDA Ireland	Statutory agency	Y	N
Ballymore Group	Property Developer	N	Y

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Yondeen Sherpa (ITU) and Deepali Sinha (Sofies Group)	Digital solutions for a circular electronics value chain	2021	*Thought-Paper-2021.pdf (weee-forum.org)*
Annika Hedberg and Stefan Šipka	The circular economy: Going digital	2020	*DRCE_web.pdf (epc.eu)*
European Commission	The Digital Economy and Society Index — Countries' performance in digitisation	2022	*Countries' digitisation performance | Shaping Europe's digital future (europa.eu)*
European Commission	COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS The European Green Deal	2019	*https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN*
European Commission	Circular Economy Action Plan	2020	*Circular economy action plan (europa.eu)*
European Commission	European Industrial Strategy	2020	*European industrial strategy | European Commission (europa.eu)*

Author(s)	Title	Date	Link
European Commission	COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS 2030 Digital Compass: the European way for the Digital Decade	2021	*EUR-Lex - 52021DC0118 - EN - EUR-Lex (europa.eu)*
European Commission	Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (Text with EEA relevance)	2020	*EUR-Lex - 32020R0852 - EN - EUR-Lex (europa.eu)*
Department of the Environment, Climate and Communications	Waste Action Plan for a Circular Economy	2021	*gov.ie - Waste Action Plan for a Circular Economy (www.gov.ie)*
Department of the Environment, Climate and Communications	Whole of Government Circular Economy Strategy 2022 – 2023 'Living More, Using Less'	2022	*gov.ie - Whole of Government Circular Economy Strategy 2022 – 2023 'Living More, Using Less' (www.gov.ie)*
Department of the Environment, Climate and Communications	General Scheme of the Circular Economy Bill 2021	2021	*gov.ie - General Scheme of the Circular Economy Bill 2021 (www.gov.ie)*
EPA	The Circular Economy Programme 2021-2027	2021	*EPA_Circular-Economy-Programme_2021-2027.pdf*
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Tukker et al	Product services for a resource-efficient and circular economy - a review	2013	*Product services for a resource-efficient and circular economy – a review - ScienceDirect*
Han et al	Circular Economy Business Models with a Focus on Servitization	2020	*Sustainability | Free Full-Text | Circular Economy Business Models with a Focus on Servitization | HTML (mdpi.com)*
Bressanelli et al	Towards Circular Economy in the Household Appliance Industry: An Overview of Cases	2020	*Resources | Free Full-Text | Towards Circular Economy in the Household Appliance Industry: An Overview of Cases | HTML (mdpi.com)*
Bressanelli et al	Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies	2018	*Sustainability | Free Full-Text | Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies | HTML (mdpi.com)*
Floow2	How Does It Work	2022	*How does it work | FLOOW2 World's Reset Button*
McKinsey and Company	Artificial intelligence and the circular economy: AI as a tool to accelerate the transition	2019	*Artificial-intelligence-and-the-circular-economy.pdf (mckinsey.com)*
Carbon	Carbon Lattice Innovation - The adidas Story		*Carbon 3D Print Lattice Innovation — The adidas Story*
Ellen MacArthur Foundation	Artifical intelligence and the circular economy	2019	*Artificial-intelligence-and-the-circular-economy.pdf (mckinsey.com)*
Ellen MacArthur Foundation	Increasing clothing use through subscription: Circos	2019	*Increasing clothing use through subscription: Circos (ellenmacarthurfoundation.org)*
European Commission	Eco-innovation and Digitlisation	2020	*eio5_eco-innovation_and_digitalisation_nov2020.pdf (europa.eu)*
World Economic Forum	Intelligent Assets: Unlocking the Circular Economy Potential	2015	*WEF_Intelligent_Assets_Unlocking_the_Cricular_Economy.pdf (weforum.org)*
ECERA European Circular Economy Research Alliance	Digital circular economy a cornerstone of a sustainable European industry transformation	2020	*201023_ecera_white_paper_on_digital_circular_economy.pdf (era-min.eu)*
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AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL

Tá an GCC freagrach as an gcomhshaol a chosaint agus a fheabhsú, mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ar thionchar díobhálach na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialáil: *Rialáil agus córais chomhlíonta comhshaoil éifeachtacha a chur i bhfeidhm, chun dea-thorthaí comhshaoil a bhaint amach agus díriú orthu siúd nach mbíonn ag cloí leo.*

Eolas: *Sonraí, eolas agus measúnú ardchaighdeáin, spriocdhírithe agus tráthúil a chur ar fáil i leith an chomhshaoil chun bonn eolais a chur faoin gcinnteoireacht.*

Abhcóideacht: *Ag obair le daoine eile ar son timpeallachta glaine, táirgiúla agus dea-chosanta agus ar son cleachtas inbhuanaithe i dtaobh an chomhshaoil.*

I measc ár gcuid freagrachtaí tá:

Ceadúnú

- Gníomhaíochtaí tionscail, dramhaíola agus stórála peitril ar scála mór;
- Sceitheadh fuíolluisce uirbigh;
- Úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe;
- Foinsí radaíochta ianúcháin;
- Astaíochtaí gás ceaptha teasa ó thionscal agus ón eitlíocht trí Scéim an AE um Thrádáil Astaíochtaí.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Iniúchadh agus cigireacht ar shaoráidí a bhfuil ceadúnas acu ón GCC;
- Cur i bhfeidhm an dea-chleachtais a stiúradh i ngníomhaíochtaí agus i saoráidí rialáilte;
- Maoirseacht a dhéanamh ar fhreagrachtaí an údaráis áitiúil as cosaint an chomhshaoil;
- Caighdeán an uisce óil phoiblí a rialáil agus údaruithe um sceitheadh fuíolluisce uirbigh a fhorfheidhmiú
- Caighdeán an uisce óil phoiblí agus phríobháidigh a mheasúnú agus tuairisciú air;
- Comhordú a dhéanamh ar líonra d'eagraíochtaí seirbhíse poiblí chun tacú le gníomhú i gcoinne coireachta comhshaoil;
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Dramhaíola agus Ceimiceáin sa Chomhshaol

- Rialacháin dramhaíola a chur i bhfeidhm agus a fhorfheidhmiú lena n-áirítear saincheisteanna forfheidhmithe náisiúnta;
- Staitisticí dramhaíola náisiúnta a ullmhú agus a fhoilsiú chomh maith leis an bPlean Náisiúnta um Bainistíocht Dramhaíola Guaisí;
- An Clár Náisiúnta um Chosc Dramhaíola a fhorbairt agus a chur i bhfeidhm;
- Reachtaíocht ar rialú ceimiceán sa timpeallacht a chur i bhfeidhm agus tuairisciú ar an reachtaíocht sin.

Bainistíocht Uisce

- Plé le struchtúir náisiúnta agus réigiúnacha rialachais agus oibriúcháin chun an Chreat-treoir Uisce a chur i bhfeidhm;
- Monatóireacht, measúnú agus tuairisciú a dhéanamh ar chaighdeán aibhneacha, lochanna, uiscí idirchreasa agus cósta, uiscí snámha agus screamhuisce chomh maith le tomhas ar leibhéil uisce agus sreabhadh abhann.

Eolaíocht Aeráide & Athrú Aeráide

- Fardail agus réamh-mheastacháin a fhoilsiú um astaíochtaí gás ceaptha teasa na hÉireann;
- Rúnaíocht a chur ar fáil don Chomhairle Chomhairleach ar Athrú Aeráide agus tacaíocht a thabhairt don Idirphlé Náisiúnta ar Ghníomhú ar son na hAeráide;
- Tacú le gníomhaíochtaí forbartha Náisiúnta, AE agus NA um Eolaíocht agus Beartas Aeráide.

Monatóireacht & Measúnú ar an gComhshaol

- Córais náisiúnta um monatóireacht an chomhshaoil a cheapadh agus a chur i bhfeidhm: teicneolaíocht, bainistíocht sonraí, anailís agus réamhaisnéisiú;
- Tuairiscí ar Staid Thimpeallacht na hÉireann agus ar Tháscairí a chur ar fáil;
- Monatóireacht a dhéanamh ar chaighdeán an aeir agus Treoir an AE i leith Aeir Ghlain don Eoraip a chur i bhfeidhm chomh maith leis an gCoinbhinsiún ar Aerthruailliú Fadraoin Trasteorann, agus an Treoir i leith na Teorann Náisiúnta Astaíochtaí;
- Maoirseacht a dhéanamh ar chur i bhfeidhm na Treorach i leith Torainn Timpeallachta;
- Measúnú a dhéanamh ar thionchar pleananna agus clár beartaithe ar chomhshaol na hÉireann.
- Taighde agus Forbairt Comhshaoil
- Comhordú a dhéanamh ar ghníomhaíochtaí taighde comhshaoil agus iad a mhaoiniú chun brú a aithint, bonn eolais a chur faoin mbeartas agus réitigh a chur ar fáil;
- Comhoibriú le gníomhaíocht náisiúnta agus AE um thaighde comhshaoil.

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta agus nochtadh an phobail do radaíocht ianúcháin agus do réimsí leictreamaighnéadacha a mheas;
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha;
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta;
- Sainseirbhísí um chosaint ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Ardú Feasachta agus Faisnéis Inrochtana

- Tuairiscú, comhairle agus treoir neamhspleách, fianaise-bhunaithe a chur ar fáil don Rialtas, don tionscal agus don phobal ar ábhair maidir le cosaint comhshaoil agus raideolaíoch;
- An nasc idir sláinte agus folláine, an geilleagar agus timpeallacht ghlan a chur chun cinn;
- Feasacht comhshaoil a chur chun cinn lena n-áirítear tacú le hiompraíocht um éifeachtúlacht acmhainní agus aistriú aeráide;
- Tástáil radóin a chur chun cinn i dtithe agus in ionaid oibre agus feabhsúchán a mholadh áit is gá.

Comhpháirtíocht agus líonrú

- Oibriú le gníomhaireachtaí idirnáisiúnta agus náisiúnta, údaráis réigiúnacha agus áitiúla, eagraíochtaí neamhrialtais, comhlachtaí ionadaíocha agus ranna rialtais chun cosaint chomhshaoil agus raideolaíoch a chur ar fáil, chomh maith le taighde, comhordú agus cinnteoireacht bunaithe ar an eolaíocht.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an GCC á bhainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóir. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig um Inbhuanaitheacht i leith Cúrsaí Comhshaoil
- An Oifig Forfheidhmithe i leith Cúrsaí Comhshaoil
- An Oifig um Fhianaise agus Measúnú
- An Oifig um Chosaint ar Radaíocht agus Monatóireacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tugann coistí comhairleacha cabhair don Ghníomhaireacht agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

TO FIND OUT MORE:

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Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Rialtas na hÉireann
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