DIGITALIZATION OF CIRCULAR BUSINESS MODELS

Digital solutions enabling the transition towards circular economy

Wuppertal Institut

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Coalition for Digital Environmental Sustainability

This technical paper has been developed as part of the Digitalization 4 Circular Economy (D4CE) Impact Initiative. D4CE is hosted by the One Planet Network and Coalition for Digital Environmental Sustainability (CODES). It is a collaborative endeavor involving a diverse community of experts and organizations with a primary objective to accelerate the transition to a circular economy by leveraging digital technologies as powerful scalers. With two dynamic intervention labs at its core, the initiative aims to accelerate the transition to a circular economy. The paper aims at delineating the rationale behind enabling and promoting circular economy business models with the help of digital technologies.

Foreword

In today's rapidly evolving landscape, where environmental pressures and digital transformation intersect, the integration of circular economy principles with digital innovation presents a compelling opportunity for sustainable growth. The Digitalization for Circular Economy (D4CE) initiative—led by the One Planet Network and the Coalition for Digital Environmental Sustainability (CODES)—is a pioneering effort to harness this synergy.

This technical paper, co-authored with the Wuppertal Institute, explores how digital technologies such as IoT, AI, and Digital Product Passports (DPPs) enable new circular business models. These tools are not only enhancing transparency and operational efficiency, but also unlocking scalable solutions across industries and geographies.

One of our highlights are ten real-world case studies—from digital waste management to product traceability platforms—demonstrating how innovation is reducing costs, increasing value and already reshaping value chains.

Three key insights emerge:

- **Digitalization reduces environmental impact at scale:** ICT-based solutions can reduce greenhouse gas emissions by up to 20%, water consumption by 30%, and solid waste by 20% in smart city applications, highlighting the potential of digital tools to drive sustainability.
- **Circular business models are gaining traction:** Europe is projected to sell 27 million refurbished smartphones by the end of 2024 —demonstrating growing consumer acceptance of reuse and refurbishment. Additionally, digital platforms that enable product-as-a-service models and facilitate peer-to-peer sharing are helping extend product lifecycles, reduce idle capacity, and promote more efficient resource use across sectors.
- **Regulatory momentum can create the right enabling environment:** Governments are increasingly relying on legislation, policies, and other frameworks that leverage digital tools and data strategies to accelerate circular economy transitions. Digital product information systems—such as the Digital Product Passports mandated by the European Union's Ecodesign for Sustainable Products Regulation—exemplify the shift toward data-driven approaches that advance sustainability goals by enabling transparency, traceability, and more informed decision-making across value chains.

This paper is both a call to action and a strategic guide. We invite business leaders, policymakers, and innovators to explore these insights and join us in building a resilient, inclusive, and digitally empowered circular economy.

Jorge Laguna-Celis,

Head of the Secretariat of the One Planet Network

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Digitalization holds immense potential to transform our economies and societies in ways that align with the principles of circularity and sustainability. At the Wuppertal Institute, we are proud to have co-authored this technical paper in collaboration with the One Planet Network and the broader D4CE initiative. This work reflects our shared commitment to exploring how digital tools can be harnessed to create more resource-efficient, transparent, and regenerative systems.

The report highlights ten compelling examples of digital solutions that are already making a difference—solutions that span continents, industries, and technologies. These cases illustrate how digital innovation can serve as a catalyst for circular business models, enabling smarter resource use, better product lifecycle management, and more informed decision-making.

I would also like to express my appreciation to the innovators and organizations whose work is featured in this report. Their pioneering efforts to develop and implement digital solutions for circularity are not only inspiring but essential to accelerating the global transition to a more sustainable economy. By turning ideas into action, they are demonstrating what is possible and paving the way for scalable, impactful change.

It is our hope that this paper will serve as both a source of inspiration and a practical guide for stakeholders across sectors who are seeking to leverage digitalization in the pursuit of a circular economy.

Dr. Holger Berg,

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Wuppertal Institut

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Special thanks go to the innovators and organizations who generously contributed case studies to this report. Their pioneering work in developing and implementing digital solutions for circularity is not only inspiring but essential to accelerating the global transition to a more sustainable economy. We gratefully acknowledge 9 innovative companies which have come forward to share insights on their journeys towards using digital solutions to scale-up circular business models:

- Circularise (Netherlands)
- Cirplus (Germany)
- Green Mining (Brazil)
- Hello Tractor (Kenya)
- Recoded™ (France)
- Resourcify (Germany)
- Sykell (Germany)
- The Surpluss (United Arab Emirates)
- TraceSurfer (Uruguay)

By turning ideas into action, these innovators are leading the way in digitalization for the circular economy and demonstrating what is possible when technology and sustainability converge.

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01

Circular economy allows for access to harmonized and reliable information

Circular economy comes as a solution to address the economic, social, and environmental issues that the linear, end-of-life model has created. Circular economy model improves supply chains by reducing, reusing, recycling and recovering materials from extraction through to design, production and consumption processes including the reduction of waste at the end-of-life.[1] As an overarching and holistic framework, it can help to simultaneously tackle issues of environmental degradation, economic prosperity and social equity.[2] Its underlying principles provide consistent guidelines on how to conduct business more sustainably.

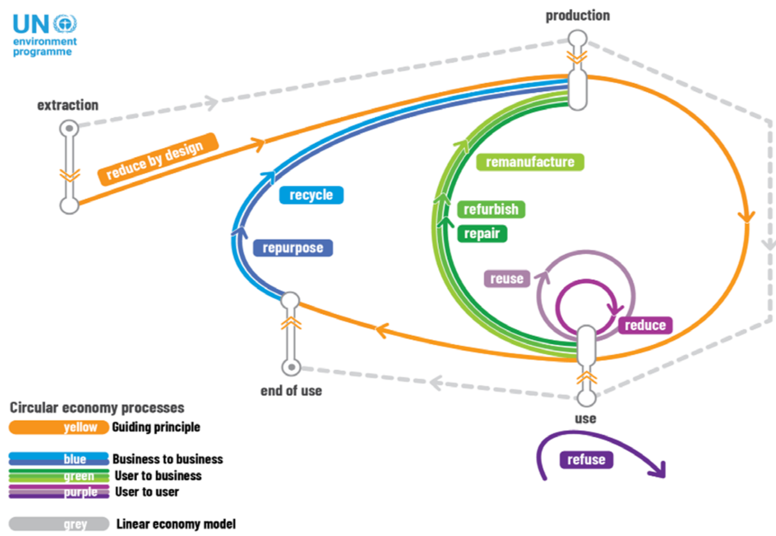

Figure 1: UNEP Circularity Approach

Source: https://www.unep.org/circularity

However, circular economy models tend to require more information than their linear predecessors, especially in today's globalized value chains. Purchasing used goods requires consumers to trust their quality. For refurbishment to be safe and efficient, detailed product information including that on its specific components is essential. Likewise, high value material recycling requires access to information on the ingredients and substance purity.[3]

Hence in many cases, obtaining, processing and sharing information with consumers (including business and supply chain as consumers of materials) is crucial for scaling-up circular business models. Fortunately, digital technologies can help with just that. Technologies such as Internet of Things (IoT), Big Data Analytics, Digital Twins as well as concepts like Data Spaces and Digital Product

[1] Kircherr et al. (2017).

[2] Ibid.

[3] Wilts, H. and Berg, H., (2017).

Information Systems such as Digital Product Passports (DPPs) enable the creation, analysis, transfer and storage of circular economy-related information.[4] Digital platforms help to match supply and demand for circular products and services such as recyclates or refurbished electronics, through making the necessary information accessible.

This technical paper explores how - with the help of digital technologies - circular business models can be supported, facilitated and realized. It reviews widely accepted circular economy frameworks[5] and presents real-life case studies also highlighting the forces that drive and promote the digitally enabled circular economy.

[4] One Planet Network (2023).

[5] One Planet Network (2023).

02

How can we utilize the 10 R-strategies to support new circular business models?

The 10-R strategies[6] are the essential practices of a circular economy. The framework emphasizes the importance of the product lifecycle approach and offers concrete approaches for increasing circularity and resource efficiency. The strategies included are Refuse, Rethink, Reduce, Re-use, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover and are organized based on their potential impact on circularity. While all strategies contribute to a circular economy, the former ones are generally considered to be more impactful. The 10R-framework groups these strategies into three action areas:

(1) Smarter product use and manufacturing
This category focuses on strategies like Refuse and Rethink aiming to reduce the consumption of natural resources and materials through stressing aspects of sufficiency and consistency.

(2) Extending lifespan of products and their components
Strategies under this action area are employed to either prolong the use of a product by instruments like maintenance, repair and refurbishment, or to re-use product parts in secondary applications through refurbishment or repurposing.

(3) Useful application of materials
This category contains end-of-life strategies including various forms of recycling (especially mechanical and chemical) and recovery of thermal energy from incineration processes.

[6] European Environment Agency (2020); Potting et al., (2017).

Smarter product use and manufacturing		
R-Strategy	Strategy Description	Practical Example
R0 - Refuse	Making a product redundant by abandoning its function or by offering the same function with a radically different product. As probably the most radical strategy, Refuse often questions our economic system itself by trying to decrease the need for more products.	A practical application can often be seen in refusing hazardous or scarce materials. Lithium batteries consist of different chemicals and scarce metals, which often are extracted under socially and environmentally harmful circumstances. Refusing these, the sodium-ion battery emerged which relies on readily obtainable materials therefore reducing the environmental impact.[7] Moreover, in fields where digital solutions can replace or enrich physical products by means of virtualization substituting for the product or parts of it, Refuse is particularly successful.
R1 - Rethink	Intensify product use (e.g. through sharing products, or by putting multi-functional products on the market). This strategy encompasses operational changes in business models.	Shifting a business model by transforming products into services can be an application of Rethink. As a result, Light-as-a-Service (LaaS) emerged. Within this model, the LaaS provider usually supplies business customers with light elements. The customers then only pay a service fee and for the electricity itself. This incentivizes the LaaS provider to develop highly efficient and long-lasting products thus further contributing to circularity.
R2 - Reduce	Increase efficiency in product manufacture through energy efficiency, reduction of water used, or use by consuming fewer natural resources and materials and 'doing more with less'.	Harnessing digitization to reduce paper use or reducing and eventually eliminating single-use plastics in products are practical examples on how Reduce can pave the way for more circularity.

Extending lifespan of products and their components		
R-Strategy	Strategy Description	Practical Example
R3 - Re-use	Re-use by another consumer of a product which is still in good condition and fulfills its original function	Used cars if in good condition can easily be Re-used. In 2023, it was estimated that nearly 36 million used vehicles were sold worldwide.[8] This model, in turn, can be transferred to all kinds of products, especially when embraced by digital online platforms.
R4 - Repair	Repair and maintenance of a defective product so that it can be used within its original function	Repair is a staple circular practice for many products. Repairing cars, electronics, machinery, clothes, etc. is a standard example. However, within complex, globalized supply chains, consumers' ability to get their items repaired has become limited. The European Union has introduced a right to repair directive including the setup of a platform dedicated to providing users with access to repair information.[9] Repair also includes maintenance, prolonging a product's life by regular checks and adjustments.
R5 - Refurbish	Restore an old product and update it	Consumer electronics are a major sector for the Refurbishment strategy. In the case of smartphones, it is estimated that 27 million refurbished devices will be sold in Europe by the end of 2024.[10]

[7] Crownhart, C. (2023).
[8] Cox Automotive (2024).
[9] European Parliament (2024).
[10] Vodafone (2024).

R6 - Remanufacture	Use parts of a discarded product in a new product with the same function.	Among the most remanufactured product categories are aircraft components, automotive parts, electrical and electronic equipment or medical equipment.[11] For the European Union, for instance, this is proposed to lead to a potential market size of EUR 90 billion by 2030.[12]
R7 - Repurpose	Use a discarded product or its parts in a new product with a different function. Broadly applied, repurposing drives the elimination of waste.	Recent studies developed a method to repurpose treated timber in eco-friendly concrete building blocks. It addresses circularity and the increasing demand for sustainable building materials at the same time.[13]

Useful application of materials

R-Strategy	Strategy Description	Practical Example
R8 - Recycle	Process materials from waste to obtain the same (high grade) or lower (low grade) quality.	Recycling can be applied to a broad field of materials such as plastics, metals or paper. If not eventually eliminated by Reduce, the Recycling of paper is a well-established example, where more than 50 million tons could be recovered for recycling in 2021, which corresponds to a recycling rate of 68%.[14]
R9 - Recover	Incineration of materials with energy recovery.	In case none of the other strategies can be applied, energy recovery by the incineration of end-of-life materials can be utilized. Waste-to-Energy technologies that make this possible include incineration but also co-combustion, pyrolysis or gasification.[15] In 2019, 15.5 % of municipal solid waste was incinerated with energy recovery on a global average.[16]

[11] Circular Economy Asia (without date).
[12] Parker et al., (2015).
[13] Gigar et al., (2023).
[14] Wakefield, F., (2022).
[15] Astrup et al., (2015).
[16] United Nations Environment Programme (2019).

03

Where does digitalization come in?

A major hurdle to circular economy transition is the problem of limited and/or reliable information which can be demonstrated with a famous re-use strategy example – Akerlof's Market for Lemons showing impact of asymmetric information using an example of the used car market. The lack of accessible information on used vehicles' quality, condition or composition is described as a key reason why customers hesitate to purchase used and instead opt for new vehicles.[17] There are psychological, business-oriented and technological factors to consider. In terms of psychology, limited information may cause lack of trust in used products as well as a perception of inferiority in comparison to new items. From the technological standpoint, lack of accessible information on a product's condition and functionality might lead to a potential fear of hidden costs of necessary repairs once the used product is purchased. As for the business perspective, attributing the right value to a used product based on lifecycle data and product transparency is crucial to combatting the prevalence of lemon markets. Higher availability and accessibility of reliable data and information for used products could significantly help to drive circularity.

Studies have shown four steps why the information deficit is hindering the transition to a circular economy.[18] These include: (1) the underdeveloped availability of information, resulting in (2) increased transaction and search costs, derived from higher efforts to find and utilize data and hence a need for detailed contracts and guarantees e.g. for secondary materials. Furthermore, (3) distorted perceptions by potential customers go along with the information deficits since secondary materials can be considered inferior. Finally, (4) technological barriers, resulting from poor design and therefore increasing recycling costs, maintain the information deficit and thus impede transition to a circular economy.

Digital technologies can help to close the information gap and need for harmonized and reliable information by effectively generating, collecting, processing and making available the volume of data needed such as material composition, use patterns, location within the waste system, etc. They fulfill crucial functions of data collection and integration, data analysis as well as communication and dissemination.[19] For instance, *cyber physical systems* could expand their information carriage from the production process to the entire lifecycle while containing environment-related information.

Effective *sensoring* is also of high importance to obtain extensive information. Reducing the hurdle of search and transaction costs could be realized by internet-based solutions such as *automated market and logistics platforms*. Supporting circular economy dedicated digital platforms in general could also contribute to reshaping consumer perception by fostering appreciation for repair, refurbishment, and second-hand goods. The resulting consumer interest in

[17] Akerlof, G., (1970).

[18] OECD (2005).

[19] One Planet Network (2023).

the circular economy could challenge manufacturers to design more durable, repairable, and upgradable goods. The Internet *of Things* (IoT) can help reduce the obstructive costs. For instance, in waste management systems, IoT can reduce costs with real-time monitoring capabilities, capturing vital data on waste generation, segregation, and collection processes, enabling agile adaptation of operations to redirect materials from wasteful withdrawal to *Recycling* facilities. This fundamentally facilitates the paradigm shift towards perceiving waste as a valuable resource. Technologies such as 3D modeling and simulation can help to reimagine product designs, whilst minimizing material use without compromising quality or functionality, and reducing waste by designing it out.

This paradigm shift will change the way we think about supply chain architecture. Circular strategies require data to move freely between the different lifecycle stages and the infrastructure to support intertwined *supply networks* in which both products and the information on them are easily transferred (see Figure 2). Businesses will need to adapt and reimagine product and service delivery within a more sustainable, interconnected framework, contributing to 10R-strategies.

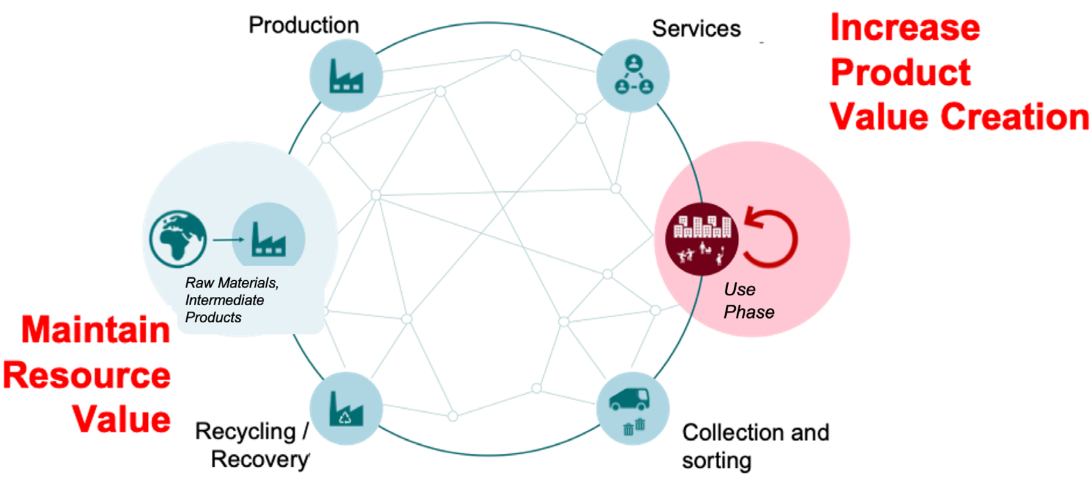

Figure 2: The Circular Economy as a Networked System

Source: Wuppertal Institute

04

How can digital technologies enable circular economy in practice?

The Smart Circular Economy framework introduced by Kristoffersen et al.[20] as shown in Figure 3 demonstrates how digital solutions can build up and complement circular business models. The framework contains three elements: (1) data transformation levels, (2) resource optimization capabilities and (3) data flow processes, linking the first two elements. The framework is based on a hierarchy where each individual level relies on the previous (lower) one. It further builds upon maturity thinking, meaning that the potential of strategies to support or unburden human decision makers (maroon arrow) and the systemic resource efficiency and productivity (green arrow) increases along the hierarchy.

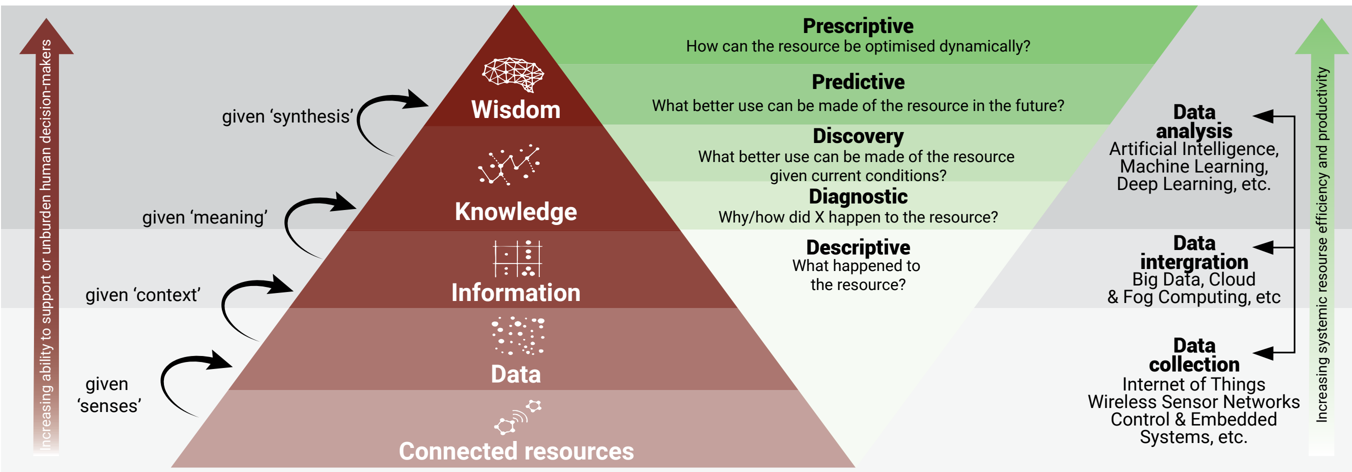

Figure 3: The Smart CE framework

Source: Kristoffersen, et al. (2020).

For *data transformation levels* this means that resources such as components or materials must be connected e.g. via an IoT device to generate data, thus enabling data collection throughout different stages of the industrial lifecycle of the resource. Data is then transformed into information by aggregation, interpretation, selection or sorting and eventually by adding context to it. While information primarily answers questions like who was responsible or what was produced, knowledge on the next level gives information a deeper meaning by refining it with inference rules and increased understanding. This refers to questions as to how and why something happened. Finally, wisdom combines knowledge with interactive processes and adaptive judgment to give a synthesis of autonomous decisions and actions and hence provides the means for automation.

[20] Kristoffersen, et al. (2020). Also cf. for the following explanations.

Resource optimization capabilities start with the descriptive level, which addresses questions about what happened to the resource. Within this framework, it contextualizes raw data and helps to transform it into information. The subsequent diagnostic level correspondingly builds on the information derived from the description to identify the reasons why something happened, therefore expanding information into knowledge. On the discovery level high volumes of information that emerge because of e.g. IoT and big data approaches are then analyzed, aiming to outline trends and clusters or unknown connections. Following this, the predictive level uses the analysis to forecast and determine future events and possible outcomes, achieving a higher level of wisdom. At the top of the hierarchy, the prescriptive level employs these forecasts to devise actions and judgments, thereby developing best practices for future scenarios and further enhancing wisdom.

The *data flow processes* are also conceptualized hierarchically. The data collection process first uses IoT devices or further resources to generate and gather data. Data integration then gives context to the gathered data by using interoperability and context-awareness. Finally, data analysis examines the integrated data using e.g. artificial intelligence or machine learning to derive a profound understanding, automate processes and draw possible future actions. However, these steps usually intersect on different levels in practice. All three processes of data collection, integration and analytics can be combined to conduct fully integrated data analysis.

This Smart CE framework can be exemplified with circular strategies of *industrial symbiosis, maintenance* and *recycling.*[21] In the case of *industrial symbiosis*, i.e. outgoing flows from one manufacturer being used by another manufacturer, at the descriptive level IoT sensors would support the specification and monitoring of the type, quantity, and timing of inputs for current material flows. The integration of analytics would then help to discover new or alternative waste-to-resource matches as well as potential eco-networks for their application along the next levels. Furthermore, self-optimizing algorithms could automatically prescribe and arrange flow exchanges via self-adapting sourcing plans at the last level. The underlying goal would always be to increase the efficiency and circularity of the manufacturing process, ultimately eliminating the reliance on virgin raw materials through full circular loops.

Data-driven *maintenance* illustrates how the Smart CE framework promotes the extension of existing use cycles and the introduction of new ones by applying strategies such as *Re-use, Refurbish, Remanufacture,* and *Repurpose*. Through deep learning methods such as artificial neural networks and operational data, reactive, condition-based or prescriptive maintenance schemes can be implemented, thus enabling e.g. automatic requests for repair, the discovery of new patterns or potentials for alternative life cycle-extending operations or autonomous maintenance and replacement mechanisms.

Finally, smart bins and digital material marketplaces promote coherent *Recycling* loops. By gathering data and information on material grades and discovering more effective material cascades at the first levels, they reduce or eliminate waste and sustain value of materials. Digital marketplaces as well as digital platforms could then connect businesses with potential users of their waste streams, thus alleviating resource exchange and enabling a digital ecosystem, where waste itself would be the start of a new production cycle. Again, self-optimizing algorithms can help to e.g. introduce automatic cost-benefit analysis or forecast optimal end-of-life strategies on the prescriptive level.

[21] Kristoffersen, et al. (2020).

05

What is driving the digital circular economy transition?

Implementing and fostering circular economy with digital solutions is a crucial part of the twin transition. The twin transition is defined as the cross-collaboration and integration of the digital transformation and the sustainability transition. The major goal is that these two processes inform and complement each other instead of hampering their respective development. Both agendas need to be considered at the same time, since digitalization is not necessarily sustainable and could lead to unintended consequences. The extensive digital transition could, for instance, lead to massive resource extraction and wastage due to the significant increase in demand for hardware and technological innovations, if not combined with the sustainability agenda. Also, high-energy-intensive technologies e.g. cloud computing or Blockchain are steadily gaining importance, which in turn leads to a high demand for energy to power data centers and for Information, Communication and Technology (ICT). ICT is thus projected to be responsible for 14% of the global electricity use by 2030.[22] However, if applied coherently in the twin transition, both the digital and sustainable agenda are reinforcing each other. So, ICT-based solutions on the other hand could according to one study reduce greenhouse gas emission by 20%, water consumption up to 30% and solid waste by up to 20% within the concept of smart cities and communities.[23] Twinning these transitions therefore may create a major potential for technology and data to drive the sustainable transition by developing green technologies, data assets and infrastructure. Current hurdles of lack of consistent approaches or complexities as well as conflicting strategic priorities need to be overcome. For a successful twin transition, it is crucial to meet requirements in the dimensions of social, technological, environmental, economic as well as political spheres.

The *need for a circular economy and novel sustainability* approaches is both influenced by environmental pressures as well as economic challenges such as supply chain shortages. The *development of new digital technologies* creates new opportunities for the realization of circular strategies. In recent years, *regulation* has also started to forcefully drive the emergence of digitally enabled circular approaches, most notably the European Union's DPPs.[24] Lastly, *increasing obligations* to provide proof of quality, conformity etc. drives the advancement of product and material specific information flows.

[22] Andrae, 2020. However, note that this is a moderate projection (expected case) with other projections going far higher.

[23] Nikolov, 2024.

[24] European Parliament, 2024

06

Towards digital Information systems for circular economy: Digital Product Passports and DPP Systems

Digitalization for Circular Economy is presently heavily influenced by the emergence of two interdependent technological systems: Digital Product Information Systems such as DPPs and so-called data spaces. Digital Product Passports are seen as structured data sets for products and/or materials. They contain master data (such as material or product name, content, repairability, environmental footprint, etc.) and lifecycle data (instances such as repair, maintenance, use patterns, special occurrences such as accidents, and so forth). DPPs are envisioned to provide information to enable circular economy. They contribute to closing the information and transparency gaps that hindered the emergence of circular economy at scale for almost all 10-R strategies. As such, they are meant to become a key component of a future digital circular economy. Drivers for the introduction of DPPs are not unlike the drivers of digital circular economy in general. However, regulation plays a decisive role in their shape and development now. Specifically, the European Union's Ecodesign for Sustainable Products Regulation introduces DPPs to a whole list of sectors from 2027 onward. While the European Union was the first to include DPPs in its regulation activities, other countries have followed. Japan, South Korea, China and others are developing similar approaches.

Digital Product Passports (DPPs) will need data from many different sources, including all suppliers. To manage this, a special digital infrastructure is needed. This is called the DPP System.[25] It's the core IT and software setup that brings together all the data needed for DPPs and provides access to the DPPs themselves. It helps different stakeholders work together and connects physical products with their digital passports without the need to share the underlying data used to create DPPs.

Co-ordinating the different sources, assembling and providing DPPs, and making sure they are available to the target groups requires a dedicated infrastructure and technological background, the so-called DPP System.[26] It is the foundational IT and software framework within which the necessary data for DPPs is provided and DPPs can be accessed. Thus, it supports interactions among different stakeholders across a product value chain and links physical products to their respective DPP.

Data spaces are constructed for data sharing and information integration which makes them a possible approach to DPP systems. Their de-centralized nature allows digital sovereignty and a chance for interoperability on a larger scale. On one hand, data can remain within the command of a contributing party, in the case of DPP this can be the economic operator bringing the product to the market. On

[25] Jansen et al., 2023

[26] Jansen et al., 2023

the other hand, it can be easily shared with users within the system, under certain rules and defined access rights. Data spaces access can be configured, which does not restrict participation to a predefined set of actors[27].

Data spaces hence are holistic information systems, as depicted in Figure 4. They are infrastructures that hold, combine and provide all relevant circular economy data to enable circular business models and strategies. As noted, it will be crucial to have systems that are both internationally interoperable and work on a cross-sector basis (inter-sector interoperability). This will require a lot of effort, but such a system would create many new opportunities for digitally enabled circular business models and services. Current efforts around digital product information systems such as DPPs provide an optimistic outlook with projects such as the Global Framework for Digital Product Information Systems and Cirpass (2024) contributing to the development.

In the journey towards a sustainable future, the transformative role of digital technologies – rightly used – stands as a beacon of innovation and collaboration. Through a suite of digital solutions, these technologies can support and even drive a systemic shift towards resource efficiency and waste reduction, facilitating circular business models. However, as we reflect on their profound impacts across various sectors, it becomes clear that they are both a challenge and an opportunity. Digital technologies not only provide the tools but also require the mindset shift necessary for businesses to thrive in a circular economy. They can be instrumental in championing a future where environmental stewardship and economic prosperity go hand in hand.

[27] Jansen et al., 2023

07

What are the real-world examples?

The digitally enabled circular economy is materializing with numerous solutions and novel approaches emerging daily. In this section, we take a practical approach and provide a broad range of examples covering different R-Strategies, business models, countries and regions, technologies, and so forth. Each of them includes insights into the underlying success factors as well as the drivers and barriers companies faced when developing these business models. The case studies were collected through a standardized survey.

[1] Kircherr et al. (2017).

[2] Ibid.

[3] Wilts, H. and Berg, H., (2017).

Circularise – Product traceability platform & Mass Balancer

CIRCULARISE

General Information

Product/solution, its main features and problem addressed

- Circularise's platform enables end-to-end supply chain traceability using patented Smart Questioning technology and cryptography.
- It allows brands, manufacturers, and suppliers to securely exchange data with tailored disclosure levels, granting each actor control over access.
- This enhances data accuracy for impact reporting for carbon footprint calculations, supports sustainable manufacturing, ensures regulatory compliance, and unlocks new value opportunities with supply chain partners

State of maturity

- Scaling to production implementation and securing Series B

Countries solution is applied in

- Europe, Japan & North America

Stages of product/ material lifecycle

- Extraction & Processing
- Manufacturing and Production
- End-of-life/Waste Management
- Throughout entire LC

Industries*

- Several with main focus on materials (Polymers & Chemicals as core market)
- Growing into other material streams

CE & Digital Technologies

R-Strategies

- R1 – Rethink, R2 – Reduce
- R3 – Re-use, R4, Repair, R5 Refurbish, R6 – Remanufacture, R7 – Repurpose
- R8 - Recycle

Digital technologies employed

- Artificial Intelligence
- Blockchain
- Cloud Computing
- Smart Sensors
- Further at development

Realisation of specific R strategy?

- Circularise's advanced end-to-end traceability platform aims to simplify data collection and sharing to enable businesses to realise a circular economy and meet the latest circularity benchmarks.
- We aim to make sure that the trustworthy data that is needed at each stage of the lifecycle is available to avoid a loss of value.

How do these technologies enable CE? Requirements?

Enable
- The technologies described above are the underpinning to our end-to-end product traceability platform

Requirements:
- We operate a SAAS model - so main requirements are the ability to access the internet

Drivers & Barriers

Success factors

- On the one hand - regulation - on the other forward-thinking companies wanting to explore Circular Economy business value - have been instrumental in helping Circularise develop tangible use cases for our end-to-end traceability platform

Barriers

- Circularise presents a networked proposition - whereby multiple actors within a supply chain need to mobilise and agree - this therefore takes time to coordinate.
- This is also challenging when the current linear system is still profitable and circular systems (and required data sharing) are nascent - but these challenges are being advanced

Cirplus – Global Procurement Platform

General Information

Product/solution, its main features and problem addressed

- Cirplus is Europe's largest B2B procurement platform for recycled plastics, connecting professional buyers and sellers.
- It aggregates and qualifies supply and demand for recycled plastics
- Goal: bring cost-efficiency, transparency and convenience to recyclates procurement in a highly fragmented market.
- Such digitization lowers the transactional costs for recycled plastics supply chains, thus catalysing the industry shift away from virgin material wherever feasible.

State of maturity	Countries solution is applied in
Pilot (seed funding)	100+ countries (digital platform accessible throughout the world)

Stages of product/ material lifecycle	Industries*
• Distribution and Transportation • Support and Service • End-of-life (e.g. take-back schemes) • Waste Management	• Construction and Building • Consumer Goods and Household Products • Packaging • Waste Mgmt. & Recycling

CE & Digital Technologies

R-Strategies	Digital technologies employed
• R2 - Reduce • R8 - Recycle	Artificial Intelligence Digital Platforms

Realisation of specific R strategy?

- By aggregating and qualifying recyclates supply accros countries and polymer types, Cirplus is building reliable supply chains for recyclates at scale.
- It unlocks previously intransparent and volatile markets for brand owners looking to increase the recycled content of their plastic products.
- Cirplus combines "baseline" digitization of material streams with standardization, having built the world's first industrial standard for high-quality recycling and digitization with EN 18065/DIN SPEC 91446

How do these technologies enable CE? Requirements?

Enable
- By collecting and standardizing data about plastic waste and recyclates across countries and industries
- AI can be developed upon this data to identify and solve supply chain risks where humans fail, as real-time complexities of mixed waste streams are too complex for the human brain power alone.

Requirements:
- baseline data of waste materials and recyclates need to be collected and standardized to allow for a "commodification" of secondary raw materials

Drivers & Barriers

Success factors

- Regulatory changes: German Packaging Act (2019); Packaging and Packaging Waste Regulation (PPWR - 2024/5); End-of-Life Directive (2024/5): these changes trigger demand from buyers that have previously been uninterested in circular plastics, and in turn, trigger interest in our product
- Standardization: our work in standardization was able to bridge the "trust gap" of industrial buyers and sellers of working with a startup/young company like Cirplus
-

Barriers

- Volatile demand for recyclates: when virgin plastic is cheaper than recycled plastics, buyers tend to lose urgency in adopting or engaging with Cirplus.
- Lack of Digital Skills: The waste and recycling industry is semi-professionalised and hence the staff members often lack literacy in the usage of digital tools.
- Inertia from industry incumbents: the linear industries who stand to lose the most, block the most.

Green Mining – Factory Price Station

General Information

Product/solution, its main features and problem addressed

- Factory Price Station aims to address two issues in Brazil's recycling chain: the low recycling rate (less than 3%) and the poor working of waste pickers.
- The project pays the real value for recyclable materials instead of the 10% to 20% that waste pickers typically received.
- The industry funds the operation, and anyone who brings recyclable waste to a unit receives the same payment they would get if they delivered the material directly to a recycling plant (no intermediaries).

State of maturity

- Growth (series A)

Countries solution is applied in

- Brazil

Stages of product/ material lifecycle

- Waste Management
- Reverse logistics

Industries*

- Consumer Goods & Household Products
- Packaging
- Waste Mgmt. & Recycling

CE & Digital Technologies

R-Strategies

- R8 - Recycle

Digital technologies employed

Blockchain

Realisation of specific R strategy?

- The National Solid Waste Policy (PNRS), in Brazil, sets goals and guidelines for solid waste management, including reverse logistics.
- The Factory Price Station project generates reverse logistics credits so that industries can fulfill their role in the shared responsibility outlined by the PNRS, while also increasing the income of those working in recycling collection.

How do these technologies enable CE? Requirements?

Enable

- Green Mining became pioneers in intelligent reverse logistics by developing technology to recover post-consumer packaging with a traceability system with blockchain that ensures all collected material is sent for recycling.
- The proprietary system is tailored to each client's needs, providing efficient recovery of recyclables with respect for the key actors in the chain.

Requirements:

- None

Drivers & Barriers

Success factors

The union of social and environmental pillars.

- By May 2025, the project had achieved impressive results:
- Over 5,100 tons of materials were collected and sent for recycling.
- The project paid R$ 4,900,000 to approximately 2,510 people, with over 80% being waste pickers and cart drivers.
- Operations are expanding, with nine active units and new units planned for other Brazilian cities.

Barriers

- Few industries/companies fulfill their role in the shared responsibility outlined in the PNRS – this is one of the reasons for the country's alarming recycling rate, which remains below 3%.

Green Mining – Recycle & Earn Station

General Information

Product/solution, its main features and problem addressed

- The Recycle & Earn station has a printer that generates a QR code linked to the ID of the customer registered in the Green Mining App.
- The person attaches the QR code to the bag of recyclable waste, deposits it at the station and earn discounts in a supermarket.
- The goal is to increase the volume of recyclables properly disposed of at those stations through the incentive of discounts.

State of maturity

- Pilot (seed funding)

Countries solution is applied in

- Brazil

Stages of product/ material lifecycle

- Waste Management

Industries*

- Consumer Goods & Household Products

CE & Digital Technologies

R-Strategies

- R8 - Recycle

Digital technologies employed

- Blockchain

Realisation of specific R strategy?

- There are few options in Brazil offering benefits to people who properly dispose of their recyclable waste.
- The most common format is a type of "vending machine," which does not allow for larger volumes or all types of recyclables, unlike Recycle & Earn Station.

How do these technologies enable CE? Requirements?

Enable

- Green Mining became pioneers in intelligent reverse logistics by developing technology to recover post-consumer packaging with a traceability system with blockchain that ensures all collected material is sent for recycling.
- The proprietary system is tailored to each client's needs, providing efficient recovery of recyclables with respect for the key actors in the chain.

Requirements:

- None

Drivers & Barriers

Success factors

- The reward - in the Recycle & Earn Station project, there was a 15% increase in the volume of recyclables delivered to the station in just 2 months

Barriers

- Few industries/companies fulfill their role in the shared responsibility outlined in the PNRS – this is one of the reasons for the country's alarming recycling rate, which remains below 3%.

Hello Tractor – Digital Sharing Platform

General Information

Product/solution, its main features and problem addressed

- Hello Tractor addresses the low mechanization and high costs in smallholder farming with its Pay-As-You-Go (PAYG) model, IoT-enabled technology, and marketplace platform.
- Farmers access affordable tractor services, paying per use, while tractor owners optimize performance with real-time data.
- Mechanization hubs provide training, spare parts, and seasonal implement rentals. This approach boosts productivity, creates jobs, reduces emissions, and increases incomes by up to 227%, transforming agriculture.

State of maturity

- Growth (series A)

Countries solution is applied in

- Nigeria, Kenya, Uganda, Ethiopia, Rwanda
- With 15 other African countries

Stages of product/ material lifecycle

- Distribution and Transportation
- Product Development
- Support and Service
- Waste Management

Industries*

- Food & Agriculture
- Transportation & Logistics
- Waste Management & Recycling

CE & Digital Technologies

R-Strategies

- R1 – Rethink
- R2 – Reduce
- R7 – Repurpose
- R8 - Recycle

Digital technologies employed

- Big Data Analysis
- Digital Platforms
- IoT
- Mobile Applications
- Smart Sensors

Realisation of specific R strategy?

- Through our Pay-As-You-Go (PAYG) tractor financing, IoT-driven asset management, and implement banks to extend machinery lifespan.
- Our shared access model enhances resource efficiency, serving up to 300 farmers per tractor, while biofuel integration reduces carbon footprints. Climate-smart mechanization and carbon sequestration; Inclusive economic development ensures affordable, sustainable mechanization.

How do these technologies enable CE? Requirements?

Enable

- These technologies optimize tractor usage, extend lifespans, and reduce waste. IoT and sensors enable real-time monitoring for preventative maintenance, while GIS optimizes deployment and routes. Mobile apps facilitate shared access.

Requirements:

- IoT-enabled tractors with telematics devices, network connectivity for real-time data transmission, and cloud services for storage and analytics. Also access to digital payment platforms for our PAYG model and minimal digital literacy

Drivers & Barriers

Success factors

- During development, IoT and data-driven insights enabled precision in asset use.
- In implementation, strong stakeholder networks and the PAYG model enhanced accessibility and affordability for farmers.
- Scaling relied on customer behavior shifts, embracing shared services and seasonal rentals, and financial inclusion strategies for rural entrepreneurs. These efforts built a resilient ecosystem, optimizing resource use and fostering sustainability.

Barriers

- Initial resistance to shared services, and cultural attachment to ownership.
- Coordinating circular practices like implement banks and seasonal rentals across stakeholders sometimes posed supply chain challenges.
- Our scaling efforts were constrained by financial barriers and market acceptance. These were mitigated by leveraging IoT-driven insights, fostering strong partnerships, educating farmers, and launching targeted outreach to build trust and adoption.

Recoded™ – Unit-level Digital Product Passports

RECODED™

General Information

Product/solution, its main features and problem addressed

- Recoded™'s platform transforms the fashion industry by seamlessly integrating circularity into future-proof consumer experiences and sustainable, high-quality, traceable products.
- Main features include Unit-level Digital Product Passport (DPP) for every product, from physical identifier to digital technology platform; Transparency and traceability across the product lifecycle up to the end consumer; Compliance with EU Digital Product Passport regulations; Scalable, white-label technology for brands, distributors, and institutions
- The solution, based on Circular Practices and Digital Product Passport principles, addresses the urgent need for transparency, traceability, and consumer empowerment in the circular economy.

State of maturity

Operational, with active customers

Countries solution is applied in

- France, Finland
- Expansion to other European countries and global markets underway

Stages of product/ material lifecycle

- Throughout the entire product LC
- Use and after-sales
- Reuse, repair and recycling (circularity)
- End-of-life / disposal (Recycle – Upcycle)

Industries*

- Fashion (particularly apparel)
-

CE & Digital Technologies

R-Strategies

- R2 (Reuse), R3 (Repair), R4 (Refurbish/Remanufacture) , R5 (Repurpose), R6 (Recycle), R7 (Recover), R8 (Reduce), R9 (Rethink), R10 (Refuse)

Digital technologies employed

- Web3 blockchain technology (smart contracts, secure cloud-based data management)
- IoT-enabled product tagging (QR codes and NFC)
- Push-technology
- AI-driven analytics
- API integrations

Realisation of specific R strategy?

- Recoded™ empowers brands and consumers to extend product life, maximize material value, and ensure responsible end-of-life management.
- Circular practices implemented by Recoded™ can reduce product's carbon and water footprint, while enabling brands and consumers to monetize circularity and empowering consumers to make better choices.

How do these technologies enable CE? Requirements?

Enable

- • QR and NFC tagging grant every product a persistent digital identity, supporting traceability and consumer access throughout its lifecycle.
- • Push-technology allows brands to maintain ongoing, personalized engagement with consumers, nudging them toward circular behaviors such as repair, resale, and recycling.
- • Blockchain and cloud infrastructure guarantee data integrity and accessibility for all stakeholders, facilitating compliance, trust, and efficient circular operations.

Requirements:

- This technology-enabled model requires an access to a phone and internet.

Drivers & Barriers

Success factors

- Being consumer- and data-driven by design
- Deep understanding of industry-specific challenges and providing relevant expertise
- Alignment with emerging regulations (EU DPP)
- Easy integration and white-label approach
- Clear consumer benefits (transparency, ownership, after-sale services)
- Scalable technology and accessible pricing

Barriers

- Varying levels of digital maturity among brands
- Building awareness and educating stakeholders on DPP and the circularity business environment
- Data integration and synchronization across complex supply chains
- Driving consumer adoption and traction

Resourcify – Digital waste management and take-back programs

General Information

Product/solution, its main features and problem addressed

- Resourcify aims to streamline operational processes around waste management through smart automation, data-driven optimisations and effortless regulatory compliance.

State of maturity

- Growth (series A)

Countries solution is applied in

- Mainly DACH but also throughout EU
- Beginning roll out in US

Stages of product/ material lifecycle

- End-of-life (e.g. take-back schemes)
- Waste Management

Industries*

- Automotive
- Electronics
- Healthcare & Pharma
- ICT
- Packaging
- Waste Management & Recycling

CE & Digital Technologies

R-Strategies

- R2 – Reduce
- R5 Refurbish
- R6 Remanufacture
- R8 - Recycle

Digital technologies employed

- Artificial Intelligence

Realisation of specific R strategy?

- Our digital waste management service streamlines processes that provide data-driven insights to businesses about how to enhance their resource efficiency.

How do these technologies enable CE? Requirements?

Enable

- Resourcify empowers companies with data-driven insights that support sustainable, resource-efficient operations while uncovering cost-saving opportunities.
- With precise metrics and standardized reporting, businesses can make informed decisions, track zero-waste progress, and communicate achievements clearly to stakeholders.

Requirements:

- The Resourcify solution is best suited to large enterprises with complex waste management needs but has no undelying technological infrastructure requirements.

Drivers & Barriers

Success factors

- Particularly throughout the scaling phase, we established a close communication with our customers and partners that brought us much closer to the market so we could understand and react to their needs and requirements.
- Perseverance was the most important success factor during the development stage as we faced many hurdles with process creation and strict legal restrictions.

Barriers

- Persuading legal authorities to endorse a circular take-back program was challenging through the development phase.
- Whereas in the implementation phase the major challenge was appealing to recyclers in spite of the initial low volumes in the early stages of our program. We committed to providing larger volumes as the program scaled to convince them of viability for their operations.

Sykell – Circular ERP

General Information

Product/solution, its main features and problem addressed

- CIRCULAR ERP is an ERP solution for circular businesses, cutting costs by up to 90% through automation, data centralization, and efficient partner coordination.
- It scales effectively, keeping operational costs and staffing steady. Features include real-time asset tracking, inventory and deposit management, and compliance-ready data, with APIs, mobile apps, and BI tools for seamless collaboration and strategic insights.
- CIRCULAR ERP maximizes growth potential while minimizing operational costs.

State of maturity

- Growth (series A

Countries solution is applied in

- Germany, Switzerland, France and Benelux

Stages of product/ material lifecycle

- Manufacturing & Prod.
- Distribution & Trans.
- End-of-life/Waste Management
- Entire Lifecycle

Industries*

- Consumer Goods & Household Products
- Food & Agriculture
- Packaging, T&L
- Retail & E-commerce
-

CE & Digital Technologies

R-Strategies

- R3 – Re-use
- R8 - Recycle

Digital technologies employed

- Big Data Analysis
- Cloud Computing
- Digital Platforms
- IoT
- Mobile Applications
- Smart Sensors

Realisation of specific R strategy?

- 1. Reuse – At the core of CIRCULAR ERP, the system tracks and manages reusable assets across their lifecycle, ensuring effective return, management, and redeployment within the supply chain.
- 3. Recycle – Enables streamlined data collection and reporting essential for recycling processes and Lifecycle Assessments, supporting material recovery and end-of-life recycling.

How do these technologies enable CE? Requirements?

Enable

- Circular ERP integrates REST APIs, EDIfact, and cloud-based data transfer for seamless partner exchange. Mobile apps and hand scanners enable asset tracking via 2D codes, RFID, and NFC. Its big data BI infrastructure pools data through a specialized layer

Requirements:

- No specific require

Drivers & Barriers

Success factors

- CIRCULAR ERP's success is driven by legislative support, enabling scalable reusable systems that challenge single-use models.
- Sykell contributed to Germany's reusable packaging solutions, navigating complex requirements and diverse models.
- The need to coordinate multiple partners efficiently led to scalable, resource-efficient software that meets circular businesses' needs, adapts to various partnership models, and achieves economies of scale essential for circular economy growth.

Barriers

- Emerging circular models required a modular solution that adapts to evolving business and partner needs.
- Legal complexities added further obstacles, with ambiguities around taxation, end-of-life definitions, and compliance creating uncertainties.
- To address these, we built a highly flexible platform that can adapt to shifting regulations, essential for supporting early adopters and diverse approaches in the circular economy.

The Surpluss – The Surpluss Platform

General Information

Product/solution, its main features and problem addressed

- The Surpluss is a multi award winning, B Corp certified climate tech company that provides a digital platform companies from all sectors to trade their excess inventory, assets and materials, enabling a profitable transition to the circular economy.
- The intelligent platform simplifies industrial symbiosis emergence through its proprietary, US patented framework, providing a sector-agnostic approach to optimizing and capitalizing on excess waste, space, by products and knowledge, creating new, circular economies, previously unimagined

State of maturity

- Growth (series A)

Countries solution is applied in

- U.A.E., Saudi Arabia, Italy, Denmark, Malaysia

Stages of product/ material lifecycle

- Manufacturing and Production
- Distribution and Transportation
- Product Development

Industries*

- Consumer Goods and Household Products
- Furniture
- Packaging, T&L
- Retail & E-commerce
- FMCG - retail

CE & Digital Technologies

R-Stategies

- R1 – Rethink; R2– Reduce; R3 – Re-use; R6 – Remanufacture; R7 – Repurpose; R8 - Recycle

Digital technologies employed

- Artificial Intelligence
- Digital Platforms
- Machine Learning

Realisation of specific R strategy?

- By identifying locally available secondary materials/assets, co-sharing warehouse space to enhance energy efficiency, servitization through experts nearby leasing depreciating assets/machinery, selling idle inventory/materials, enhancing localization by giving visibility to solution providers to companies unaware of these functions, reducing reliance on virgin materials and boosting innovation, profitably

How do these technologies enable CE? Requirements?

Enable

- Proprietary machine learning algorithm to simplify industrial symbiosis that deviates from challenging input/output models, generating matches based on organizational behavior and compatibility; via intelligent insights on environmental/financial indicators to reduce the barriers to circular economy, smart matching with reverse-logistics opportunities to decrease transaction costs and build profitability

Requirements:

- more standardized mechanisms for circular economy particularly in emerging economies

Drivers & Barriers

Success factors

- Our unique framework which enhances successful adoption, the right partners, business model innovation through PPPs, apetite for profitability, access to policy makers to better understand local nuances for product-market fit, limited tools for bridging the digitalization gap for circular economy, ease of use and reinforcing credibility through IP and proprietary tech to ease IT/security concerns, a strong knowledge on industrial symbiosis (founder is a PhD researcher at University of Cambridge

Barriers

- Enterprise customers with specific needs that are self-serving, i.e, requesting white label products, APIs with their complex ERPs, etc.
- A lack of interest from regulators, fragmentation with customs and inconsistent HS codes that inhibit regional circular economy progress
- Market acceptance in the GCC where environmental regulations are at early stages, long sales cycles (B2B) so we had to pivot to partnership models.

TraceSurfer – SaaS Platform for Digital Product Passports

TraceSurfer

General Information

Product/solution, its main features and problem addressed

- TraceSurfer is a SaaS platform that enables the creation and management of digital product passports for the fashion and food industries. It addresses the growing demand for traceability, transparency, and regulatory compliance (e.g., the EU ESPR 2024/1781 regulation) empowering small and medium-sized enterprises (SMEs) to meet these strict requirements. Key features include:
- Creation of digital passports aligned with emerging standards (ESPR 2024/1781).
- Granular and remote data collection via web, API, and WhatsApp, including low-connectivity environments.
- Controlled data sharing with various stakeholders.
- User validation and product assignment through mobile interfaces.

State of maturity

- Operational, with active customers and pilots in multiple countries.

Countries solution is applied in

- Colombia, Uruguay and Argentina, and pilot phase in Portugal and Brazil.

Stages of product/ material lifecycle

- Supply Chain and manufacturing
- Distribution
- Use and after-sales
- Reuse, repair and recycling (Circularity)
- End-of-life / disposal (Recycle – Upcycle)

Industries*

- Fashion and textiles (particularly apparel)

CE & Digital Technologies

R-Strategies

- R0 – Rethink; R2 – Reduce; R3 - Re-use ; R4 – Repair; R6 – Remanufacture; R8 – Recycle; R9 - Recover

Digital technologies employed

- Cloud computing
- Open APIs
- QR codes and unique identifiers
- WhatsApp integration and mobile-first interfaces for granular data collection.
- Optional blockchain layer for data immutability (optional)
- Interoperability with emerging digital product passport (DPP) standards

Realisation of specific R strategy?

- TraceSurfer enables companies to map and monitor materials and products throughout the value chain, supporting circular design, reverse logistics, and material reuse. The platform empowers data-driven decisions and gives suppliers tools to participate in sustainability and circularity goals. DPP's also enable new circular business models such as repair, resell or return of products in an efficient and cost-effective way as the consumer gets involved in the process as an active stakeholder of the lifecycle of the product.

How do these technologies enable CE? Requirements?

Enable

- These technologies enable end-to-end traceability, attribute verification, field data collection, and stakeholder integration. This facilitates reuse, recycling, and sustainable product design and circularity

Requirements:

- Basic internet connection (even intermittent), camera-enabled mobile devices, and minimum stakeholder engagement for data input.

Drivers & Barriers

Success factors

- Participation in initiatives like the CIRPASS project, working of establishing a global standard in DPP architecture.
- Adaptability for SMEs, fostering digital inclusion
- Interoperability-focused design aligned with regulatory standards
- User-friendly interface and use of accessible channels like WhatsApp 95% of use in global south and emerging markets.

Barriers

- Digital adoption resistance among small suppliers
- Connectivity limitations in remote areas
- Need to constantly adapt to evolving regulations and technical standards
- Cultural reluctance to full transparency in supply chains

References

Akerlof, G., (1970): *The Market for 'Lemons': Quality Uncertainty and the Market Mechanism. Explorations in Pragmatic Economics.* The Quarterly Journal of Economics, President and Fellow of Harvard College, Vol. 84(3), pages 488-500.

Andrae, A. S. G. (2020). New perspectives on internet electricity use in 2030. *Engineering and Applied Science Letters*, 3(2), 19-31

Astrup et al., (2015): Life cycle assessment of thermal Waste-to-Energy technologies: Review and Recommendations. Waste Management, Volume 37. https://doi.org/10.1016/j.wasman.2014.06.011.

Bluem, S., (2022): What is the 'twin transition' - and why is it key to sustainable growth? World Economic Forum. Retrieved from: https://www.weforum.org/agenda/2022/10/twin-transition-playbook-3-phases-to-accelerate-sustainable-digitization/, (last retrieval: 07.06.2024).

Circular Economy Asia (without date): *Remanufacturing for the Circular Economy*. Retrieved from: https://www.circulareconomyasia.org/remanufacturing/#:~:text=Remanufacturing%20for%20the%20Circular%20Economy&text=Some%20of%20the%20benefits%20of,waste%20(and%20associated%20disposal%20costs), (last retrieval: 17.05.2024).

Cirpass (2024): *Project Results*. Retrieved from: https://cirpassproject.eu/project-results/, (last retrieval: 8.04.2025).

Cox Automotive (2024): *Estimated Monthly Used-Vehicle SAAR and Volume*. Retrieved from: https://www.coxautoinc.com/market-insights/estimated-monthly-used-vehicle-saar-and-volume/#:~:text=Overall%2C%20Cox%20Automotive%20estimates%20the,out%202023%20at%2019.0%20million, (last retrieval: 17.05.2024).

Crownhart, C. (2023): *This abundant material could unlock cheaper batteries for EV*. MIT Technology Review. Retrieved from: https://www.technologyreview.com/2023/05/09/1072738/this-abundant-material-could-unlock-cheaper-batteries-for-evs/?utm_source=the_spark&utm_medium=email&utm_campaign=the_spark.unpaid.engagement&utm_content=*%7Cdate:m-d-y%7C*, (last retrieval: 17.05.2024).

Ellen MacArthur Foundation (2013): *Towards the circular economy Vol. 1: an economic and business rationale for an accelerated transition*. Retrieved from: https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an.

European Environment Agency (2020): *Bellagio Declaration Circular Economy Monitoring Principles*. Retrieved from: https://www.eea.europa.eu/themes/waste/measuring-europes-circular-economy/BellagioDeclaration.pdf/view.

European Parliament, (2024): Right to repair: *Making repair easier and more appealing to consumers*. Press Releases. Retrieved from: https://www.europarl.europa.eu/news/en/press-room/20240419IPR20590/right-to-repair-making-repair-easier-and-more-appealing-to-consumers, (last retrieval: 15.05.2024).

European Parliament (2024): Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC (Ecodesign for Sustainable Products Regulation). Official Journal of the European Union, L, 2024/1781. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1781

Gigar et al., (2023): Recycling timber waste into geopolymer cement bonded wood composites, Construction and Building Materials, Volume 400. https://doi.org/10.1016/j.conbuildmat.2023.132793.

Gupta, M., (2024): *Cross-sector and sector-specific DPP roadmaps*. CIRPASS Consortium. Retrieved from: https://cirpassproject.eu/wp-content/uploads/2024/03/CIRPASS_Cross-sector_and_sector-specific_DPP_roadmaps_1.1.pdf.

IPBES (2019): *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (Version 1). Zenodo. https://doi.org/10.5281/zenodo.6417333.

Jansen et al., (2023): *Stop Guessing in the Dark: Identified Requirements for Digital Product Passport Systems*. Systems 2023, 11, 123. https://doi.org/10.3390/systems11030123.

Kirchherr et al., (2017): *Conceptualizing the circular economy: An analysis of 114 definitions*, Resources, Conservation and Recycling, Volume 127, 2017, https://doi.org/10.1016/j.resconrec.2017.09.005.

Kristoffersen et al., (2020): *The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies*. Journal of Business Research, Volume 120. https://doi.org/10.1016/j.jbusres.2020.07.044.

Lacy, P. and Rutqvist, J. (2015): *Waste to Wealth: The Circular Economy Advantage*. Palgrave Macmillan Books. London.

McKinsey Global Institute (2018): *Smart Cities: Digital Solutions for a more livable future*. Retrieved from: https://www.mckinsey.com/capabilities/operations/our-insights/smart-cities-digital-solutions-for-a-more-livable-future.

Muench et al., (2022): *Towards a green and digital future*. Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/54, JRC129319.

Nikolov, Nikolay. (2024). Smart cities as a tool for environmental sustainability: opportunities and challenges. Environment Technology Resources Proceedings of the International Scientific and Practical Conference. I. 261-266. 10.17770/etr2024vol1.7948.

One Planet Network (2023): *Rethinking, Extending, Re-using. Harnessing Digital Technologies for the Circular Economy*. Retrieved from: https://www.oneplanetnetwork.org/sites/default/files/2023-11/RETHINKING%2C%20EXTENDING%2C%20REUSING-%20HARNESSING%20DIGITAL%20TECHNOLOGIES%20FOR%20THE%20CIRCULAR%20ECONOMY%20-%205%20%281%29.pdf

Parker et al., (2015): *Remanufacturing Market Study*. European Remanufacturing Network. Retrieved from: https://www.remanufacturing.eu/assets/pdfs/remanufacturing-market-study.pdf.

Potting, J.; Hekkert, M.; Worrell, E.; Hanemaijer, A. (2017): *Circular Economy:*

Measuring Innovation in the Product Chain. The Hague, 2017, PBL Netherland Environmental Assessment Agency.

United Nations Environment Programme (2019): *Waste-to-Energy: Considerations for Informed Decision-Making*. Retrieved from: https://www.unep.org/ietc/resources/publication/waste-energy-considerations-informed-decision-making

United Nations Environment Programme (2021): *Making Peace with Nature: A scientific blueprint to tackle climate, biodiversity and pollution emergencies.* Nairobi. Retrieved from: https://www.unep.org/resources/making-peace-nature

United Nations Environment Programme (2024): *Global Resource Outlook 2024: Bend the Trend - Pathways to a liveable planet as resource use spikes. International Resource Panel.* Nairobi. https://wedocs.unep.org/20.500.11822/44902

VDMA (2023): *VDMA-Leitfaden zu zirkulären Geschäftsmodellen*. June 2023, VDMA Umwelt und Nachhaltigkeit. https://www.vdma.org/documents/34570/86033569/Leitfaden+zu+zirkul%C3%A4ren+Gesch%C3%A4ftsmodellen_Inhalt+5+Okt+(1).pdf/c11f6927-9351-4381-54d3-0b751f07c45a (Last Retrieval: 12.04.2024).

Vodafone (2024): European demand for refurbishing smartphones grows in 2023. Retrieved from: https://www.vodafone.com/news/planet/european-demand-for-refurbished-smartphones-grows-in-2023, (last retrieval: 17.05.2024).

Wakefield, F., (2022): Top 25 recycling facts and statistics for 2022. World Economic Forum. Retrieved from: https://www.weforum.org/agenda/2022/06/recycling-global-statistics-facts-plastic-paper/#:~:text=Top%20recycling%20statistics%20of%202022&text=1.,equivalent%20of%20290%20million%20pounds, (last retrieval: 21.05.2024).

Wilts, H. and Berg, H. (2017): *The digital circular economy: can the digital transformation pave the way for resource-efficient materials cycles?* Retrieved from: https://epub.wupperinst.org/frontdoor/deliver/index/docId/6978/file/6978_Wilts.pdf (last retrieval: 17.05.2024)

DIGITALIZATION OF CIRCULAR BUSINESS MODELS

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The One Planet Network/the 10-Year Framework of Programmes on Sustainable Consumption and Production

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