ECDF
WORKING PAPER
SERIES

EINSTEIN
CENTER
Digital Future

#001

Sustainable Digital Market Design: A Data-Based Approach to the Circular Economy

Dominik Piétron, Philipp Staab,
Florian Hofmann

This Working Paper Series is published by the
Einstein Center Digital Future (ECDF).

All issues of the ECDF Working Papers Series can be downloaded free of charge at:
www.digital-future.berlin/forschung/ecdf-working-paper-series

The ECDF Working Paper Series serves to publish initial results from the ongoing research projects of ECDF members and is intended to promote the exchange of ideas and academic discourse. The publication of a preprint in the ECDF Working Paper Series allows the authors to publish it again in another format from the viewpoint of the ECDF, but the subsequent publication is governed by the rules of the respective medium. The copyright remains with the authors. The authors are responsible for the observance of copyrights and exploitation rights of third parties.

Einstein Center Digital Future
Robert Koch Forum
Wilhelmstraße 67
10117 Berlin Germany

E-Mail: info@digital-future.berlin

This discussion paper emerges from the project “Digitalization for Sustainability - Science in Dialogue” (D4S). D4S is dedicated to develop a progressive vision for a digitalization that fosters environmental and social sustainability. The research network unites European researchers and practitioners representing a variety of institutions and discourses. The project is supported by the Robert Bosch Foundation and coordinated by Prof. Dr. Tilman Santarius and his team at the Einstein Center Digital Future and the Technical University of Berlin, Department of Social Transformation and Sustainable Digitalization.

More information:
digitalization-for-sustainability.com

D4S Digitalization for Sustainability Science in Dialogue

Citation: Dominik Piétron, Philipp Staab, Florian Hofmann (2022): *Sustainable digital market design: a data-based approach to the Circular Economy.* ECDF Working Paper Series #001, Policy Paper for the D4S-Network, 28th January 2022, Berlin. http://dx.doi.org/10.14279/depositonce-15014

DOI: http://dx.doi.org/10.14279/depositonce-15014
Author(s) for this issue: Dominik Piétron, Philipp Staab, Florian Hofmann
Reviewer for this issue: Tilman Santarius, Felix Biessmann

Sustainable Digital Market Design: A Data-Based Approach to the Circular Economy

Policy Paper for the D4S-Network

28th January 2022

Dominik Piétron, Philipp Staab, Florian Hofmann

Abstract

The European Union is currently making great regulatory efforts to shape digital markets. Yet despite existential pressures from environmental crises, little attention is being paid to sustainability goals. In this paper, we argue that the design of digital markets holds great potential for an environmental transformation of the economy. Therefore, we combine the market design approach with the circular economy concept to highlight the need for new market rules that focus on the environmental governance of data. The focus is on product-related data that can help connect material and product flows and create new collaborative ecosystems. We present a policy framework that includes the specific selection criteria for relevant data sets at each level of the product life cycle. We conclude with concrete suggestions on how sustainable digital market design can be implemented in upcoming EU policy initiatives to increase product transparency and enable systematic digital tracking of goods and materials for a circular economy.

Dominik Piétron is a research associate at the Department of Social Sciences at Humboldt University Berlin. He works on the political economy of digital capitalism with a special focus on data and infrastructures. dominik.pietron@hu-berlin.de

Prof. Dr. Philipp Staab is Professor of the Sociology of the Future of Work at the Humboldt University in Berlin. His work focuses on the sociology of work and industry, political economy, economic sociology, and social inequality. philipp.s.staab@hu-berlin.de

Florian Hofmann works at the Technical University Berlin as a researcher, lecturer, and consultant focusing on circular economy, and transitions to sustainable futures. florian.hofmann@tu-berlin.de

TABLE OF CONTENTS

List of abbreviations

API	Application Programming Interface
B2B	Business-to-business
B2G	Business-to-government
BOM	Bill of Material
CAD	Computer-aided design
CE	Circular Economy
CO_2	Carbon Dioxide
DPP	Digital Product Passport
EPREL	European Product Database for Energy Labeling
EU	European Union
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
ICT	Information and Communication Technologies
IoT	Internet of Things
IPR	Intellectual Property Rights
NGO	Non-governmental Organization
PDP	Product Data Platform
PEF	Product Environmental Footprint
RMI	Repair and Maintenance Information

1. INTRODUCTION

"The lesson of market design for political debate is that to understand how markets should be operated and governed, we need to understand what rules particular markets need."
(Alvin Roth, 2015, p. 227)

Markets must be designed properly to serve the common good. This is particularly evident in the digital economy, where platform companies have profoundly restructured value chains over the last 20 years. According to a basic definition, digital platforms constitute infrastructures that enable interaction between different parties. As "Transaction Platforms" (Gawner & Srnicek, 2021), they often operate as marketplaces, connecting supply and demand, as in E-Commerce, App Stores and IoT-Marketplaces. Platform companies such as Amazon, Google or Salesforce use their power over their respective marketplaces to set up precise rules for sellers and buyers via software code. This type of algorithmic market design generates trust and decreases transaction costs, but it also leads to huge power asymmetries and socioeconomic distortion. Many platform marketplaces have grown to be so large that substantial parts of the overall market are controlled by a single entity, creating new market barriers and jeopardizing the independence of market participants.

In this context, The European Union is undertaking a major regulatory effort to improve the design of digital platform markets. A series of recent legislative proposals such as the Digital Markets Act, the Digital Services Act, the Data Governance Act and the Data Act are an attempt to combat the negative effects of excessive market power and reclaim market design as a matter of public interest. The drafts reflect the classic objectives of competition policy by protecting market openness, sanctioning abuse of market power and creating more transparency for platform users. However, they also contain a whole range of new regulatory instruments that acutely affect the privatized market design exercised by platform companies.

The forthcoming European digital regulations represent a new type of policy intervention that is more focused on the technical infrastructure of platform markets and especially addresses the algorithmic design of data flows. In that spirit, mandatory data-sharing and interoperability obligations for operators of platform markets are increasingly debated as powerful tools to tackle digital market power. The new data policies include, for example, the provision of standardized data for effective data portability, mandatory interoperability against abusive market exclusions, a right for users to access data generated by themselves and an obligation for platforms to provide information on how their algorithms function. The EU generally encourages businesses to share data with governments and other companies to foster innovation. Furthermore, the European Data Space is built as a "rulebook" for cloud platforms including a publicly designed "marketplace for cloud services" (COM(2020)66) that enshrines European values such as competitiveness and data protection.

EU's Digital Market Regulation – Disconnected From the Resource and Climate Crisis?

The European Commission increasingly sees data as an "enabling condition" (COM(2020)66) and a powerful resource that needs to be governed cautiously. However, the European regulation of the digital economy has so far paid surprisingly little attention to achieving ecological goals. EU digital market regulation addresses a whole number of negative externalities of digitization, such as market tipping, lock-in-effects, rent extraction, tax avoidance, labor rights violations, data abuse, mass surveillance, dark patterns, etc., but sustainability goals such as reducing CO_2 emissions, encouraging material reuse and minimizing waste are missing. This neglect of ecological issues is puzzling: Data-based companies such as Google and Amazon are among the most powerful in the world, but their responsibility for climate and the environment plays almost no role in the current regulation debates.

At the same time, there is growing recognition of the view that digital transition and sustainability agendas have to merge to address existential ecological threats. The European Green Deal with its NextGen funding stipulates that one-third of the 750 bn euros must be spent on digitization projects and one-third on sustainability. Nevertheless, the integration of the omnipresent "twin transition" of digitalization and sustainability into common EU regulations is relatively limited. Infrastructure projects such as the European Green Deal Data Space touch on the potential of data-based climate protection through gathering environmental data but remain basically disconnected from resource extraction and waste generation in the economic system.

Digitalization as an enabler for the ecological transformation

In this paper, we argue that the creation of new market rules for generating, storing, accessing and using product-related information holds great potential for sustainably transforming the economy, especially ecologically. The basic idea is to use available digital infrastructures to ensure economies are more ecologically governed. One key to realizing this idea lies in the sustainable governance of data. Digitally monitoring ecological costs and connecting value chains could foster a structural change towards more sustainable market ecosystems.

In this vein, digital market design can create data infrastructures that *inform* stakeholders better about how to support the ecological transition. The specific use cases are as follows.

→ **report and monitor ecological costs** of our economy by collecting environmental footprint data of products and services

→ **improve availability of sustainability-related product information** and ease access to sustainably manufactured products/services

→ **promote longer product life** by providing repair and maintenance information as well as compositional data

→ **enhance shared usage of infrastructure services** through data-based connection of providers

→ **help to close material flows** with reliable data flows on byproducts and recyclable waste

→ **regulate production patterns** according to their environmental impact and their necessary contribution to emission savings

→ **enable better decision making** by analyzing Big 'environmental' Data

The design of digital information flows to help develop ecological ecosystems with fewer emissions, less waste and high natural resource efficiency has been especially proposed by Circular Economy (CE) researchers. The CE has emerged as a new paradigm in redesigning production and consumption systems in that it reduces greenhouse gas emissions by managing natural resources effectively and minimizing waste generation. CE scholars have repeatedly stressed that a deficit of information hinders the ecological transition of our economies (Agrawal et al., 2021; Berg et al., 2020; Berg & Wilts 2019; Hedberg & Šipka, 2020; Jabbour et al., 2019; Kristoffersen et al., 2021). In the European Circular Economy Action Plan which serves as the strategic cornerstone of the European Green Deal, the collecting, providing and linking of product information with a digital product passport (DPP) plays a major role in making the European economy future-fit.

However, little has been done so far to overcome the deficits in ecological product information. There is still no clear roadmap as to what specific data is needed and how it should be reliably collected and provided, and ecological transparency is further complicated by power asymmetries in production networks and financial interests in old industries. Achieving the needed transparency requires a systematic approach from European regulators.

Policies for a sustainable digital market design

The paper aims to provide a systematic approach to a data-based CE, with a particular focus on mandatory data exchange at the market level. It follows the main research question of how the regulation of the digital economy can also support the ecological transformation of the European economy. In the **second section**, we argue that the objectives of the regulatory design of digital markets must be adapted to the actual social-ecological needs. Market architecture can no longer serve only the optimization of prices through competition, as is the case in neoclassical economic theory. Instead, the objectives of market design also have to be in line with comprehensive climate and natural resource protection measures and support an ecological transformation of production and consumption patterns.

The main contribution of the paper is the *circular-data-action-matrix* – an integrated policy framework for a data-based CE presented in **section three**. The matrix highlights the yet unused potential of a sustainable data governance and shows how data-based market regulations can take place in each phase of a product life cycle. Here, the key message is: The availability, accessibility and usability of product and ecological impact data via new digital intermediaries can substantially contribute to reducing CO_2 emissions, material consumption and waste. Rather than a data economy that focuses exclusively on tracking human behavior, we need more product transparency and a systematic digital tracking of material flows to allow a better reuse, repair and recycling of products.

Finally, **section four** presents sustainability principles for a digital market design and links them to upcoming legislative initiatives at the European level. We formulate policy recommendations related to a coordinated development of the European Digital Product Passport as a basis for the standardized collection and provision of product-related environmental data. Covering three upcoming European policy initiatives – the Data Act, the Green Deal Data Space and the Sustainable Product Initiative – we give policy recommendations that show how European data regulation initiatives can contribute to the economy's ecological transition.

2. THE CONCEPT OF SUSTAINABLE DIGITAL MARKET DESIGN

"Climate change is a result of the greatest market failure the world has seen", wrote Sir Nicholas Stern (2007, i) in his famous climate report. In fact, our production and consumption patterns cause persistent ecological problems such as climate change, massive biodiversity loss and growing resource scarcity (IPCC, 2021). But any contributions to those ecological costs are not included in the market prices, so that market participants are incentivized to maintain any negative behavior. This way, markets are programmed to constantly extract more natural resources, produce new products and generate large amounts of waste to increase profits as ecological and social costs are externalized .

Stern's definition of the sustainability crisis as a market failure highlights an important point: If we analyze the flaws in the architecture of markets that threaten our natural livelihoods, we also should be able to develop new rules for markets to function within planetary boundaries. But how could markets in the digital age be designed in ways that make them contribute to sustainability?

The art of designing markets

A common adage among liberal economists and their critics states that markets do not emerge and survive naturally. Instead, they need public protection and active regulation to function properly and deliver the best allocative outcomes[1]. This perspective has been taken up by market design approaches, an area of study that has gained popularity within economics in the last decades (Milgrom, 2011; Posner & Weil, 2018). One of the most prominent proponents of market design, Nobel laureate and Stanford professor Alvin Roth, wrote: "the lesson of market design for political debate is that to understand how markets should be operated and governed, we need to understand what rules particular markets need" (Roth, 2015, 227).

In this sense, market design can be defined as a type of economic regulation that sets up rules for marketplaces – the social space in which sellers and buyers meet to trade products and services. Right from the start, marketplaces were shaped by norms and rules that offered market participants protection against unfair practices. Since the late 1970s, market design has developed into an economic discipline of its own (Mirowski & Nik-Kah, 2017). In ever more social domains, economists have been mandated to implement market-like allocation processes. By analyzing market failures, they tried to develop and implement new rules for market participants to make markets' overall allocation performance more efficient and stable (MacKenzie et al., 2007).

---

1 In particular, the founding fathers of neoliberalism criticized the idea of self-regulation of markets and tried to identify the necessary conditions for functioning markets. Hayek wrote: "Probably nothing has done so much harm to the liberal cause as the wooden insistence of some liberals on certain rules of thumb, above all the principle of laissez-faire" (Hayek, 1944, p. 13).

"Markets can be dramatically improved when their design encourages people to communicate essential information they might otherwise have kept to themselves."
(Roth, 2015, p. 170)

Rooted in the tradition of game theory and behavioral economics, market design theories acknowledge that "prices don't do all the work" (Roth, 2015, 5), as neoclassical economists stipulate. Instead, they rest heavily on the control of information flows and on the difference between private and public information in particular. Inspired by Hayek's notion of markets as ultimate information processors, market engineers seek to redesign market institutions to create incentives for market participants to reveal their true preferences. In this way, strategic gaming behavior is to be discouraged and market failures prevented (Hitzig, 2020).

In practice, market designers need to match two types of information to implement stable and efficient market matching mechanisms – first, signals from the supply side about the characteristics and quality of products and signals and, second, signals from the demand side about consumers' interest and willingness to pay. To ensure that no one is at a competitive disadvantage, market designers ensure that all market participants provide the necessary data by establishing common rules and standardizing transaction processes. For example, to ensure that matching processes such as the distribution of school places function smoothly, all applicants must make their information available in a standardized form; the same applies to auctions, which must follow a clear procedure so that participants can rely on them. In any case, an intermediary or platform is required to collect the information of both market sides and perform the allocation.

Data governance as a market design tool

Over time, market design has become increasingly codified and formalized, culminating in today's online platform markets, such as eBay, Amazon, Uber or Airbnb. The success of these digital markets is based on their ability to process much more information than traditional sales channels such as malls or catalogs (Mayer-Schönberger & Ramge, 2019). Online platform markets can do more than simply bring together an unlimited number of sellers and buyers, since spatial restrictions no longer apply and advantageous network effects and economies of scale increase the value for users. They can also allow for user feedback and ratings to generate trust and enable matches between geographically dispersed strangers. For both purposes, platform market designers must ensure reliable information about trading partners, their preferences, and the products and services traded (Chen et al., 2020).

Online platforms determine on a software basis how market participants interact, i.e. search, comment, trade, pay and deliver. Here it becomes clear how much market design in the digital economy depends on the governance of digital data. The data-based management of platform markets gives market owners full control over the frames of social interaction, making the question of proper market design particularly relevant. Staying in control of the data gathered via their respective platforms is essential for the platforms' success as it enables control over market access, prices and the performance of users who want to participate (Staab, 2019).

Thus, in the ongoing process of platformization, the process of market design is increasingly shifting towards the governance of data flows. To establish a functioning matching mechanism, each market designer must determine who should provide what data, how the data should be processed and who should have access to which data sets. In addition, the completeness, quality and security of the data must be ensured. The different steps that need to be taken for a data-driven market design can be illustrated along the **data value chain** (Li et al., 2019):

→ *Data collection*: Market designers need to regulate what data sellers and buyers must provide to participate in the market. Typically, this regulation involves collecting mandatory product information to make it easier for buyers to search for and compare products. Today, digital platform markets focus on user data and feedback data on products. As users interact with the app or website, they generate copious behavioral data that is tracked and aggregated to improve matching and advertising.

→ *Data sharing*: Markets have to determine which data is shared internally between market participants and externally with regulators or other companies. Internally, market designers have to decide on the data sets suppliers and buyers should see without risking information overload. The selection and presentation of data crucially impact participants' behavior and market outcome. When data is shared externally with other stakeholders in a standardized format, new downstream markets for intermediate applications can emerge.

→ *Data usage*: Data on market development has always been of high private and public interest. Private platform operators usually keep the data they collect to themselves and use it to generate advertising revenue or optimize their own business model. Public actors, on the other hand, try to analyze markets in order to adjust their regulation and take antitrust and tax measures.

→ *Data standardization*: The data collected can only be understood and used meaningfully if it is of good quality and has a consistent data format. To this end, market designers must ensure that data is comparable and that, to avoid errors, its accuracy is independently verified.

In general, online platform marketplaces seek to keep their platforms closed in order to harvest the value of the data generated on their platforms. However, this exclusive de facto ownership of the data leads to welfare losses and encourages anti-competitive behavior (Martens, 2018). Against this backdrop, data sharing obligations are discussed as tools for regulating markets to increase the overall social value derived from data. Especially the mandatory provision of standardized data by certain companies can foster the creation of new downstream markets, as was the case, for example, with the European Open Banking Directive of 2015, which decisively contributed to the spread of digital financial services (Brown, 2020).

What would a sustainable digital market design look like?

In designing data flows, market designers can efficiently design market "institutions so that the behavioral incentives of individual market participants are consistent with the overall goals of the market architect" (Ockenfels, 2013). It is a distinctive feature of market design approaches that they can define goals relatively arbitrarily in terms of formal criteria. In practice however, these overall goals of mainstream market design are mostly limited to a number of economic objectives based on preference utilitarianism as the default normative position, like matching market participants more efficiently, increasing consumer choice and maximizing revenue for the platform owner (Li, 2017). Broader socio-ecological goals such as the struggle against "ecological externalities" of markets in the form of environmental degradation or global warming are neglected.

Most markets fail from an ecological perspective because information about actual ecological costs of products is externalized and not adequately acknowledged – a process which is obvious in markets from resource extraction to the manufacturing of goods and services as well as in consumer markets. To solve this problem, data-based market design has a prominent strategy to offer –collecting and providing additional information about the ecological costs of products and services.

To set this strategy in motion, the first and foremost need is for trustworthy and comprehensive data about the ecological externalities of goods and services. However, data is clearly lacking in this regard, as can be seen, for example, in the certification of products with eco-labels. Eco-labels are an important policy tool that shows how additional product information could support sustainable consumption patterns. But the impact of many label initiatives is limited because they are not mandatory and there is often no trustworthy auditing of the respective eco-standards. Basically, eco-labels can only be as good as the information they provide about the actual ecological costs of the certified products, and this information can only be as good as the data it builds upon. Climate-friendly businesses and ecological production and consumption patterns can only be supported through a standardized and trustworthy collection of data on the ecological externalities of products and their supply chains.

"The circular economy's implementation is primarily a problem of information."
(Berg & Wilts, 2017, p. 4)

As sustainability research in the previous decade has shown (Frantzeskaki et al., 2012; Grin et al., 2010), the availability of ecological data alone will not solve complex problems of socio-economic coordination, and policy makers should be cautious when looking for 'simple' technological fixes. However, a standardized and trustworthy collection of CO_2 emission data on ecological externalities can significantly advance an ecological transition of the economy far beyond the promotion of sustainable consumption and can also *inform* new ways of (re-)production. For example, data about the material composition of products can help reduce overall material and energy consumption through practices of reusing, repairing and recycling. Moreover, additional information flows can even create new markets and encourage cooperation between companies. In this way, an industrial symbiosis can be created in which by-products are reused in the supply chain, or fragmented services are linked to form holistic value networks in the sharing economy.

But how exactly can market engineers determine which information is needed for ecological transformation? Creating information flows that support sustainable production and consumption patterns requires a comprehensive vision of an economy that operates within planetary boundaries. Such a guiding paradigm can be found in the idea of the Circular Economy.

The Circular Economy as a market design paradigm

The concept of the CE is a promising ecological transition path that has gained popularity among politicians, corporate representatives, business consultancies and academic researchers (Korhonen et al., 2018). The CE differs from the orthodox 'take-make-dispose' value creation and destruction logic[2], by explicitly incorporating approaches that support the creation and delivery of economic value through using already existing products and materials in multiple-use cycles (Blomsma & Brennan 2017; Friant et al., 2020; Hofmann, 2019). The assumption is that a CE will downscale overall consumption levels and thus reduce the anthropogenic pressure on nature by closing material flows, extending product lifetimes, dematerializing value creation processes and value propositions, and sensitizing and empowering users to rethink their consumption behavior (Hofmann & Jaeger-Erben, 2020). Various actors are trying to implement CE rationalities in different arenas of society: the European Commission through mission-oriented CE innovation policy programs such as the European Green Deal and the Circular Economy Action Plan, several national governments (e.g., the Netherlands, Japan and Germany), economic think tanks (such as the Ellen MacArthur Foundation), business pioneers such as Patagonia, Interface or Fairphone and business consultancies.

CE solutions cannot be driven successfully by one company alone but require the collaboration of many. They are system innovations (Hekkert et al., 2020), as reflected in the circular ecosystem perspective (Konietzko et al., 2020). The isolated shift and optimization of a focal actor's business model must be overcome and replaced with the right configuration, optimization and distribution of value creation architectures (Hansen & Revellio, 2020) within a circular ecosystem. A circular ecosystem describes the interplay of legally independent complementors that jointly create circular value propositions with the collective purpose of prolonging product lifetimes and closing material flows. Hence, it involves a bundle of actors with different business models from various industries and markets that pursue a variety of CE action principles – designers, producers, service producers, repair contractors, refurbishers, remanufacturers, users, recyclers – along the whole value cycle. The role of each actor in the ecosystem becomes relevant at different points in the product life cycle, as illustrated in Figure 1.

---

2 The "take-make-dispose" value creation and destruction logic starts with the extraction of finite natural resources, which are transformed into human artifacts, followed by distribution and consumption that finally culminates in landfilling and incineration. Compared to products and services that have temporary benefits (sometimes only fractions of a second), their social and ecological costs have a disastrously accumulated impact on the present and future of human development and planet earth.

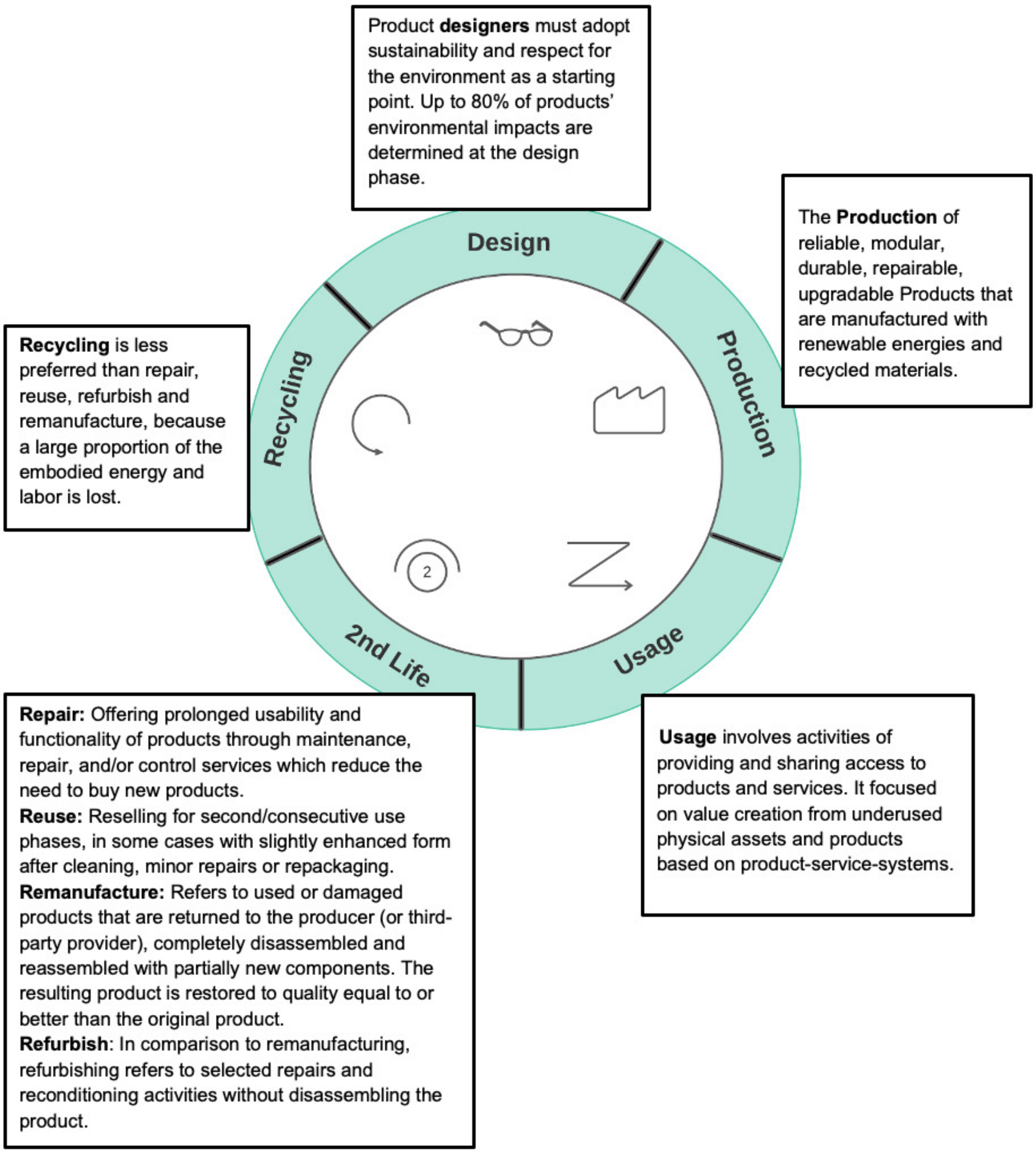

Figure 1: Five phases of the product life cycle with Circular Economy principles.

In light of the sustainability potential arising from CE solutions, we are facing the question of why we are still so far from operating circular ecosystems. One reasons for the failure of CE solutions is insufficiently and inadequately organized data access, information flows and information distribution[3]. A lack of information on supply, quality and availability paired

3 There are a variety of other reasons why the shift towards a CE is still in its infancy: Lack of market incentives (e.g., low raw material prices, high-quality materials not competitive in price); technical path dependency (lock-in) through long-term investments; rapid innovation cycles and corresponding consumer expectations (especially regarding repair and maintenance); policies that encourage recycling, incineration or disposal rather than other circular strategies such as reuse or repair; lack of tax on environmental degradation (e.g., CO2 tax); lack of resource taxation; lack of incentives for circularity investments. For further information see Hansen et al. (2021).

with missing knowledge on suitability and feasibility lead to failures in the processing of recycled materials and in the uptake of reused, repaired, refurbished or remanufactured products. These failures result in a (false) preference for brand new manufactured goods and virgin materials, blocking the emergence of CE ecosystems.

Several factors contribute to information asymmetries and market non-transparencies that facilitate a "take-make-dispose" system logic (Berg & Wilts, 2019; Hedberg & Šipka, 2020):

→ *Lack of information about used products and secondary materials* (value, price, quantities, qualities etc.) lead to high search costs.

→ *Externalization of ecological costs of new products* lead to unjustified price advantages for primary materials.

→ *Lack of data regarding product and material compositions* prevent repairing, remanufacturing and recycling of products. This lack is often triggered by concerns over intellectual property rights (IPR).

→ *Lack of data standards affect the comparability of environmental costs* of products. For example, limited or inadequate data can prevent efficient labeling of products.

→ *Misconceptions about quality and suitability of used products and secondary materials* lead to preference for new products and virgin materials.

Newly designed and redirected information flows are some of the essential prerequisites for effectively establishing and efficiently orchestrating circular ecosystems. In most cases, circular ecosystems are held together by one designated keystone actor. Today, as digital transformation has progressed considerably, cohesion of circular ecosystems is increasingly based on digital platforms that enable collaboration independent of time and place (Konietzko et al., 2020).

Digital CE-platforms should be designed so that they can organize data streams, economic interactions and social exchange processes among the stakeholders in the circular ecosystem. To this end, many digital CE-platforms are constructed as multi-sided, digital marketplaces, where participants exchange used products, product components or secondary raw materials (e.g., ebay, cirplus, or madaster), build communities (e.g., Upcycling-Movement, Open Source-Movement), match information providers and service contractors with users (e.g., repair services, product repair instructions or labeling organizations), or peer-to-peer exchanges of offline services (e.g., ridesharing, tools sharing) etc..

Better management of data through establishing digital CE-platforms with a view to improving information sharing and knowledge transfer could raise awareness and provide a breakthrough for circular ecosystems. Digital CE-platforms can facilitate connections and collaboration between stakeholders and create additional information flows for products and materials along the value chains (Figure 2).

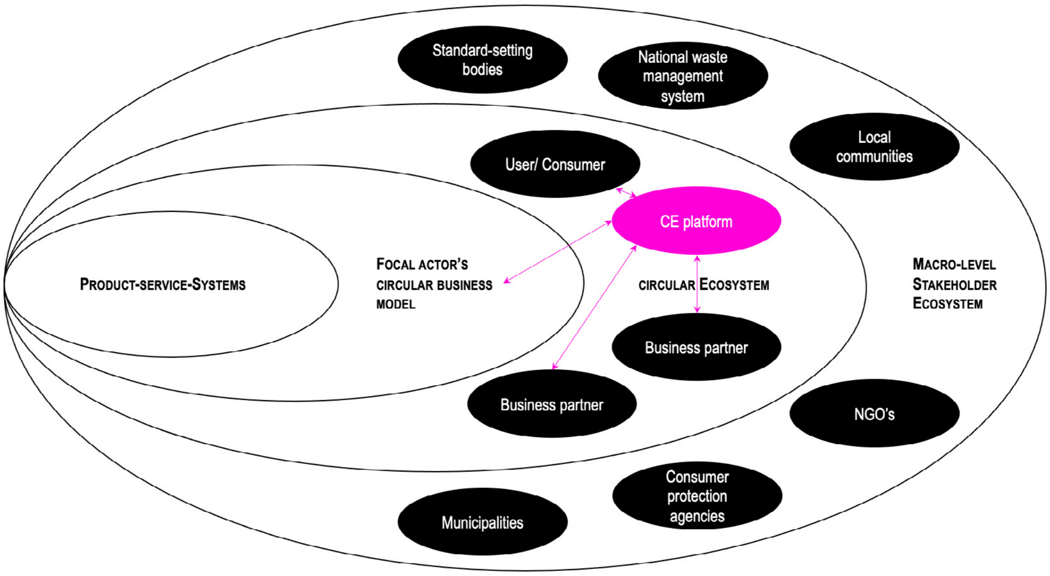

Figure 2: Circular Ecosystem Map

Although a greater use of data and digital CE-platforms can contribute substantially to diffusing circular ecosystems, it will not automatically reduce CO_2 emissions and natural resources consumption. An integrated digital-circular market design strategy can irritate current "take-make-dispose" practices and empower new economic procedures, but it is not without problems. First, although better information on sustainability issues does impact consumption decisions of environmentally conscious people, it will likely have limited impact on changing mainstream consumer behavior unless it is designed to connect into existing decision-making processes (O'Rourke & Ringer, 2015). Second, if not guided and governed well, digital approaches to sustainability always risk unwanted rebound effects such as overall increased energy demand (Lange et al., 2020). Therefore, the broader diffusion of successful digital CE-platforms can only be achieved when contextual factors of the macro-level stakeholder ecosystem, such as policies, market designs and broader institutions, facilitate the transition towards sustainability-oriented circular ecosystems.

Current digital-circular policy initiatives in the EU

The digital-circular approach described above has already been implemented in several policy initiatives at the European level. The initiatives recognize the lack of reliable information and see digital provision of additional product data as key to more sustainable markets:

→ The *European Green Deal* (COM(2019)640) stresses that "reliable, comparable and verifiable information also plays an important part in enabling buyers to make more sustainable decisions". The report points out that this requires companies to employ "a standard methodology to assess their impact on the environment" and that "regulatory and non-regulatory efforts to tackle false green claims" are needed.

- → The *Circular Economy Action Plan* (COM(2020)98) highlights a number of areas where the "digitalization of product information" can enable the CE. This support would require digital technologies to track the journeys of products, components and materials and make the resulting data securely accessible.

- → The *European Data Strategy* (COM(2020)66) supports the Circular Economy Action Plan by envisioning a "European data space for smart circular applications". The data space provides a digital architecture and governance infrastructure to make available the "most relevant data for enabling circular value creation along supply chains".

- → The latest *Rolling Plan for ICT Standardization* (European Commission, 2021) lists a whole range of actions to bring together the many CE initiatives of the biggest Standard Development Organization. These actions primarily involve technical guidelines in the area of data governance such as "identifiers, vocabularies, semantics, taxonomies, ontologies for circular economy".

- → The *Sustainable Product Initiative* (European Commission, 2020a) aims at making products more sustainable by "establishing EU rules for setting requirements on mandatory [...] disclosure of information to market actors along value chains".

A key policy tool previewed in all initiatives is the *digital product passport (DPP)*. This passport is a data set that combines information on all phases of a product's life cycle, such as "product's origin, composition, repair and dismantling possibilities, and end of life handling" (COM(2019)640, 8). It should foster collaboration among companies and enable transparency for consumers and regulators by being available to all players in the CE ecosystem in a standardized format. Furthermore, modularly designed products are expected to have integrated sensor technology that allows the collection, storage and evaluation of real-time information about the current condition of those products, improving their local accessibility and integration in sharing ecosystems. However, such a passport has not yet been established. Approaches for a DPP exist, but they have not yet been institutionalized through mandatory standard data sets or central databases.

The initiatives are a good start, but essential components of a digital market design for the CE are still missing. First and foremost, a mandatory data sharing obligation for companies and the relevant data sets must be specified as soon as possible. Furthermore, it is necessary to regulate how this data is collected, provided and used by establishing general standards on which all stakeholders can rely. The following section presents a comprehensive framework on how the processing of product data at all levels of the product life cycle can foster the sustainable transformation of our economy.

3. CIRCULAR-DATA-ACTION-MATRIX

Data-based market design measures for the CE can start at every single phase in the product life cycle. The following table combines the product lifecycle phases with the data value chain and serves as a ***policy framework to combine sustainability and digitalization goals***. It shows which actors can collect, provide, use and standardize which data sets in order to enable a data-based CE.

	Data collection	**Data sharing**	**Data usage**	**Data standardization**
Design	Producers create **digital 3D-models** of spare parts during product development	Producers share 3D-models via trusted intermediaries that protect IPR-rights	Users can buy 3D-model-data to print spare parts with a local 3D-printer-dealer	Standardization body develops standards for computer-aided design-models to enable broad application independent of suppliers
Production	Producers create *life cycle inventory (LCI)* data for products to track all material inputs	Producers share LCI data via open Application Programming Interfaces (APIs) with sellers, buyers and regulators	Labelling organizations use LCI-data to create Life Cycle Assessments (LCA) to evaluate products Sellers monitor LCA data in their shops Producers and consumers can adjust their purchases according to the ecological impact of products Regulators develop transition plans for industries and can monitor progress	Standardization body develops harmonized standards for the Product Environmental Footprint to generate reliability and comparability

Usage	Products and services are connected to the Internet of Things and **status data** is sent about their location, condition, availability, energy consumption and emissions	Infrastructure operators share product status data via open API with users and platforms Producers of privately owned products share status data via secure API with users and maintainers	Sharing-platforms integrate products as a service to increase product efficiency and accessibility Users and producers monitor product quality and allow for collaborative maintenance to prolong product lifetime Producers and users monitor energy consumption and environmental data during use	Standardization bodies develop standards for status data in different product categories to increase comprehensibility of defect products and interoperability of shared services
2nd Life (Repair/ Reuse/ Remanu-facturing)	Producers create repair and maintenance information (RMI) for products	Producers share RMI data via open APIs with consumer and repairer	Repairers use RMI data to facilitate product recovery and prolong product lifetime	Standardization bodies develop standards for RMI data in different product categories to increase repairability
Recycling	Producers create bill of material (BOM) data of products to declare recyclable materials and components	Producers share BOM data via open APIs with recyclers and platform intermediaries	Recyclers use BOM data to disassemble complex products and facilitate resource recovery	Standardization bodies develop standards for BOM data in different product categories to enhance data usability

Table 1: The Circular-Data-Action-Matrix

The following sections elaborate and explain the starting points of the Digital Circular Action Matrix . Along the five phases of the product life cycle, we outline which data categories[4] are needed for the CE, how these datasets can drive circular ecosystems and which projects are already implementing the idea.

Phase 1: Design/3D-models of spare parts prolong product lifetime

Today, in most industries, every part of a product is digitally developed with computer-aided design (CAD) software. That software allows manufacturers to create geometric, three-dimensional (3D) digital twins of their products to increase designer productivity and improve communication. In addition, the 3D models serve as templates for 3D printing, so-called "additive manufacturing" – a viable industrial production technology in which various materials such as plastics, ceramics or metals are layered by a computer-controlled printer.

By combining these technologies, 3D-models of spare parts can help repair broken products and prolong their lifetime. To this end, the producer, consumer and local 3D printing hubs must be connected in a data-based ecosystem. For example, if a plastic part becomes porous or breaks after a long period of use, consumers can request the CAD data of the broken part from the producer and send it to the local 3D printing hub, have it 3D printed there and install the new replacement part themselves or at a repair store. The benefits are clear:

→ Spare parts can be manufactured at low cost and on-demand, without large stockholding or long delivery distances. This way, the cost for repairing and remanufacturing of products can be reduced substantially.

→ The availability of spare parts is ensured regardless of a manufacturer's business strategy.

→ This process is particularly important for older products where spare parts can no longer be supplied or where the manufacturers are no longer active on the market.

To guarantee an IPR-consistent data management and to facilitate payment and data traffic, the use of platforms as trusted data intermediaries is crucial. Within this process, platforms must not only collect, validate and host the data; they must also make it available to registered users for selected purposes. Based on the "remote-access model" (European Commission, 2020b, 63), this access can be achieved without releasing the raw data, and IPR rights can be protected. These platforms can evolve as a new online business model for aggregating and selling CAD data in the additive manufacturing of spare parts.

4 The explicit focus on product data generally does not necessitate using personal data. However, datasets are often mixed and the boundaries of personal data are fluid so data protection must always be considered (Graef et al., 2018).

Best practice: The EU-funded FIL3D Project (FIWARE Service for Spare Parts Logistics in 3D Printing Digital Supply Chains) developed a business model to provide "the spare parts industry with an open platform [...] where a 'virtual stock' is 3D-printed on demand by local producers" (González-Varona et al., 2020, 3). The FIL3D project covered the entire logistics chain by involving all stakeholders: industrial manufacturers, local 3D printers and customers. In its center was a platform database gathering data sets of 3D models from different manufacturers, with their associated information about IPR, materials, tolerances, colors and printing specifications. To safeguard IPR, the 3D-model was never stored anywhere other than in the FIL3D database. The FIL3D database served as a data trust that provided printing instructions for certified printers and handled payments between consumer, manufacturer and printer.

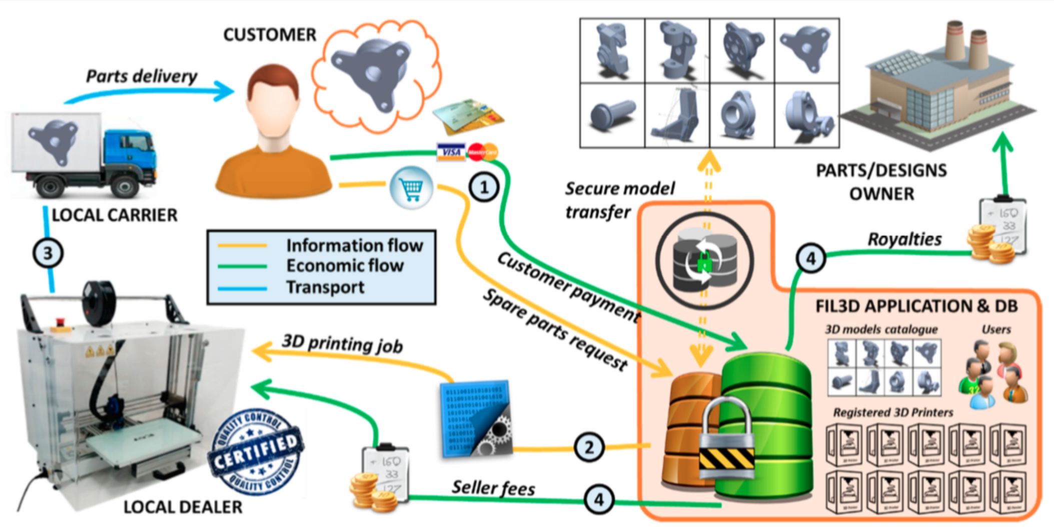

Figure 3: Flow diagram of the service provided by the FIL3D project, by González-Varona et al. 2020

Currently, there are a large number of proprietary file formats from different CAD software suppliers. Thus, there is a lack of relevant standards and recommendations that stakeholders can rely on, creating uncertainties and high risks. To make 3D printing technology useful for spare parts production, a publicly set data standard is needed, such as the ISO/ASTM 52915 standard, which includes not only the shape of parts but also general information such as material properties. However, the most important basis for this sustainable business model is that manufacturers are legally obliged to provide 3D models of spare parts.

Phase 2: Production/LCI data makes ecological costs transparent

Market prices still hide the real ecological costs of our consumption and create misleading incentives. In fact, companies themselves are often unaware of the real environmental costs of their products. Thus, many climate protection measures are striving for better transparency about products' environmental footprints. The current database on the ecological impact of products and services, however, is far from sufficient. The most common way to provide markets with additional information is by certifying products with voluntary labels, but these often suffer from a lack of data and data quality as well as from too weak data verification. Europe's most important instrument against climate protection, the Emission Trading System, also applies to only a few sectors and ignores emissions in the extraction of raw materials, transport and manufacturing at the end of the value chain.

Setting the right incentives in the market requires a more reliable and comprehensive database on the environmental burden of products and services. If every product had a price tag that reflected its true environmental cost, production and consumption patterns could be adjusted accordingly and regulators could ensure that each industry was doing its part to address climate change, e.g., by implementing industry transition plans through a system of "ecological allowances" (Reichel & Seeberg, 2011) based on the planetary boundaries.

Reliably calculating the actual ecological costs requires an *LCI* that is defined as a "compilation and quantification of inputs and outputs for a given product system throughout its life cycle" (Suh & Huppes, 2005). Based on LCI data, independent organizations can calculate comprehensive life cycle assessments to determine, for example, the exact amount of greenhouse gas emissions in each product life cycle phase – from raw material extraction, the processing of pre-products, assembly, packaging and transport to disposal. To this end, each company along the value chain must estimate its CO_2 equivalents per unit, add these to the CO_2 equivalents of its suppliers and pass the total sum of emissions on to the next company in the value chain. Together with other environmental indicators, product LCI data can be synthesized in the Product Environmental Footprint (PEF) (COM(2013)0196) as a simplified information set that would support sustainable consumer decision-making. On this basis, effective eco-labeling can be strengthened and market operators can monitor ecological costs along with the market price, thus allowing an environmental comparison of products.

Implementing such mandatory LCI data sharing for producers has to be supported by effective data governance. LCI data must be collected according to harmonized standards, verified by independent auditors and made available via open APIs so that platform-based data intermediaries can collect the data and provide it to sellers and other stakeholders (Hischier et al., 2014; von Cappelleveen et al., 2018). LCIs are already being conducted today by numerous institutes and industries. However, policymakers must set a uniform standard for LCI measurement, such as the PEF, otherwise powerful private interests will dominate the standardization process.

Best practice: The business-to-business (B2B)-network Catena-X, involving a group of German companies in the automobile sector, is developing a digital tool that will bundle all CO_2 data in the supply chain. Based on the new cloud standard Gaia-X, companies such as BASF, BMW, Bosch, Fraunhofer, Mercedes-Benz, Siemens, VW, Trumpf and several small and medium-sized enterprises are building a platform for sovereign data exchange to make their ecosystem more efficient and controllable[5]. One goal is making suppliers provide the life cycle assessments of their preliminary products through the cloud-platform Catena-X so that automakers can calculate the real footprint of their cars. Yet, since car production involves up to 10,000 individual parts from more than 1,000 suppliers, an automated solution is needed. To this end, German software company SAP is providing its new "Carbon Footprint Analytics" tool, which promises to network the enterprise-resource-planning (ERP) systems of every company along the value chain to analyze and track CO_2 emissions. One of the main tasks will be to harmonize CO_2 calculations and develop a uniform industry standard for measuring LCI data.

Phase 3: Usage/Product status data increases material efficiency

Important data for the CE is also generated when products and services are used. If models are to be shared and products predictively maintained, the main focus must lie on product status data that tracks the location, condition and availability of a product. For many products, status data is already collected by integrated sensors and transmitted in real time over the Internet, making the product an active part of a broader network – the Internet of Things (IoT) (Bressanelli et al., 2018). Keeping energy consumption of IoT networks as low as possible and avoiding resource-intensive hardware solutions is important. That way, the data-driven integration of products into one ecosystem turns these networks into a service that can be accessed by many people via online platforms and hence improves resource efficiency. This can be illustrated by two different business models.

First, the so-called sharing economy has recently achieved great success in restructuring consumption patterns from privately owned products to publicly shared products. Sharing business models connect products via online platforms and make them accessible, like public infrastructure. This sharing is particularly evident for shared mobility, where cars, bikes and scooters can be easily borrowed at any time using a smartphone app. But many more under-used physical assets such as tools, machines, boats or apartments are digitally allocated via sharing platforms and offered to a broad group of customers to decrease overall consumption. However, their potential impact on the environment is mixed: sharing platforms can support sustainable consumption patterns by reducing overcapacity, but they can also hinder them by simply creating additional products to rent out, making additional sectoral regulation necessary (Konietzko et al., 2019).

Second, predictive maintenance has evolved as a business strategy to extend product lifetime. Manufacturers of household devices increasingly offer their products as a service including a permanent performance guarantee. The IoT-devices constantly send

5 Most industrial companies in Germany have already digitized cross-company material cycles, but only two-fifths of them use them as a tool to optimize manufacturing processes fu(Neligan, 2018, 103)

information about their condition and possible defects and indicate necessary repairs. Based on AI-driven big data analysis, the product health and wear can be predicted and maintenance can be scheduled right on time to reduce production downtime.

In both the sharing economy and predictive maintenance, the sustainability potential depends on data access for third parties and on data format standardization. Without data access and standardization, producers can use incompatibilities to eliminate competition and increase switching costs for users. In that case, B2B cooperation and the establishment of circular ecosystems are prevented. Therefore, operators of shared products and IoT device manufacturers should make the product status data accessible in a standardized format: In the sharing economy, sharing platforms can bundle shared services efficiently only if they can access product status data in a standardized data format. And in predictive maintenance, collaborative ecosystems can evolve only if users can freely decide who receives the product status data and can repair the device. For local repairers to be able to repair IoT washing machines, vacuum cleaners or refrigerators, they must be given access to the status data of the products from the IoT producer.

Best practice: In mid-2018, Finland became the first country to introduce an open data obligation for private and public mobility service providers (Finnish Government, 2017). Cab companies, bus and train operators and sharing providers have to make their data freely available. The regulation does not only apply to the status data of vehicles but also stipulates an interoperable exchange of booking and ticket data. Following the principle of interoperability, mobility services have to grant each other access to their ticketing and payment platforms via an API, so that a ticket can be purchased for provider B via provider A (Pursiainen, 2019). This way, the law aimed to facilitate intermodal, i.e. cross-provider, mobility services and thus increase resource efficiency of vehicles and create a convenient alternative to private cars.

Phase 4: Repair/RMI data facilitates reparation of broken products

Repairing complex products such as cars, household appliances or computers requires extensive knowledge. Manufacturer-specific error codes must be interpreted, the functionality of the products must be understood to avoid faulty repairs and spare parts must be identified, procured and installed correctly. Without access to this information, repair is often not possible, products lose value quickly and product lifetime is unnecessarily shortened.

To extend product life cycles, producers should provide repair and maintenance information (RMI) for their products. RMI data can have a positive impact on the environment by enabling local and fast repairs of products, avoiding unnecessary emissions from faulty repairs and increasing resource efficiency of products with an extended product life cycle (COM(2016)782). Today, some manufacturers already share RMI data. In most cases, however, only a small group of licensed repairers have data access while independent third-party repairers do not and therefore cannot participate in product aftermarkets. Therefore, viable circular ecosystems are prevented, and many repair and maintenance services cannot be carried out effectively.

Best practice: Under the Vehicle Emissions Regulation, EU car manufacturers are obliged to provide unrestricted RMI data access for independent repairers "through websites using a standardised format [...] and in a manner that is non-discriminatory compared to the provision given or access granted to authorised dealers and repairers" (Regulation EC No 715/2007). The regulation is considered successful as it has increased both competition for repairs in the automotive aftermarket and consumer choice. However, an investigation by the EU Commission in 2014 brought some problems to light (COM(2016)782): Car manufacturers were using many different websites and interfaces to provide their RMI data without using a common standard. Independent repairers were therefore challenged with bundling different data formats from different sources. Spare parts could not be clearly identified and divergent contract clauses and costs for data access led to many missed or overpriced repairs.

The EU Vehicle Emissions Regulation shows that the conditions in which data sets are disclosed have to be specified in detail and with caution. In particular, the standardization and provision of RMI data should be specified and verified by regulators so that subsequent markets can benefit from a reliable data ecosystem. With this in mind, the Commission also recommends a more structured process for exchanging RMI data in "open data formats" (Regulation EC No 715/2007) that reflect the interests and needs of repairers and users. Data intermediaries such as online platforms have a special role to play in bundling, validating and publishing RMI data.

Furthermore, consideration should be given to how market rules on publishing RMI data can be applied to other sectors beyond the automotive sector. Especially for electronic devices with high resource consumption, such as smartphones or computers, fair access to RMI data could significantly extend product life. A number of companies already want to simplify the repair of their products for end users (Wiens, 2018). Standardized provision of high-quality RMI data could help them reduce the existing uncertainties and, moreover, make the repair of products more enticing for users.

Phase 5: Recycling/BOM data facilitate the recovery of raw materials

When products reach the end of their life cycles, recycling is a costly process. Products need to be collected, disassembled and sorted, melted down, reprocessed and made available as secondary raw materials. Numerous information deficits among the stakeholders further complicate and slow down the recycling processes.

In the first recycling step, when unrepairable products are collected, disassembled and sorted, additional product information can be of great help in increasing the recovery of raw materials. Only if materials such as thermoplastic polymers or metals are properly separated can they be melted down and reprocessed into high-quality recyclates. Therefore, in addition to a product design that supports recycling, information about the composition of products can greatly simplify the separation of products and the correct sorting of components.

To this end, producers should disclose *bill of materials* (BOM) data describing the mass and special materials and components in each part of a product. Moreover, BOM data should include chemical composition data to enable additional recovery options (Burnley, 2007). For most complex products, BOM data already exists since it is a basic requirement for

Enterprise Resource Planning. If recycling companies had access to this information, they could improve their planning, develop special recycling processes and collect the materials in a targeted manner to further reduce waste disposal.

Best practice: Since almost one third of all waste is generated in the construction sector, the recycling of components such as windows, doors, bricks or facade elements can significantly increase material efficiency. As demonstrated by the Dutch company Stonecyclingold, new recycling technologies enable the crushing and incineration of building blocks, cement residues, waste glass, tile, or gravel into new material. However, recyclers need to be able to collect and separate materials efficiently, and building owners need to know the value of their building components. To overcome this scarcity of information, the so-called building passport can play a key role: For example, the Dutch company Madaster provides material passports of buildings as a digital inventory dataset that documents "all the materials, components and products used in a building, as well as detailed information about quantities, qualities, dimensions, and locations of all materials" (Heisel & Rau-Oberhuber, 2020). The data is collected on site, merged in the material passport and finally made available via the Madaster platform so that recyclers can find and collect the individual resources.

To incentivize the tracking and separation of material flows, circular ecosystem orchestrators like Madaster are needed. Orchestrators can reduce waste disposal and recycle as many materials as possible by providing reusable materials marketplaces and thus closing the information loops. However, for a competitive circular ecosystem to emerge, up-to-date information on the financial value of materials, their removability, toxicity and recycling potential needs to be collected and made available in standardized and industry-specific data formats. These standardization processes can be based on other product data sharing obligations, such as the REACH regulation, that could contribute important chemical composition data to further material recycling.

4. POLICY RECOMMENDATIONS

The central thesis of this paper is that mandatory data sharing obligations for suppliers, producers and operators can create the basis for sustainable innovation and circular value creation networks. The paper describes how digitalization can be an enabler of the CE by building product transparency, e.g., information about the design, ecological impact, status, repairability and material composition of products. The more stakeholders have access to and can use this information, the more products can be reused, remanufactured, repaired and recycled. In addition, particularly environmentally friendly products can be consciously purchased and put to shared use. Consequently, collecting and providing product data in a standardized format can substantially contribute to replacing the orthodox logic of "take-make-dispose" by a CE that closes material loops and minimizes waste disposal.

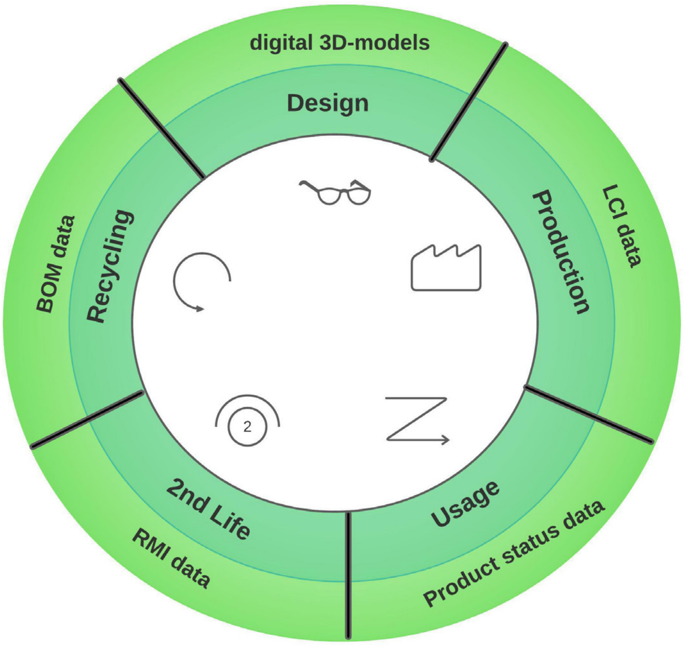

Figure 4: Five Circular Economy phases with supporting data categories

Market designers can consider data governance as an effective regulatory tool to make markets more sustainable. In each phase of the product life cycle, the availability of certain data sets is a precondition for stable market relations and the emergence of circular B2B-ecosystems. Hence, we can derive three general tasks for regulators to foster a data-driven, sustainable transformation – the publication, standardization and distribution of product-related public interest data.

Task 1: Mandatory data sharing for producers

Most markets set an incentive for producers to hide the true environmental footprint of their products and exploit their information asymmetry to increase revenue. Furthermore, in the digital economy, companies hold exclusive control over the product status data generated during use, thus creating consumer lock-ins and monopolistic rent-seeking. Against this backdrop, mandatory sharing of repair and maintenance information or 3D-models of spare parts can help to "unlock" markets and to foster the emergence of stable B2B-ecosystem collaboration. Furthermore, an open data obligation for producers is necessary to promote sustainable products. The REACH regulation or the European energy labels emphasize that specific product information should be required to make the ecological impact of products transparent.

In essence, the aim is to shift the focus of datafication from consumers to products. Thus, a sustainable market design has to address the question of which product-related information is essential to the Green Deal. In principle, all information on the environmental impact of products, services and infrastructure should be considered essential 'public interest data'. Often, these data sets are already available at the company level and simply need to be published in an open standard format, like the 3D models of spare parts or material composition data. Other data sets, such as LCA or RMI data, should be mandatorily collected and disclosed by companies upon market entry. In its discussion on environmentally relevant disclosure requirements for products, the European Commission also goes beyond a mere collection of already existing data and addresses all phases of the product life cycle (COM(2019)640).

The extent to which environmental product data can influence production and consumption patterns depends to a large extent on the trustworthiness of that information and on whether deficiencies in information quality can be sanctioned. Moreover, better access to environmental product data can benefit businesses. For example, continuous feedback during the use phase could improve a product's ecological quality and establish new B2B and business-to-consumer relationships. Moreover, a comprehensive standardization of product information could simplify the existing reporting obligations for producers.

Task 2: Data standardization with DPPs

Market designers must determine not only what information should be provided but also how and in what form it should be provided. To build stable and cooperative relationships, they must ensure market participants can easily access the required information with a clear structure that enables comparability of different offerings. For this purpose, a common data standard is required that creates a level playing field for all market participants. In addition to a common technical vocabulary that all stakeholders can work with, this standard should also include a harmonized method for data collection and a detailed description of how the data has to be published.

A particularly promising data format for product-related environmental data is the DPP. On the European level, the DPP is previewed in the Green New Deal as well as in the Circular Economy Action Plan and the Sustainable Product Initiative. It is intended to bundle all product data of public interest, such as environmental impact data or RMI data, and serve as a "single point of truth" for other circular ecosystem stakeholders to rely on. All manufacturers would be required to submit the DPP upon market entry so that the multiple reporting requirements can be merged and simplified.

Currently, several standardization initiatives for the DPP are underway, but a uniform data standard has not yet been established (Adisorn et al., 2021, 2). They are mostly company-driven networks, such as GS1, in which industry and sector associations agree on new standards. However, access to these expert panels is often limited and insufficient, resulting in insufficient recognition of the interests of small businesses, NGOs and consumer protection associations. To prevent these power asymmetries in standardization processes, the statement by Nobel Prize winner Jean Tirole applies: "As was the case for telecommunications or open banking standards, such [interoperability] standards probably could only be set by governments or neutral not-for-profit bodies." (Tirole, 2020,16)

Task 3: Increasing data accessibility through product data platforms

Many of the existing sharing obligations for product data impose a decentralized and topic-specific data management. For example, the usability of RMI data has suffered from the fact that repairers could not readily access the information they needed because it was spread across numerous producers' private websites (COM(2016)782). There was a lack of a central data intermediary that could aggregate and process the information to improve stakeholder accessibility.

Market designers must ensure that the relevant information is not only collected in a standardized way but that it is also accessible to other participants in the circular ecosystem, such as consumers, companies or regulators. To this end, we recommend establishing *product data platforms,* (PDPs), which bundle product related data, validate it and make it accessible. PDPs can be operated by a variety of actors, from government agencies to industry initiatives at the European, national or municipal levels, as long as they are competent, independent and trustworthy:

→ PDPs need to be *competent* to steward large volumes of data from various sources and provide a stable and reliable data ecosystem. Statistical institutions such as Eurostat can be helpful partners with great experience in merging and providing various data sets.

→ PDPs must be sufficiently *independent* of vested interests if they are to diligently validate the quality of product data. If necessary, they should be able to ensure data quality by imposing sanctions.

→ PDPs should be *trustworthy* to data users and data providers. Especially when sensitive IPR-related data is managed, decisions should be made transparently and comprehensibly to prevent misuse.

Generally, regulators should foster the emergence of appropriate data intermediaries to distribute environment-related product data. For this distribution, the EU has already set up two platforms for product data. Since 2021, the European Product Database for Energy Labeling (EPREL) collects all energy labels for household devices, such as fridges, freezers and dishwashers, and makes them available to consumers. In addition, the SCIP-Database of the European Chemicals Agency bundles product data on particularly harmful substances and makes it publicly available over a product's entire life cycle, including disposal.

With regard to the sort of product-related data, data intermediaries can take different forms of "data access regimes" (Martens, 2018) with different levels of openness. Since high data availability is expected to have the highest sustainability effects and personal data can actively be excluded, most product data can be published as data commons under an open data regime. However, to protect IPR, sensitive product-related data sets should be managed by independent "data trusts" (Open Data Institute, 2019) that are accountable to data providers. Data trusts can function like an online marketplace, releasing data to users only after payment and/or a thorough review of the intended use according to transparent guidelines, thus protecting the legitimate interests of data providers.

Addressing EU policy initiatives

At the European level, a series of current and upcoming legislative initiatives are aimed at improving the design of digital markets by regulating the flow of data. Major regulation packages such as the Digital Markets Act clarify data rights between different stakeholders and introduce comprehensive data sharing obligations such as mandatory interoperability for social media platforms. Since these initiatives are primarily located in competition law, consumer protection or digital infrastructure development, emphasizing the sustainable digital market design approach is particularly important: Even if ecological aspects do not usually play an explicit role, controlling data streams and preparing and providing product-related information can make important contributions to ecologically modernizing market infrastructures. Especially dominant platforms such as Amazon or Google Search guide buyers' choices and, therefore, also have a responsibility for sustainability in consumption and production patterns. However, the central prerequisite for this is the availability of product data, which in turn can only be demanded from producers through additional regulation. The following selected policy initiatives should be suitable for this purpose.

The Data Act

The European Data Act proposal, previewed for early 2022, intends to facilitate access to and use of data, including B2B and B2G data sharing (Data Act Impact Assessment, 2021). The Commission is planning compulsory data-sharing obligations to solve market failures, which makes the regulation an ideal vehicle with which to foster a data-based sustainability approach.

One intention of the act is to provide the public sector with fair, reliable and transparent access to privately held data. Here, it is important to complement the objectives of B2G data sharing with environmental and climate-related targets and to recognize data on the ecological impact of products as "public interest" data that enables better decision-making and public regulation. Government demand for B2G data sharing should be explicitly used to create the regulatory foundations for the DPP.

Nevertheless, the act is primarily concerned with data rights of companies in B2B data sharing. It must be made clear that companies' excessive rights of access to non-personal data can severely hamper the development of circular ecosystems. Particularly important for a digital CE is legal clarity on data sharing between companies, whereby producers' (intellectual property) rights over product data must be carefully weighed against the interests of society and the environment. The goal is to build trust between market participants and along the value chain, ensuring data privacy and property rights while enabling a data-driven ecosystem in which the flow of information promotes the circularity of natural resources.

European Green Deal Data Space

The EU Commission stressed the contribution of data-driven innovation in implementing the European Green Deal. In this context, the EU Data Strategy announces an "EU Green Deal Data Space" to create a common framework for sharing environmental data. The data space should be built in "support of the Green Deal priority actions on climate change, circular economy, zero-pollution, biodiversity, deforestation and compliance assurance" (COM(2019)640, 22).

The focus of the Green Deal Data Space is the revision of two existing legislations: the Directive on Access to Environmental Information (2003/4/EC) and the INSPIRE Directive (2007/2/EC). Both directives oblige public administration bodies and certain private bodies to provide access to environmental information. In the revision of these directives, which is expected to start at the beginning of 2022, it must be made clear that relevant geospatial data is held not only by government bodies but increasingly by private actors.

The data sets covered in the directives should be extended to include data on factories as well as on the state of soils, water, air quality and emissions. For example, producers must be obliged to increase transparency to improve the tracking of CO_2 emissions' generation. In this respect, factory-level environmental information systems should be required to systematically record and process environmentally relevant data and information in a company and provide it to third parties.

Sustainable Product Initiative

The EU Commission's data strategy also envisages the "introduction of a sustainable product policy with product passport" (COM(2019)640, 27). To this end, the revision of the Ecodesign Directive of 2009 will create concrete rules for the mandatory disclosure of product information to market participants along the entire value chain. Product information should be bundled in the DPP and contain data on each phase of a product's life cycle, including the origin, durability, composition, reuse, repair, dismantling possibilities and end-of-life handling of products.

The initiative is promising as it focuses on collecting environmental product data from private producers. However, mandatory product data exchange can only have the desired effect if common sector-specific standards for the DPP are included, as well as clear guidance on how the data should be provided by producers and made available through data intermediaries. To this end, we recommend close coordination with the European Multi-Stakeholder Platform on ICT Standardization, which already brings together the many DPP initiatives of Standard Development Organization with its Rolling Plan for ICT Standardization.

Outlook and limitations

Strategic governance of environmental product data is key to designing digital markets as circular ecosystems with low carbon emissions and minimized consumption of natural resources. This governance would not only enable sustainable consumption and improve decision-making but also create new economic production networks and business opportunities: The more information is available on the design, ecological footprint, accessibility, repairability and recyclability of products, the more sustainable business models can be established that contribute to developing a CE. Regulators must move beyond the enterprise level and address the interplay of different business models in a circular ecosystem at the market level.

However, this approach has its limitations. Firstly, the success of a data-based CE depends on the scope of producers' data-sharing obligations. Without detailed specifications and constant data verification, the DPP remains a toothless tiger. Secondly, whether the action-knowledge-gap of consumers can be reduced crucially depends on the visibility of ecological product information in shops and e-commerce-platforms. Avoiding rebound effects and reducing overall consumption of natural resources will require further action. Thirdly, the progressing digitization of product data will itself raise the demand for digital technology and cloud services, possibly resulting in an overall increase in energy requirements. Therefore, the growing ecological footprint of ICT needs to be taken into account and balanced with the opportunities offered by extensive data collection. To address these potential challenges, a stronger public discourse on the possibilities of sustainable digital-circular market design is needed.

5. REFERENCES

Adisorn,Thomas, Tholen, Lena & Götz, Thomas (2021), Towards a Digital Product Passport Fit for Contributing to a Circular Economy, *Energies* 2021, 14(8), 2289, https://doi.org/10.3390/en14082289.

Agrawal, Rohit, Wankhede, Vishal, Kumar, Anil, Upadhyay, Arvind, Garza-Reyes, Jose Arturo (2021), Nexus of circular economy and sustainable business performance in the era of digitalization. International Journal of Productivity and Performance Management, https://doi.org/10.1108/IJPPM-12-2020-0676

Berg, Holger, Wilts, Henning (2019), Digital platforms as market places for the circular economy. Requirements and challenges, *NachhaltigkeitsManagementForum,* 27, 1–9, https://doi.org/10.1007/s00550-018-0468-9.

Berg, Holger, Le Blèvennec, Kèvin, Kristoffersen, Eivind, Streè, Bernard, Witomski, Arnaud, Stein, Nicole, Bastein, Ton, Ramesohl, Stephan, Vrancken, Karl (2020), Digital circular economy as a cornerstone of a sustainable European industry transformation, White Paper - ECERA European Circular Economy Research Alliance,

Blomsma, Fenna & Brennan, Geraldine (2017), The emergence of circular economy: A new framing around prolonging resource productivity, *Journal of Industrial Ecology*, 21(3), 603–614, https://doi.org/10.1111/jiec.12603.

Bressanelli, Gianmarco, Adrodegari, Federico, Perona, Marco, & Saccani, Nicola (2018), Exploring how usage-focused business models enable circular economy through digital technologies, *Sustainability*, *10*(3), 639, https://doi.org/10.3390/su10030639.

Brown, Ian (2020), Interoperability as a tool for competition regulation, *OFA Research Paper*, OpenForum Academy.

Burnley, S. J. (2007), The use of chemical composition data in waste management planning – A case study, *Waste Management*, *27*(3), 327-336, https://doi.org/10.1016/j.wasman.2005.12.020.

Chen, Yan, Cramton, Peter, List, John A., & Ockenfels, Axel (2020), Market design, human behavior, and management, *Management Science*, 67(9), 5317-5348, https://doi.org/10.1287/mnsc.2020.3659.

COM 2013/0196 (2013), Building the Single Market for Green Products Facilitating better information on the environmental performance of products and organisations, European Commission, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52013DC0196.

COM 2016/782 (2016), *Report on the operation of the access to vehicle repair and maintenance information*, European Commission, https://ec.europa.eu/transparency/documents-register/detail?ref=COM(2016)782&lang=en.

COM 2019/640 (2019), *Commission Communication The European Green New Deal*, European Commission https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF.

COM 2020/66 (2020), *A European strategy for Data*, European Commission, https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf.

COM 2020/98 (2020), *A new Circular Economy Action Plan for a cleaner and more competitive Europe*, European Commision, https://ec.europa.eu/environment/pdf/circular-economy/new_circular_economy_action_plan.pdf.

European Commission (2020a), *Sustainable products initiative,* https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-products-initiative_en.

European Commission (2020b), Towards a European strategy on business-to-government data sharing for the public interest, Final report prepared by the High-Level Expert Group on Business-to-Government Data Sharing, European Union Brussels.

European Commission (2021), *Rolling Plan for ICT standardization, Circular Economy*, https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/circular-economy.

Data Act Impact Assessment (2021), *Data Act & amended rules on the legal protection of databases*, European Commission, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13045-Data-Act-&-amended-rules-on-the-legal-protection-of-databases_en.

Finnish Government (2017), *Good and flexible transport services through a new act*, press release, 24/5/2017, https://valtioneuvosto.fi/en/-/liikennepalvelu-laki-mahdollistaa-hyvat-ja-joustavat-liikenteen-palvelut.

Frantzeskaki, Niki, Loorbach, Derk & Meadowcroft, James (2012), Governing societal transitions to sustainability, *International Journal of Sustainable Development*, 15(1/2), 19–36, doi:10.1504/IJSD.2012.044032.

Friant, Martin, C., Vermeulen, Wwalter, J. V. & Salomone, Roberta (2020), A typology of circular economy discourses: Navigating the diverse visions of a contested paradigm, *Resource, Conservation & Recycling*, 161, 104917, https://doi.org/10.1016/j.resconrec.2020.104917.

Gawer, Annabelle, & Srnicek, Nick (2021), *Online Platforms: Economic and Societal Effects*, European Union, Brussels, https://www.europarl.europa.eu/RegData/etudes/STUD/2021/656336/EPRS_STU(2021)656336_EN.pdf.

Graef, Inge, Gellert, Raphael & Husovec, Martin (2018), Towards a Holistic Regulatory Approach for the European Data Economy: Why the Illusive Notion of Non-Personal Data is Counterproductive to Data Innovation, *TILEC Discussion Paper* No. 2018-029.

Grin, John, Rotmans, Jan, Schot, Johan, (2010), Transitions to Sustainable Development: New Directions in the Study of Long Term Trans- Formative Change, Routledge, New York/Oxford.

González-Varona, José M., Poza, David, Acebes, Fernando, Villafáñez, Félix, Pajares, Javier, & López-Paredes, Adolfo (2020), New business models for sustainable spare parts logistics: A case study, *Sustainability*, *12*(8), 3071, https://doi.org/10.3390/su12083071.

Hayek, Friedrich A. (1944), *Road to Serfdom,* University of Chicago, Chicago.

Hansen, Erik, Wiedemann, Patrick, Fichter, Klaus, Lüdeke-Freund, Florian, Jaeger-Erben, Melanie, Schomerus, Thomas, Alcayaga, Andres, Blomsma, Fenna, Tischner, Ursula, Ahle, Ulrich, Büchle, Daniel, Denker, Ann-Kathrin, Fiolka, Karsten, Fröhling, Magnus, Häge, Alexander, Hoffmann, Volker, Kohl, Holger, Nitz, Tara, Schiller, Cchristian, Tauer, Rebecca, Vollkommer, Dieter, Wilhelm, Dieter, Zefferer, Hartmut, Akinci, Seda, Hofmann, Florian, Kobus, Jörn, Kuhl, Pierre, Lettgen, Johanna, Rakowski, Marcel, von Wittken, Reinhard & Kadner, Susanne (2021), *Circular Economy Initiative Deutschland – Circular business models: Overcoming Barriers, Unleashing Potentials*, acatech/SYSTEMIQ, Munich/London, https://doi.org/10.48669/ceid_2021-7.

Hansen, Erik G. & Revellio, Ferdinand (2020), Circular value creation architectures: Make, ally, buy, or laissez-faire, *Journal of Industrial Ecology*, 24(6), 1250-1273, https://doi.org/10.1111/jiec.13016.

Hekkert, Marko, P., Jansse, Matthijs, J., Wesseling, Joeri, H. & Negro, Simona, O. (2020), Mission-oriented innovation systems. Environment Innovation and Societal Transitions, 34, 76-79, https://doi.org/10.1016/j.eist.2019.11.011.

Heisel, Felix, & Rau-Oberhuber, Sabine (2020), Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and Madaster, *Journal of Cleaner Production*, *243*, 118482, https://doi.org/10.1016/j.jclepro.2019.118482.

Hedberg, Annika & Šipka, Stefan (2020), The circular economy: Going digital, European Policy Centre.

Hischier, Roland, Achachlouei, Mohammad A., Hilty, Lorenz M. (2014): Evaluating the sustainability of electronic media: Strategies for life cycle inventory data collection and their implications for LCA results. *Environmental Modelling & Software* 56, 27–36, https://doi.org/10.1016/j.envsoft.2014.01.001.

Hitzig, Zoë (2020), The normative gap: mechanism design and ideal theories justice, *Economics & Philosophy, 36*(3), 407-434.

Hofmann, Florian (2019), Circular business models: Business approach as driver or obstructer of sustainability transitions?, *Journal of Cleaner Production*, 224, 361-374, https://doi.org/10.1016/j.jclepro.2019.03.115.

Hofmann, Florian & Jaeger-Erben, Melanie (2020), Organizational transition management of circular business model innovations, *Business Strategy and the Environment*, 29(6), 2770-2788, https://doi.org/10.1002/bse.2542.

IPCC (2021), Climate Change 2021. The Physical Science Basis, *Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

Jabbour, Charbel Jose Chiappetta & Jabbour, Ana Beatriz Lopes de Sousa & Sarkis, Joseph & Filho, Moacir Godinho, (2019), Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda, Technological Forecasting and Social Change, 144(C), 546-552.

Konietzko, Jan, Bocken, Nancy, & Hultink, Erik J. (2019), Online platforms and the circular economy, in: Bocken, N., Ritala, P., Albareda, L. & Verburg, R. (eds.), *Innovation for Sustainability*, Palgrave Macmillan, Cham, 435-450, doi:10.1007/978-3-319-97385-2_23.

Korhonen, Jouni, Honkasalo, Aantero & Seppälä, Jyri (2018), Circular economy: The Concept and its Limitations, *Industrial Ecology*, 143, 37-46, https://doi.org/10.1016/j.ecolecon.2017.06.041.

Kristoffersen, Eivind, Mikalef, Patrick, Blomsma, Fenna, Li, Jingyue (2021), The effects of business analytics capability on circular economy implementation, resource orchestration capability, and firm performance, International Journal of Production Economics, 239, 108205, https://doi.org/10.1016/j.ijpe.2021.108205

Lange, Stefan, Pohl, Johanna, Santarius, Tilman (2020), Digitalization and energy consumption. Does ICT reduce energy demand?, *Ecological Economics,* 176, 106760, https://doi.org/10.1016/j.ecolecon.2020.106760.

Li, Shengwu (2017), Ethics and market design, *Oxford Review of Economic Policy, 33*(4), 705–720, http://dx.doi.org/10.2139/ssrn.3026961.

Li, Wendy C., Nirei, Makoto, & Yamana, Kazufumi (2019), Value of data: There's No Such Thing as a Free Lunch in the Digital Economy, *Discussion Paper 19022*, Research Institute of Economy, Trade and Industry.

MacKenzie, Donald A., Muniesa, Fabian, & Siu, Lucia (2007), *Do Economists Make Markets?: On the Performativity of Economics,* Princeton University Press, Princeton.

Martens, Bertin (2018), The impact of data access regimes on artificial intelligence and machine learning, *JRC Digital Economy Working Paper* No. 2018-09, JRC Technical Reports.

Mayer-Schönberger, Viktor, & Ramge, Thomas (2018), *Reinventing capitalism in the age of big data,* Basic Books, London.

Milgrom, Paul (2011), Critical issues in the practice of market design, *Economic Inquiry, 49*(2), 311-320, https://doi.org/10.1111/j.1465-7295.2010.00357.x.

Neligan, Adriana (2018), Digitalisation as Enabler Towards a Sustainable Circular Economy in Germany, *Intereconomics*, *53*(2), 101-106, https://doi.org/10.1007/s10272-018-0729-4.

Ockenfels, Axel (2013), *Marketdesign,* Gabler Wirtschaftslexikon, https://wirtschaftslexikon.gabler.de/definition/marktdesign-51491/version-176807.

Open Data Institute (2019), Data trusts: lessons from three pilots, *Open Data Institute Report.*

O'Rourke, Dara & Ringer, Abraham (2015), The Impact of Sustainability Information on Consumer Decision Making, *Journal of Industrial Ecology,* 20(4), 882-892, doi:10.1111/jiec.12310.

Posner, Eric A. & Weyl, E. Glen (2018), R*adical Markets. Uprooting Capitalism and Democracy for a Just Society,* Princeton University Press, Princeton.

Pursiainen, Harri (2019), When the going gets easier, The OECD Observer.

Regulation 715/2007 (2007), Type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles and on access to vehicle repair and maintenance information, European Parliament.

Reichel, André, & Seeberg, Barbara (2011), The Ecological Sllowance of Enterprise: An Absolute Measure of Corporate Environmental Performance, its Implications for Strategy, and a Small Case, *Journal of Environmental Sustainability*, *1*, 81-93, DOI:10.14448/jes.01.0006.

Roth, Alvin E. (2015). Who Gets What—and Why: The New Economics of Matchmaking and Market Design. Houghton Mifflin Harcourt, Boston/New York.

Staab, Philipp (2019), Digitaler Kapitalismus. Markt und Herrschaft in der Ökonomie der Unknappheit, Suhrkamp Verlag, Berlin.

Stern, Nicholas H. (2007), *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, https://doi.org/10.1017/CBO9780511817434.

Suh, Sangwon & Huppes, Gjalt (2005), Methods for Life Cycle Inventory of a product, *Journal of Cleaner Production,* 13(7), 687-697, https://doi.org/10.1016/j.jclepro.2003.04.001.

Tirole, Jean (2020), Competition and the industrial challenge for the digital age, *paper for IFS Deaton Review on Inequalities in the Twenty-First Century*.

van Capelleveen, Guido, Pohl, Johanna, Fritsch, Andreas, Schien, Daniel (2018), The Footprint of Things: A hybrid approach towards the collection, storage and distribution of life cycle inventory data, *ICT4S2018, 5th International Conference on Information and Communication Technology for Sustainability*, Toronto, pp. 350–334, https://doi.org/10.29007/8pnj.

Wiens, Kyle (2018), iFixit: A case study in repair, in: Charter, Martin (ed.), *Designing for the circular economy*, Routledge, 307-315.

Umweltbundesamt (2021), *Der Europäische Emissionshandel,* Umweltbundesamt, https://www.umweltbundesamt.de/daten/klima/der-europaeische-emissionshandel#teilnehmer-prinzip-und-umsetzung-des-europaischen-emissionshandels.

DOI: http://dx.doi.org/10.14279/depositonce-15014

Technische Universität Berlin
Einstein Center Digital Future

Coordination: Samira Franzel, Friedrich Schmidgall (ECDF)

info@digital-future.berlin
www.digital-future.berlin