**Circular economy and digital technology enabled innovation:**
**Advances, applications, and prospects**

**Special Issue Call for Papers**
**R&D Management**

## Background

The circular economy (CE) is a cyclical system that aims to eliminate waste by turning goods at the end of their life cycle into resources for new ones (Stahel, 2016), an as such, is the anti-thesis for the "linear economy" that is responsible for major environmental challenges globally. To respond to an increasing pressure on natural resources, circular economy (CE) aims to create value with the ultimate goal of achieving a more resource effective and efficient economic system (EMF, 2015). CE will be central to global efforts towards sustainability and to achieve climate neutrality targets. For example, EU Circular Economy Action Plan targets how products are designed, promotes circular economy processes, encourages sustainable consumption, and aims to ensure that waste is prevented and the resources used are kept in the economy for as long as possible (European Commission, 2020). The implementation of CE principles requires a fundamental redesign of product concepts, service offerings, and channels towards long-life solutions (Lewandowski, 2016) the development and innovation of CE-specific business models (Khan et al., 2020; de Arroyabe et al., 2021; Santa-Maria et al., 2021; Marrucci et al., 2021; Bocken and Ritala, 2022), and of ecosystems and platforms that support CE principles (Aarikka-Stenroos et al., 2021).

The broad movement towards CE coincides with another important trend of digital transformation, defined as "socioeconomic change across individuals, organizations, ecosystems, and societies that are shaped by the adoption and utilization of digital technologies" (Dąbrowska et al., 2021). Many firms have started using digital technologies to manage their innovation processes (Urbinati et al., 2020), and more broadly, utilized digital technology in multiple processes across their organizations (Hanelt, 2021). Digital technologies such as 3D printing, blockchain, artificial intelligence, and IoT have seen increased adoption in recent years. Especially the COVID-19 pandemic pushed these technologies ahead (Brem et al., 2021), and going forward, the development is expected to accelerate further. Digital technologies are expected the to support innovation for CE activities and products, and in realization of different types of CE business models and ecosystems. Adopting digital technologies to help CE can potentially lead to enhanced competitiveness,

productivity, and performance (Dibrell et al., 2008; Kleis et al., 2011). In this special issue, we call for submissions that explain how innovative uses of variety of digital technologies support creating products, services, processes, business models, and ecosystems and platforms aligned with CE principles. In the following paragraphs, we highlight some technologies with highest potential in this regard (even if this description is by no means exhaustive).

*3D Printing* has the potential to alter the economics of the existing manufacturing value chain and can also enable local economically viable small-scale production using plastic or metal waste by turning those into 3D printing feedstock (Despeisse et al., 2017; Garmulewicz et al., 2018). However, significant barriers exist in designing products with recycled 3D printing feedstock due to potential variation in the quality of the 3D printed products and difficulty in economic and environmental justification of using such recycled materials for 3D printing (Garmulewicz et al., 2018).

*Artificial Intelligence (AI)* can help in the circular design and optimisation process by accelerating the firms' regenerative approaches (Rajput and Singh, 2019). By combining real-time and historical data from products and users, AI can help increase product circulation and asset utilization through pricing and demand prediction, predictive maintenance, and smart inventory management. AI can help process data about product characteristics, its usage, processing parameters of different options such as reuse, recycle and remanufacturing to choose the optimal option (Wilson et al., 2022).

Similarly, *blockchain* can benefit circular economy practices across industries by authenticating the flow of raw materials and products across the supply chain (Kouhizadeh et al., 2020) and ensuring transparent payment to people who collect recycled materials (Chaudhuri et al., 2022). A Blockchain enabled digital material passport can enable traceability of raw materials, thereby enabling secondary use and substitution (Adisorn et al., 2021). Relevant data captured using the material passport can support the development and implementation of different CE strategies such as material substitution, recycling, repair and refurbishment. For example, Circularise facilitates a shift to CE by digitising and tracing materials across complex supply chains on a public blockchain without risking confidentiality. It allows companies to access real material information coming from their suppliers to improve sustainability and compliance, and meet regulatory requirements and customer demand.[1]

[1] https://www.circularise.com/

*Internet-of-Things (IoT)* bolsters CE initiatives by supporting data-driven solutions for resource and materials optimisation (Chauhan et al., 2019). IoT facilitates conversion of traditional equipment into smart objects, making it easier to 3D print parts using recyclable materials (Forlastro et al., 2018). IoT also improves tracking and record keeping, enables monitoring and maintenance, improves estimations of the remaining lifetime of products in use and helps firms to make informed design decisions to improve product durability (Ingemarsdotter et al., 2020). IoT can aid in the assessment of CE measures (Ouyang and Ma, 2014) through the real-time tracking of CE indicators and early warning systems.

Despite the accumulating evidence, the literature is yet to consolidate, explain and theorize the role of the above mentioned and other digital technologies' role in driving innovation in CE context. Indeed, Chauhan et al. (2022) recently pointed to the need of future studies to take a more distinctive view on the relationship between CE and digital technologies. In the current state, the extent to which digital technologies can support product, process and business model innovation for CE is unclear. One reason for the scattered evidence is that applications of 3D Printing, blockchain, AI and IoT for CE will vary due to product, process, supply chain, and other characteristics. Moreover, motivations for digital transformation and CE might address dissimilar organizational and societal goals that may be in conflict and hence have to compete for organizational resources (Ardito et al., 2021). Thus, unless adoption of digital technologies is specifically considered a part of an environmental orientation strategy (de Sousa Jabbour et al., 2018), the effect of digitalization on CE may not be realised. This special issue calls for papers to understand the potential synergies (and pitfalls) in the intersection of digital technology in different levels of analysis and contexts, as discussed in the following.

**Product and process innovation for digital technology enabled CE**

Across the three largely ecological-based notions of innovation eg. green, ecological and environmental innovation, eco-innovation seems to be the most precise and well-developed concept (Schiederig et al., 2012). Eco-innovation defined, by the European Commission, as "resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources." (European Commission, 2011, p. 2). Blomsma et al. (2019) developed a Circular Strategies Scanner to connect eco-innovation with CE. How such circular strategies can be converted to innovative product and service ideas while also considering digital technologies

can be an interesting avenue of research. Another relevant stream of research is around frugal innovation, which refers to products (both goods and services), that seek to minimize the use of material and financial resources with the objective of reducing the cost of ownership while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards (Tiwari and Herstatt, 2012; Brem and Ivens, 2013). Frugal innovations create value from waste, reuse existing components and materials and due to modularity and ease of repair of such products, the effective life of frugal innovation is extended (Albert, 2019). There is potential to extending the thinking behind "frugal" more broadly as circular principles, where the amount of resource use is minimized via product and process innovation utilizing digital technology.

A few inspiring examples of innovative products combining digital technologies and CE include 3D printed coffee stations produced from coffee waste by Swedish coffee group Löfbergs or future workspace designed by Dutch architecture firm ArchiTech and manufactured by Royal 3D using recycled PET plastic. Whether digital technologies can indeed act as enablers for such eco-innovations and frugal innovations and the capabilities which will be needed by both larger organisations and SMEs to develop digital technology enabled solutions for CE remain important questions for research.

**Business Models associated with digital technology enabled CE**

A circular economy business model (CEBM) is defined as the rationale of organisations or an ecosystem of organisations to create, deliver, and capture value by (i) slowing; (ii) closing; or (iii) narrowing flows of resources (i.e. energy or materials) (Bocken et al., 2016; Pieroni et al., 2021; Bocken & Ritala, 2022).Technologies like 3D Printing have the potential to create unique value proposition and hence create alternate business models through delivery of on-demand, customised products (Hahn et al., 2014). If products can be developed to use recycled materials and produced or serviced using 3D printing, it can alternate business models. For example, Yuma Labs partners with companies, cities, and events, such as the Tomorrowland music festival to collect plastic waste generated at the event and 3D print custom sunglasses from it that can then be sold to event attendees to cover the cost of the plastic collection. SMEs can indeed come with unique business models to capitalise on the above opportunities. Similarly, waste2wear uses recycled plastic waste for textile production and adopts blockchain to ensre the authenticity of the recycled plastic (Chaudhuri et al., 2022). Though CE and digital capabilities needed by SMEs to provide value to customers have been identified (Chaudhuri et al., 2022), how such SMEs can adopt digital technology enabled CE based business models is

not fully understood. Another digital technology such as AI can enhance the competitive strength of circular economy business models, such as product-as-a-service and leasing. For example, AI powered waste sorting solutions developed by ZenRobotics offer opportunities to improve performance and efficiency of waste sorting. This increases the value that can be generated from material streams through improved recovery rates and overall quality of output (Ellen Macarthur Foundation, 2019). Similarly, Rubicon's cloud-based, big-data platform connects waste producers with a network of independent waste haulers across 50 states in the US and Canada, as well as 18 more countries. This enables higher diversion rates from landfill, creative reuse of waste material, optimized truck routes and the detailed analysis of waste data (Lacy, 2017).

**Ecosystems for digital technology enabled CE**

Ecosystem lenses to CE include knowledge, innovation, platform, and industrial ecosystems, among others (for review, see Aarikka-Stenroos et al., 2021). Ecosystem lenses are particularly well-suited to analyze CE, given the requirements to understand how resources and materials flow in a circular system, and what types of innovations and business models could be developed to address those flows. The recognition of a systemic nature of different flows related to CE calls out for ecosystem lenses to understand how firms can put forward compelling value propositions or an innovations aligned with different stakeholders (Adner, 2017).

One alternative is to examine innovations in CE ecosystems from a hub-actor driven platform-based business model perspective. In those cases, digital technology is used to provide connectivity between different actors who either provide or utilize resources in a within a CE platform and related business model (Ciulli et al., 2020; Bocken & Ritala, 2022). For example, Excess Materials Exchange is digital marketplace that enables companies across industries to exchange excess materials and products, with the idea that there is wealth in waste and that a world without waste is possible.[2] Such examples demonstrate how digital platforms and other digital interfaces can become a driver for circularity; yet, research on the particular value propositions, services, and business models draving from CE-focused digital platforms is still scarce.

[2] https://www.wartsila.com/insights/article/swipe-right-for-circular-economy

Another alternative is to look at the CE ecosystem from the macro level, where the interaction between different subsystems (educational, industrial, political, social and natural environment) of the Quintuple Helix Model and the circulation of knowledge flows act as inputs between them, promote innovations, create value and contribute to a sustainable future (Carayannis and Campbell, 2019; Durán-Romero et al., 2020). In this regard, variety of actors in ecosystems and beyond have been found critical for CE. For instance, different stakeholders exert a critical influence on both eco-innovation and green innovation as they can affect both its content and implementation process (Fliaster and Kolloch, 2017; de Jesus et al., 2018), In recycling oriented models individuals and citizens become also important stakeholders, e.g. when they participate to circular systems by e.g. collect plastic (Chaudhuri et al., 2022). Similarly, the role of NGOs is highlighted in cases where they can support local communities e.g. in recycling, repurposing, or reusing resources and materials. Hence, there is a need to understand the role of a broader ecosystem involving multiple stakeholders in digital technology enabled CE innovation.

**Overarching goal of the special issue**

There remain several open questions related to the adoption of digital technologies for CE activities, such as i) understanding the key capabilities needed by organizations to develop products and services supported by digital technology enabled CE, ii) business model innovations to support digital technology driven CE initiatives, iii) role of SMEs and start-ups in adoption of digital technology enabled CE, iv) Role of ecosystems and open innovation to support digital technology-enabled CE.

Hence, now is the right time for R&D and innovation management scholars to address the key challenges associated with adopting CE principles while designing new products, services, examine how digital technologies can help in such efforts and assess the business model implications of digital technology-enabled innovations for CE. This Special Issue will provide a unique opportunity for scholars in R&D Management to play a critical role in shaping the discourse around CE, digital technologies, and innovation. We invite conceptual papers, empirical analyses, and case studies to describe and deepen this understanding of digital technology-enabled innovations for a circular economy. Some potential research questions and themes are discussed in the following.

*Processes and capabilities for digital technology enabled CE innovation*

- What are the unique processes which need to be followed to identify opportunities to develop innovative products and services based on CE principles?
- What are the unique capabilities which need to be developed to design innovative products and services based on CE principles?
- What are the unique capabilities which need to be developed to design digital-technology enabled green innovations, eco-innovations, or frugal innovations for CE?

*Business Models associated with digital technology enabled CE innovation*

- How can innovative business models be developed to support digital technology driven CE initiatives?
- How can large organisations manage the interplay between their CE and digitalisation driven innovation agendas?
- How do SMEs and start-ups adopt digital technology enabled CE based business models?

*Ecosystems and platforms for digital technology enabled CE innovation*

- How does the innovation ecosystem and different stakeholders influence adoption of digital technology enabled CE based products and services?
- How can open innovation and innovation tournaments facilitate adoption of digital technologies for CE?
- What is the role of digital platforms and interfaces, and platform ecosystems in developing CE innovation and CE business models?

*Challenges, tradeoffs and contradictions regarding digital technology enabled CE innovation*

- How can we make sure that digital innovations for CE are "truly sustainable"?
- Do digital technologies do potentially more harm than good in the context of CE; for instance, is there a risk that the total materials or energy consumption rises during adoption of CE business models?

  Are there risks of sub-optimization if CE-innovation focuses on piecemeal solutions or processes, while overlooking larger systems?

Beyond addressing the special issue topic or themes, all potential papers should also address the journal's core aims and readership. Manuscripts should be submitted no later than February 28, 2023 and should conform to format of R&D Management (see formatting and submission

instructions in). When submitting your article, please choose the Special Issue "**Circular economy and digital technology enabled innovation**".

**An expected timeline**

- Manuscript submission starts: January 1, 2023
- Manuscript submission ends: February 28, 2023
- Final manuscript submissions to publisher: 30th September, 2023

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