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Report 2

Digital circular economy: A new perspective on digitalisation as a driver for sustainability?

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Abstract: Digital circular economy: A new perspective on digitalisation as a driver for sustainability?

The European Green Deal states that moving from a linear to a circular economy is a key strategy to reduce resource consumption by repairing, reusing, remanufacturing, and recycling materials and products. Yet, the establishment of a circular economy in the European Union (EU) is still in an early stage. This report thus outlines how digitalisation can support the implementation of a circular economy and discusses the key role that governance for circularity can play in this context. The overall aim is to formulate recommendations for priorities for action, which the German government can link to the activities of the European Commission. The recommendations are based on an analysis of the role of Germany's Presidency of the Council of the EU regarding topics related to digitalisation and sustainability (REPORT 1), an expert workshop on digital circular economy (DCE) carried out in April 2022 and a literature review that deepened some of the workshop discussions. The analysis found that the potentials of a DCE are manifold and relate to improving products and business models along the entire circular value chain. Underlying these potentials is often the use of digital technologies for product tracking and monitoring as well as for a transparent digital data exchange. Further, it is argued that governance for circularity can be a key issue to empower stakeholders to move towards a DCE. Based on these findings, recommendations for EU and national policy makers are outlined to support the development of a systemic and coherent strategy for a DCE within the EU.

Kurzbeschreibung: Digitale Kreislaufwirtschaft

Der Europäische Green Deal betrachtet den Wandel von einer linearen zu einer Kreislaufwirtschaft als eine Schlüsselstrategie zur Reduzierung des Ressourcenverbrauchs durch Reparatur, Wiederverwendung, Wiederaufbereitung und Recycling von Materialien und Produkten. In der Europäischen Union (EU) steht die Umsetzung einer Kreislaufwirtschaft jedoch noch am Anfang. Dieser Bericht zeigt auf, wie die Digitalisierung die Umsetzung einer Kreislaufwirtschaft unterstützen kann und diskutiert die Schlüsselrolle, die Governance in diesem Kontext einnimmt. Das übergreifende Ziel ist, Handlungsprioritäten, die die deutsche Regierung mit den Maßnahmen der Europäischen Kommission verknüpfen kann, zu empfehlen. Die Empfehlungen basieren auf einer Analyse der Rolle der deutschen EU-Ratspräsidentschaft in Bezug auf Themen der Digitalisierung und Nachhaltigkeit (BERICHT 1), eines im April 2022 durchgeführten Experten*Expertinnen-Workshops zur digitalen Kreislaufwirtschaft und einer Literaturrecherche, die einige der Workshop-Diskussionen vertieft hat. Die Analyse zeigte, dass die Potenziale einer digitalen Kreislaufwirtschaft vielfältig sind und Verbesserungen von Produkten und Geschäftsmodellen entlang der gesamten Wertschöpfungskette erreicht werden können. Insgesamt liegt dabei oft die Nutzung digitaler Technologien für die Produktverfolgung und -überwachung sowie für einen transparenten digitalen Datenaustausch zugrunde. Des Weiteren wird argumentiert, dass die Governance der Kreislaufwirtschaft, ein Schlüsselthema ist, um Stakeholder zu befähigen, eine digitale Kreislaufwirtschaft umzusetzen. Basierend auf diesen Ergebnissen werden Politikempfehlungen auf nationaler und auf EU-Ebene skizziert, um die Entwicklung einer systemischen und kohärenten Strategie für eine digitale Kreislaufwirtschaft in der EU zu unterstützen.

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Abbreviation	Explanation
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
CE	Circular economy
CEAP	Circular Economy Action Plan
DCE	Digital circular economy
DPP	Digital Product Passport
EC	European Commission
EGD	European Green Deal
EU	European Union
SDG	Sustainable Development Goals
UBA	German Environment Agency (Umweltbundesamt)
2030 Agenda	2030 Agenda for Sustainable Development

Summary

Digitalisation is said to offer a wide range of opportunities and risks for achieving sustainability goals. Thus, the European Commission (EC) has argued that digital technologies are key enablers for reaching the sustainability objectives set in the European Green Deal (EGD) and has set the so-called twin transition of digitalisation and sustainability as a priority (EC 2020). In this context, the project 'Digitalisation and Sustainability at the EU level: Opportunities and risks of digitalisation for the implementation of the 2030 Agenda at EU level', which is carried out on behalf of the German Environment Agency (UBA), and financed by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), aims to develop policy perspectives on how to make better use of digitalisation to achieve sustainability goals.

One essential component of the EGD is the decoupling of economic growth and resource consumption by moving from a linear to a circular economy (CE). This report outlines how digitalisation can support the implementation of a CE in the EU by analysing the importance of improved information flows along circular value chains and governance for circularity. The overall aim is to support the German government's position by formulating recommendations for priorities for action, which the German government can link to its activities within the EC. This is done by drawing on an analysis of the role of Germany's Presidency of the Council of the EU regarding topics related to digitalisation and sustainability (REPORT 1), an expert workshop on digital circular economy (DCE) carried out in April 2022 and a literature review that deepened some of the workshop discussions.

The circular economy concept

As part of the EGD, the Circular Economy Action Plan (CEAP) is intended to form a cohesive framework for a transition to a CE in the EU. The CE concept aims at closed material loops, meaning that a product serves as a resource for a new product at the end of its use phase, instead of being burned or going to landfill. In order to maintain the material and use value of materials and products for as long as possible, the CE applies the principles of repairing, reusing, remanufacturing, and recycling. This approach aims at reducing the use of resources, greenhouse gas emissions and waste and thus at contributing directly to achieving goal 12 "Responsible Consumption and Production" of the United Nations Sustainable Development Goals (SDG).

Potentials digitalisation offers for realising a circular economy

Yet, the establishment of a CE in Europe is still in an early stage. Digitalisation is increasingly seen as a possible enabler among researchers, business stakeholders and policy actors to move towards a CE. The potentials are manifold and relate to improving products and business models along the entire circular value chain. Underlying these potentials is the use of digital technologies for product tracking and monitoring as well as for a transparent digital data exchange. By enabling a more reliable and far-reaching information acquisition and exchange (VDMA European Office 2019; Cagno et al. 2021; Bressanelli et al. 2022), digital technologies can help to overcome information asymmetries along value chains which are currently one of the biggest barriers for the implementation of a CE within the EU (e.g. Alcayaga and Hansen 2022; Jäger-Roschko and Petersen 2022). Product information, especially about the products' characteristics, used materials and use status is currently often unavailable to stakeholders (such as manufacturers, users and end-of-use managers) along the products' lifecycle. As proposed in the EGD, the development and introduction of a digital product passport (DPP), which can save the environmental and material data of a product along its entire lifecycle, is

likely to play a central role in this context to optimise the products' (re-)use and recycling. Thus, digital product tracking and monitoring as well as a digital data exchange can be key enablers for a DCE and support the twin transition.

Governance for a digital circular economy

Transparent information flows along circular value chains depend on whether (all) stakeholders are willing and able to collaborate and share information in an accessible and comprehensible way. Therefore, a governance for a DCE that empowers stakeholders to move towards a CE is crucial. The report discusses mainly three governance dimensions: (1) data management (relating to aspects like data ownership, security, and privacy), (2) standardisation (relating to common data standards and technological integration of different data management systems), and (3) empowerment (relating to the governance of relationship between actors along the circular value chain).

In general, digitalisation should not be an end in itself, but an enabler to make circular products and processes more efficient. The establishment of a DCE thus should build on existing data infrastructures and aim for a realistic development in time and space as the current digitalisation maturity level of businesses is often relatively low.

Policy recommendations

This report outlines several recommendations to support the twin transition for digital and sustainable development within a DCE and presents opportunities to integrate new ways of governing for circularity into policy. The development of a holistic and coherent strategy at the EU level that coordinates the efforts of the Member States and stakeholders along the product lifecycle (such as companies and users), is urgently needed to support the twin transition within a DCE.

The policy recommendations for EU policy makers are:

- Strengthening a participatory, inclusive and equitable approach to circularity by empowering consumers to take an active role within a digital circular economy
- Facilitating a transparent data exchange by exploring options for standardisation and developing the digital product passport as a governance instrument
- Exploring possibilities to allow for data altruism while respecting intellectual property rights and privacy regulations for all stakeholders.

The policy recommendations for German policy makers are:

- Gaining new perspectives on developments towards a circular economy based on a twin transition by putting its governance at the centre
- Working towards the establishment of a data infrastructure for digital data collection and exchange by using Gaia-X as a starting point
- Advocating for coherent digital and sustainability policies for the twin transition that frame digitalisation as an enabler for circularity and sustainability.

Zusammenfassung

Der Digitalisierung wird nachgesagt, ein breites Spektrum an Chancen und Risiken für die Erreichung von Nachhaltigkeitszielen zu bieten. Auch die Europäische Kommission sieht digitale Technologien als wichtige Voraussetzungen für die Erreichung der im Europäischen Green Deal (European Green Deal, EGD) festgelegten Nachhaltigkeitsziele an, und erklärt die sogenannte doppelte Transformation (twin transition) von Digitalisierung und Nachhaltigkeit zu einer Priorität (EC 2020). Vor diesem Hintergrund zielt das Projekt ‚Digitalisierung und Nachhaltigkeit auf EU-Ebene: Chancen und Risiken der Digitalisierung für die Umsetzung der Agenda 2030 auf EU-Ebene', das im Auftrag des Umweltbundesamtes (UBA) durchgeführt und vom Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUV) finanziert wird, auf die Entwicklung politischer Perspektiven zur besseren Nutzung der Digitalisierung zur Erreichung von Nachhaltigkeitszielen ab.

Ein wesentlicher Bestandteil des EGD ist die Entkopplung von Wirtschaftswachstum und Ressourcenverbrauch durch die Transformation von einer linearen zu einer Kreislaufwirtschaft. Dieser Bericht zeigt auf, ob und wie die Digitalisierung die Umsetzung einer Kreislaufwirtschaft in der EU unterstützen kann, indem die Bedeutung eines verbesserten Informationsflusses entlang der zirkulären Wertschöpfungskette und einer Governance für die Kreislaufwirtschaft analysiert werden. Das übergeordnete Ziel ist es, die Position der deutschen Bundesregierung zu unterstützen, indem Empfehlungen für Handlungsprioritäten formuliert werden, die die Bundesregierung mit ihren Aktivitäten innerhalb der Europäischen Kommission verknüpfen kann. Dies geschieht auf der Grundlage einer Analyse der Rolle der deutschen EU-Ratspräsidentschaft in Bezug auf Themen der Digitalisierung und Nachhaltigkeit (BERICHT 1), eines im April 2022 durchgeführten Experten*Expertinnen-Workshops zur digitalen Kreislaufwirtschaft und einer Literaturrecherche, die einige der Workshop-Diskussionen vertieft hat.

Das Konzept der Kreislaufwirtschaft

Als Teil des EGD soll der Circular Economy Action Plan (CEAP) einen kohärenten Rahmen für die Transformation zu einer Kreislaufwirtschaft in der EU darstellen. Das Konzept der Kreislaufwirtschaft zielt auf geschlossene Materialkreisläufe ab, was bedeutet, dass ein Produkt am Ende seiner Nutzungsphase als Ressource für ein neues Produkt dient, anstatt verbrannt oder deponiert zu werden. Um Produkte möglichst lange zu nutzen und ihren materiellen Wert möglichst lange zu erhalten, werden die Grundsätze der Reparatur, Wiederverwendung, Wiederaufbereitung und des Recyclings angewendet. Ziel ist es, den Ressourcenverbrauch, die Treibhausgasemissionen und die Abfallaufkommen zu reduzieren und damit einen direkten Beitrag zur Erreichung von Ziel 12 „Nachhaltiger Konsum und nachhaltige Produktion" der 17 Ziele für nachhaltige Entwicklung der Vereinten Nationen zu leisten.

Potenziale der Digitalisierung für die Umsetzung einer Kreislaufwirtschaft

Die Umsetzung einer Kreislaufwirtschaft steht in der Europäischen Union (EU) jedoch noch am Anfang. Die Digitalisierung wird von Forschung, Wirtschaft und Politik zunehmend als mögliche Schlüsselkomponente für die Transformation zu einer Kreislaufwirtschaft gesehen. Die Potenziale sind vielfältig und betreffen Verbesserung von Produkten und Geschäftsmodellen entlang der gesamten Wertschöpfungskette. Grundlegend ist dabei die Nutzung digitaler Technologien für die Produktverfolgung und -überwachung sowie für einen transparenten digitalen Datenaustausch. Indem sie einen zuverlässigeren und weitreichenderen Informationsaustausch ermöglichen (VDMA European Office 2019; Cagno et al. 2021; Bressanelli et al. 2022), können digitale Technologien dazu beitragen, Informationsasymmetrien entlang der

Wertschöpfungsketten zu überwinden, die derzeit eines der größten Hindernisse für die Umsetzung einer Kreislaufwirtschaft in der EU darstellen (Alcayaga und Hansen 2022). Produktinformationen, insbesondere über die Eigenschaften der Produkte, die verwendeten Materialien und den Verwendungsstatus, stehen den Akteurinnen*Akteuren (wie Herstellungsunternehmen, Nutzer*innen und End-of-Use-Manager*innen) entlang des Lebenszyklus der Produkte derzeit oft nicht zur Verfügung. Wie im EGD vorgeschlagen, dürfte die Entwicklung und Einführung eines digitalen Produktpasses, der die Umwelt- und Materialdaten eines Produkts während seines gesamten Lebenszyklus speichern kann, in diesem Zusammenhang eine zentrale Rolle spielen, um die (Wieder-) Verwendung und das Recycling von Produkten zu optimieren. Somit können die digitale Produktverfolgung und -überwachung sowie der digitale Datenaustausch wichtige Voraussetzungen für eine digitale Kreislaufwirtschaft sein und die doppelte Transformation unterstützen.

Governance einer digitalen Kreislaufwirtschaft

Ein transparenter Informationsfluss entlang zirkulärer Wertschöpfungsketten hängt davon ab, ob (alle) Stakeholder bereit und in der Lage sind, zusammenzuarbeiten und Informationen auf zugängliche und verständliche Weise auszutauschen. Daher ist eine Governance für eine digitale Kreislaufwirtschaft, die die Stakeholder dazu befähigt, Schritte in Richtung einer Kreislaufwirtschaft umzusetzen, von entscheidender Bedeutung. Der Bericht erörtert hauptsächlich drei Governance-Dimensionen: (1) Datenmanagement (in Bezug auf Aspekte wie Dateneigentum, Sicherheit und Datenschutz), (2) Standardisierung (in Bezug auf gemeinsame Datenstandards und technologische Integration verschiedener Datenmanagementsysteme) und (3) Befähigung (in Bezug auf die Governance der Beziehungen zwischen den Akteurinnen*Akteuren entlang der zirkulären Wertschöpfungskette).

Grundsätzlich sollte die Digitalisierung kein Selbstzweck sein, sondern ein Mittel, um Kreislaufprodukte und -prozesse effizienter zu gestalten. Eine digitale Kreislaufwirtschaft sollte daher auf bestehenden Dateninfrastrukturen aufbauen und eine realistische zeitliche und räumliche Entwicklung anstreben, die den derzeitigen oft relativ geringen Reifegrad der Digitalisierung in den Unternehmen berücksichtigt.

Politikempfehlungen

In diesem Bericht werden Empfehlungen zur Unterstützung der doppelten Transformation zu digitaler und nachhaltiger Entwicklung im Rahmen einer digitalen Kreiskaufwirtschaft gegeben und Möglichkeiten aufgezeigt, neue Formen der Governance für Kreislaufwirtschaft in die Politik zu integrieren. Die Entwicklung einer ganzheitlichen und kohärenten Strategie auf EU-Ebene, die die Bemühungen der Mitgliedstaaten und der Stakeholder entlang des (wie Unternehmen und Nutzer*innen) koordiniert, ist dringend erforderlich, um die doppelte Transformation innerhalb einer DCE zu unterstützen.

Die politischen Empfehlungen auf Ebene der EU sind:

- Stärkung eines partizipativen, inklusiven und gerechten Ansatzes für die Kreislaufwirtschaft durch Befähigung der Verbrauchenden, eine aktive Rolle in einer digitalen Kreislaufwirtschaft zu übernehmen
- Unterstützung eines transparenten Datenaustauschs durch die Sondierung von Optionen für die Standardisierung und Entwicklung des digitalen Produktpasses als Governance-Instrument
- Sondieren von Optionen zur Ermöglichung von Datenaltruismus unter Wahrung der Rechte an geistigem Eigentum und der Datenschutzbestimmungen für alle Beteiligten.

Die politischen Empfehlungen für die deutsche Regierung sind:

- Gewinnung neuer Perspektiven für die Entwicklung hin zu einer Kreislaufwirtschaft auf der Grundlage einer doppelten Transformation, indem die Governance in den Mittelpunkt gestellt wird
- Aufbau einer Dateninfrastruktur für die Sammlung und den Austausch digitaler Daten unter Verwendung von Gaia-X als Ausgangspunkt
- Eintreten für eine kohärente Digital- und Nachhaltigkeitspolitik für die doppelte Transformation, die die Digitalisierung als Wegbereiter für Kreislaufwirtschaft und Nachhaltigkeit sieht.

1 Introduction

In 2015, the United Nations defined 17 Sustainable Development Goals (SDG) as part of the **2030 Agenda for Sustainable Development** (2030 Agenda) to promote ecologically, socially and economically sustainable development. The goals include ambitions towards climate action, human well-being and economic growth. In order to work towards these goals, strategies and regulations have been developed worldwide. At the European policy level, the European Green Deal (EGD) was adopted in 2019 as a key strategy in this context. Further, in March 2020, the European Commission (EC) argued that digital technologies are key enablers for reaching the sustainability objectives set in the EGD and set the so-called twin transition of digitalisation and sustainability as a priority policy area (EC 2020). Steps towards a twin transition should thus be welcomed (Ortega-Gras et al. 2021).

Within the context of the 2030 Agenda and the twin transition of digitalisation and sustainability, the **project 'Digitalisation and Sustainability at the EU level: Opportunities and risks of digitalisation for the implementation of the 2030 Agenda at EU level'**, which is carried out on behalf of the German Environment Agency (UBA), and financed by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), aims to develop policy perspectives on how to make better use of digitalisation to achieve sustainability goals. One essential task of the EGD is to decouple economic growth from resource consumption by moving from a linear to a circular economy (CE). This report is thus aimed at discussing how digitalisation can support the implementation of a CE in the EU. More precisely, the report analyses the potentials of improved information flows along circular value chains for moving towards a digital circular economy (DCE). Further, the importance of governance for circularity will be discussed and policy recommendations for promoting a DCE will be derived. The aim is to support the German government's position and formulate recommendations for priorities for action, which the German government can link to its activities within the EC.

The remainder of the report is structured as follows:

- Section 2 describes the methodology used to collect the data for this report and its analysis to be able to derive at several policy recommendations linked to a DCE.
- Section 3 gives an overview of the DCE in the EU and describes the potentials that digitalisation, especially digital data collection and exchange, offer for circularity.
- Section 4 highlights the importance of governance for circularity, in particular regarding data management, standardisation and empowerment.
- Section 5 outlines several policy recommendations for EU and German policy makers.

2 Methodology

This report aims to deepen the understanding of the DCE linked to digitalisation and sustainability debates to strengthen the position of the German government's work on a sustainable orientation of digitalisation at the level of the EU beyond the course set by the German EU Council Presidency in the second half of 2020. To this end, this report builds on the results of the document analysis of press releases, articles and speeches published during the German Council Presidency (REPORT 1) which pointed to several future priority areas, including the role of digitalisation within circular economies. Based on these findings, the project team in collaboration with the German Environment Agency (UBA) and the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) decided to deepen the work on digitalisation for a CE. The topic was selected due to its central role within existing EU strategies (e.g. EGD, Circular Economy Action Plan (CEAP), cf. chapter 3 about the DCE) and its yet still largely unrealised potential.

An online survey, a half-day expert workshop on the DCE and a follow-up literature review on selected topics linked to the DCE were initiated as a subsequent step to the document analysis.

In preparation for the online survey and expert workshop, a short **background paper** was produced on the DCE and sent out to the invited participants. The paper included an overview of four areas of potentials that digitalisation offers for circular economies: (1) product tracking and monitoring, (2) transparent data exchange, (3) circular business models, and (4) networks and new roles within a DCE. As part of a short survey, workshop participants were invited to respond to the short background paper online to be able to frame the discussion of the workshop and its agenda.

The invitation to the **expert workshop** was widely distributed through the project partners' social media and newsletter channels. Some of the participants were directly contacted due to their expertise on the topics of the twin transition and CE. Due to the COVID-19 pandemic, the decision was taken to hold the expert workshop online. This had the advantage of reaching out more widely to participants across the EU. In total, eighteen participants joined the half-day workshop (including the project team). This included policy makers, NGOs, think tanks and academic researchers from seven different EU countries. The expert workshop took place on 28th of April 2022. It kicked off with a welcome and introduction to the topic. Afterwards, the participants could choose from two break-out groups: (1) "Product tracking and data exchange" and (2) "Circular business models, networks and roles". A plenary discussion rounded up the workshop. The workshop was recorded, and notes were taken during the event. The recordings and notes formed the basis for the analysis of this report. Two weeks later, a workshop summary was sent to the participants to gain feedback and additional insights.

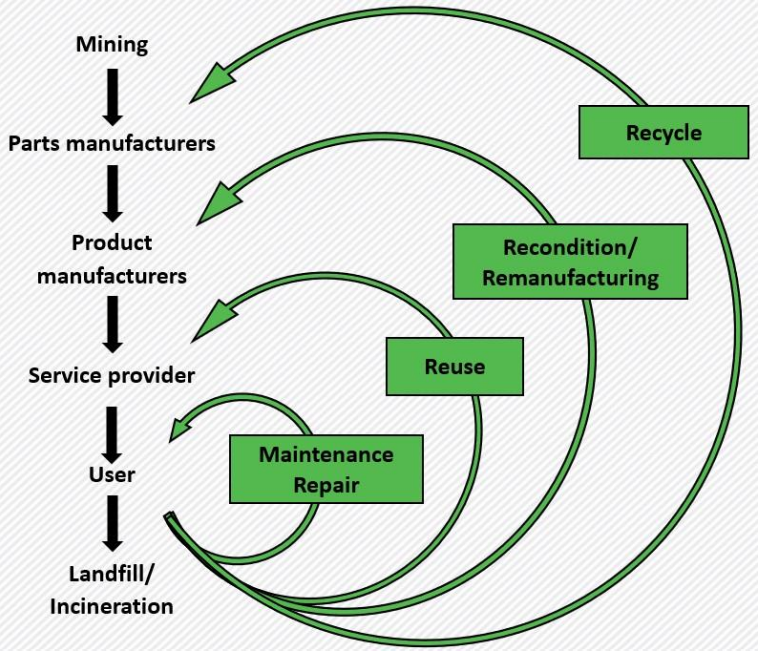
To deepen some of the discussions and arguments raised during the workshop, a follow-up **literature review** was carried out. Literature searches were conducted in academic and more generic search engines to find additional work on digitalisation, sustainability, and CE. Based on the findings, a comprehensive overview of the key potentials of a DCE and recommendations for EU and national policy makers on how to foster these potentials at the EU level are provided in this report.

3 Digital circular economy

3.1 The circular economy concept

The CE concept rethinks and redirects current production and consumption patterns. It is based on the **principles of repairing, reusing, remanufacturing, and recycling** materials and products in order to maintain their use and material value to the maximum extend (see Figure 1). Ideally, materials flow in closed loops, meaning that a product is not discarded at the end of its use phase but rather serves as a resource for a new product. This approach aims at increasing resource efficiency, extending a product's lifetime and recovering materials, thereby reducing the use of resources, greenhouse gas emissions and waste (Ellen MacArthur Foundation 2012, 2016; Hedberg and Šipka 2020). Thus, a CE contributes to achieving goal 12 "Responsible Consumption and Production" of the United Nations SDGs. The EC affirmed the relevance of the transition towards a CE for sustainability by adopting the first CEAP in 2015. A new CEAP was adopted in 2020 as a central element of the EGD (EC 2022a).

Figure 1: Schematic illustration of material/product flows within a circular economy



The vertical linear value chain on the left (black) represents the currently widely distributed economic system that builds on taking resources from the environment in order to produce products which are then used and discarded as waste. The circular loops on the right (green) represent the principles of a CE system that aim at maintaining the use and material value of products for as long as possible.
Source: own illustration, Institute for Ecological Economy Research (based on Ellen MacArthur Foundation (2012, p. 6).

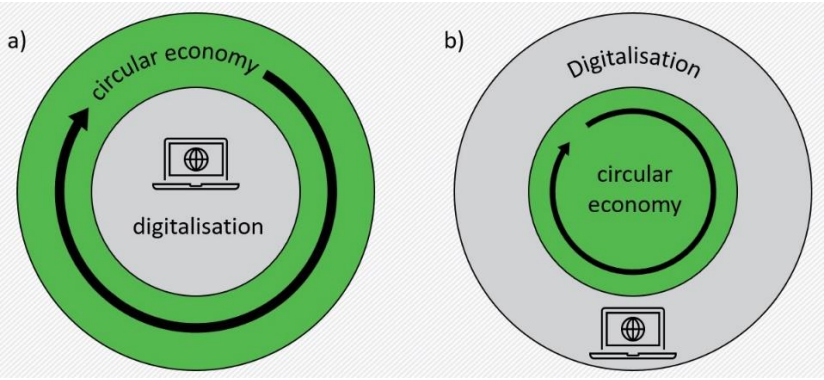
Yet, the establishment of a CE in Europe is still in an early stage. Whilst scientific and conceptual discussions on how circular value streams could be designed have been advanced over the past years (e.g. Ellen MacArthur Foundation 2012, 2015; Jäger-Roschko and Petersen 2022), closed loops remain the exemption in current production and consumption processes indicating a circularity gap. In 2020, only 8.6 % of the global economy was circular (Circle Economy 2022). Organisational, regulatory, technical and financial barriers as well as poor transparency along the value chain currently still hinder a CE (Kadner et al. 2021).

3.2 Digitalisation as an enabler for implementing a circular economy

In recent years, an increasing number of strategies and regulations regarding circular economy (e.g. the CEAP) and digitalisation (e.g. the Data Act and Digital Services Act) have been published by the EC. Both policy areas are oftentimes discussed separately with only loose connections of how they could be brought together in a holistic, integrative manner. As shown in REPORT 1, such an integrated perspective of how digitalisation and CE can be addressed together stays rather general and vague in current EU policies. Yet, in order to realise the full potential of a twin transition, an integrated perspective that focusses on the connections between digitalisation and CE is crucial. The connection between the two developments can be clustered into two categories:

- On the one hand, a **circular digitalisation** (cf. Figure 2a) encompasses initiatives that aim at reducing the resource and energy consumption as well as the waste generation of digital technologies through the application of CE principles. For instance, electronics as well as information and communications technology are key sectors named in the CEAP in which sustainable product norms should be established (EC 2022a). Moreover, the EC announced the introduction of a Right to Repair, which is intended to support the repair of electronic devices (Šajn 2022).
- On the other hand, **digitalisation for a circular economy** (cf. Figure 2b) describes initiatives that focus on the usage of digital tools and solutions to achieve the realisation of a CE in the EU. In this context, digitalisation is increasingly seen as a possible enabler among researchers, business stakeholders and policy makers to move towards a CE and close the currently existing circularity gap (see above; De Felice and Petrillo 2021; Rejeb et al. 2022; Wynn and Jones 2022). The collection and provision of the necessary information for circular production methods and circular business models will likely be a future priority area for digitalisation and a CE. For instance, the introduction of digital product passports (DPP) could improve the information exchange between stakeholders along the value chain of products (EC 2022a). However, overall, more guidance and supporting regulations are still needed to combine a digital and circular transition.

Figure 2: Illustration of circular digitalisation (a) and digitalisation for a circular economy (b)



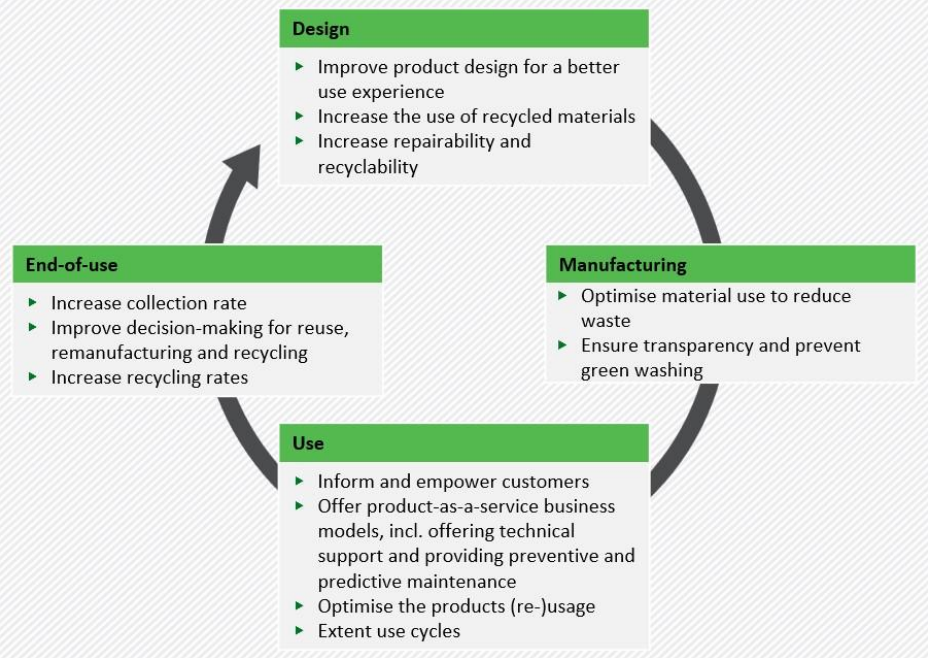
Source: own illustration, Institute for Ecological Economy Research.

Initiatives regarding a sustainable, circular digitalisation are already well-established in the EU agenda and will therefore not be the focus of this report. Instead, this report aims at describing the potentials that digitalisation, especially improved information flows, offer for a CE. Further, the importance of governance for circularity will be discussed and policy recommendations for promoting a DCE will be derived.

3.3 Digital potentials along the circular value chain

The potentials that digital technologies offer for implementing a CE are gaining increasing attention among researchers, business stakeholders and policy actors. Due to the heterogeneity of technologies linked to digitalisation and the diversity of economic sectors they have been/might be applied to, these potentials are manifold and relate to improving products and business models along the entire circular value chain (see Figure 3). Examples of such potentials are redesigning products, attracting and informing customers, offering technological assistance, providing preventive and predictive maintenance, enhancing product use, as well as improving renovation and end-of-use performance (Bressanelli et al. 2018; Jäger-Roschko and Petersen 2022). These measures, in turn, are likely to promote social-economic value creation and reduce material and energy consumption along a product's lifecycle. This shows that there are potential benefits stemming from digitalisation that can shape environmental, economic and social realms. Therefore, digital technologies can drive the transition towards a more sustainable CE and contribute to the SDG (Bressanelli et al. 2022; Rosário and Dias 2022).

Figure 3: Overview of exemplary potentials of a digital circular economy towards sustainability along a product's lifecycle



The circular lifecycle shows the four main phases design, manufacturing, use and end-of-use management with exemplary potentials that digitalisation offers for implementing a CE towards sustainability for each phase.
Source: own illustration, Institute for Ecological Economy Research.

The variety of potentials that digitalisation offers in the different phases of a product's lifecycle and the various stakeholders (designers, manufactures, users, recyclers etc.) that are involved in this context show the complexity of issues and interactions that are attached to a DCE and the need to govern such issues and interactions. Yet, this complexity is often not reflected in current research, business investments and policy efforts to promote a DCE. Oftentimes, these efforts have a narrow focus on the development of single technologies or technological fields like big data or artificial intelligence. Here, advancing digitalisation is the main goal rather than asking how much and what type of digitalisation is needed to implement a circular economy that aids the achievement of sustainability goals. **Digitalisation should not be an end in itself, but an enabler to make circular products and processes more efficient and sufficient.** One of the

currently biggest barriers for the implementation of a CE that can be addressed with digital technologies are information asymmetries along value chains (e.g. Alcayaga and Hansen 2022; Jäger-Roschko and Petersen 2022). Product information, especially about the products' characteristics, used materials and use status is currently often unavailable to stakeholders along the products' lifecycle. For instance, recyclers often lack access to detailed information about the materials and additives used in a product which are important for an efficient recycling process. This means that for realising a DCE, shared or at least integrated systems are needed to allow communication and data exchange along the circular value chain. By enabling a more **reliable and far-reaching data collection and sharing** (VDMA European Office 2019; Cagno et al. 2021; Bressanelli et al. 2022), digital product tracking and monitoring (section 3.3.1) as well as a digital data exchange (section 3.3.2) can be key enablers for a DCE and the twin transition.

3.3.1 Digital data collection: Digital product tracking and monitoring

Many businesses try to evaluate the use of their products through methods like quality tests, costumer surveys or complaint management. However, businesses often lack systemised and representative information about the current condition and location of a product or how customers use and discard the product. Data on the real wear rate, the use frequency, damages, losses, and the place of final destination – especially in case the product is no longer used or exported outside the EU – is often rare. This knowledge gap hinders a targeted design for and operationalisation of circularity. Digital technologies, such as **sensors**, can be used to collect and analyse data about a product and related processes along the product's lifecycle to optimise its design, usage and end-of-use management (e.g. Ingemarsdotter et al. 2020). The digital exploitation of data (Antikainen et al. 2018) and consequently data collection, integration and analysis (Ranta et al. 2021) are thus key enablers for a CE. For instance, information about a products lifecycle could enhance the condition report of the product before reuse, a decrease of production failures and losses, and improvement in the output quality (Alcayaga et al. 2019). Moreover, the remanufacturing and recycling process could be better facilitated by storing and updating the condition and usage history of a product and its components (Jäger-Roschko and Petersen 2022). In addition, instructions for disassembly or dismantling could be better informed and implemented (Hansen et al. 2020). So-called product lifecycle management applications can manage the data and facilitate the communication between a smart product and its corresponding data storage (Alcayaga and Hansen 2022). The collected data may, for instance, be used for further research and development of product design, material flows and business model innovation (Kadner et al. 2021). Digital product tracking and monitoring thus improves businesses' ability to retain or even create value (Lopes de Sousa Jabbour et al. 2018; Alcayaga et al. 2021) and their ability to make adequate decisions about their products and services. According to Alcayaga and Hansen (2022), a better understanding of the use phase is presently the main driver for businesses to adopt digital technologies because it allows them to advance their product/service for an improved customer experience.

Another way to digitally capture and trace real-world processes are **digital twins**. Digital twins are virtual copies of physical products or processes that allow to digitally simulate and monitor the characteristics and performance of their physical counterparts. They aim at enabling an overarching exchange of information by providing all relevant information about a certain product or service at a single interface (Kuhn 2017). Circular supply chains could benefit from this technology, but research is needed on how the concept of the digital twin can be effectively implemented (Preut et al. 2021). One application example could be a digital copy of all waste streams within a community, which allows efficient waste management, including re-directing waste streams to other facilities where waste can be used as a resource (industrial symbiosis).

Digital twins can also facilitate simulations of the operation of a product and the effects of different product designs (Kadner et al. 2021).

However, there is often a wide gap between the current – modest – **digitalisation maturity level** of businesses and visions of a highly digitalised value chain. The high costs of digitalising and servitising products and processes are a key barrier for businesses to move towards digital circular value chains. To address this barrier, the EU rolled out a new funding programme Digital Europe Programme (DIGITAL) aimed at making digital technology accessible to economic and civic actors as well as public administrations. The trade-offs between the benefits and the costs of collecting the data thus need to be carefully evaluated regarding sustainability (and other) principles in each application context. Instead of gathering all data possible, it is much more efficient to first evaluate, which information is needed to move towards a sustainable CE. In the workshop, the experts had different opinions regarding the level of digitalisation that is needed for a circular economy. In principle, a CE could be applied even without the use of digital technologies. This shows that digitalisation is neither a requirement, nor an end in itself, but a possible enabler to make circular products and processes more efficient. Over-engineering of digital solutions for a CE should thus be avoided to not overwhelm businesses to follow this development and to prevent unnecessary resource usage for digital technologies. Yet, as described in this report, it can be beneficial to move towards higher levels of digitalisation despite the needed financial investments (Vanhamäki et al. 2020; Rejeb et al. 2022). Potential digital solutions should build on already existing hardware and established systems.

3.3.2 Digital data exchange: The digital product passport

Wynn and Jones (2022) showed that current business activities towards circularity often focus on in-house operations, i.e. the activities within their own organisation. This means that while businesses may have internal data organisation and storing systems, they keep the information private. Considerations of circularity along value chains or possible circular business models are rare. If information is shared, it is most commonly shared bilaterally between direct business partners (Jäger-Roschko and Petersen 2022). Yet, in a DCE, the aim is to follow data for resources and assets along value chains. For this to work, information systems and value creation networks that transcend different supply chains need to be established. Such a data exchange does not only enable **informed and conscious purchase decisions but also ensures the traceability and recyclability** of the materials used (Beier and Pohl 2017). A transparent flow of relevant information between different stakeholders will thus support the implementation of circular product, component and material flows and the establishment of circular business models (Kadner et al. 2021). Digital applications, such as markers or tracking IDs, can enable a transparent flow of information between manufacturers, users, and recyclers of a product, thus facilitating the communication between different stakeholders in forward and reverse supply chains (Alcayaga et al. 2021; Kadner et al. 2021). The degree of integration and coordination along supply chains can therefore be increased (Del Giudice et al. 2021).

As proposed in the EGD, the development and introduction of a **digital product or material passport**, which can save the environmental and material data of a product/material along its entire life cycle, will play a central role in this context (BMU 2020). When connected to the corresponding database, such a passport can create end-to-end traceability that provides (all) relevant information to stakeholders along the value chain. Information stored on a DPP may include the source and composition of the material as well as guidelines for using, reusing, repairing, disassembling and recycling a product (EC 2020; Kadner et al. 2021).

By gaining access to this information,

- producers can improve the circular product design, verify the quality of their materials (e.g. recyclates), as well as monitor and report on circularity or even wider sustainability indicators,
- users are enabled to make informed decisions about which products and services they want to purchase and can actively support circularity by (re)using, repairing and disposing the product as intended,
- repairers and recyclers can access relevant product information to retain the product and material value to a maximum extent, and
- authorities can improve the enforcement of legal requirements (e.g. regarding circular product design) and market surveillance.

The EU's upcoming Ecodesign for Sustainable Product Regulation will hold central definitions and regulations regarding the DPP. These general guidelines will need to be complemented with product-specific guidelines that determine what exact information should be included in the DPP (EC 2022b). In the upcoming two-year project Cooperation Support Action, initiated by DG Connect, DPP for three product groups (batteries, electronic devices, and textiles) will be discussed with relevant stakeholders. Based on these experiences, passports for more product groups such as information and communications technology, furniture, steel and cement, will follow. Moreover, products that are imported into the EU and products that contain substances of concern, i.e. substances which could impair circularity, are obligated to have a DPP (EC 2022b). In addition to obligatory information, the DPP could also offer a shared framework for further voluntary provision of product information (CISL and Wuppertal Institute 2022). In the context of a DCE, **data altruism** can be understood as the idea that people voluntarily share data regarding a product, service, or process with other stakeholders in order to support circularity.

4 Governance for a digital circular economy

The benefits of digital data collection and exchange for circularity are widely agreed upon. Yet, it is not commonly used in businesses and their value chains so far (Jäger-Roschko and Petersen 2022). And even if data is being collected and processed, the activities are often limited to industry actors and do not integrate, for instance, policy makers or civil society organisations. An integrated perspective on circular systems and connections between actors within them is still often lacking, pointing to the need to govern steps towards circularity. However, for a digital data collection and especially for a digital data exchange to work smoothly at the EU level, (all) stakeholders need to be willing and able to collaborate and share information in a transparent, accessible, and comprehensible way. Therefore, a governance for a DCE, especially a governance of information flows and actor's relationships for circularity, that empowers stakeholders to move towards CE is needed. During the expert workshop, three dimensions of governance were seen as crucial in this context and discussed in greater depth:

- **Data management**: The stakeholders' willingness to exchange data depends on their trust in the data infrastructure and in the other actors and is influenced by the way the data is managed regarding aspects like ownership, security, and privacy.
- **Standardisation**: The stakeholders' ability to exchange data for circularity depends on the establishment of common standards for the content of the data and for technological integration between different actors and organisations.
- **Empowerment**: By supporting the stakeholders' willingness and ability to actively participate in a DCE, governance of information flows and with that also governance of relationships between the actors along the circular value chain can act as an empowering mechanism.

These dimensions show that governance processes are made up of an interplay between diverse types of actors that participate in the intentional coordination of CE and thereby move beyond purely considering the role of political institutions as relevant for governance. The governance of how to move towards a CE has been considered to be an important issue to move from a linear to a circular economy but also has largely been unexamined (Cramer 2022; Khitous et al. 2020; Patterson et al. 2017). The following sections thus focus on the governance dimensions of data management (section 4.1), standardisation (section 4.2), and empowerment (section 4.3).

4.1 Data management as a governance dimension

A DCE requires communication and data exchange between previously separated CE stakeholders. **Trust** between actors along circular value chains that the information will not be misused or used to one's disadvantage by a competitor is crucial for realising a transparent data exchange (Jäger-Roschko and Petersen 2022). Without such a trust, stakeholders will not be willing to share organisational or product-related information with others. A good governance for circularity thus needs to build trust between these actors and communicate the benefits of digital data exchange clearly to incentivise information sharing. Apart from applying common regulations for all stakeholders (cf. section 4.2 on standardisation), the way the data is managed regarding ownership, security and privacy are key issues in this context.

Within current debates it remains unclear, who should have the **data ownership** and the user rights of the collected data. Theoretically, there are different possibilities for data ownership, e.g.:

- The data belongs to the individual person or organisation that generated it.
- The data belongs to the lifecycle stage where the data was generated.
- The data is commonly shared and belongs to everyone.
- The data ownership is transferred to a central public or private organisation.

In addition, it remains unclear, where the data should be saved and how the required infrastructure should be built and realised (CISL and Wuppertal Institute 2022). Thus, the question of who should have the rights and responsibility to manage data spaces and flows and how data can be certificated to ensure its quality and accuracy needs to carefully be governed. During the workshop, several experts have pointed out that this question should not be answered with the logic of the linear economic system, but rather in the context of a CE that builds on circular business models. Regarding the **management of data spaces**, a discussion on the dichotomy between 'a centralised management' and 'a decentralised responsibility' arose in the expert workshop. The spectrum between these two extremes holds many possible system configurations that need to be analysed to determine a fitting solution for the specific contexts of a DCE that takes into account the twin transition. A **decentralised system** is preferred by most businesses as it is perceived to be more practical than establishing a new centralised management (CISL and Wuppertal Institute 2022). In line with this view, the EC has advocated for establishing a decentralised system which is maintained by economic operators (EC 2022b).

Moreover, with regards to detailed data sharing, **intellectual property rights and data protection** need to be governed. This requires a socio-technical perspective on a DCE (and not only a technical and institutional/regulative one), considering issues such as privacy rights. The concept of **data sovereignty** describes that the data an organisation collects, analyses and stores needs to be treated in accordance with the laws of the country the organisation is located in. Requiring data sovereignty from all actors who are in contact with product and process data along a circular value chain, for instance via a DPP, will promote the compliance with EU data protection regulations. However, too strict data protection obligations can also pose bureaucratic obstacles for sharing information (Veil 2021).

Moreover, it can be difficult to draw a line between legitimate data, e.g. for maintenance purposes, and data that could be misused to uncover company secrets. Therefore, there is a need for companies across a value chain to jointly discuss the crucial information that needs to be shared to alleviate concerns that the data exchange, e.g. via a DPP, may contain information that violates intellectual property rights. As proposed by the EC, providing access to certain information only on a 'need-to-know' basis, instead of freely sharing all information, will also help to ease concerns regarding data protection. The goal is that "different people will have access to different sets of information, based on access rights defined for each product group" (EC 2022b, p. 3). In order to decide who should have access to which information, it may be useful to distinguish between

- **product-composition data**, e.g. the materials and additives used in a product,
- **product-consumption data**, e.g. data reporting consumption patterns, and
- **process data**, e.g. details about the manufacturing or recycling process.

Moreover, **blockchains** could be used to guarantee the reliable and forgery-proof documentation of the data (BMU 2020). An example of this is the EC's proposal to further establish a resource information system for data exchange and the promotion of best practices for circular resource streams (EC 2015). However, "a lack of knowledge and management support, reluctance to change and technological immaturity" (Rejeb et al. 2022, p. 16) currently hinder blockchain adoption for a CE. Adoption barriers associated with investment costs, security risks and scalability were found to be less significant in this context (Rejeb et al. 2022).

4.2 Standardisation as a governance dimension

To support a transparent, comparable, and smooth data exchange, a certain degree of EU-wide standardisation is needed regarding:

- **The kind of information that should be made available**: An EU-wide standardisation of the type and depth of information to be covered by a DPP is needed for enabling the exchange of comparable, overarching data. Instead of aiming to create one overarching 'one-size-fits-all' standardisation it may be more conceivable to use multiple standards that consider product- and sector-specific differences. During the workshop, the experts emphasised that no master solution fits all businesses and industries and that there must be space for sector- or possibly even company-specific adaptations to a general standardisation. Moreover, the reference to common norms and quality standards can guarantee the reliability and correctness of the information.
- **The technologies that should be used for the data exchange to guarantee technical compatibility**: The usage of common or at least compatible technologies and (open) data formats should focus on the interoperability of systems between different scales, both within the EU and with trading partners internationally. Therefore, already existent (global) approaches should be considered during the development and maintenance of standardised digital solutions along the value chain (CISL and Wuppertal Institute 2022).

Moreover, standardised or at least harmonised regulations have the potential to expand markets and reduce costs related to compliance and administration in the EU (EC 2022b). With that, a level-playing field for businesses in the EU is created and market fragmentation is counteracted. The experiences with the Madaster Material Register (https://madaster.com) can be an exemplary guide for the design of a standardised DPP. Since 2017, this online platform facilitates the creation of material passports and centralises their standardised registration. It already is in use in several European countries such as the Netherlands, Switzerland and Germany (Totaro 2022).

4.3 Empowerment as a governance dimension

Shifting from a linear to a circular economy fundamentally changes the structure of economic activities as well as the relationships of different actors along a product's lifecycle. At the same time, the potential of a DCE can only be realised when all relevant stakeholders are involved (Leclerc and Badami 2022; Rejeb et al. 2022). This new configuration needs to be considered when designing governance structures and policies for a DCE within a twin transition.

Especially, the role of consumers becomes central and more diverse in a (digital) CE: Consumers are no longer simply associated with the usage of a product, but also with its (re)creation, maintenance and transfer to the other stakeholders, such as another user or a recycler. In this context, consumers can potentially become so-called '**prosumers**', who not only consume but also produce products and services by reusing, sharing or repairing products (Kadner et al.

2021). Digital data collection and exchange can support this active role by providing information about products and services when the information is provided in an accessible, transparent, and inclusive manner. The pace and level of digitalisation for a CE thus needs to reference the current capabilities of different stakeholders. It should be avoided, for instance, that certain groups are (involuntarily) excluded from services because they lack the education, technologies and/or other skills such as language needed to access the data (Jäger-Roschko and Petersen 2022). Moreover, the discussions about data management (section 4.1) and standardisation (section 4.2) should ideally be held in a democratic, participatory, inclusive multi-stakeholder process to guarantee that all interests (economic, environmental, and social) are represented.

In this context, data and its governance become an empowerment mechanism that increase the **agency** of consumers (and other stakeholders). Consumers are empowered to retrieve and use product data which is, for instance, provided via a DPP and also provide data to the manufacturers about the use phase of the product via digital interfaces. As customers play a central role in a CE as users of products and services, it is considered necessary to improve a business's marketing from one-way business-to-consumer communication to a two-way communication that fosters information exchange between businesses and consumers (Antikainen et al. 2018). **Digital platforms** have the potential to facilitate such networking processes across several actors along the entire lifecycle of a product, in particular manufacturers, consumers, end-of-use managers and recyclers (VDMA European Office 2019). By connecting these actors, products can potentially be designed holistically and circularly from their cradle. Digital platforms can provide ways to coordinate the reverse logistics of 'waste' streams in a decentralised way that empowers consumers and opens up new responsibilities for users and businesses (Kurniawan et al. 2022). Moreover, such platforms potentially allow a connection of value chains of to enable collaboration between different businesses and circular material streams.

The EC already acknowledged the importance of empowerment as a governance dimension towards circularity in its newest CE action package which was presented on 30th March 2022 (EC 2022a). In line with this, the EC proposed to revise the Consumer Rights Directive and oblige businesses to make accessible and understandable data about the durability and reparability of their products available to consumers (EC 2022c).

5 Recommendations for EU and national policy makers

In order to facilitate the widespread adoption of a DCE within a twin transition, the question arises of how EU and national policy makers can foster its potentials and overcome some of the challenges. Currently, EU policies linked to steps towards a DCE are often fragmented and lack a holistic representation of the complex interactions between different stakeholders along a product's lifecycle. Often, policies focus only on waste and end-of-use management instead of considering all phases of a product's lifecycle. However, **circularity is a system characteristic** that relates to all phases of a product's lifecycle involving all associated stakeholders. It should therefore be integrated into all production- and consumption-related policies. In order to support the twin transition, a DCE needs to be governed in a way that supports and empowers all stakeholders regarding their willingness and ability to work together towards circularity. In this context, the governance of information flows and stakeholder relationships for circularity will need to be a future priority area for digitalisation and CE. Only if all relevant actors are willing and able to share and use relevant data, processes can be changed from being linear to being transparent and circular.

The development of a strategy at the EU level that coordinates the actions of the Member States and other stakeholders in a holistic and coherent manner while also acknowledging the country-specific differences (e.g. the current digital circularity levels), is urgently needed to **transition towards a DCE within a twin transition**. The recommendations below thus aim to support the twin transition within a DCE by presenting opportunities to integrate new ways of governing for circularity into policy. They focus on the different dimensions of governance for circularity derived from our empirical work (and therefore do not present all possible recommendations for governing and implementing a DCE). By combining digital and environmental policies, the currently observable mode of approaching them as silos can potentially be overcome. Such an integrated systems perspective can address that policy proposals do not counteract each other and may open up significant potentials for new policy alliances and synergies that support a twin transition. National policy makers, such as the German government, can use these recommendations to strengthen the priorities for action in their activities within the EC.

5.1 Recommendations for EU policy makers

- **Strengthening a participatory, inclusive and equitable approach to circularity by empowering consumers to take an active role within a DCE**

Within a DCE, the empowerment of consumers so that they can take an active role in 'prosuming' products and services as well as sharing and processing data is an essential foundation. On the EU level, enabling consumer empowerment within a DCE can build on previous policy efforts, especially the new initiative on Empowering Consumers for the Green Transition that was presented as part of the new CE Action Package on 30th March 2022. The initiative aims at ensuring that consumers have access to relevant information about the environmental performance, durability and reparability of products to make conscious consumption decisions. Still, to be able to implement this request, the EC in collaboration with other stakeholders need to determine more concretely, which information needs to be made available by whom and how consumers can access it. One starting point is to require businesses to make transparent statements about their products, as it is called for in the EU Green Claims Initiative from 2020. In order to use governance for circularity as an empowering mechanism, the EC can explore different options how digital data collection and exchange needs to be formulated. Multi-stakeholder dialogs that include consumers as well as other stakeholders in a transparent,

inclusive, and equal manner can help to gain an integrated perspective on the different needs and concerns regarding these matters.

- **Facilitating a transparent data exchange by exploring options for standardisation and developing the DPP as a governance instrument**

EU policy makers should make it a priority to facilitate the coordination and exchange of data between different stakeholders by establishing common standards that guarantee the compatibility and quality of data and material flows. Due to differences between industries, the use of multiple, more specific standards may be more conceivable than referring to one standardisation. In general, an important aspect is the interoperability of different data management systems to avoid missing linkages between (already) stored information. The concept of DPP as a standardised method to exchange data is already referred to in several initiatives and strategies, such as the overarching Sustainable Product Initiative and product-specific regulation, e.g. the EU battery regulation, the EU strategy for sustainable and circular textiles and the revision of the Construction Products Regulation. While these initiatives describe the use of DPP in broad terms, a specific strategy for its implementation still needs to be developed. Therefore, the EC should explore options for more detailed standards and guidelines on the type and depth of information to be covered by a DPP, possible ways of storing the data and its availability as well as the accessibility of certain information. Together with cross-sectoral industry representatives and other stakeholder within a CE, the EC could explore the understanding of DPPs not only as an informative instrument towards circularity, but also as a governance instrument regarding data that actively shapes which information is shared between whom and how and why.

- **Exploring possibilities to allow for data altruism while respecting intellectual property rights and privacy regulations for all stakeholders**

While a transparent flow of information is crucial for a DCE, policies need to balance the incentive to share data with data protection. While the EC already refers to the concept of data altruism in order to increase data collection and exchange, its adoption remains uncommon. Altruistic behaviour is more likely to be shown when people trust that their data is protected and not misused, and when the process of data sharing itself is practicable for them. Consequential, the EC can assign an expert group to explore two starting points to promote data altruism: (1) Passing clear guidelines and regulations on the use rights for data for circularity. In line with the idea of sharing information on a 'need-to-know' basis, the possibility of creating different DPPs for different stakeholder groups can be evaluated further to determine what information should be accessible for which stakeholder group. (2) Evaluating under which circumstances data protection obligations for altruistic behaviour as they are currently defined by the General Data Protection Regulation and the Data Governance Act can be loosened in order to lower bureaucratic obstacles for data exchange and processing. Still, data sovereignty should be a corner stone of new/revised policies to ensure that the data is subject to EU laws and best practices.

5.2 Recommendations for German policy makers

- **Gaining new perspectives on developments towards a CE based on a twin transition by putting its governance at the centre**

The political discussion about implementing a CE often focusses on Ecodesign regulations and the promotion of technological innovation. However, this focus neglects the governance of data and actors' relationships within a DCE. The BMUV can therefore explore how the policy

discourse and institutional innovation can be refocussed from technology to governance for circularity and integrate this new perspective into (existing) national regulation, such as the German Digital Strategy (German Federal Government, 2022), and discussions on the EU level, e.g. regarding a further development of the Sustainable Product Initiative or the Data Governance Act. The question to be explored is, how (existing) policies could be enriched by incorporating a focus on governance for circularity, including goals like consumer empowerment, democratic participation, and data-oriented innovation for the common good. Such an integrated systems approach still needs to be configurated – but it could be crucial for implementing a DCE towards sustainability as it truly breaks with the linear, efficiency-driven logic and replaces it with perspective that puts data governance for circularity into the centre. In order to gain new and diverse perspectives on how the focus on governance can establish a new innovation approach towards circularity, the BMUV could conduct workshops on 'Governance for Circularity' with different stakeholders from science, business, civil society, etc.

- **Working towards the establishment of a data infrastructure for digital data collection and exchange by using Gaia-X as a starting point**

Building on the new understanding of governance for circularity, the BMUV could support the development of the systemic and integrated data infrastructure that is needed for digital data collection and exchange. As described also in the German Digital Strategy (German Federal Government, 2022), the European Gaia-X project could be developed into such a data system that enables data sovereignty. Gaia-X (https://gaia-x.eu/) aims to be a cross-sectoral and openly usable data infrastructure that connects different cloud services via open-source applications. In Germany, the Federal Ministry for Economic Affairs and Climate Action currently runs a funding competition to promote innovate and practical applications for Gaia-X. So far, however, the aspects of a DCE do not play a role here. The BMUV could fill this gap by bringing in the perspective of how Gaia-X could be used for governance for circularity. More precisely, the BMUV can set up an expert working group to develop a position on how public and private data for circularity can be governed and how a data cloud like Gaia-X can create easy access to relevant information for different stakeholders along circular value chains.

- **Advocating for coherent digital and sustainability policies for the twin transition that frame digitalisation as an enabler for circularity and sustainability**

Digitalisation should not be framed as an end in itself, but as an enabler to make circular products and processes more efficient. The push towards a DCE needs to come from systemic governance and regulation by giving a reliable and strategic long-term perspective for companies and other stakeholders. To support the twin transition, the BMUV can help to build an understanding of how policies for a DCE should address digitalisation, sustainability and circularity aspects together in a coherent policy approach. Policies should not be classified as 'sustainable' or 'digital' but as 'sustainable and digital'. This means addressing opportunities and challenges of digital technologies in policies related to sustainability and circularity, as well as addressing sustainable and circular objectives in digital policies. In order to leave no one behind, the BMUV could advocate for policies to be based on the current digitalisation and circularity levels of industries and to develop future pathways that allow stakeholders to build up their capacities and competences to implement a DCE. This way, policies for a DCE can represent a 'win-win-win' solution having positive effects on economy, society and environment.

In conclusion, putting governance at the centre of a DCE has the potential to create an innovation system for circularity that focusses on data management, standardisation and empowerment of stakeholders, especially consumers. Part of such governance processes need to be critical and regular reviews whether the efforts of creating a DCE reflect the interests of different stakeholder groups and provide net sustainability benefits for the environment, society and the economy. Corvellec et al. (2022) have discussed the risks that CE policies could rather normalise and perpetuate existing intensive and fast production and consumption cycles rather than bringing about change towards sustainability. Instead of focusing on the idea of unlimited (green) growth, policies should strive for governance towards a resilient and sustainable DCE. The aim of a CE to decouple economic growth from its environmental impact still remains a utopia (Corvellec et al. 2022; Cullen 2017). Digitalisation can support the development of a CE into this direction – when it is actively governed and framed in the context of social-ecological transformations that prioritises reduced environmental impacts and social benefits.

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