Greening of Industry Networks Studies

Aldo Roberto Ometto
Joseph Sarkis
Steve Evans *Editors*

A Systemic Transition to Circular Economy

Business and Technology Perspectives

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Greening of Industry Networks Studies

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About the Editors

Aldo Roberto Ometto has a degree in Production Engineering – Chemistry from the Federal University of São Carlos (1997), a Master's degree in Environmental Engineering Sciences from the University of São Paulo – USP (2000), and a PhD in Hydraulic Engineering and Sanitation from the University of São Paulo (2005) about Life Cycle Assessment (LCA), with a PhD period at Technical University of Denmark (DTU), in Denmark. Since 2006, he has been a professor at the University of São Paulo (USP). In 2011, he did a Postdoctoral at the Autonomous University of Barcelona (UAB), Spain. In 2023, he was a visiting professor at Griffith University, Cities Research Institutes and Griffith Centre of System Innovation, Griffith Business School, Brisbane, Australia, and he worked at the Industrial Transformation Research Hub for Nutrients in a Circular Economy (NiCE) in the Australian Research Council (ARC). He leads the Research Centre for Circular Economy (RC4CE) within the Innovation Centre at USP – InovaUSP, developing innovative projects with multi-stakeholders, mainly in partnership with the industrial sector, focusing on system and impact innovation, sustainability transition, life cycle management/assessment, circular business models, and circular ecosystems. He is the author of more than 200 scientific papers in journals and conference proceedings, 4 books, and 26 book chapters. In 2018, he was the finalist of the World Economic Forum Award "The Circulars", in the Global Leadership category. He is a member of the FutureEarth Research Coalition – Circular Economy Working Group and the lead from USP of the Profiled Universities Network Program in Circular Economy from the Ellen MacArthur Foundation.

Joseph Sarkis is a professor of Management in the Business School at the Worcester Polytechnic Institute. He earned his PhD in Management Sciences from the University of Buffalo. He previously served as a faculty member at the University of Texas at Arlington and at Clark University's Graduate School of Management. His teaching interests include topics in Business and the Environment, Operations, Logistics, Quality, Technology, Information and Supply Chain Management, and Multicriteria Decision Making. He has also taught courses on topics in Business and the Natural Environment. He has published over 350 publications in peer-reviewed archival journals. Topics covered in his research are similar to those covered by his teaching interests. He has also published over 250 additional papers as chapters in books and in conference proceedings. His research interests range from practical application research to conceptual and theoretical research. Currently, he serves on a number of editorial boards for a broad variety of journals including operations and manufacturing, technology management, production, environmental, and information systems journals. He has previously served as editor-in-chief of *IEEE Engineering Management Review* and *Management Research Review*. He has served as special issue editor for a number of journals in which he has covered topical areas including Green Supply Chain Management, Sustainability, Manufacturing Technology Management, Enterprise Resource Planning, E-commerce and Manufacturing, Agile and Virtual Enterprises. His publications include 13 books, and 2 of his books include topics on Circular Economy and Facilitating Collaboration for Sustainable Innovation and Greening the Supply Chain, both published by Springer. He has served as a visiting scholar at various international locations including Cardiff University's BRASS Center, a visiting scholar in the EU Erasmus Mondus MESPOM program and a Sea-Sky Scholar at Dalian University of Technology; and visiting professor and international scholar at the Hanken School in Finland; and the Chair d'Excellence at Université Polytechnique Hauts-de-France. He is a member of a number of professional organizations. He has been recognized as one of the world's most productive and highly cited researchers on the topics of operations research, general business, sustainability, and supply chain management.

Steve Evans has 30 years of experience in improving industrial performance first at Cranfield University, where he gained his first chair as the professor of Life Cycle Engineering in 1998 and at the University of Cambridge where he leads the internationally recognized Centre for Industrial Sustainability. Steve worked in the industry for 12 years starting at Marconi Radar Systems and ending as the Engineering Systems Manager at the world leading ejection seat company Martin-Baker Engineering, responsible for design and manufacturing improvement. Steve remains industrially active as a co-founder of multiple cleantech start-ups. At Cambridge, Steve has secured over $20M in funding, always in direct collaboration with the industry, where he has extensive experience in designing, building, and delivering industry-academia research partnerships with organizations including Toyota Europe, Nissan Europe, Airbus, Marks & Spencer, Unilever, General Motors, Morgan Cars, plus many smaller manufacturers. Under his leadership, the Centre has worked with over 300 companies. Throughout his academic career, Steve has demonstrated the capacity to build research collaborations to deliver high-quality use-inspired research underpinned by innovative fundamental research (e.g., the COGENT project with Nissan and 120 suppliers; COGENT Construction with BRE and 20 suppliers; LIFEcar with Morgan Motor Co, Oxford, Qinetiq, etc.; THERM with Airbus, Toyota, and IES ltd.; and leading the UK National Centre for Innovative Manufacturing in Industrial Sustainability with Toyota, M&S, Unilever, Adnams, Riversimple, and others). This approach has been combined with thought leadership, holding the first UK grants in Eco-Design, WEEE take back, and product service systems. Steve is also active with government organizations (UK and international), informing policy at all levels. He has been the co-chair of the parliamentary Manufacturing Commission with Lord Bilimoria, Special Adviser to the UK House of Lords, and a lead author of the Government Foresight Report into the Future of Manufacturing. Steve has advised the UN on setting up industrial policy for six countries. Steve's thought leadership has recently been recognized by the invitation to become a Member of Academia Europaea, the leading academy of Europe.

Chapter 1
Introduction: Circular Economy as a Part of the New and Sustainable Economy in the Twenty-first Century

Aldo Roberto Ometto, Joseph Sarkis, and Steve Evans

Abstract This chapter introduces the context, justification, and goal of this edited book. The ultimate goal is to present fundamental knowledge and practical insights into the circular economy related to business and technology. The book champions a value-based approach and a system perspective in order to support sustainable innovation with effective positive impacts. This chapter also comments on the content of the works, presenting the authors, title, highlights, and integrative nature of the chapters. The book can be read and evaluated holistically or separately as chapters.

Keywords Circular economy · Sustainability · Innovation

1.1 Introduction

The linear economic model of production-consumption-disposal is close to exhaustion. This model has proven to be ineffective in addressing the main challenges facing contemporary society, which include reducing poverty and social inequalities and addressing climate change, water scarcity, loss of biodiversity, and the exhaustion of natural resources. From the standpoint of business, it is a

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traditional model solely based on cost reduction and the belief in an infinitely abundant world and offers a short-term approach that does not give priority to generating differential values in the market, such as more durable and better-quality services and products.

To achieve economic development combining prosperity with sustainability, we need to move away from a scarcity-based, short-term, and process-focused economy toward a value-based, long-term economy with a systemic view. One of the ways to address this problem is by adopting a circular economic model that aims to link economic growth to a cycle of continuous positive development that preserves and improves our natural capital, optimizes resource production, and minimizes systemic risks through the management of finite inventories and renewable flows.

Also evolving during the first three decades of this century is business and commerce. The evolution in the twenty-first century has been rapid. We can look at those changes through many lenses, from a specific aspect to a system perspective. The purpose of this book is to present the circular economy not only as a technological innovation – from a material or physical resource perspective – but as a systemic transition integrated into the contemporaneous innovation process. Some of the issues in this century are related to sustainability, as such global warming; resource scarcity; poverty; pandemic; and wars, among other major societal disruptions. All of the examples presented are related to the risk of human survival, with sustainability as the main global goal of humanity.

Kates et al. (2001) argued that sustainability science is about understanding the interactions between nature and society, addressing issues in complex self-organizing systems, and about the responses to multiple stresses. Figure 1.1 represents an example evolution of the interactions of the three dimensions of sustainability from: (a) the triple bottom line in which economy, society, and environment are considered of equal importance; to (b) the understanding of the economy as part of the society and both depended on the environment; and (c) considering economy as the linkage of environment and society and a tool to organize resources to maintain or enhance social well-being, environmental quality and economic prosperity (Velenturf and Purnell 2021, p. 1447).

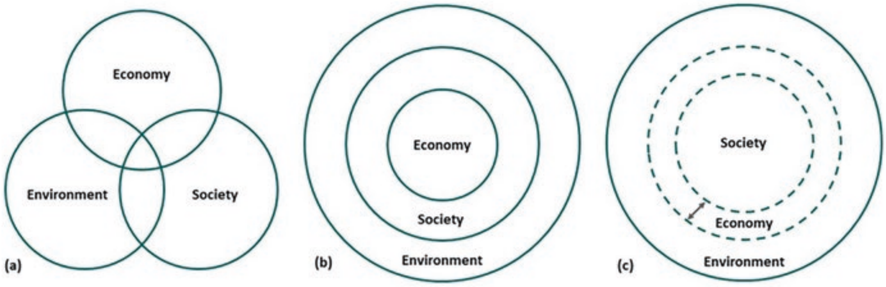

Fig. 1.1 The evolution of sustainability perspectives. (Velenturf and Purnell 2021)

One of the core research questions of sustainability science is: "How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability?" (Kates et al. 2001, p. 642). The transition needs to address society's main challenges – indicated by the sustainable development goals (SDGs) from the United Nations, which include reducing poverty and social inequalities, addressing climate change, water scarcity, loss of biodiversity, and exhaustion of natural resources as part of their 17 major goals.

SDG challenges are at the center of societal needs. They should also be integrated and evaluated within the context of current business and technological changes facing new business models. These changes include such social and technological innovations as sharing, digitalization, and product as service; and technologies, such as blockchain, 3D Printing, artificial intelligence; and consumer behavior. These innovations are an example of a current and critical transformation – where we emphasize function rather than product. Function means that these innovations are more related to their use rather than their possession. This functional need can be achieved very fast, by a digital device for instance, from many options. In this complex and dynamic transition, the linear economy – characterized by extraction, production, consumption, and discharge – requires transformations to a new economy that needs to be more regenerative, inclusive, circular, biobased and restorative, resulting in positive outcomes for all – *people, planet, and economy*.

Circular economy (CE) is considered a recent field attempting to support this sustainable development transition (Antikainen and Valkokari 2016; Ghisellini et al. 2016; Kirchherr et al. 2017; Murray et al. 2017; Geissdoerfer et al. 2018; Manninen et al. 2018; Prieto-Sandoval et al. 2018; Schroeder et al. 2018; Hofmann 2019; Wright et al. 2019; Barros et al. 2021; Velenturf and Purnell 2021; Sinha 2022), defined as "a regenerative economic system which necessitates a paradigm shift to replace the 'end of life' concept with reducing, alternatively reusing, recycling, and recovering materials throughout the supply chain, with the aim to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations" (Kirchherr et al. 2023, p. 7).

Taking diversity and complementary approaches of CE, Blomsma and Brennan (2017) characterize CE as an umbrella concept that builds a connection among concepts that already exist but that were not previously related, mainly in value-based and system perspective. In order to establish the basis for CE, the British Standards Institute presented a set of CE principles, defined as (BSI 2017, p. 27):

- Systems Thinking: "organizations take a holistic approach to understand how individual decisions and activities interact within the wider systems they are part of".
- Innovation: "organizations continually innovate to create value by enabling the sustainable management of resources through the design of processes, products, services, and business models".

- Stewardship: “organizations manage the direct and indirect impacts of their decisions and activities within the wider systems in which they are members”.
- Collaboration: “organizations collaborate internally and externally through formal or informal arrangements to create mutual value”.
- Value Optimization: “organizations keep all products, components, and materials at their highest value and utility at all times”.
- Transparency: “organizations are open about decisions and activities that affect their ability to transition to a more circular and sustainable mode of operation and are willing to communicate these in a clear, accurate, timely, honest and complete manner”.

This evolution of CE strategies and practices can be seen through many lenses (Ghisellini et al. 2016; Friant et al. 2020; Tuladhar et al. 2022). According to Friant et al. (2020), the first stage – and using the now popular x.0 type approaches for defining evolutionary developments – until 1980, can be defined as *Circularity 1.0*, in which strategies are focused on waste management. The second period, from 1980 until 2010, is indicated as *Circularity 2.0*, which has connected strategies for eco-efficiency, as in cleaner production (UNEP 1996), with life cycle thinking, as in industrial ecology (Frosch and Gallopoulos 1989), life cycle engineering and ecodesign (e.g., Alting and Legarth 1995) and closed-loop supply chains (e.g., Guide and Van Wassenhove 2003).

Friant et al. (2020) also suggested the *Circularity 3.0* period, from 1990 until 2020, as one where business takes an integrated approach to resources, consumption, and waste, as with Cradle-to-Cradle (Mcdonough and Braungart 2002) and performance and sharing economy (e.g., Stahel 2010; Frenken 2017) thinking. Mainly since 2010, CE has been focusing on business model innovation (e.g., Linder and Williander 2015; Antikainen and Valkokari 2016; Bocken et al. 2016; Geissdoerfer et al. 2018; Pieroni et al. 2019).

A *Circularity 4.0* period is now emerging emphasizing ecosystem considerations (Ometto et al. 2018; Parida et al. 2019; Konietzko et al. 2020; Aarikka-Stenroos et al. 2021; Kanda et al. 2021; Trevisan et al. 2022; Gomes et al. 2023a). Among many types and definitions of ecosystem, one that firmly seeks to establish a relationship with sustainability is a CE ecosystem, defined as “communities of hierarchically independent, yet an interdependent heterogeneous set of actors who collectively generate a sustainable ecosystem outcome” (Aarikka-Stenroos et al. 2021, p. 261).

Contemporary CE is value-centered, yet most of the literature and practices of CE still focus on material cycles and management of physical resources and waste (e.g., Stahel 2016; Blomsma and Brennan 2017; Kirchherr et al. 2017; Prieto-Sandoval et al. 2018; Geng et al. 2019). According to Kirchherr et al. (2017), in a sample of 114 definitions of CE, 79% of definitions include “recycling”, 75% with “reuse”, and 55% “reduce”; in contrast, 11% include business models and up to 27% in the analysis made from 221 definitions (Kirchherr et al. 2023).

Greater emphasis on providing a broader and more sustainable CE has received increased attention. CE practices may not guarantee a strong sustainability situation

(Schröder et al. 2019). A more transformative approach is seen as necessary to identify opportunities from a more systemic and interdisciplinary perspective (Murray et al. 2017; Jaeger-Erben et al. 2021), in which a broader set of stakeholders – broader than business and supply chains – are engaged in the CE ecosystem (Parida et al. 2019). According to Konietzko et al. (2020), the transition to a CE requires innovations in the product, in the business model, and in the ecosystem. By mapping stakeholders and identifying new collaborations who hold shared values with social and environmental opportunities – such as global inclusion and collaboration – the CE may provide new and greater value propositions, with a mindset for transformation to effective business models and ecosystems (Kunz et al. 2018; Frishammar and Parida 2019; Bertassini et al. 2021; Gomes et al. 2023b).

Hence, the transition to a more sustainable CE goes "beyond a technocratic or materials focus, building on environmental goals and designing-in diverse enterprise models and regenerative practices that improve wellbeing outcomes for people and places" (Yunus Centre 2021, p. 4). Therefore, the transition is not only technical, but also a sociotechnical transition, or even an ecological transition, as it is a system transition, which may be identified as the *Circularity 5.0* period; where some have argued for a circular society (Jaeger-Erben et al. 2021).

A CE transition demands a multilevel and polycentric approach, which can be related to innovations across different systems – products, organizational, value chain – or as innovations in dynamic processes as practices in different phases and levels or innovation across individual parts (micro), organizations (meso), and social systems (macro).

It is commonly recognized that CE needs a systemic transition requiring collaboration and interaction among different stakeholders, a transformation in organizational and behavioral mindsets, new production and consumption patterns, and value optimization through design and circular supply chains. Integration of such characteristics requires fundamental changes in technological interactions, organizational capabilities, products or services, business models, value networks, and business ecosystems.

Novel institutions based on CE require that firms widen their mindset and governance, including new actors and stakeholders and combining various business models to achieve a common goal in an ecosystem (Konietzko et al. 2020; Aarikka-Stenroos et al. 2021). According to Manninen et al. (2018), traditional individual firm business models have difficulties reaching systemic and effective changes as it is based mainly on firms and customers.

Therefore, this book seeks to provide insights into the Circular Economy (CE) from business and technology (B&T) perspectives. We have multiple perspectives from multiple contributors covering two critical aspects for CE success in B&T: a value-based approach and a systems perspective. Going beyond a linear-economic perspective – the traditional perspective – CE needs to develop intentional and integrated paths to help restore physical resources and regenerate the functions of natural and anthropic systems, creating greater economic and social opportunities, with environmentally positive outcomes. Whether this is feasible and possible within the context of CE and B&T is something that will be central to the discourse and insights made in this book.

For transformation, the business models promoted in CE represent solutions on how to propose, create, deliver, and capture value, increasing positive environmental and social impacts. Nonetheless, this transition is disruptive and requires new attempts and solutions to well-known or new problems to an organization and its stakeholders, challenging their capability to manage innovation. It is imperative to gather knowledge about theoretical and practical business and technological solutions with a systemic perspective in the CE context.

Based on the two key aspects, the value-based approach and system perspective, the book is structured in two parts, one from a more theoretical and conceptual basis in Part I, and a more applied perspective in Part II. The chapters in Part I are presented from the lens of *Business and Systems Transitions*. In Part II, the chapters present the challenges and opportunities of those key aspects in cases about *Business Strategies, Processes, Practices, and Technologies.*

By reading this book, the goal is to acquire fundamental and practical knowledge of B&T CE insights combining value-based approach and system perspective for innovation leading to sustainable transitions and effective positive impacts.

1.2 Introduction to the Content of the Book

This book has been edited from the original works of their authors. In total there are twelve chapters, including this Introduction chapter. They are characterized by being collaborative, transdisciplinary, and international efforts.

We have grouped the chapters into two major sections – "Business and Systems Transitions" and "Business Strategies, Processes, Practices, and Technologies". The first half of the book is relatively more theoretical and conceptual, setting the stage for further understanding and providing a framing for chapters in the second section. The second section includes a variety of practical and technical prescriptions to CE.

After this introductory chapter, the first section of the book – Business and Systems Transitions – starts. Chapter 2 is titled "A Value Flow Perspective in the Circular Business Model" by Graziela D. A. Galvão, Paulo S. S. Ferrer, Steve Evans, and Marly M. Carvalho. This conceptual chapter evaluates the central element of the circular economy in business perspective – its value. The chapter addresses the specificities of business models in the circular economy context. The methods used were bibliographic review, bibliometric analysis, and survey. A survey was used for the results related to the "Challenges and Opportunities for Value Generation in the Circular Economy" and was carried out with 233 people from different companies in European countries, India, and Brazil. Bibliometric analysis was used for the "Current Scenario and Trends" and data analyses were performed by NVivo software. The authors proposed a framework that represents the strategic logic of value construction in the circular context. This Circular Business Model framework presents a hierarchical structure, ranging from value generation to value capture, guided by the classic organizational strategic direction set (vision, mission, and values). The hierarchy includes three stages: value creation, customer/market perception, and value capture. The value creation stage brings together two levels of processes: support processes and enabling processes. Subsequently, the challenges and opportunities for the implementation of Circular Business Models are discussed. Finally, the scenarios and trends that the academic literature reveals for the circular economy are presented.

Chapter 3 is titled "The Design of Sustainable Product-Service Systems to Foster Circular Economy for All" by Carlo Vezzoli and Luca Macrì. This chapter highlights the system perspective in design as a key enabler for circular economy practices and building competitive advantage. The chapter introduces practical examples, approaches, skills, and a method for designing sustainable product-service systems (S.PSS). S.PSS represents an opportunity to foster circular economy businesses and technologies for *All*. The most important principle of circular economy practices – the systems perspective – is addressed in the design of product-service systems taking into account sustainability, especially the usually neglected social aspect. Although social issues are not a major aspect of this book, we would like to mention that social aspects of the circular economy are not lost in the book series (the Greening of Industry Networks series). A sister companion book with a theme of Social Issues in the Circular Economy will be provided concurrently with this book. This book does not explicitly focus on social dimensions, but, of course, mention will be made throughout, and it is considered crucial for circular economy transition as the economy is part of society and so is a social science. The chapter is replete with a variety of cases and explanations on how S.PSS fits with technical and biological cycles. It also provides some insights into an overview of methods for system design for sustainability. A process-based method ranges from building a strategic vision to operationally communicating capabilities of product-service outcomes and their characteristics. The chapter is comprehensive and worth a read for those interested in how PSS fits within CE.

Chapter 4 titled "Initiating a Minimum Viable Ecosystem for Circularity" by Jan Konietzko, Brian Baldassarre, Nancy Bocken, and Paavo Ritala introduces an ecosystem perspective for organizations in order to achieve a CE transition. The methods used were a review of the ecosystem literature and three European case studies related to footwear, personal care, and water products. Similar to other chapters in this book introducing various CE frameworks, a beginning point for organizations and their partners is to begin with a vision. The expansion of the organization's vision and relations beyond the traditional supply chain, based on a common value, including other processes and actors that are interdependent, is an important systems perspective application. The systems perspective in the conceptual proposed Framework for a Minimum Viable Ecosystem for Circularity (MVEC) includes six major steps that interact with each other and form the basis for a circular economy transition: (1) Put forward a circular economy vision, (2) Design an ecosystem value proposition and outcome, (3) Develop an actor engagement strategy, (4) Develop a governance model, (5) Develop fair value capture mechanisms, and (6)

Keep track of environmental and social impact. It is interesting to notice the cases highlight the importance of ecosystems for positive outcomes in environmental, social, and economic dimensions.

Circular economy transition requires strategic changes in organizational culture and relying on innovative operational organizational practices. This organizational interactive hierarchical and systemic perspective occurs across the many frameworks in this book. It is further explored in Chap. 5, which is a result of a transdisciplinary project for developing a roadmap for circular economy transitions. The project was financed by the National Council for Scientific and Technological Development (CNPq), from the Ministry of Science and Technology (MCT), in Brazil, including academics, business, and civil society partners, such as the National Confederation of Industry (CNI), in Brazil. This project also included a launch on the CNI website (https://economiacircular.cni.com.br/) for an interactive process for companies to self-assess their maturity level in circular economy. Thus, this approach was not only conceptual and academic but meant to take action for actual transition.

Chapter 5 is titled “Organizational Practices, Values, and Mindsets as a Basis for Circular Economy Transition” by Camila dos Santos Ferreira, Giovana Gomes, Danika A. Castillo-Ospina, Ana Carolina Bertassini, Camila Zaguetto, Nathália Feltrin, Efigênia Rossi, Isadora Miyuki Kano Carmo, Julia Carderan Nardy Vasconcellos, Luisa Barboza, Rodolfo Tonelli, Giovana Dionisio, Mateus Cecilio Gerolamo, Adriana Marotti Mello, Leonardo Augusto de Vasconcelos Gomes, Cara Beal, and Aldo Roberto Ometto. The chapter proposes, based on subject matter experts and literature review, a conceptual roadmap for an organizational transition to a circular economy in a circular business ecosystem context. Circular values and mindsets from consumers and organizations, circular practices, and a maturity mapping of levels in order to support organizations in the transition to a CE are each presented. The roadmap provides a cycle for analysis of the situation – aligned to other chapters in this book that consider dynamic improvements of CE over time. At the center of the roadmap development is the “value co-creation” as a transdisciplinary principle. Transdisciplinary is needed to address the complex issues facing the circular economy (Bergendahl et al. 2018). The six-step process of this framework includes diagnosis, identifying opportunities, setting goals and objectives, circular design and planning, implementing circular practices, monitoring the implementations, and feeding back lessons. Each stage has its own set of tools and cases to provide exemplary situations that practitioners and organizations can benchmark in their own efforts.

The last chapter of Part I of the book and the sixth overall chapter of the book is titled “From Socio-technical Innovations to Ecological Transitions: A Multilevel Perspective on Circular Economy”, by Ken Webster and Stefano Pascucci. This conceptual chapter amplifies the socio-technical analysis to include the socio-ecological relations. The chapter emphasizes the deeper idea of using insights from living systems to design eco-effective systems, reflecting the perspectives of the original circular economy school of thought, such as Industrial Ecology and Biomimicry. The authors highlight the importance of system eco-effectiveness to generate positive impacts instead of reducing negative ones and the generation of a *Window of Viability* by balancing efficiency and resilience, with diversity enhancement, as living systems. Following the metaphor of an economy working as a living system, the authors propose to think of a more decentralized and open-access-based circular system. To achieve it and improve the chances of keeping the system into the *Window of Viability*, the authors apply the lens of *panarchy* in socio-economic systems to discuss the need to include socio-ecological relations in a system transition to CE. In this transition, some pairings, which present a continuum between each of the two opposites, are presented, such as large scale and small scale; accumulate and distribute. The authors conclude by suggesting the application of a multilevel complex systems perspective application to the challenge of locking a way of making policy around an effective circular economy.

The second part of the book concerns Business Strategies, Processes, Practices, and Technologies for Circular Economy system transition. Chapter 7, the first chapter of the second part of the book, is titled "The Importance of Circular Economy in HP Sustainable Impact Strategy" co-authored by Paloma Cavalcanti and Ryan Kanzler. In this empirical chapter, the authors outline how the business case for the circular economy has been playing a key role in HP's global sustainability strategy. The chapter describes each of the programs and initiatives introduced as part of HP's global strategy. Product design, innovative service-based solutions and repair, reuse, and recycling programs, with people's inclusion and economic well-being are all examples of HP's programs and initiatives. For products end of life, HP provides take-back programs in 76 countries, including social impact solutions. The programs at HP are rather extensive and carry out many of the theoretical and conceptual practices identified in the first part of the book (the first six chapters). The observation we make is on how extensive these practices are and how they include all levels of the product and process life cycles from conception to end-of-life. Even HP recognizes the need for inclusiveness and the socio-economic and environmental issues facing their products and processes. What they show is an exemplary company that can not only do well economically, but do good socially without being forced to complete all these activities. It makes business sense. The next chapter also builds on this perspective with Unilever.

Chapter 8 is another significant business case from a large and global company. This chapter explores Unilever about its procurement and supply chain management strategy and operations from a circular economy systemic perspective. The chapter is titled "Purchasing and Supply Management Journey into Unilever's Circular Economy Strategy", by Fabio Ferraz de Arruda Pollice and Marcelo Scarcelli. With a rich discussion and two empirical study cases on plastics and palm oil suppliers in Brazil, the authors describe the changes in procurement and supply chain management in Unilever for a circular economy, specifically from the launch of Unilever Sustainable Living Plan in 2010, when started a journey to bring a net positive impact to the environment. A central aspect described was the necessity for developing a new mindset for buyers and procurement professionals as they also become sellers in the design of a circular ecosystem. They also highlight in the chapter the product-as-a-service business model, the importance of engagement with suppliers for circular ecosystem design, and the much deeper relations with customers. The chapters also address circular supply chain management, linked to procurement, not only through the reverse logistic lens but also by value generation for a new set of stakeholders, including renewable solutions. The cases prove again how organizations can have a broad upstream, internal, and downstream set of perspectives and concerns related to CE and its innovations.

Chapter 9 shifts the focus to a company that has embraced business and systemic CE practices in a Bioeconomy. This chapter titled: "Circular Economy in the Paperboard Industry: Ibema Cases" is co-authored by Alessandra Lhais Pavelski, Andrea Alice Noziglia Lacerda Pegorini, Diego Gracia, Eduardo Muller, Fernando Wagner Sandri, and Indaia Pasotti Sanchez. This empirical chapter introduces insights into a successful circular economy business case from the forest in Brazil. In this case, whereas the focus of the previous chapters was mostly concerning the technical cycles, this chapter's foundation is the biological cycle and integrative technical circular solutions. Practically, the authors present the importance of forests, also as a business value source for society, the renewable applications in products and as an energy source, as well the paper recycling to close the loop. Those practices are presented as part of the company's business evolution based on a culture with a system perspective and sustainable purpose to build a multi-value circular and regenerative ecosystem. They provide a number of paper products companies to show various efforts and opportunities in this industry, especially with respect to the South American environment.

Chapter 10 "Circular Economy Principles in Urban Agri-Food Systems: Potentials and Implications for Environmental Sustainability" is co-authored by Martí Rufí-Salís, Susana Toboso-Chavero, Joan Rieradevall, Laura Talens-Peiró, Anna Petit-Boix, Gara Villalba, Cristina Madrid-López, and Xavier Gabarrell. The chapter presents circular economy in an urban agriculture (UA) context. UA is an alternative form of low-environmental impact agricultural production – at least relatively low-environmental impact – that positions agricultural production within urban settings or at the edge of urban regions. Based on the literature review, the authors present CE practices in UA including struvite (as a fertilizer), composting, rainwater harvesting, and water and nutrient recirculation. Within these contexts, they carefully examine or pursue the effort to the environmental analysis, as by Life Cycle Assessment in order to support practices decisions. Burden shifting analysis is completed to make sure that the overall environmental performance of these CE practices is met; unfortunately, many times CE practices are introduced with the assumption that the environmental burden is minimal and not shifted. Recognizing this and applying environmental assessment tools, such as LCA, are important practices to help achieve strongly sustainable CE.

Chapter 11 titled "A Systems Perspective on the Industry 4.0 Technologies as Enablers of Circular Economy Transitions" is co-authored by Vinícius Picanço Rodrigues and Eduardo Zancul. This chapter presents Industry 4.0 technologies innovation applied in a systemic perspective for CE transitions. Based on a content analysis of the fundamental literature of Industry 4.0 technologies and high-level CE strategies, with selected illustrative cases, and using the leverage points framework proposed by Donella Meadows, the authors analyzed CE transitions, positioning Industry 4.0 technologies as critical enablers. The analysis showed that the relationship between the I4.0 technologies (physical-digital interface; network; data-processing; and digital-physical process) and the high-level CE strategies varies significantly. Therefore, the I4.0 technologies' effectiveness is not all the same in terms of enabling CE transitions. This chapter provides some insights into some other chapter topics. For example, HP in Chapter 7 spoke to additive issues, and the procurement case of Unilever considered traceability. These practices, as many other practices in CE, can be supported with technology such as blockchain technology (e.g., see Kouhizadeh et al. 2020) and 3D manufacturing. These emergent concepts of linking CE and Industry 4.0 technologies have become issues of great interest in the early 2020s (e.g., see Bai et al. 2022). Nevertheless, this chapter concludes that I4.0 technologies alone may not be enough for CE transition and might include unlocking novel circular business models.

Chapter 12, the last chapter of the book, explores the crucial phase of consumption in a Circular Economy and is titled "Psychological and Systemic Factors Influencing Behaviour in Circular Consumption Systems. *Lessons from the Fast-Moving Consumer Goods and Apparel Industries*" and is co-authored by Żaneta Muranko, Giovana Monteiro Gomes, Marco Aurisicchio, and Aldo Roberto Ometto. This conceptual chapter on the fast-moving consumer goods and apparel industries context, explores the consumption phase of circular economy, presented as a circular consumption system, and the influence of the psychological and systemic factors on the consumer adopting a circular behavior, such as repair, reuse, and recycling. This chapter suggested that both consumer psychology and the environment play a pivotal role in guiding consumer journeys through circular patterns. As a practical takeaway for the promotion of the circular behavior of the consumer, the authors suggested designing consumption systems that "1) onboard the first-time consumer in the circular journey, 2) ensure the consumer performs behavior chains correctly and completely in order to reach the specific objective of a circular offering, and 3) encourage the consumer to repeat behavior chains, fully or partially depending on the system requirements, and eventually incorporate circular consumption in their daily routine".

This book can be read by linking topics and sections, or as separate chapters. Although there are overlaps, there are significant unique characterizations and insights in each chapter. Whether it is conceptual, theoretical, or philosophical, such as the first sections of the book; or it can be read with more practical concerns and operations in the second half. The proof of the concepts from the first part of the book exists in the second half. A broader understanding of specific cases in the second part of the book can be found in the first half of the book. We provide a broad and initial perspective here, whether the goal of the reader is to understand the theoretical and systemic foundations or actual examples of successful pragmatic practices. Overall, the complexities of CE from a Business and Technology perspective are made accessible to the average reader, but there are also insights even for the most experienced researchers and experts. We feel the readers will find something useful for them as they go through the chapters. Enjoy the book!

1.3 Conclusion

We want to welcome you, with this book, to look to Circular Economy as a Part of the New Economy of the twenty-first Century. For this purpose, the book was built based on two pillars of circular economy: value and systemic perspectives. Those bases intend to present CE beyond the traditional focus on material and product physical circularity, addressing it as a system innovation focused on long-term value creation with positive impacts for all, integrating business and technology with the ecological and social dimensions.

Those bases were constructed by two complementary approaches of the parts of the book: Part I, with more conceptual fundamentals; and Part II: with business and technologies applications.

We hope this book can seed substantial insights for system and impact innovations by managers, researchers, policy-makers, stakeholders, and all of society in order to build solutions for the main challenges of humanity. Let's make this urgent transition together!

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Part I
Business and Systems Transitions

Chapter 2
A Value Flow Perspective in the Circular Business Model

Graziela D. A. Galvão, Paulo Sergio Scoleze Ferrer, Steve Evans, and Marly M. Carvalho

Abstract Circular economy emerges as a viable solution for sustainable development; however, organizations need to adapt to the new value stream logic. Based on the linear value production logic, the current traditional models no longer serve this purpose, demanding that organizations review their business models, migrating to circular logic. The challenges are many, as are the opportunities. In this sense, a framework is suggested to guide the design and implementation of a circular business model.

Keywords Circular economy · Circular business model · Value stream

2.1 Introduction

The classic Hobbesian view of *Homus economicus* suggests that we act in a way that maximizes value. In other words, we rationally seek a final result that is more satisfactory than the initial, traditionally, measured from an economic perspective.

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If we start from this classic vision, but include the environmental and social perspectives, we outline the purpose of sustainable development (Galvão et al. 2022).

While the construction of the concept of sustainability is supported in the balanced coexistence of those three dimensions, in general terms, a circular economy is about maximizing the flow of sustained value (Batista et al. 2023). That is, it seeks to maintain the growing pace of the current global production system and social development, however, without compromising the environment.

The interplay between these three dimensions – economic, environmental, and social – presents challenges due to their apparent conflicts. Historically, the consequences of population growth on environmental pollution have been a topic of concern, highlighted by publications such as “The Tragedy of the Commons”. This classic work, starting with Garrett Hardin’s 1968 essay, emphasized the impact of population growth on the environment.

The detrimental effects of uncontrolled economic activity on the environment were illustrated by events like the collapse of the Pacific sardine industry, causing widespread unemployment and environmental disturbances. This scenario underscores the essence of contemporary sustainability concerns (Lloyd 1837).

The tension between economic and environmental aspects is mirrored in the relationship between global GDP growth and Overshoot Day, the day when we exceed Earth’s biocapacity. While economic growth often postpones Overshoot Day, a long-term trend suggests increasing resource depletion.

This complex interdependence also relates to the 2030 Agenda for Sustainable Development[1] and poses a question: Can economic growth be reconciled with environmental preservation? This query delves into the challenge of shifting focus towards sustainable practices without compromising economic and social aspects.

The emergence of the circular economy concept offers a potential solution. This holistic approach advocates for recycling, eliminating toxic emissions, and replacing traditional energy sources with renewable ones. The circular economy aims to integrate economic activity with environmental sustainability through collaborative efforts among nations, companies, and communities (Rizos et al. 2016).

This shift requires transitioning from a linear to a circular value generation model. The circular economy presents challenges and opportunities that extend beyond environmental concerns, encompassing economic and social dimensions as well.

It is not difficult to infer that the challenges to the circular economy are many, as it implies a profound change in the current production model, consumption habits and even in society’s perception of value (De los Ríos and Charnley 2015). This transformation implies the need to change the way value is generated, which is, while in the current economic model, the value is maximized in a linear

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[1] https://sdgs.un.org/2030agenda

arrangement, which goes from extraction to final disposal at the planet's expense, in the CE model, the products and by-products are idealized and constituted in order to circulate among the different players, from different countries, communities, etc., reducing both the extraction of natural resources and the final disposal in the environment (Evans et al. 2017).

It is reasonable to assume that this transformation involves a slow paradigm shift, which counteracts the need for speed in reversing the pace of environmental degradation. In other words, it is expected to be a systematic transition to circular economy (Fig. 2.1).

In this way, the institutional arrangements advocated by Ostrom gain particular prominence. They aim at large-scale circular integration, with the support of public policies of incentive and regulation, already existing in several countries, and the gradual awareness of society about the importance of adhering to the logic of the new model, as an essential link to close the circle. At this point, the role of government policies can be a catalyst that mediates paradoxical and conflicting points.

Despite the importance of public policies and other external stimuli as catalysts for this process of the paradigm shift, it is essential that drivers start from the heart of generating economic value, that is, within organizations. The current traditional productive logic is linear, as we will discuss in the following topic. Therefore, organizations urgently need to migrate to the circular model of value generation, which

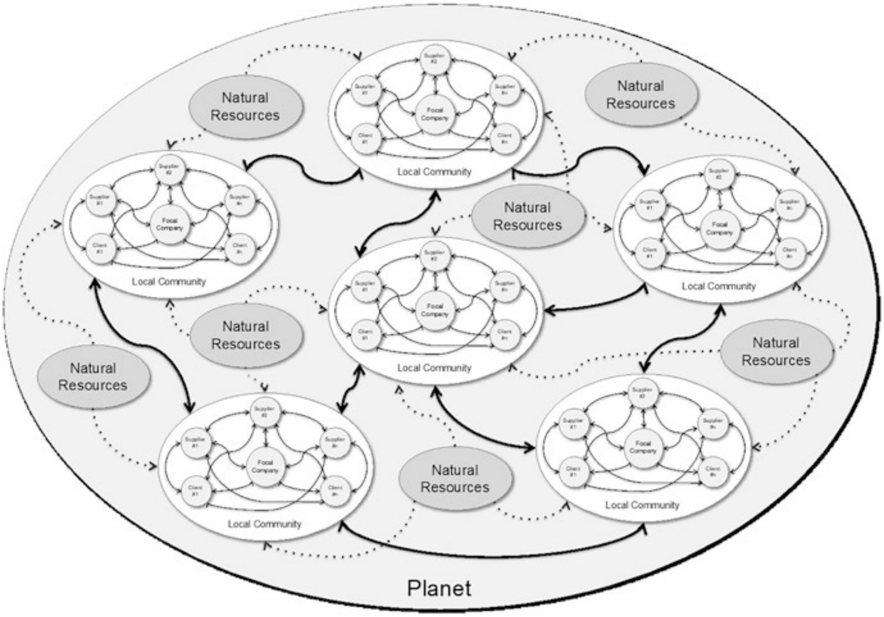

Fig. 2.1 The integrative and holistic vision contemplated by CE

requires deep strategic and operational adaptations. In this sense, the importance of developing and implementing new business models, now circular, is revealed (Galvão et al. 2022). For its implementation, obstacles may arise – on the other hand, and it can represent new ways to generate and capture value. Ultimately, the implementation of truly sustainable strategies depends on well-aligned circular business model.

The circular business model is not limited to environmental issues. As it is a systemic transition, it encompasses social policies and economic results. The circular economy results in the creation of many new business models, often the positive results in addition to generating value; it also results in value sharing. Value flows differently and in different ways in the circular logic, through various interactions external and internal to the organization. The value varies between the three dimensions of sustainability, and trade-offs emerge with particular importance and complexity. As an illustration, a financial gain in the short term can be converted into social value (Battilana et al. 2022). It can also return economically in greater volume in the medium or long term; longer-lasting products may result in a reduction in sales volume over time but carry greater added value per unit. However, these are new ways to generate and capture the value that demands new circular business models.

In pursuit of this transformation, the role of public policies, institutional arrangements, and individual organization efforts is critical. Elinor Ostrom's work on sustainable relationships between humans and ecosystems underscores the potential for effective governance mechanisms.

This chapter is designed to answer the following research question: How can organizations effectively transition from linear value generation models to circular business models, considering the interplay between economic, environmental, and social dimensions within the context of sustainable development?

Therefore, this chapter will present a value flow model of an organization inserted in the circular ecosystem, shedding light on the interactions that catalyse or generate tensions in the existing dynamics (Galvão et al. 2020). This model was formulated from the objectives, barriers, incentives, drivers, and the theoretical and practical implications collected in scientific publications about the circular economy. Therefore, a framework that represents the strategic logic of value construction in the circular context is proposed. Subsequently, the challenges and opportunities for the implementation of circular business models are discussed. Finally, the scenario and trends that the academic literature reveals for the circular economy are presented.

We used mixed methods: review, survey, bibliometric analysis. For the session "Challenges and Opportunities for Value Generation in the Circular Economy" we performed a survey. A study was carried out by us with 233 people from different companies in European countries, India and Brazil. For "Current Scenario and Trends" we used bibliometric analysis. For most of the articles we apply a review of the literature. Data analyses were performed with the help of NVivo software.

2.2 Linear Business Model Versus Circular Business Models

Although the term "Business Model" has been part of corporate jargon since *Peter Drucke's 1954* publication,[2] there is apparently no consensus on its scope. While some authors emphasize customer identification for a particular business and understand how this customer perceives value, other authors address the entire value creation logic, from organizational transactional structure and flow to value delivery. We will adopt the overarching idea that the business model describes the logic of value creation, delivery, and capture. The differences between the linear and circular business model of production and consumption are discussed in this topic.

The traditional and predominant form of business is supported by linear logic, whose value generation is proportional to the intensity of the flow (Galvão et al. 2020), as shown in Fig. 2.2. In this model, we observe the prioritization of the economic dimension, to the detriment of the environment. As the generation of economic value is accelerated, the extraction of raw materials, energy use, the volume of waste, leftovers, and the emission of pollutants also increase. Integration into the social dimension is tenuous and with little or no integration into the corporate value proposition. Isolated initiatives that aim to recycle some materials, reuse leftovers,

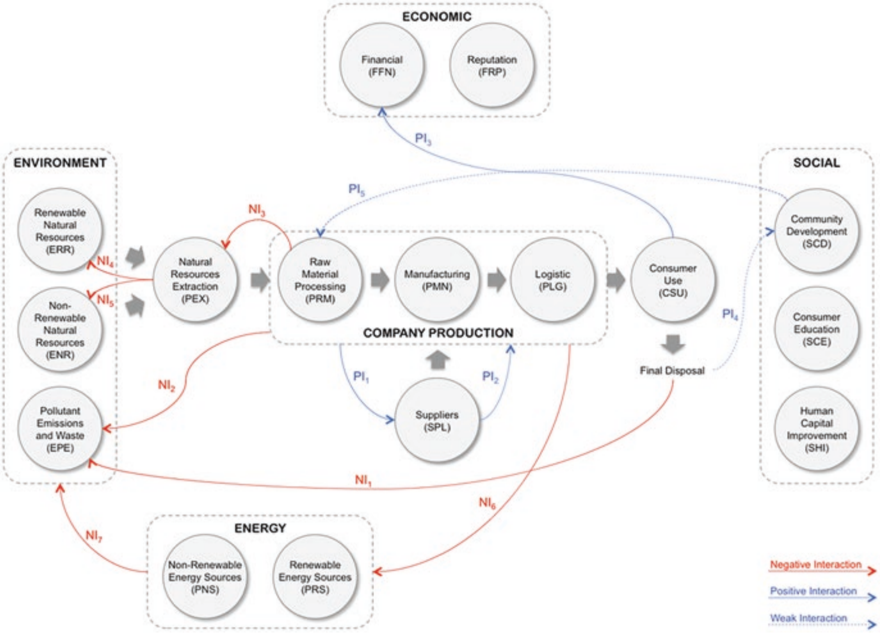

Fig. 2.2 Company production in the context of linear business model (LBM)

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[2] Drucker, Peter, The Practice of Management, Harper and Row Publishers, 1954.

reduction of pollutant emissions, reduction of energy consumption, and social inclusion are measures that can even be incorporated into more sustainable organizations, but even if they do not occur, the generation of value remains protected.

As shown in Fig. 2.2, the greater the positive impact represented by the PI_3 vector, the greater the negative impact on the environment, represented by vectors NI_4, NI_5, and NI_7. Even interrupting these sustainable initiatives, the way of generating value is not damaged. This aspect of the LBM suggests certain fragility to perpetuating or even maintaining sustainable initiatives in the long term. If necessary, these measures may be discontinued. For example, suppose a source of social value generation is not an effective part of the organization's value proposition in a moment of financial crisis. In that case, the initiative may be discontinued as a cost-cutting measure. "Loose ends" are more easily recognized as generators of cost than revenue.

The decision-making in the logic of linear business models is predominantly anchored in the (Julkovski et al. 2022) economic dimension. Therefore, the analyses of value generation, delivery, and capture are focused on the achievable economic gains. Since the customer is the final link in the chain, there is an overlap between delivery and value capture.

It is characterized as the "cradle to grave" sustainability paradigm. The value generation model is built between the limits of resource extraction and disposal at the end of its useful life. The result is directly proportional to the flow of materials: the higher the consumption, therefore the productive flow, the greater the financial input into the organization (FV) (Vargo and Lusch 2004). Consequently, the greater is the need for extraction of natural resources and energy consumption, decreasing environmental value (EV). In this model, the relationship between consumption and the generation of social value (SV) may be negative, null or slightly positive, respectively, when an organization competes with the community. When it does not relate or when there is some synergistic effect, such as individual or small groups that collect materials to be recycled.

Figure 2.3 represents those relationships in the function of consumption. The analysis of the curve represented reveals the linear business model (LBM) inconsistency from a perspective of sustainability. Considering that sustainability demands the balanced integration of the economic, environmental, and social dimensions (Geissdoerfer et al. 2017), in the LBM, this would occur only at the theoretical point where the consumption is equal to zero ($CSU = 0$). It is observed, therefore, that the greater the consumption, the greater the imbalance among economic, environmental, and social dimensions, which would explain the difficulty of sustainable initiatives consolidating themselves over time, based on the current economic model.

However, changes in society's awareness, posture, and habits foment new business models towards a more sustainable way of life, production, and consumption (Murray et al. 2015). In this sense, the circulating economy presents itself as a fundamental solution. The circular economy is based on principles such as lifecycle extension, sharing, reuse, recycling, remanufacturing and refurbishment. Its viable implementation depends on rethinking operations and supply chain management, especially product and service lifecycles.

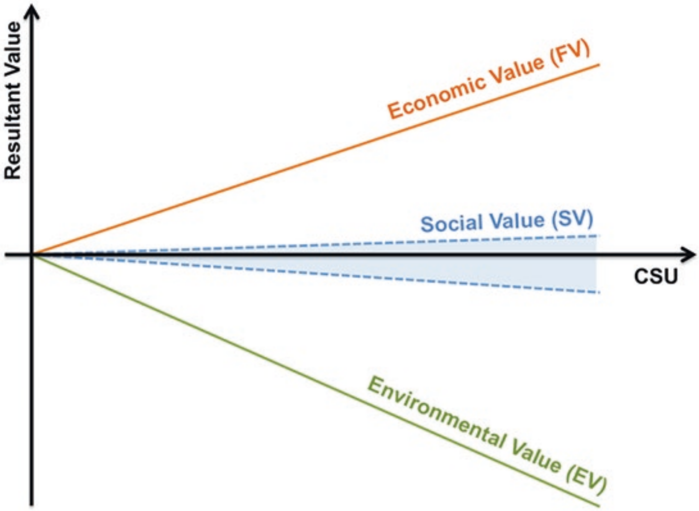


Fig. 2.3 Generation of value as a function of consumption in the LBM

In turn, the circular business model (CBM) contemplates an extended and integrated perspective of the value stream, as they represent a new strategic business structure, in line with the CE logic, inserting the particularities of a new dynamic in the value flow (Galvão et al. 2020). Differently from the linear “take-make-dispose” logic, in circular logic, the value flows in a closed circuit. For organizations to be included in the context of a circular economy, it is crucial that they adopt an “outside-to-inside” perspective, choosing strategies capable of making the business economically viable but still contemplating positive contributions to the challenges of sustainability (Evans et al. 2017).

This new approach, aimed at creating new business opportunities, leaps from the “cradle to grave” vision to the new perspective “cradle to cradle”, connecting the end of life of processes and products to new lifecycles, thus, in addition to the classic “supplier-business-customer” model (Bocken et al. 2014). This new holistic model implies a profound change in the way of doing business, requiring a new understanding and perception of value with dynamic and intelligent solutions, which demand staff capable enough to go beyond the mere use of traditional management tools of sustainability. Therefore, there is the understanding that companies should rethink their business models to make an effective contribution to sustainable development (Evans et al. 2017).

In this business model, there is a clear separation of value delivery and capture, which connect to each other and reconnect with the generation of value in the productive core in continuous cycles (Galvão et al. 2022). The value presents itself in a three-dimensional way, and the several trade-offs that occur under this paradigm also challenge decision-making. The complexity involved in the circularity of value demands anticipation, often visionary, considering three pillars:

(i) Organizational structure: invest in raising awareness of stakeholders and other workers have a team with the good managerial capacity to perceive opportunities, invest in necessary resources and corporate knowledge; be aware of issues external to organizations and consumer behaviour (Paletta et al. 2019).

(ii) Technologies: lack of appropriate technology (Sousa-zomer et al. 2018). Be aware of the opportunity to develop technology to increase circularity. The company can invest in technology for its use or identify an external need.

(iii) Market: the consumer of linear logic buys, uses, and then throws the products. In the circular logic, customers or users cannot see themselves as the final step but as a link in a larger system. Likewise, awareness of the inherent value of extended life cycle products, remanufactured or used products should be reset. This significant change in consumer habits takes corporate marketing to another level. Likewise, reverse logistics channels may need to be reinvented to reconnect the user to the organization at the end of the product's life (Saruchera and Darko 2021). Usually, this can imply cost, and therefore, the need to create other ways of capturing value (through image, for example) reaffirms the importance of a new business model.

2.3 Towards CBM: Building Value in Circular Logic

One of the difficulties is still to develop forms of value generation in the circular mode, considering that the organizational mindset inhibits the entry of new business models suitable for this purpose (Evans et al. 2017).

Considering the purpose of identification and perception of value inherent to business models, CBMs can absorb new opportunities provided by the circular economy. Yang et al. (2017) suggest an extension of the value perspective provided by the traditional view of business model, incorporating the proposal of the uncaptured value, according to 4 sources: (i) value surplus, which exists, but is ignored because it is not required; (ii) value absence, which initially doesn't exist, but that needs to be provided; (iii) value missed, which exists and would be required but is not properly captured by the current business model; and (iv) value destroyed, whose existence has negative consequences for the system.

A circular business model must be built to maximize sustainable value generation, delivery, and capture. Each organization must analyse the context to identify the potential value available in its market and make the connections. However, we propose a framework representing the strategic logic of value construction in the circular context (Fig. 2.4).

Importantly, a business model is a dynamic artefact. The framework, in this case, only marks the formulation of the strategic construction in the circular context. In this way, it can be applied in the design of new businesses. It can be used in business models structured by a traditional linear logic, which want to migrate to a circular value generation logic.

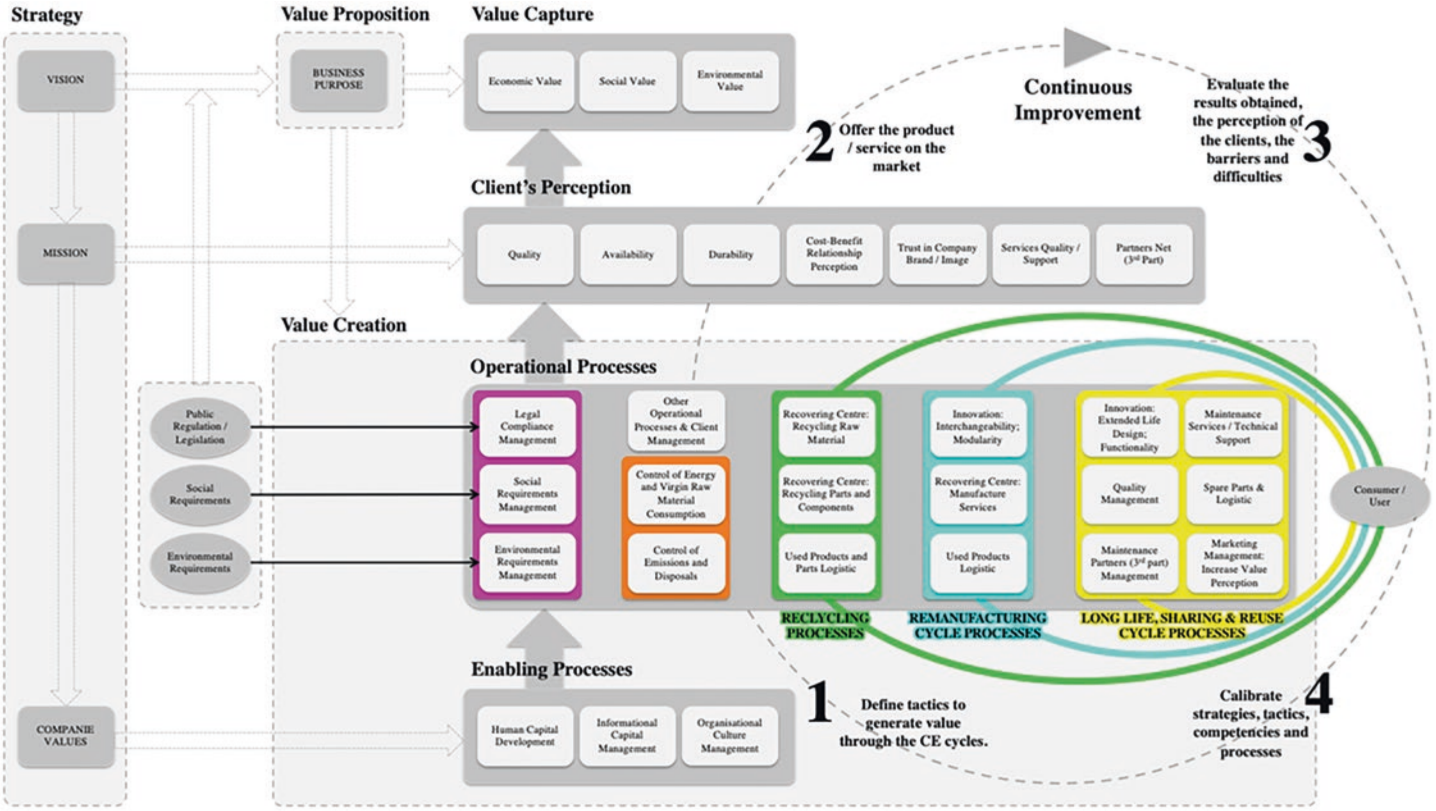


Fig. 2.4 Towards CBM: building value in circular logic

Also, as an advantage, the adaptive and progressive cycles meet the complex nature of this change to circular logic since it demands great changes in the traditional production and consumption models now practised. In other words, this proposed framework is based on the premise that changes of this magnitude cannot be easily achieved unless through gradual increments (principles of continuous improvement applied to this profound transformation).

The CBM framework focuses on how value is generated in organizations, offering a structure with hierarchically arranged levels, ranging from value generation to value capture, guided by the classic organizational strategic direction set (vision, mission and values). The hierarchy includes three stages: value creation, customer/market perception, and value capture. The value creation stage brings together two levels of processes (support processes and enabling processes).

Initially, the organization needs to absorb CE ideals in strategic construction. The vision, mission, and values must absorb the CE principles. The vision also feeds the formulation of the purpose that will guide the value generation in the business; the mission suggests the type of business to be carried out and how it will impact the customer, and values reflect in what way value will be created.

Effective construction begins at the level of support processes, which comprise the structuring and basic organizational values. At this level, there is the planning and development of the necessary human capital and informational capital (including organizational learning retention bases). All of this wrapped in an organizational culture managed to maintain adherence to CE principles. This level receives direct influence from the set of strategic values that come to govern the organization.

With a base of support processes, the planning and construction of enabling processes to begin. The great difference of traditional structures is the fact of the set of processes capable of operationalizing the CE cycles: quality and innovation to extend the useful life, which still allows the reuse and sharing among users; innovation and design that allow interchangeability and/or modularity from product conception, as well as reverse logistics capable of recovering used parts and other recyclable raw material leftovers; and processes capable of promoting the recycling of collected raw material.

The framework also provides for waste management processes and missions, management of energy consumption and virgin raw materials, and customer management. It includes marketing to change the perception of market value to circular logic) and management of legal requirements, environmental and social issues that orbit the organization (compliance).

The next step reflects the perception, by the market/customer, about the value created. As there is a perception of quality, favourable image & reputation, cost-benefit, etc., there is customer acquisition and loyalty. Finally, value is determined through 3 dimensions: economic, environmental and social (here, there is still a need to develop adequate indicators, depending on the reality of each business).

The results obtained, market perception and barriers encountered are continually evaluated. The information collected fosters an action plan to promote the strategic and tactical adjustments needed to improve results. The most important thing is that when inserting any of these strategies into the circular business model, the company does not think and do it in isolation. When thinking systematically, it is possible to add a value stream.

However, the perception of the value of different players requires elaborate management of stakeholders, as the business model must be able to respond to expectations from the perspective of each technical cycle throughout the entire length of the value chain. Figure 2.5 schematically represents some typical stakeholders associated with each technical cycle.

By understanding the domains and proximity of stakeholders and the expectations associated with the product, the organization can adjust its strategies and tactics within the business model to develop ways to capture value.

Some technical cycles, such as "reuse" and "sharing", are apparently distant from the organization in value circulation. In order for these cycles to be effective, the perception of stakeholders would probably be of greater longevity and less economic devaluation over time. The business model, therefore, should be able to add economic value from the highest quality.

Additionally, developing alternative revenue models related to services, parts sales, product subscriptions (such as a subscription car), and other modalities can capture the value that can be included in the business model. Based on an understanding of stakeholders' expectations, organizations can develop their structures for operationalizing the business.

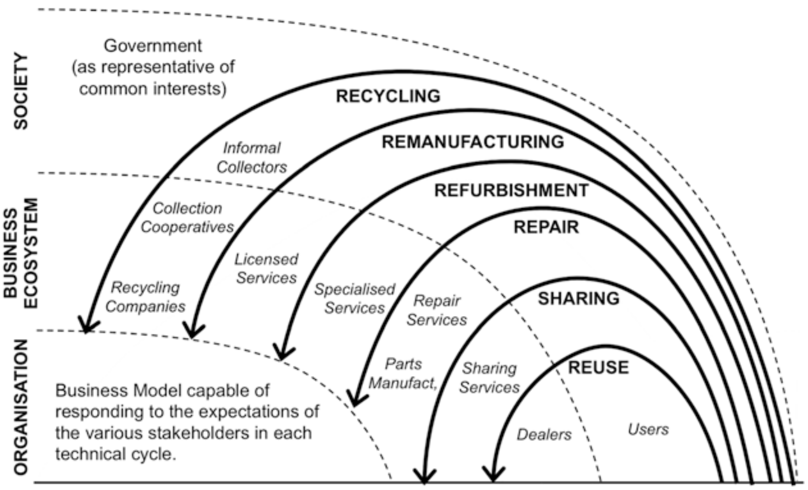


Fig. 2.5 Technical cycles and stakeholders

2.4 Challenges and Opportunities for Value Generation in the Circular Economy

As discussed, some challenges may delay the implementation of CE in some organizations. A study carried out by us with 233 people from different companies in European countries, India and Brazil, pointed out some challenges and opportunities to implement CE or strategies to increase circularity.

One of the main challenges that arose is related to the value stream, as this presents itself in trade-offs, which are not always attractive in the first analysis. For example, the exchange of a financial value for an image value can be trade-offs that need to be considered for a sustainable equilibrium in the circular economy.

Furthermore, in some countries, especially developing ones, CE is introspective and isolated views of each party, without considering their roles and responsibilities in the big picture. This disruptive character that some organizations perceive needs to change towards a holistic view. Companies need to see beyond the apparent loss of economic advantage, a point also presented in research by Rizos et al. (2016). In this way, organizations may identify other forms of value not yet captured in the system. Consumers also need to be included in this system, so they can change the way they value products and services. Another item raised in the study is that public actors need to act as supporters and aggregators of the various actors in the CE.

The respondents also mentioned the lack of a way to measure how much circularity results, that is, what are its effects in the environmental, social, or economic dimensions. Here, then, there are new opportunities for the development of technologies or models to measure circularity.

Yes, the difficulty in changing the traditional linear to circular business model was also presented, as this would involve considerable changes in the form of production. Some pointed out that the problem could be the need for high investment or the lack of technology to make their products circulate.

To obtain value through the CBM and being necessary to consider the use of all constituents of renewable resources in cascades and ring roads, it is necessary to consider that these challenges or barriers that may delay the implementation of CE may become opportunities to be developed. In other words, these challenges can result in opportunities to generate value in the circular economy.

In the study mentioned at the beginning of this topic, it was possible to verify that it is possible to capture value through technical cycles and increase the flexibility of new products. It asserts that cycling through recycling, remanufacturing, and reuse can be excellent opportunities for new business models for organizations. According to these conditions, value flow management would be associated with a strategic and operational approach to business, aiming to analyse, capture value throughout the organization, maximizing efficiency (Hines et al. 1998).

Companies also report that these new businesses allowed new companies. In this context, there are many recycling cooperatives in developing countries that focus a lot on the social aspect.

Another study also carried out by the authors of this chapter, with 40 different companies (Galvão et al. 2022), resulted in interesting analyses on challenges of implementing the circular economy or increasing circularity. Among the results, the authors suggest the change of name from "barrier" to obstacles because barrier refers to something more definitive. The points reported in the interviews were about temporary obstacles that, when worked, became opportunities for the business. Even the most difficult challenges, in this case, barriers, can become opportunities to be explored.

As for the side effects, smaller companies without capital for an initial investment to change production can result in a distance between the small and the big ones. In addition, large companies can invest so that consumers know their brand and their circular actions. In this sense, the more society is aware of, the greater the chance that those who have the structure will prepare themselves beforehand and gain market share. In both cases, there is a side effect that can become an opportunity for those who are prepared (Galvão et al. 2018).

This perspective encourages reflection on the positioning of organizations in the face of challenges. Barriers, in this sense, would be common to all, such as the lack of a technology necessary for a certain advance. However, many of these challenges are not absolute, but relative – that is, when the organization overcomes them, it ends up developing a competitive advantage – these would not be insurmountable barriers, but obstacles. Transporting this idea to the new environment of great transformation that frames the dissemination of the circular economy, it is reasonable to infer that there are many opportunities for growth and appreciation of sustainable businesses (Galvão et al. 2022).

2.5 Current Scenario and Trends

Currently, a large part of the production chain operates in linear concepts, focusing on economic growth and consumption, which removes natural resources from the environment – including non-renewable ones, which are processed and transformed into waste. A 2019 Circle Economy report on circular economy revealed that only 9% of the world economy is circular.

The circular economy is a relatively new topic in the academy, and for companies, in 2016, studies began to increase interest. The studies were more focused on designing new production models, which innovations would be needed to be circulated and sought to understand how much could reflect in an improvement for a sustainable future. The studies were developed, adding tools and frameworks so that the business model could develop. New challenges emerged, and new strategies were suggested to overcome obstacles. For sustainable consumption, circular strategies are always being developed in companies that are more concerned with performance. Proper management is important for the circular economy to add value to the organization. Right from this aspect, the environmental and economic aspects are, the social aspects are more treated after 2018, but even less.

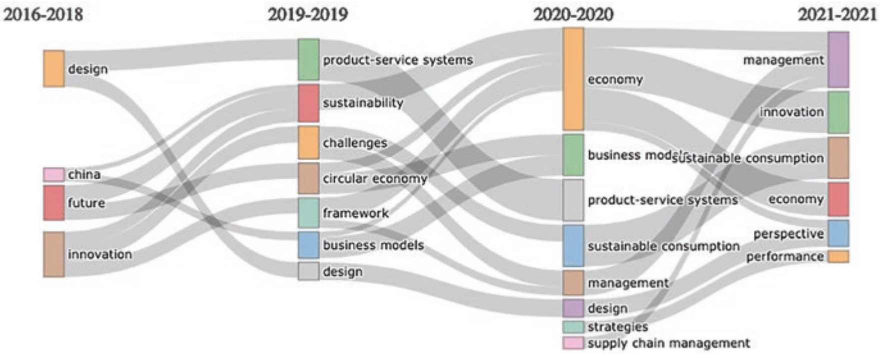


Fig. 2.6 Most researched topics in CBM and value. This figure was performed with Bibliometric/R by software using extracted data from the ISI

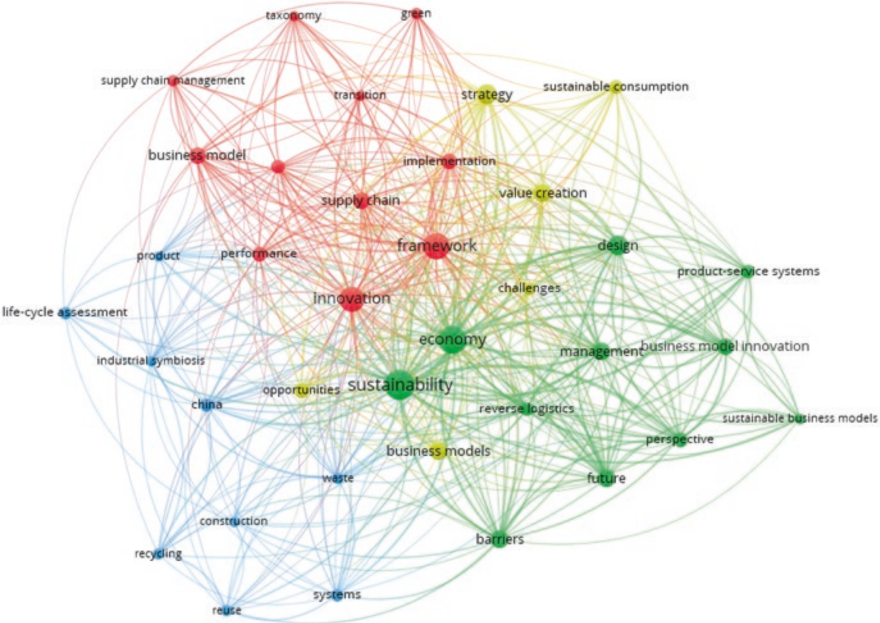


Fig. 2.7 Key Words. Performed with VOSviewer software using extracted data from the ISI and Scopus database

Isolated solutions do not make the circular economy from business as the traditional model. That is, the solutions are systemic. For this votive, its implementation and the studies of the theme encompass several other aspects (Fig. 2.6).

If we look at the words in the yellow group (Fig. 2.7), for example, they deal with strategies, opportunities, sustainable consumption, and value creation. These words are discussed in shields of CBM and value. If we look closely and understand their relationships, we can see that they are almost equally connected.

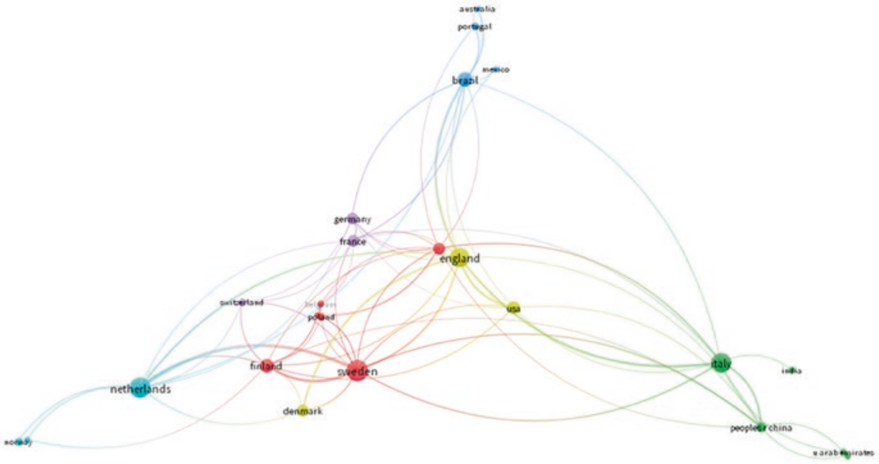


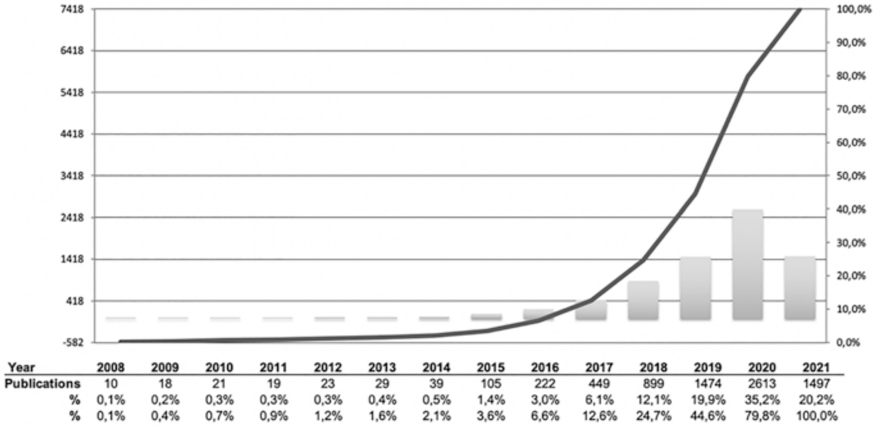
Fig. 2.8 Countries' co-authorship for the CBM/value sample. This network was performed with VOSviewer software using extracted data from the ISI and Scopus database

Yes, the transition from the linear to the circular model must bring some challenges, and during the transition, it has to face obstacles and barriers. Most importantly, it must be done systemically, and this can also bring many opportunities, generate innovations, and result in benefits for the whole system, especially thinking in the long term.

To understand the current scenario, country co-authorship was created using the VOSviewer (Van Eck and Waltman 2010). The countries' co-authorship netdraw is composed of six clusters (Fig. 2.8). The main countries in terms of the number of publications and collaborations are England, Netherlands, Italy, and Sweden. It has changed over the years, as until 2017, China was the country with the most publications on the subject. Italy, India, China, and the Arab Emirates form a group with the closest relationship with the group in England and Sweden. The England, the USA, and Denmark group is in the centre of the netdraw, and there is a collaboration with almost all or other countries. Brazil, Portugal, Mexico, and Australia form another grouping, and finally France, Sweden, and Germany.

In common, the clusters present barriers and challenges to implementing CBM. There is a concern about how to innovate and restructure processes, and rethink the supply chain. In addition, strategies are discussed on generating value for stakeholders systemically through remanufacturing, recycling, reuse and other loops.

The CBM approach is more implemented in developed countries. The aspects that influence implementation, life cycle assessment of innovative circular business models, analyse circular business models, challenges faced by a manufacturing firm when implementing CBM, discussions performance and circular supply chain management towards sustainable development. Always generate value for the stakeholder and contribute to a systemic transition to a circular economy.



Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Publications	10	18	21	19	23	29	39	105	222	449	899	1474	2613	1497
%	0,1%	0,2%	0,3%	0,3%	0,3%	0,4%	0,5%	1,4%	3,0%	6,1%	12,1%	19,9%	35,2%	20,2%
%	0,1%	0,4%	0,7%	0,9%	1,2%	1,6%	2,1%	3,6%	6,6%	12,6%	24,7%	44,6%	79,8%	100,0%

Fig. 2.9 Interest in the topic

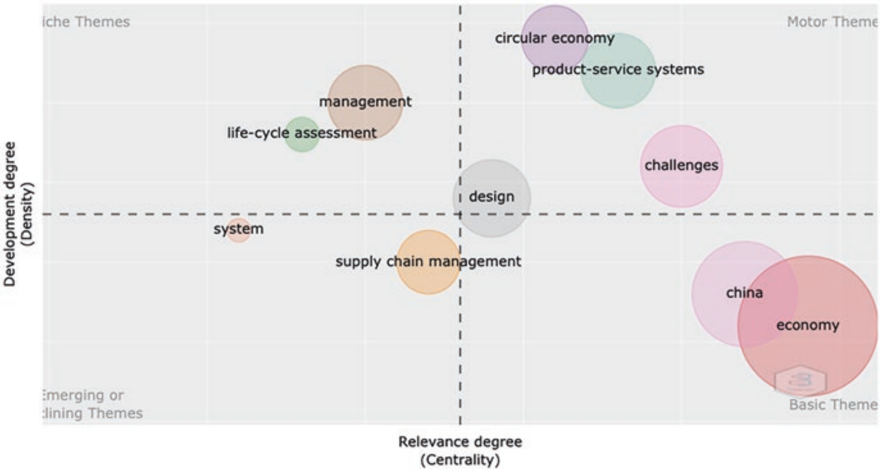


Fig. 2.10 Thematic researched topics in CBM and value. This figure was performed with Bibliometric/R by software using extracted data from the ISI

Out the interest in the subject by the academy, it is interesting to note that in 2018 a survey on the circulating economy resulted in 664 publications (Homrich et al. 2018). If we repeat the same research, the results can be around 8000 articles (Fig. 2.9).

In addition to the basic and motor themes discussed in value through CBM, other themes in Fig. 2.10 are considered niche and emerging. The main trend theme is supply chain management. The discussion is related to moving from the traditional supply chain to the circular model to obtain economic and social benefits without harming the environment.

2.6 Discussion and Results

The chapter presents a comprehensive framework for understanding and implementing circular business models (CBMs) while addressing challenges and opportunities in the context of the circular economy. Let's analyse how this article compares with previous literature on circular economy business models:

- *Value Generation in the Circular Mode:* The article acknowledges the difficulty of developing value generation methods within the circular paradigm due to organizational mindset barriers. This aligns with the existing literature that emphasizes the need to overcome mental and structural barriers when transitioning to circular business models.
- *Extension of Value Perspective:* The article introduces the concept of uncaptured value, including value surplus, value absence, value missed, and value destroyed. This extension of the value perspective builds upon traditional business models, which is in line with previous literature that emphasizes redefining value in the context of circularity.
- *Strategic Logic of Value Construction:* The proposed framework for value construction in the circular context adds to the existing literature by providing a structured approach to maximize sustainable value generation, delivery, and capture. The hierarchical levels of value creation, customer perception, and value capture align with the multi-dimensional approach often discussed in circular economy research.
- *Systemic Transition and Challenges*: The article emphasizes the need for systemic thinking during the transition from linear to circular models. This resonates with prior research that stresses the systemic nature of circular economy implementation and the challenges associated with rethinking supply chains, innovation, and stakeholder engagement.
- *Stakeholder Engagement and Value Capture*: The article's focus on stakeholder management and capturing value across technical cycles adds depth to the discussions found in the literature. It emphasizes the importance of considering various stakeholders' perspectives and expectations, which is consistent with circular economy research advocating for holistic approaches.
- *Challenges and Opportunities*: The article's insights into challenges, such as trade-offs in value streams and the need for holistic views, are in line with previous research highlighting the hurdles faced during circular economy implementation. The transformation of barriers into opportunities, as emphasized by the article, aligns with the notion of turning challenges into drivers for innovation and value creation.
- *Side Effects and Sustainable Growth*: The article's consideration of side effects, like the gap between smaller and larger companies, and the potential for sustainable growth, resonates with literature discussing the broader socio-economic implications of circular business models.
- *Empirical Research and Practical Insights*: The reference to empirical studies conducted by the authors highlights a valuable contribution to the literature.

These studies add practical insights to the theoretical framework, showcasing how real-world challenges and opportunities manifest in implementing circular business models.

In summary, "Towards CBM: Building Value in Circular Logic" contributes to the existing literature on circular economy business models by providing a comprehensive framework that addresses value generation, stakeholder engagement, challenges, opportunities, and practical insights. It aligns with previous research in terms of recognizing barriers, systemic thinking, and stakeholder engagement while adding novel concepts like uncaptured value and a detailed framework for value construction. The empirical studies conducted by the authors add a practical dimension to the theoretical framework, enhancing the overall contribution of the article to the field of circular economy business models.

Other contributions of this chapter are discussed below. These points were considered when we elaborated the framework.

Difficulty in Developing Circular Business Models: Organizations face challenges in adopting circular business models due to the inhibiting effects of their traditional organizational mindset (Evans et al. 2017).

Uncaptured Value in Circular Business Models: Circular business models can incorporate the concept of uncaptured value, which includes value surplus, value absence, value missed, and value destroyed, according to Yang et al. (2017).

Framework for Circular Business Models: A proposed framework outlines the strategic construction of circular business models, focusing on value creation, customer perception, and value capture (Fig. 2.4).

Gradual Paradigm Shift: Circular business model transformation should be gradual to address the complexity of transitioning from traditional production models (Evans et al. 2017).

Hierarchical Value Generation Process: The value creation process in circular business models involves support processes (organizational culture, human capital) and enabling processes (innovation, design, recycling) (Fig. 2.4).

Customer Perception of Value: Market/customer perception of value is influenced by factors such as quality, image, reputation, and cost-benefit, leading to customer acquisition and loyalty.

Stakeholder Management and Value Capture: Stakeholder management is crucial for capturing value in technical cycles of circular business models. Different stakeholders require tailored strategies for value capture (Fig. 2.5).

Challenges and Opportunities in Implementing Circular Economy: Challenges to implementing circular economy strategies include trade-offs between different value aspects and introspective views. Overcoming challenges can lead to value creation (Galvão et al. 2022).

Conversion of Barriers to Opportunities: Challenges or barriers can be transformed into opportunities for value generation, especially in technical cycles like recycling, remanufacturing, and reuse (Galvão et al. 2022).

Effects on Small and Large Companies: Implementing circular actions can create opportunities for both small and large companies. Smaller companies may face initial investment challenges, while larger ones can leverage circular practices for brand recognition and market share (Galvão et al. 2018).

Adaptive Responses to Challenges: Barriers in the circular economy context are often not insurmountable, but rather relative challenges that organizations can overcome to gain a competitive advantage (Galvão et al. 2022).

These main results highlight the challenges, opportunities, and strategies involved in transitioning from traditional linear value generation models to circular business models. The study emphasizes the importance of stakeholder management, value perception, and gradual implementation in achieving sustainable value generation within the circular economy framework.

2.7 Conclusions

The 2030 Agenda for Sustainable Development aims to reach a set of goals through an agreement of the great world leaders. However, the typical business model in vogue, with linear logic, tends to generate unsustainable value, as it presents an inverse relationship between the economic and environmental dimensions. In other words, based on the traditional linear logic, the desired advances towards environmental sustainability conflict with economic development.

However, the circular economy's implementation depends on a profound transformation in production logic, consumption habits, and the perception of the value of stakeholders. Logical and structural connections for value to flow in a network that does not exist today and new forms of value trade-off make up the complexity of this new economic scenario. In this sense, organizations need to adapt to this new logic, reinventing their business models.

Therefore, there is an urgent need to implement circular business models capable of absorbing the characteristics of this new reality, incorporating new ways of transferring value to its strategic precepts and new organizational processes adapted to circularity. A framework was presented to show the strategic logic of value construction in the context of the circular economy.

This structuring naturally brings many challenges and opportunities, arising from different sources of value that had not been captured or even non-existent before. This scenario is transcribed in academic research trends, showing the growing interest in the subject and several initiatives addressing overcoming challenges and support for organizational restructuring.

Considering the scenario of great changes that takes shape due to the growing interest and practical and theoretical recognition of the benefits of the circular economy, a fertile field for the development and valorization of existing businesses, as well as opportunities for new proposals, emerges.

Change carries the need to adapt to the challenges that arise. Companies that develop effective circular business models capable of overcoming these obstacles have the opportunity to leverage competitive advantage.

The circular economy, therefore, brings hope for a more sustainable future, as well as an opportunity for businesses that adapt more quickly to the new scenario.

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Chapter 3
The Design of Sustainable Product-Service Systems to Foster Circular Economy for All

Carlo Vezzoli and Luca Macrì

Abstract The role of design for sustainability to promote a Circular Economy (CE) is increasingly recognized as a key leverage. The CE Action Plan adopted by the European Union in 2020 reports that "up to 80% of products' environmental impacts are determined at the design phase" (European Commission, Circular economy action plan: for a cleaner and more competitive Europe. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/05068, 2020). The same CE Action Plan recognizes also as a key strategy "incentivizing product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle". Indeed, this shift in the offer model has been defined and studied as the Sustainable Product-Service System (S.PSS) since the end of the 1990 (Cooper and Evans, Products to services. Friends of the Earth, London, 2000; Brezet et al., The design of eco-efficient services: method, tools and review of the case study based «designing eco-efficient services» project. Industrieel Ontwerpen, 2001; UNEP, Product-service systems and sustainability: Opportunities for sustainable solutions. UNEP. https://wedocs.unep.org/xmlui/handle/20.500.11822/8123, 2002; Manzini and Vezzoli, Product Serv Syst Sustain Consump 11(8):851–857. https://doi.org/10.1016/S0959-6526(02)00153-1, 2003; Mont, Ecol Econ 50(1):135–153. https://doi.org/10.1016/j.ecolecon.2004.03.030, 2004; Tukker, Bus Strateg Environ 13(4):246–260. https://doi.org/10.1002/bse.414, 2004; Baines et al., Proc Inst Mech Eng Part B J Eng Manuf 221(10):1543–1552. https://doi.org/10.1243/09544054JEM858, 2007; Charter and Tischner, Sustainable solutions: developing products and services for the future. Routledge, 2017).

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In this framework, the chapter aims at contributing on how the most updated knowledge on design for sustainability – focusing on S.PSS and their potential win-win benefits – could foster the transition towards a Circular Economy. Moreover, it investigates how recent understanding and research outcomes about S.PSS could position them as promising models to extend the access to good and services even to low-income contexts, so forth enhancing even social inclusion. Within this understanding, a new promising role of design in developing S.PSS capable of fostering a sustainable CE for all is hypothesized.

The covered topics follow the learnings of the *LeNSin* international research project funded by the EU Erasmus+ Programme, gathering 36 partner Universities from Mexico, Brazil, South Africa, India, China, and in Europe UK, Finland, The Netherlands, and Italy. The project aimed at developing curricula on Design for Sustainability focused on S.PSS applied to Distributed Economies (DE). The project's preliminary phase, undertaken by all the involved countries, started with desk research, a case studies analysis and context-specific need analysis, as well as their sustainability benefits and barriers and the role of design in their development. This phase was used to instruct and conduct five country seminars (Mexico, Brazil, South Africa, India, and China) with expert stakeholders. The acquired knowledge was shared among all partners and was the basis to build a first round of 5 pilot courses in partner universities in the five extra-UE countries. In each course companies/organizations were involved verifying both the knowledge-base and the design tools that far developed, by designing sustainable solutions for them. With the knowledge acquired and shared, a second round of 5 pilot courses was organized in the same countries, through different universities/cities. A key outcome is a set of learning resources on S.PSS&DE design for all: the ten full courses (videos and slides of all lectures), case studies, system design tools and innovative projects. These are available in open access on the LeNS platform (www.lens-international.org).

On the basis of project outcomes, further desk research has been conducted on the existing literature about the main principles, strategies, and business models related to Circular Economy. Moreover, the analysis of the LeNS international repository (www.lens-international.org) of more than a hundred case studies has been conducted to identify S.PSS cases operating also on a CE level.

With these premises, the chapter makes a step further, investigating the relationship between the abovementioned learnings on S.PSS and the core principles of CE, going beyond the mere association of two concepts: it outlines an updated theoretical framework on why and how S.PSS win-win benefits and design approach can foster the development of circular business models. In particular, why and under which circumstances applying an S.PSS approach to CE makes the economic interest of the producer/provider in designing and developing products & services for extending the technical cycles of materials and product through use intensification, product durability, maintainability/repairability, reusability, enabling remanufacturing and high-quality recycling, as well as extending biological cycles enhancing material biodegradability and resources renewability.

Furthermore, the chapter outlines why an S.PSS is a promising approach to design and offer products & services to foster a CE accessible and preservable over time in low-income contexts, to both final users and entrepreneurs. In particular, why and under which circumstances applying an S.PSS approach to CE is promising to cut both the initial investment costs and the running cost of maintenance, repair, etc.

Finally, in relation to CE principles and practices, an overview of the applicability of the Method for System Design for Sustainability (MSDS) method and its tools supporting the S.PSS design process is given. The MSDS method has been developed and refined within a series of projects funded by the European Union and the United Nations Environmental Program (UNEP) since 2002. International public funded project contributing to the development and refinement of actual MSDS method with its set of support tools:

- MEPSS: MEthodology for Product Service System development (EU funded V FP project, 2002–2005).
- Design for Sustainability (D4S): A Step-By-Step Approach (UNEP funded, 2005–2009)
- LeNS: Learning Network on Sustainability (EU funded Asia-Link project, 2008–2010).
- LeNSes: Learning Network on Sustainable energy system, focused on System Design for Sustainable Energy for all (EU funded EdulinkII project, 2013–2016).
- LeNSin: international Learning Network of networks on Sustainable, focused on designing S.PSS applied to DE as a promising approach for designing sustainability for all (EU funded Erasmus+ project, 2015–2019).

Keywords Sustainability · Circular economy · Product-service systems · Design for sustainability

3.1 An Introduction: System Design for Sustainability as a Key Enabler for Circular Economy

3.1.1 Circular Economy and Sustainable Product-Service Systems (S.PSS): Synergy of Approaches and Knowledge Base

In the very first place, it is useful to discuss the relationship between S.PSS and the concept of Circular Economy. Although there are a huge variety of definitions, high research fragmentation and the blurred contours within the topic of sustainability (Geissdoerfer et al. 2017; Kirchherr et al. 2017; Korhonen et al. 2018), in this context we refer to the Ellen MacArthur Foundation, that originally defined Circular Economy as *“an industrial economy that is restorative or regenerative by intention and design”* (Ellen MacArthur Foundation 2013). Starting from this definition, the foundation outlined and refined the concept of Circular Economy over the years, and nowadays it is summarized by three key principles (Ellen MacArthur Foundation 2021):

- *Design out waste and pollution*, i.e., to intervene at the design stage to prevent the generation of waste and pollution in the first place.
- *Keep products and materials in use*, i.e., to design products and components to extend their lifespan through practices like maintenance, repair, reuse, re-manufacturing or – for materials – recycling.
- *Regenerate natural systems*, i.e., not only to reduce the consumption of natural resources, but also to return those resources as a benefit for the environment.

As noted by some authors, even if the concept of Circular Economy has been popularized and branded by Dame Ellen MacArthur, it can be considered as an umbrella concept that encompasses different principles that have been around for a long time, e.g., industrial ecology, biomimicry and cradle-to-cradle (Ceschin and Gaziulusoy 2016, 2019). Indeed, CE has been debated and – by some authors – considered as a holistic approach to gather the sustainability challenges of the current economic development (Stahel 2019; Stahel and MacArthur 2019), thought, in the opinion of the authors, some issues like energy resources reduction and the whole socio-ethical dimension of sustainability are not clearly focused by the CE paradigm shift. This chapter is not aimed at deepening this debate, but better still the synergies between S.PSS design and Circular Economy models.

To understand the relevance of S.PSS design in enabling and fostering Circular Economy is useful to introduce how the latter relates to business and offer models like S.PSS. As noted by Ceschin and Gaziulusoy (2019), with the popularization of the Circular Economy concept, the term circular business model (Nußholz 2017) has gradually emerged. Through the definition of a strategy framework for circular business models, Bocken et al. (2016) have proposed six strategies, grouped into two main categories:

- *Strategies for slowing loops*, which include extending product value, classic long-life model, and encouraging sufficiency.
- *Strategies for closing loops*, which include extending resource value and industrial symbiosis.

More recently, also the importance of intensifying the use phase of products and dematerializing resource loops (replace products with the access to performances) have been emphasized as enablers for circular business models (Geissdoerfer et al. 2018).

A first interesting overlap between S.PSS and circular business models can be noticed by considering “slowing the loops” and “dematerializing resource loops”: all these approaches were introduced in the late nineties within the definition of PSS and have evolved along the last 20 years towards the key concept behind S.PSS, which is to decouple the creation of value from resource consumption and negative environmental impact (Cooper and Evans 2000; Brezet et al. 2001; UNEP 2002; Manzini and Vezzoli 2003; Mont 2004; Tukker 2004; Baines et al. 2007; Charter and Tischner 2017). As regards the concept of closing resource loops and industrial symbiosis, e.g., collection of otherwise “wasted” materials/resources to turn them into new forms of value (Bocken et al. 2016), a connection can be acknowledged with some recently updated strategies for S.PSS design, that are already considering the development of industrial symbiotic partnerships (Vezzoli et al. 2021).

Similar synergies and mutual enabling frameworks have been acknowledged by other authors in the specific domain of S.PSS & CE. In general, PSS are often proposed as models to foster a Circular Economy (Tukker 2015). More specifically, some authors have worked on favorable approaches and strategies: Kjaer et al. (2019) have identified a framework based on PSS enablers and requirements to ensure the absolute decoupling of resource consumption and value creation. Pieroni et al. (2019) have defined key conditions to be fulfilled in order to develop CE-oriented business models based on PSS, while Hernandez (2019) highlighted the need of focusing on the development of external systemic conditions before pushing on the application of S.PSS and CE business models within companies. Another bunch of authors focused on a more verticalized level, discussing the potential of S.PSS and Circular Economies in specific domains, like housing (Ghafoor et al. 2023), washing machines (Bressanelli et al. 2017), and mobile phones (Hobson et al. 2018).

Despite the abundance of synergies in terms of key concepts and general approaches, a lack of knowledge base – that the chapter contributes to fill – has been identified regarding the potential compatibility of the two models in terms of design approaches, especially taking S.PSS design as an enabler for Circular Economy.

Moreover, as previously mentioned, since S.PSS started to be studied also as valuable offer models to foster social equity and inclusion (Vezzoli et al. 2021) – specifically for what concern the extended accessibility to goods and services – their application in relation to circular business models could enhance social inclusion and prosperity also in a Circular Economy framework. Indeed, the social dimension of Circular Economy is being increasingly studied, as well as its socio-ethical sustainability benefits (Padilla-Rivera et al. 2020; Piesik et al. 2018; Social Circular Economy 2018).

The following paragraphs present the concept of S.PSS as a valuable enabler of any Circular Economy and enhancing its value in terms of social equity and inclusion, going in coherence – and even beyond – the strategies defined by the above-mentioned “EU Circular Economy Action Plan” (European Commission 2020).

3.2 Sustainable Product-Service Systems (S.PSS): An Opportunity to Foster Circular Economy Businesses and Technologies

3.2.1 Sustainable Product-Service System: A Win-Win Opportunity for Sustainability

As anticipated, the concept of Sustainable Product-Service System (S.PSS) has been studied since the end of the 1990s as a promising offer/business model capable of creating (new) value, decoupling it from material and energy consumption. In other words, significantly reducing the environmental impact of traditional production/consumption systems.

More recently, S.PSS has been demonstrated (Vezzoli 2010; Vezzoli et al. 2018) to be a clearly promising offer model to extend the access to goods and services even to low- and middle-income contexts, thus enhancing social equity and cohesion as well.

Finally, it is a win-win offer model combining the three dimensions of sustainability, the economic with the environmental and the socio-ethical. An S.PSS can be defined as follows (Vezzoli et al. 2021):

> ***Sustainable Product-Service System (S.PSS) is an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer/user demand (to deliver a "unit of satisfaction"), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the ownership of the product/s and/or the life cycle services costs/responsibilities remain with the provider/s, so that the same provider/s continuously seek/s environmentally and/or socio-ethically beneficial new solutions, with economic benefits.***

S.PSSs are value propositions introducing considerable innovation on different levels (see also Fig. 3.1), which are aligned with the approach adopted by the European Union within the Circular Economy Action Plan (2020):

- They shift the business focus from selling (only) **products** to offering a so-called "**unit of satisfaction**",[1] i.e., a combination of products and services jointly capable of achieving ultimate user satisfaction.
- They shift the value perceived by the customer/end-user from **individual ownership** to **access** to goods and services.
- They shift the primary innovation from a **technological** one to innovation on a **stakeholder interaction** level.

Finally, in the key understanding of our discourse, S.PSSs are offer models with a win-win sustainability potential, i.e., they are offer/business models capable of creating (new) value, decoupling it from resource consumption and increase of

Fig. 3.1 S.PSS: a paradigm shift from a traditional product offer. (Adapted from Vezzoli et al. 2021)

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[1] The Unit of Satisfaction has been defined as (Vezzoli et al. 2018): "*a defined (quantified) satisfaction of a customer that could be fulfilled by one or more mix of products and services, used as a reference unit to design and to evaluate the sustainability benefits and impacts*".

negative environmental impact whilst extending access to good and services to low- and middle-income people and, at the same time, enhancing social equity and cohesion.

3.2.2 S.PSS Applied to CE: Examples and Types

Three main S.PSS approaches to system innovation have been studied, adapted, and listed as favorable for eco-efficiency and indeed well fit even for the Circular Economy approach (Hockerts and Weaver 2002; UNEP 2002; Tukker 2004; Vezzoli et al. 2014), and they can be adapted as below:

1. *CE Product-oriented S.PSS*: offer model providing added value to the product life cycle (either technical and/or biological).
2. *CE Use-oriented S.PSS*: offer model providing "enabling platforms" for customers.
3. *CE Result-oriented S.PSS*: offer model services providing "final results" for customers.

Example: Herman Miller – 12 Years Service[2]
Aeron and other chairs sold by Herman Miller have a 12-year warranty. During the warranty period, Herman Miller promotes CE models by offering repairs or replaces (at its option) any product, part, or component which fails as a result of a defect in material or workmanship, with a comparable product, part, or component. This additional service is in turn complemented with an appropriate design to extend the lifespan of the product (Fig. 3.2).

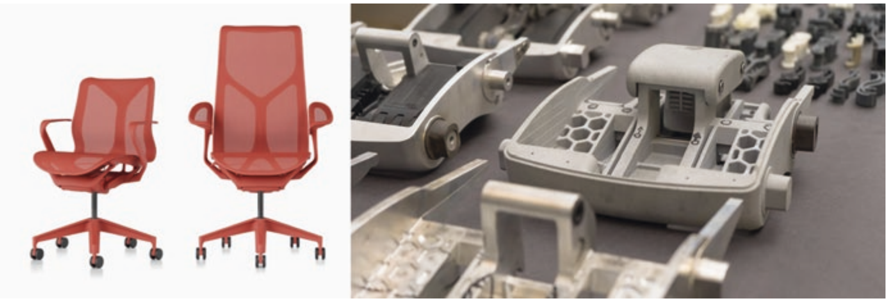

Fig. 3.2 Example of a Herman Miller chair with a 12-year warranty (CE Product-oriented S.PSS)

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[2] Available on www.lens-international.org

The presented case is an example of Product-oriented S.PSS applied to Circular Economy principles, i.e., through the extension of product's technical cycle through the practices of repair and reuse of components. In the following lines we see how – and with which characterizations – the different S.PSS approaches can be valuable within a Circular Economy framework.

CE Product-Oriented S.PSS (Type I): Adding Value to the Product Life Cycle (Either Technical and/or Biological)

In summary, a ***CE Product-oriented S.PSS*** *innovation* adding value to the product life cycle is defined as (adapted from Vezzoli et al. 2021):

> ***a company/organization (alliance of companies/organizations) that provides all-inclusive life cycle services – maintenance, repair, reuse, re-manufacturing and product take-back (for recycling/composting and/ or energy recovery) – to guarantee the life cycle performance of the product/semi-finished product (sold to the customer/user) and its materials.***

A typical contract would include services aimed at regenerating the technical cycle (e.g., maintenance, repair, reuse, re-manufacturing, recycling) or restoring the biological cycle of a product (e.g., take-back services aimed at composting or energy recovery) over a specified period of time. The customer/user responsibility is reduced to the use and/or disposal of the product/semi-finished product (owned by the customer), since she/he pays all-inclusively for the product with its life cycle services, and the innovative interaction between the company/organization and the customer/user drives the company/organization's economic interest in continuously seeking Circular Economy principles and practices (environmentally beneficial new solutions), i.e., the economic interest becomes something other than only selling a larger amount of products.

CE Use-Oriented S.PSS: Offering Enabling Platforms for Customers (Type II)

In summary, a ***CE use-oriented S.PSS*** *innovation* offering an enabling platform to customers is defined as:

> ***a company/organization (alliance of companies/organizations) that provides access to products, tools and opportunities enabling the customer to get their "satisfaction". The customer/user does not own the product/s but operates them to obtain a specific "satisfaction" (and pays only for the use of the product/s).***

Depending on the contract agreement, the customer/user could have the right to hold the product/s for a given period of time (several continuous uses) or only for one use.

Commercial structures for providing such services include sharing, collective use (as well as other variations like pooling or leasing) of certain goods for a specific use. The customer/user consequently does not own the products, but operates on them to obtain a specific final satisfaction (the client pays for the use of the product). Again, in this case, the innovative interaction between the company/organization and the customer/user drives the company/organization to continuously seek Circular Economy principles and practices (environmentally beneficial new solutions) together with economic benefits, e.g., to design long-lasting products[3] that are easy to maintain, repair, reuse, re-manufacture, and recycle.

CE Result-Oriented S.PSS: Offering Final Results to Customers (Type III)
A ***CE result-oriented S.PSS*** *innovation* offering final results to customers can be defined as:

> ***a company/organization (alliance of companies/organizations) that offers a customized mix of services, instead of products, in order to provide a specific final result to the customer. The customer/user does not own the products and does not operate on them to obtain the final satisfaction (the customer pays the company/organization to provide the agreed results).***

The customer/user benefits by being freed from the problems and costs involved in the acquisition, use, and maintenance of equipment and products. The innovative interaction between the company and the customer/user drives the company's economic and competitive interest to continuously seek Circular Economy principles and practices (environmentally beneficial new solutions), e.g., products that are easy to maintain, repair, reuse, re-manufacture, and recycle.

3.3 S.PSS Win-Win Promising Benefits to Diffuse Circular Economy Solutions

When is an S.PSS eco-efficient and how does it foster circular strategies, so forth decreasing damaging environmental impacts?

In other words, why and when is an S.PSS producer/provider economically incentivized in designing for environmental sustainability within a CE framework? The following S.PSS & CE environmental and economic win-win benefits could be highlighted, as a specification of the conducted desk research on S.PSS general win-win strategies and based on the case study analysis that has been carried out, supported by brainstorming sessions with experts (adapted from Vezzoli et al. 2018):

3.3.1 Benefits Related to Products' Technical Cycle

(a) *Product technical cycle extension*: As far as the S.PSS provider is offering the products retaining the ownership and being paid per *unit of satisfaction*, or offering all-inclusive the product with services for its maintenance, repair, reuse, and/or re-manufacturing, the **longer** the product/s or its components'

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[3] In relation to Use-oriented and Result-oriented S.PSS, a potential win-win benefit could be also fostering the design for products' resources minimization, specifically when the producer/provider is also owner/responsible for resource consumption (Vezzoli et al. 2021).

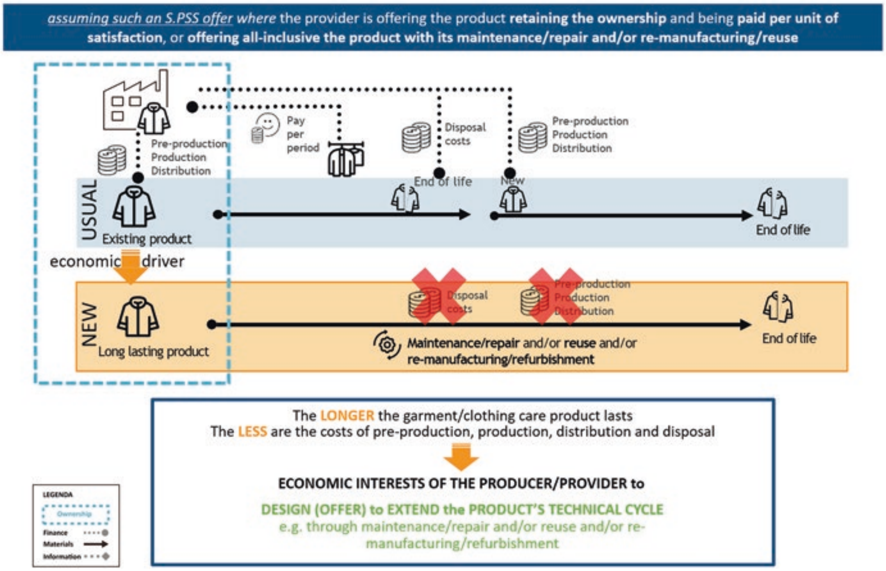

Fig. 3.3 S.PSS applied to a CE model fostering the design (offer) for the extension of a product's technical cycle. (Adapted from Vezzoli et al. 2021)

technical cycle last (environmental benefits), the **more** the producer/provider avoids or postpones the disposal costs plus the costs of pre-production, production and distribution[2] of a new product substituting the one disposed of (economic benefits). Hence the producer/providers are driven by economic interests to design (offer) for extending products' technical cycle, e.g., through maintenance/repair and/or reuse and/or re-manufacturing/refurbishment (which has implications in terms of eco-efficient design for circularity) (Fig. 3.3).

(b) *Intensive use of product*: As far as the S.PSS provider is selling a shared or collective use of products (or product's components) to various users, the **more** intensively the product/s (or some product's components) are used, i.e., the more time within their technical cycle (environmental benefits), the **higher** the profit, i.e., proportionally to the overall use time (economic benefits). Hence, the producer/providers are driven by economic interests to design for intensifying the products' technical cycle, e.g., through shared and/or collective use modes (which has implications in terms of eco-efficient design for circularity) (Fig. 3.4).

(c) *Material technical cycles extension*: As far as the S.PSS provider is selling the product all-inclusive with its end-of-life treatment/s, the **more** the materials are recycled (environmental benefit), the **more** costs are avoided of both landfilling and the purchase of new primary materials. Hence, the producer/provider is driven by economic interests to design for extending the materials' technical cycle, i.e., recycling (which has implications on eco-efficient design for circularity) (Fig. 3.5).

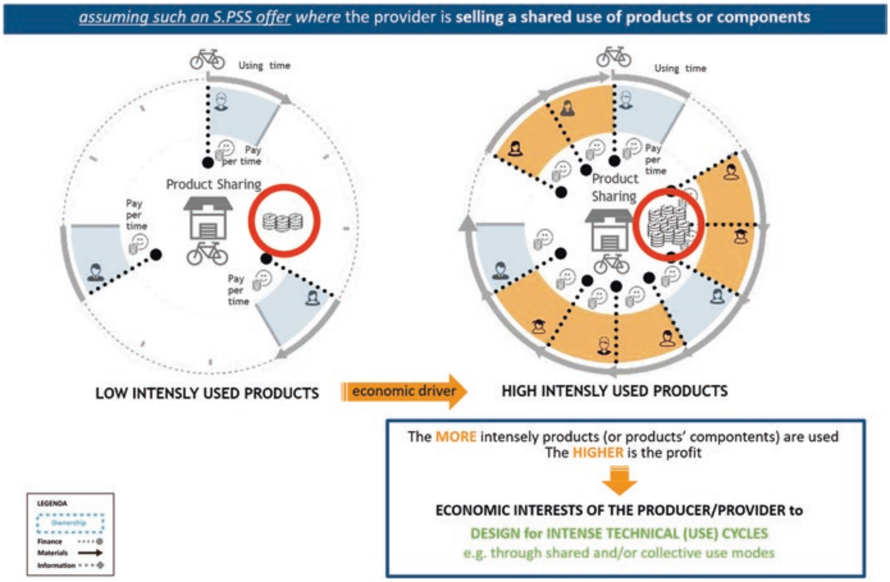

Fig. 3.4 S.PSS applied to a CE model fostering the design (offer) for intensive technical (use) cycles. (Adapted from Vezzoli et al. 2021)

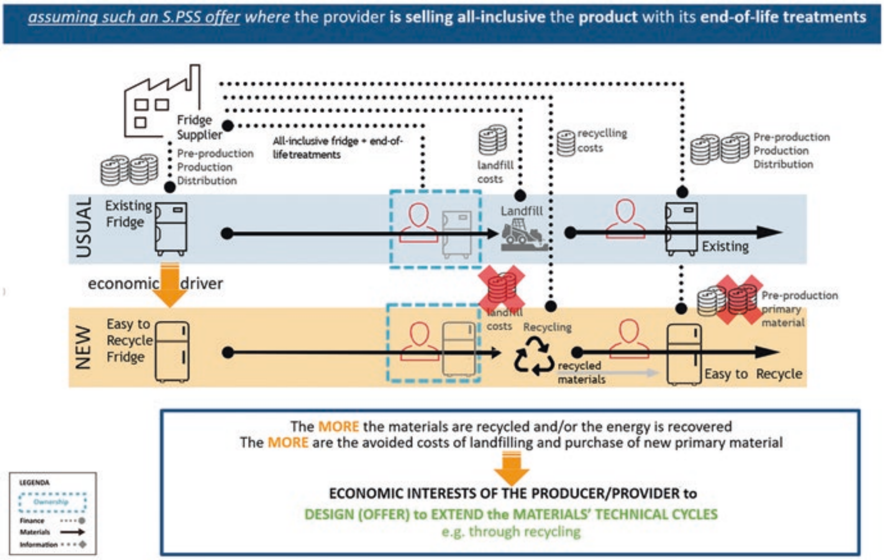

Fig. 3.5 S.PSS applied to a CE model fostering the design (offer) for the extension of materials' technical cycles (recycling). (Adapted from Vezzoli et al. 2021)

3.3.2 *Benefits Related to Products' Biological Cycle*

(d) *Resources' renewability*: When the S.PSS provider has an all-inclusive offer of a utility, with pay per period/time/satisfaction (e.g., energy production unit ownership by the producer/supplier), the **higher** the proportion of passive/renewable sources is in relation to non-passive/non-renewable (environmental benefits), and the **higher** is the profit, i.e., the payment minus (among others) the costs of non-passive/non-renewable sources (economic benefits). Hence, the producer/provider is driven by economic interests to design (offer) to extend the biological cycles, e.g., through a regenerative flow management of resources and/or cascade approach (which has implications in terms of eco-efficient design for circularity) (Fig. 3.6).

(e) *Material biological cycles extension*: As far as the S.PSS provider is selling the product all-inclusive with its end-of-life treatment/s, the **more** the materials are either composted or processed with renewable energy recovery (environmental benefits), the **more** costs are avoided of either landfilling or the purchasing of new primary compost or energy (economic benefits). Hence, the producer/provider is driven by economic interests to design for extending the materials' biological cycles, i.e., through composting or renewable energy recovery (which has implications on eco-efficient design for circularity) (Fig. 3.7).

To conclude, when an S.PSS make eco-efficient an offer within Circular Economy framework? When the product ownership and/or the economic responsibility for its

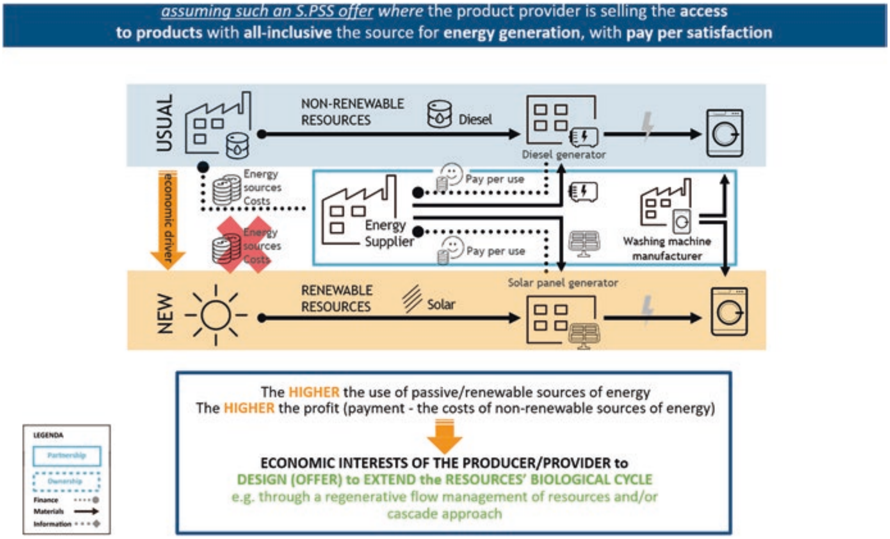

Fig. 3.6 S.PSS applied to a CE model fostering the design (offer) for passive/renewable resource optimization to extend the resources' biological cycle. (Adapted from Vezzoli et al. 2021)

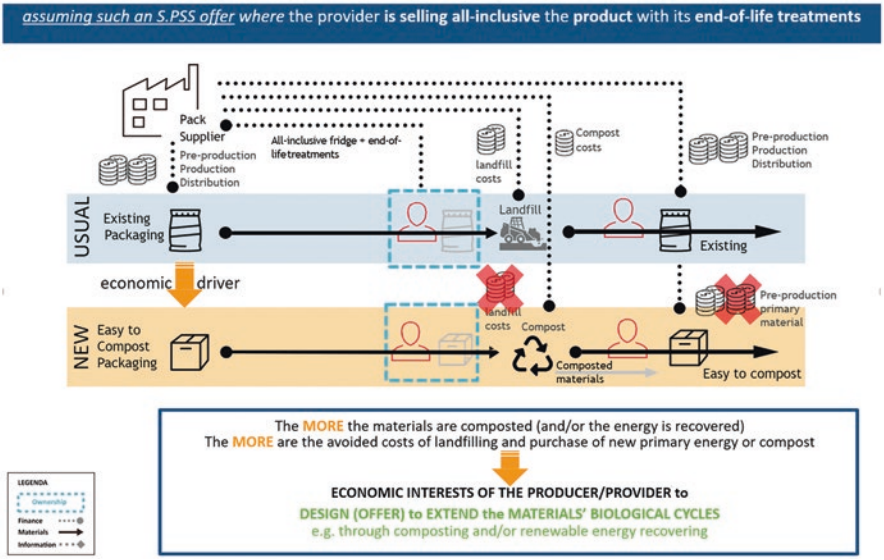

Fig. 3.7 S.PSS applied to a CE model fostering the design (offer) for the extension of materials' biological cycles (composting or renewable energy recovery). (Adapted from Vezzoli et al. 2021)

life cycle performance remains with the producers/providers who are selling a unit of satisfaction rather than (only) the product. And why does this happen? Because this way, we shift or allocate the direct economic and competitive interest to reduce the products' and/or the services' environmental impacts, onto the stakeholder responsible for their design and development. Consequently, within an S.PSS model, a product design embracing Circular Economy principles and practices is economically beneficial (Fig. 3.8).

In other words, an S.PSS producer/provider is economically interested in:

- *Design out waste and pollution*
- *Design to keep products and materials in use*
- *Design to regenerate natural systems*

3.4 S.PSS Win-Win Promising Benefits to Make Circular Economy Solutions Accessible for All

The social dimension of Circular Economy is being increasingly studied, as well as its socio-ethical sustainability benefits (Padilla-Rivera et al. 2020; Piesik et al. 2018; Social Circular Economy 2018). Will S.PSS applied to Circular Economy framework also foster socio-ethical benefits? It has been studied (Vezzoli et al. 2021) that S.PSS – if properly conceived – are opportunities to make goods and services economically accessible and preservable over time to both final users and

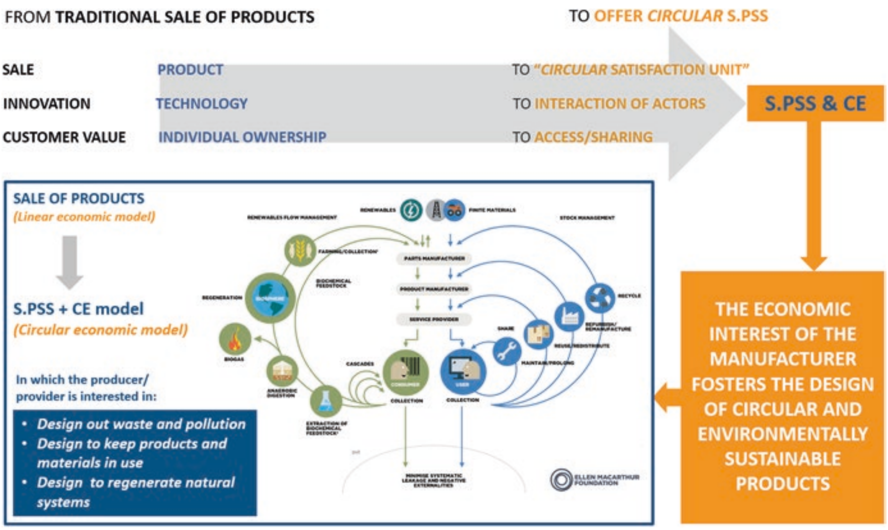

Fig. 3.8 S.PSS as a model making product design for Circularity economically beneficial for the manufacturer/provider

entrepreneurs/organizations, also in low- and middle-income contexts (i.e., by cutting/reducing initial costs and cutting/reducing life cycle costs).

Indeed, as far as S.PSS can be applied in a Circular Economy offer of ownerless products and/or with all-inclusive the life cycle costs, the following S.PSS socio-ethical and economic win-win benefits could be highlighted as enabling for a sustainable Circular Economy for all (updated from Vezzoli et al. 2018). The first two are related to end-users and the third, fourth, and fifth are related to entrepreneurs/organizations:

(a) *End-user product accessibility*: As far as an S.PSS model is applied to a Circular Economy by selling the access rather than mere product ownership, this reduces or avoids purchasing costs of products that are frequently too high for low- and middle-income end-users *(economic benefits),* i.e., making goods and services more easily accessible (*socio-ethical benefits*) (Fig. 3.9).

(b) *Reduction of interrupted product use*: As far as an S.PSS model is applied to a Circular Economy by selling the "unit of satisfaction" including life cycle services costs, this reduces or avoids running costs for maintenance, repair, reuse, and re-manufacturing, that are too high for low- and middle-income end-users (economic benefits), i.e., who can avoid interruption of product use (socio-ethical benefits) (Fig. 3.10).

(c) *Entrepreneurs/organizations' equipment accessibility*: As far as the S.PSS model is applied to a Circular Economy by selling access rather than the (working) equipment itself, this reduces or avoids initial (capital) investment costs of equipment, which are frequently too high for low- and middle-income entrepreneurs/organizations (economic benefits), i.e., facilitating new business start-ups in low- and middle-income contexts (socio-ethical benefits) (Fig. 3.11).

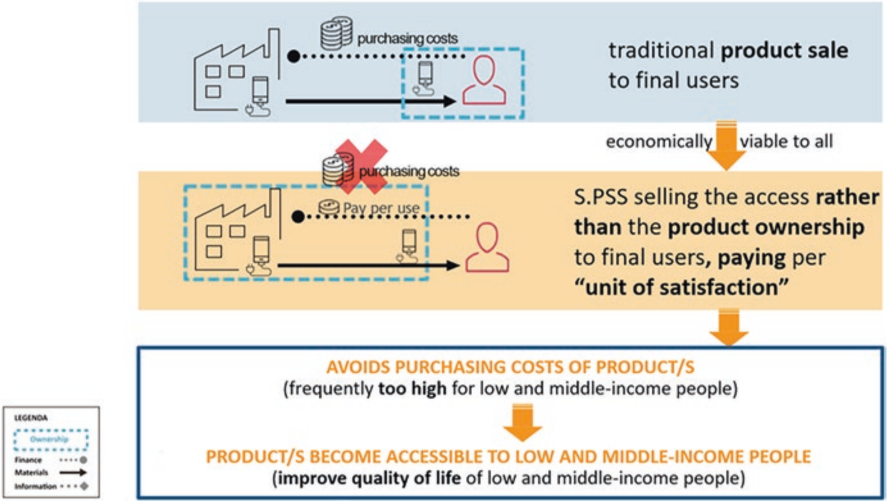

Fig. 3.9 S.PSS applied to a CE as a model making product/s accessible to low- and middle-income end-users. (Adapted from Vezzoli et al. 2021)

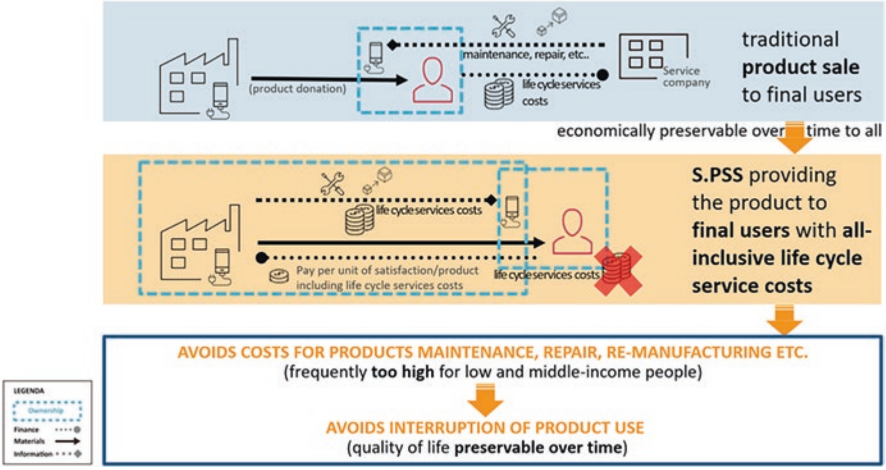

Fig. 3.10 S.PSS applied to a CE as a model making quality of life preservable over time in low- and middle-income contexts. (Adapted from Vezzoli et al. 2021)

(d) *Reduction of interrupted equipment use*: As far as the S.PSS model is applied to a Circular Economy by selling all-inclusive life cycle services with the equipment offer to entrepreneurs, this reduces or avoids running costs for equipment maintenance, repair, reuse, re-manufacturing, etc. that are frequently too high for low- and middle-income entrepreneurs/organizations (economic benefits), i.e., this avoids interruption of equipment use and subsequently working activities (socio-ethical benefits) (Fig. 3.12).

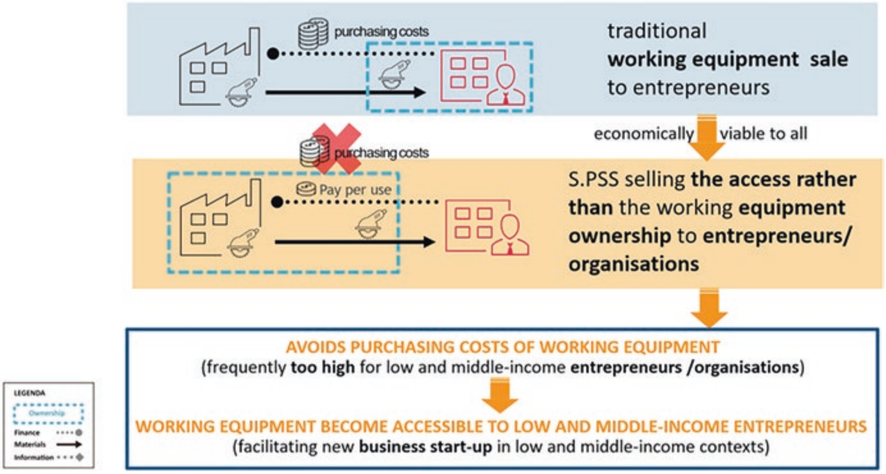

Fig. 3.11 S.PSS applied to a CE model facilitating new business start-ups in low- and middle-income contexts. (Adapted from Vezzoli et al. 2021)

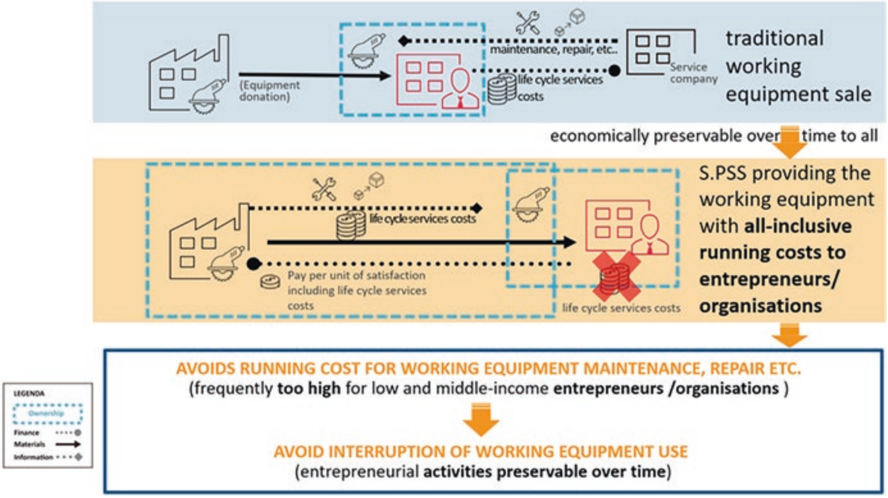

Fig. 3.12 S.PSS applied to a CE model making entrepreneurial activities preservable over time. (Adapted from Vezzoli et al. 2021)

(e) *Local employment and competencies improvement*: As far as an S.PSS model is applied to a Circular Economy by offering goods and services without product purchasing costs, they open new market opportunities for local entrepreneurs via new potential low- and middle-income customers, i.e., potentially empowering locally based economies and life quality (socio-ethical benefits) (Fig. 3.13).

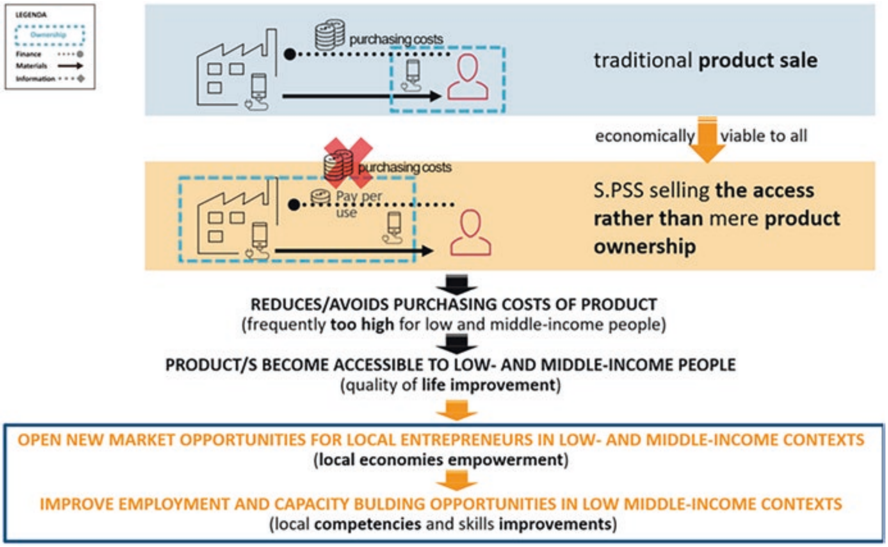

Fig. 3.13 S.PSS applied to a CE model improving local employment, competencies, and skills

Due to the presented benefits, as well as for their inherent principles, S.PSSs are also aligned with business approaches which are considered to be promising for the Bottom of the Pyramid (BoP). Indeed, like for other business models (e.g., Natural capitalism, social enterprises, closed-loop models), being sustainability – in its environmental, social, and economic pillars – directly connected with the overall economic interest, the concept of poverty gets considered in its whole complexity as a systemic issue, and not just as a matter of economic disadvantage (Dembek et al. 2018).

In particular, the service dimension of an S.PSS is suitable for local providers, thus generating local jobs related to Circular Economy. This contributes directly to social cohesion, as it reduces the need for migration or long commutes; this also increases the likelihood of better balance between work and social life; and thus provides a context where the social fabric can be built up and/or consolidated. All this considered, S.PSS potentially facilitates both the delivery and the sourcing of CE products and services for BoP communities, which are recognized as promising approaches to generate value on a system level (Dembek et al. 2018)

Finally, within a CE framework adopting an S.PSS model the producer/provider is economically incentivized in designing for social equity, i.e., to extend sustainable access to products/equipment for low- and middle-income people (see Fig. 3.14), by designing for:

- Improving the quality of life of low- and middle-income people through economically accessible goods and services preservable over time.
- Supporting new business start-ups and their survival over time in low- and middle-income contexts; empowering local economies by improving competencies and skills.

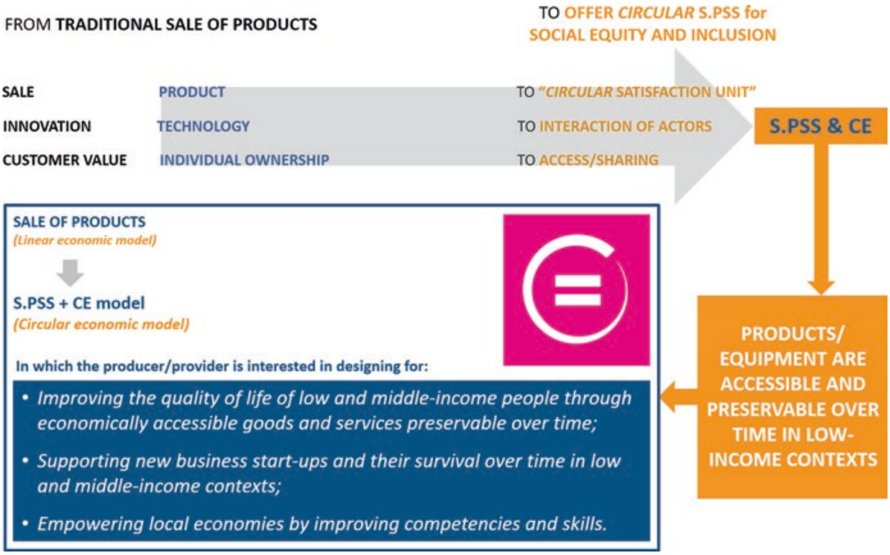

Fig. 3.14 S.PSS applied to a CE as a model making the design of accessible and preservable products/equipment economically relevant for the manufacturer/provider

Though S.PSS can be considered as promising to enable CE business models for all – also within low-income contexts – there are still some potential barriers to be addressed, especially considering poverty as a complex and systemic problem. Indeed, even if S.PSS potentially facilitates access to products and services over time as well as empowers local communities with competences and skills, they don't consider specific factors like psychosocial issues, knowledge deprivation, or adverse power relationships, which could affect communities' response toward the success of a business model (Arora and Romijn 2011; Nakata and Weidner 2012)

Said this, it is also true that S.PSS can be designed in combination with other business models and system approaches, so forth integrating features to overcome above-mentioned barriers. It is the case of Distributed Economies (DE), which have been recently highlighted as complementary to S.PSS in order to reach sustainability for all. Indeed, DE is based on a shift from centralized to decentralized/distributed systems in which a small-scale unit of production is locally based, i.e., nearby or at the point of use, and where the user can become a producer. This integrates S.PSS with a set of additional socio-ethical benefits, giving to local users direct access to resources and increasing their participation in the whole system life cycle, e.g., democratize the access to resources; add value to resources in the region; improve the connection between producers and consumers – removing intermediaries – hence improving knowledge on sustainability; increase local information/knowledge, know-how and local people's capabilities (Vezzoli et al. 2021, 2022).

Moreover, as the next paragraph will mention, different methods and tools allow to design S.PSS for specific conditions and requirements, which would allow to go in depth with complex situations in low-income contexts, also known as Bottom of the Pyramid.

3.5 Designing S.PSS Applied to CE for All: Approaches, Skills, and a Method

The introduction of PSS innovation for sustainability into design has led design researchers to work on defining new skills of a more strategic nature (Brezet et al. 2001; Manzini and Vezzoli 2003; Tischner et al. 2009; Ceschin 2012; Vezzoli et al. 2014), which aim at system innovation for sustainability through a convergence of stakeholder interests and are coherent with the satisfaction-based approach. "Strategic" here also refers to the necessary acknowledgment of cultural contexts and inherent opportunities and barriers built into the social fabric.

In relation to the characteristics of S.PSS and their inherent connection with Circular Economy principles described in the previous section, three main approaches and related skills for Product-Service System Design for circularity (and Sustainability more widely) could be highlighted (adapted from Vezzoli et al. 2018):

- A **CE** "**satisfaction-system**" approach: calling for skills to design the satisfaction of a particular demand (a "satisfaction unit") and hence all its related CE products and services.
- A **CE** "**stakeholder configuration**" approach: calling for skills to design the interactions of the stakeholders of a particular CE satisfaction-system.
- A **CE** "**system sustainability**" approach: calling for skills to design such CE stakeholder interactions (CE offer model) that make the providers economically incentivized to continuously seek both techno-cycles and bio-cycles new beneficial solutions accessible to all.

The first key point lies in the so-called *satisfaction-based CE approach*, where the focus is no longer on delivering a single CE product. It is thus inadequate to merely design or assess a single CE product, but instead we consider the whole process of every product and service associated with satisfying certain needs and/or desires. This is indeed also one of the principles considered within the definition of Circular Economy itself (Ellen MacArthur Foundation 2021). The second key issue is to introduce a *stakeholder CE configuration approach*. If we want to design the CE stakeholder interactions, the system design approach should project and promote innovative types of interactions and partnerships between appropriate socio-economic stakeholders, while responding to a particular social demand for satisfaction. Therefore, designing the configuration of a CE system means understanding what stakeholder profiles should be in place and what the best interrelationships are, in the sense of financial, resource, information, or labor flows. Last but not least, it must be emphasized that, as stated by various authors (O. K. Mont 2002; UNEP 2002; Cooper 2005; Vezzoli 2010; Ceschin 2012), not all PSS innovations are driven by the economic interest to promote techno-cycles or bio-cycles (more in general to have a reduced environmental impact), nor do they necessarily promote good and services accessible to all (i.e., to promote social equity and cohesion). For this reason, it is expedient to operate and adopt appropriate criteria and guidelines in the design process towards CE-oriented (more in general sustainable) stakeholder interactions/relationships. Having understood this, **Product-Service System design for Circular Economy for all (more in general sustainability for all)** can be defined as follows (adapted from Vezzoli et al. 2021):

> ***the design of the Circular Economy system of products and services that are together able to fulfil a particular customer demand (to deliver a "unit of satisfaction"), based on the design of innovative interactions between the stakeholders of the CE value production system (CE satisfaction system), where the ownership of the CE product/s and/or the life cycle services costs/responsibilities remain with the provider/s, so that the same provider/s continuously seek/s technical cycles or biological cycles eventually accessible to all, together with economic benefits.***

Given that the S.PSS applied to CE design approach moves toward the design of innovative stakeholders interactions able to respond to a particular social demand, new skills are required from the designer, directly or as a facilitator of a design process:

- A designer must be able to design both products and services with a CE approach, in relation to a given demand (needs and/or desires), i.e., a satisfaction system that fulfills a given demand of needs and/or desires, as a single satisfaction unit.
- A designer must be able to identify, promote, and facilitate innovative CE configurations (i.e., interactions/partnerships based on a Circular Economy approach) between and among different stakeholders (entrepreneurs, users, NGOs, institutions, etc.).

Moreover, since S.PSS applied to CE design aims at developing innovations that have a low environmental impact throughout technical cycles and/or biological cycles, eventually accessible to, with economic benefits – it is clear that a designer must be capable to design S.PSSs applied to CE systems (and related stakeholder interactions) as win-win beneficial new solutions. Consequently, new skills are required from the designer:

- The ability to orientate the CE system design process towards *eco-efficient* solutions, encompassing both environmental and economic sustainability.
- The ability to orientate the CE system design process towards *socio-efficient* solutions encompassing both socio-ethical and economic sustainability.

Moving to a more operative dimension, it is worth mentioning that methods and tools to design S.PSS have been developed since 2005, supported by a set of research projects funded by the European Union and the United Nations Environment

Programme (UNEP), the main ones being D4S,[4] SusHouse,[5] ProSecCo,[6] HiCS,[7] MEPSS,[8] SusProNet,[9] LeNS,[10] LeNSes,[11] and LeNSin.[12]

One of the most adopted by the international design community is the Method for System Design for Sustainability (MSDS) (Vezzoli et al. 2021). Indeed, this method and its tools consider most of the CE principles, so forth it is introduced in its main scope here.

3.5.1 Method for System Design for Sustainability (MSDS)

The MSDS method – adapted from (Vezzoli et al. 2021) – has been developed and refined in the course of a couple of decades with the aim of supporting the design of Product-Service System, in order to orient the system innovation development process toward win-win solutions for sustainability, among which even the regeneration of technical cycles and the restoration of biological ones. The MSDS method is conceived for designers and companies but is also appropriate for public institutions, NGOs, and other types of organizations. It can be used by an individual designer, by a wider design team, or by a multidisciplinary team facilitated by a designer. In all cases special attention has to be paid to facilitating co-designing processes both within the organization itself (between people from different disciplinary backgrounds) and outside, bringing different socio-economic actors and end-users into the design process.

The scope of the method is to support design processes for the development of S.PSS (eventually applicable to CE), and it is characterized by a flexible modular structure that makes it easily adaptable to specific design requirements, diverse design contexts and conditions, and usable in existing design procedures/practices. All the tools developed are open access and free to download at www.lens--international.org.

Without going into a detailed description, a scheme is presented below to introduce it, by highlighting its processes and related aims and support tools (related to each design stage). A detailed description can be found on www.lens-international.org and in several international publications (Vezzoli et al. 2014, 2018, 2021) (Table 3.1).

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[4] Design for Sustainability (D4S): A Step-By-Step Approach, UNEP funded, 2005–2009.

[5] SusHouse: Strategies towards the Sustainable Household, EU-FP4 funded, 1998–2000.

[6] ProSecCo: Product-Service Co-design, EU-FP5 funded, 2002–2004.

[7] HiCS: Highly Customerised Solutions, EU funded, 2001–2004.

[8] MEPSS: MEthodology for Product Service System development, EU- FP5 funded, 2002–2005.

[9] SusProNet: Sustainable Product-Service co-design Network, EU-FP5 funded, 2002–2005.

[10] LeNS: Learning Network on Sustainability, EU-EuropAid funded 2008–2010.

[11] LeNSes: Focused on System Design for Sustainable Energy for all, EU-Edulink funded, Oct 2013–Oct 2016.

[12] LeNSin: focused on designing S.PSS applied to DE as a promising approach for designing sustainability for all, EU-Erasmus+ funded, 2015–2019.

Table 3.1 The aims, processes, and tools of MSDS, in relation with the typical Product-Service System design stages

System design stages	Method for system design for sustainability		
	Aims	Processes	Tools
Strategic analysis	To obtain the information necessary to facilitate the generation of sustainable system innovation ideas	Analysis of project proposers and outline the intervention context Analysis of the context of reference in relation to its technical and biological cycles Analysis of the carrying structure of the system in relation to its technical and biological cycles An Analysis of S.PSS & CE best practices Analysis of sustainability of existing system and determine priorities for the design intervention in view of sustainability (for both technical and biological cycles)	Checklist for the analysis of the existing system and priority set (SDO toolkit) S.PSS Innovation Diagram
Exploring system opportunities	To make a "catalogue" of sustainability-promising and CE system possibilities	Generation of circular and sustainability-oriented ideas Outline a design-oriented sustainability and CE scenario	Sustainable idea boards (SDO toolkit) SDOScenario Polarities
System concept design	To design one or more CE system concepts oriented toward sustainability	Select clusters and single ideas Develop S.PSS & CE concepts Environmental, socio-ethical, and economic qualitative check assessment	S.PSS Innovation Diagram S.PSS Concept description form Checklist for the system sustainability improvement evaluation (SDO toolkit)
System detailed design (and engineering)	To develop the most sustainability promising CE system concept into the detailed version necessary for its implementation	Detailed sustainability and CE system design Environmental, socio-ethical, and economic qualitative check and visualization	System map for S.PSS Stakeholders motivation and sustainability table Interaction table Stakeholders interaction storyboard Satisfaction offering diagram Checklist for the system sustainability improvement evaluation (SDO toolkit) Radar (SDO toolkit)
Communication	To draw up reports to communicate the sustainable characteristics of the designed CE system	Draw up the documentation for communications of sustainability	Animatic for S.PSS

3.6 Discussion and Final Considerations

Sourcing from the learnings of the LeNSin project and from the ongoing research activity of the LeNS network, the chapter makes a step forward, following the hypothesis that the theory and practice of S.PSS design can be valuable to develop Circular Economy systems accessible to all – even to low-income contexts and communities. Based on these premises and from the key concepts of CE, the chapter considers the existing literature on circular business models and S.PSS & CE. Besides multiple synergies in terms of knowledge base and principles, and a growing empirical research context, there are still debates regarding the solid integration and design of the two models. Secondly, the chapter recognizes the paucity of research that amalgamates S.PSS with CE models to foster socio-economic inclusivity, especially in low- and middle-income contexts.

All this considered, an unexplored convergence between the two models is identified. Key findings in this sense are S.PSS win-win benefits applied to CE, highlighting different configurations in which the economic interest on a system level is proportional to environmental and socio-ethical benefits. So forth, S.PSS design capabilities are depicted as potentially fundamental to bring circular business models into practice, making organization and designers able to manage specific methods and tools (e.g., the MSDS method).

In this sense, the chapter represents a contribution to the theoretical and practical knowledge base on both S.PSS and Circular Economy, transcending the mere alignment of concepts and focusing on how the former could become an enabler, even from a socio-ethical point of view.

Even though a general framework has been here outlined, indeed, this research hypothesis needs to be further investigated. As described in the text, it seems to be quite promising, but a further and articulated research action plan needs to be taken, to advance the knowledge-base and know-how up to a level where it can become an effective leverage for a sustainable change. For example, an extended variety of S.PSS sub-types and specifications could be analyzed from a system perspective as enabler Circular Economy.

Although this contribution took into analysis the three main S.PSS typologies (product-oriented, use-oriented, and result-oriented), many specifications exist and have been evolving along the years, both in the literature and in the industry, e.g., product pooling, product-related services, pay-per-service unit.

Furthermore, also MSDS method and its tools would benefit from dedicated research activities to make it more specific and so forth more effective to support designer in S.PSS design when the issue is that of designing and implementing CE adopting an S.PSS offer model. This is even more evident and open to be developed when we want to generate and consolidate the new knowledge to design CE systems accessible and preservable over time even to low- and middle-income context. Indeed, a consolidation of this research path may finally give a concrete contribution to the diffusion of CE systems accessible to all.

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Chapter 4
Initiating a Minimum Viable Ecosystem for Circularity

Jan Konietzko, Brian Baldassarre, Nancy Bocken, and Paavo Ritala

Abstract To achieve a transformation toward the circular economy, organizations need to take an ecosystem perspective and consider multiple complementary actors that are needed to deliver circularity as a collective outcome. However, practitioners and scholars lack an understanding of the initial phases of ecosystem creation, in terms of how to get started, and what to consider. We therefore investigate *how organizations can initiate an ecosystem for a circular economy.* The method consists of a concise review of the ecosystem literature and three instrumental cases, to identify important activities that are needed when initiating an ecosystem for circularity. The cases include: (1) an alliance for circular safety footwear, (2) a startup that turns old coffee ground and orange peel waste from another company into new products, and (3) a multi-stakeholder project aimed at recovering resources from wastewater. We propose a framework for a Minimum Viable Ecosystem for Circularity (MVEC) that includes a set of key activities to perform when building ecosystems for a circular economy. These activities provide a useful roadmap for scholars and practitioners for establishing and assessing ecosystems for circularity. We call for further research and practical applications to test and demonstrate the utility of this framework in different contexts.

Keywords Circular economy · Circular business model · Business ecosystem · Ecosystem perspective · Systems thinking

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4.1 Introduction

In a circular economy, organizations maximize the value of products, components, and materials, and minimize absolute resource use, emissions, waste, and pollution (Geissdoerfer et al. 2017). To innovate for a circular economy, organizations need to collaborate with external actors, often beyond classical industry and supply chain boundaries (Konietzko et al. 2020a). Coordination and alignment are needed to, for example, ensure the compatibility of products, components, and materials to enable repair, reuse, and recycling, or to support higher resource efficiency by sharing assets among several organizations and end customers (Brown et al. 2021a).

In the strategy and management literature, the concept of "ecosystem" has received increasing attention in the past years. It describes complex forms of inter-organizational alignment and coordination, and extends beyond formal alliance networks to incorporate broad complementarities among loosely connected actors (Aarikka-Stenroos and Ritala 2017; Shipilov and Gawer 2020). Compared to other cross-organizational concepts like supply chains or networks, an ecosystem is primarily characterized by a joint value proposition or an ecosystem-level outcome, delivered by complementary organizational actors (Adner 2017). An example of such an outcome is a seamless, affordable, and sustainable mobility system in a city. The ecosystem then describes the diverse participants that are needed to deliver a joint value proposition and achieve the ecosystem-level outcome. These participants are mostly not hierarchically governed (although some formal relationships might exist), and they have varying degrees of multilateral interdependence (Brown et al. 2021a; Thomas and Autio 2020).

Circularity can be described as a particular ecosystem-level outcome. To ensure that products, components, and materials are kept in use for as long as possible, diverse and loosely connected actors from across industries need to align and coordinate their activities (Konietzko et al. 2020b). These actors usually include customers who will buy or use recirculated products and components, service providers who will maintain, repair, refurbish, and remanufacture them, and recycling companies who will recover their materials. The ecosystem serves as a useful analogy to explain the inter-organizational coordination and alignment needed to achieve circularity (Aarikka-Stenroos et al. 2021).

However, the question of how organizations can initiate circular ecosystems remains unclear in the current literature. In general, the initiation of an ecosystem in business innovation — along its lifecycle of birth, expansion, leadership, and self-renewal or death (Moore 1993) — has received little attention (Dedehayir et al. 2018). Furthermore, research on ecosystems for circularity is still in its infancy (Baldassarre et al. 2020; Konietzko et al. 2020b). As a consequence, organizations lack support in effectively initiating ecosystems for a circular economy, and researchers lack visibility to the necessary processes and practices relevant for the early stages of circular economy ecosystems.

In this chapter, we therefore address the following research question:

How can organizations initiate an ecosystem for a circular economy?

To address this question, we first describe the theoretical background, including the origins and evolution of the ecosystem concept in management research and its application to a circular economy context. We then describe the method: a concise literature review and three case studies to identify important activities during the initiation of ecosystems for circularity. We then present the results in the form of the following six activities: (1) Develop a circular economy vision, (2) Design an ecosystem value proposition and outcome, (3) Identify and engage relevant actors, (4) Develop an initial governance model, (5) Develop fair value capture mechanisms, and (6) Keep track of environmental and social impact. We then discuss the contributions and limitations of this chapter, and provide some concluding remarks and outlooks for future research.

The goal of this chapter is to guide innovators with these proposed activities to ensure successful initiation of ecosystems for circularity. To theory, we contribute a review of important activities during ecosystem initiation in the context of a circular economy, which is based on prior findings on generic ecosystem roles and activities (Dedehayir et al. 2018).

4.2 Theoretical Background: How to Initiate Ecosystems for a Circular Economy

4.2.1 Origins and Evolution of the Ecosystem Concept

The analogy of an ecosystem in business innovation emerged in the early 1990s, to describe a new industrial landscape shaped by competition among groups or communities of collaborating organizations rather than competition among single organizations (Moore 1993). Since then, the ecosystem concept has evolved and become distinct from other community concepts in business and management, like supply chains, networks, or organizational fields (Adner 2017; Shipilov and Gawer 2020; Thomas and Autio 2020). The main distinction is a coherent, customer-facing value proposition or ecosystem-level output (Adner 2017). Furthermore, the ecosystem concept consists of non-hierarchical governance and primarily non-contractual relationships, it contains diverse and heterogeneous participants, and the participants in an ecosystem have varying levels of technological, economic and cognitive interdependencies (Thomas and Autio 2020; Thomas and Ritala 2022; Shipilov and Gawer 2020; Möller et al. 2020).

Central to the ecosystem concept is an ecosystem value proposition or defined system-level outcome that requires multiple actors to be realized (Adner 2006, 2017; Talmar et al. 2020; Lingens et al. 2020). Ecosystems are often driven by an "orchestrator" – a central actor that coordinates the complementarities across the ecosystem by utilizing economical or technological (e.g., a digital platform) mechanisms to do so (Thomas and Ritala 2022). Oftentimes the orchestrator (one organization or a group of organizations) also proposes the initial vision of the ecosystem and its value proposition and desired outcome, concretely in the form of an offering idea or a business model concept, sometimes backed with relevant intellectual property rights.

An example of an ecosystem value proposition in the context of a circular economy is "Loop", an online platform for groceries shopping in reusable packaging. Their value proposition is "*A new way to shop, waste-free*" (Loop 2021). To deliver this value proposition (a new way to shop) and ecosystem outcome (no waste), Loop had to convince a minimum viable number of food brands to provide their products in reusable packaging. It had to organize a supplier for the reusable packaging, organize a delivery service that takes back the empty food packaging, and it had to organize a cleaning service for the reusable packaging. Loop orchestrates these complementors and suppliers through an online platform that customers can order from. This example shows how the ecosystem orchestrator does not only need to establish a multi-sided market structure (Kretschmer et al. 2020), but also to create initiatives for circularity together with different participants of the ecosystem.

4.2.2 Ecosystems and the Circular Economy

The example of the Loop store shows that an ecosystem – next to a customer-facing value proposition – can generate circularity as an outcome. In a circular economy, organizations redesign and reorganize materials, products, business models, and supply chains, to narrow, slow, close, and regenerate inter-organizational material and energy flows (Konietzko et al. 2020a; Bocken et al. 2016). Circularity can be characterized as an ecosystem outcome, because it results from how a diverse set of actors — like manufacturers, users, suppliers, and recycling firms — interact with and relate to each other, to enable the circular flow of resources over time (Konietzko et al. 2020b; Aarikka-Stenroos et al. 2021).

The discussion on the ecosystem concept in relation to the circular economy can be traced to seminal ideas about resource-efficient manufacturing, focusing on tangible, inter-organizational material and energy flows, and how these can be influenced to achieve environmental gains (Frosch and Gallopoulos 1989). In this context, the concept of ecosystem has been leveraged by the discipline of industrial ecology, which seeks to translate the working principles of natural ecosystems (e.g., balanced, self-sustaining interdependencies) into industrial settings, processes, and products (Blomsma and Brennan 2017). Emulating nature, industrial ecosystems seek to optimize the consumption of materials and energy, and minimize waste by channeling them as inputs into other processes (Harper and Graedel 2004). This may happen within one factory (Despeisse et al. 2012), an eco-industrial park with a variety of organizations exchanging materials and energy (Côté and Cohen-Rosenthal 1998), or within an extended urban context, which goes beyond production, and includes the consumption and end-of-life stages of products (Harper and Graedel 2004; Leduc and Van Kann 2013).

One of the older and most renowned examples of industrial ecosystems catalyzing a circular economy in Europe is the Kalundborg eco-industrial park in Denmark (Jacobsen 2006). Here, several companies exchange waste and/or energy, materials, infrastructure to jointly optimize their environmental and economic performance (Massard et al. 2014). Recent research provided insight into how such industrial ecosystems for circularity function both from a business and sociotechnical perspective, illustrating a case in the south of the Netherlands (Baldassarre et al. 2019). Here, residual heat and carbon emissions from a chemical company are collected and channeled through a piping system into nearby greenhouses, where farmers use them as inputs for growing tomatoes (see Kokoulina et al. 2019, for a similar example). The circular outcome is based on several years of collaborative trial-and-error efforts of several actors, including the chemical company, farmers, a commercial bank, a construction company, the local government, as well as an ecosystem coordinator taking care of project development, implementation, and management. In this chapter, we follow the recent conceptualization of circular ecosystems (Aarikka et al. 2021) and view the ecosystem more broadly than the industrial ecosystem, to include any multi-actor ecosystem that focuses on circularity as the ecosystem outcome.

4.2.3 Research Gap and Contribution

An ecosystem is subject to an evolutionary lifecycle of birth, expansion, leadership, and ultimately self-renewal or death (Moore 1993). Research on the birth phase of ecosystems — which consists of invention and startup sub-phases (Dedehayir and Seppänen 2015) — has emerged only recently. Early research has suggested that organizations need to create a "Minimum Viable Ecosystem" to start an ecosystem, i.e., an initial alignment structure that can create economic value (Adner 2012; Pidun et al. 2020). This alignment structure can be seen as a boundary object that helps people across disciplines to generate the knowledge needed to succeed in the innovation process (Carlile 2002). A Minimum Viable Ecosystem as a boundary object can take different forms. It can be, for example, in the form of a "value blueprint", a visual graphic of the complementary innovations needed to jointly deliver an end-user facing value proposition (Adner 2012). Dedehayir et al. (2018) have offered a detailed account of roles and activities during ecosystem genesis. Baldassarre et al. (2019) outlined a high-level process, as well as underlying methods and tools, to iteratively turn an initial shared vision of the proposition into a business that generates circular impact. Further contributions include visual tools that help establish an early alignment structure, for example, the Ecosystem Pie

Model, a pie-shaped canvas to map out the needed complementary actors for an ecosystem value proposition (Talmar et al. 2020), or the Circular Collaboration Canvas, a tool that aids in identifying needed partners to deliver a value proposition for a circular economy (Brown et al. 2021b).

In this chapter, we build on this emerging body of work by identifying important activities that facilitate the initiation of an ecosystem for a circular economy, based on literature and the experience from three cases. We investigate these activities and develop a boundary object (Carlile 2002) – a framework for a Minimum Viable Ecosystem for Circularity (MVEC) – with key activities that can serve as guidance when forming an initial alignment structure to solve a circular economy problem. So far, research on the types of activities needed to initiate ecosystems is scant, especially in the context of a circular economy. This refers to aspects of, for example, ecosystem governance, partnership building, and value management (Dedehayir et al. 2018). We assume here that the initiating actor is an orchestrator or ecosystem leader. In the following, we describe how we identified these activities.

4.3 Method: Identifying Important Activities from the Literature and Three Cases

This research identified relevant activities during ecosystem initiation for circularity by concisely reviewing relevant ecosystem literature and by analyzing three cases of organizations that have initiated an ecosystem for a circular economy.

As a first input, we used the 90 articles on ecosystem genesis identified in earlier research (Dedehayir et al. 2018) and in addition, searched for literature since 2018, using the search string (ecosystem AND genesis OR creat* OR design OR initiat* OR start* OR emerg*), filtered for titles, and limited to business, management and accounting literature (117 results). We reviewed the literature and applied snowballing to identify further relevant articles.

We read the studies in the search of knowledge that uses design and theory building to inform and propose how to "*devise courses of action aimed at changing existing situations into preferred ones*" (Simon 1996, p. 111). In the context of innovation practice, this refers to knowledge that can help to improve the process of innovating (Romme and Reymen 2018). This knowledge usually comes in the following forms: (1) as an explicit purpose of the article, for example, to develop a tool or boundary object to improve practice (see e.g., Talmar et al. 2020), (2) in the managerial implications sections of the publications, (3) or implicitly in the form of normative statements about what organizations should do. We filtered the articles that contained any of these forms of useful knowledge and coded important and recommended activities of initiating innovation ecosystems. The final pool of articles for review contained 37 studies.

Second, we used three instrumental case studies to provide further insight into the activities particular to the context of initiating innovation ecosystems for a circular economy (Stake 1995): The Circular Footwear Alliance, Unwaste, and Clean Water. Case studies can be based on rich and diverse data to inform the analysis (Eisenhardt 2021). The analysis in the cases focused on how the ecosystem was initiated. During the case interviews and workshops, themes discussed included how the ecosystem started, who was involved, what the goal was, and what activities were pursued in the initiation process. Data on the Circular Footwear Alliance consists of notes from two interviews and one co-creation workshop with people from the orchestrating company (EMMA Safety Footwear), several internal presentations, and online information (websites, social media posts). Data on Unwaste includes notes and visual outputs from three co-creation workshops to develop the business ecosystem. Data on Clean Water include 21 interviews and two co-creation workshops with the 20 involved organizations that aimed to develop their business ecosystem. We describe the three cases in turn.

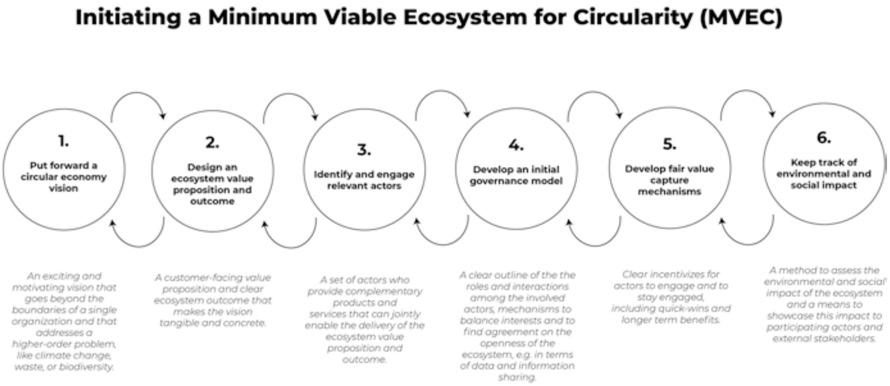
Circular Footwear Alliance The Circular Footwear Alliance was founded by two competing safety footwear manufacturers (EMMA Safety Footwear and Allshoes Safety Footwear), as well as a service company called FBBasic, to enable the circularity of safety footwear. Both manufacturers realized that they could achieve more together than alone. They joined forces to develop a project to enable the returning, sorting, separating, and recycling of old safety shoes.

Unwaste Unwaste is a startup from Amsterdam, Netherlands that provides personal care products like soap and handspray, made from recovered ingredients such as old coffee ground and orange peel waste. The company is embedded in an ecosystem that organizes the separate collection, processing, and manufacturing of the ingredients into new products. The ambition of Unwaste is to close the loop for its clients' waste.

Clean Water Clean Water (project name has been anonymized to ensure confidentiality) is a EU innovation project related to the wider policy framework of the Circular Economy Action Plan. The project is a large cross-organizational endeavor where multiple stakeholders are collaborating to pilot a solution to recover valuable minerals from industrial wastewater in a European Port Area, to then put them back on the EU market.

4.4 Results: Activities to Initiate an Ecosystem for a Circular Economy

We propose that the following activities need to be performed to initiate an ecosystem for a circular economy: (1) Put forward a circular economy vision, (2) Design an ecosystem value proposition and outcome, (3) Develop an actor engagement strategy, (4) Develop a governance model, (5) Develop fair value capture mechanisms, and (6) Keep track of environmental and social impact (Fig. 4.1).



An exciting and motivating vision that goes beyond the boundaries of a single organization and that addresses a higher-order problem, like climate change, waste, or biodiversity.

A customer-facing value proposition and clear ecosystem outcome that makes the vision tangible and concrete.

A set of actors who provide complementary products and services that can jointly enable the delivery of the ecosystem value proposition and outcome.

A clear outline of the the roles and interactions among the involved actors, mechanisms to balance interests and to find agreement on the openness of the ecosystem, e.g. in terms of data and information sharing.

Clear incentivizes for actors to engage and to stay engaged, including quick-wins and longer term benefits.

A method to assess the environmental and social impact of the ecosystem and a means to showcase this impact to participating actors and external stakeholders.

Fig. 4.1 A framework of key activities to initiate a Minimum Viable Ecosystem for Circularity (MVEC)

In practice, people can initiate an ecosystem by starting with any of these sets of activities. Here we propose them in a clear order observed in the cases. The innovation process ideally starts with someone who puts forward a vision (1), which is translated into a defined and more concrete ecosystem value proposition and outcome (2), which in turn can be used to engage actors (3). Actors are identified who share the same vision to make the ecosystem value proposition a success. This engagement then requires a governance model (4) to facilitate effective exchange and interactions among the actors, as well as mechanisms for fair value capture (5). For example, in terms of how revenue streams are divided among the different actors. Finally, to ensure the intended impact, it is important to keep track of the environmental and social impacts (6). The latter step, perhaps because of the complexity, is often omitted, but the ample research on unintended consequences of innovation suggests that this is an essential step. Along the process, the innovators may need to jump back and forth between these sets of activities, hence the arrows in Fig. 4.1.

4.4.1 Put Forward a Circular Economy Vision

An important set of activities for a Minimum Viable Ecosystem is the development of a convincing and ambitious vision, one that puts forward an exciting and motivating idea about a desirable future state (Bocken et al. 2021; Wiek and Iwaneic 2014). This may start with ideas for a new technology or new way of doing business, often driven by passionate individuals (Dedehayir and Seppänen 2015). Communicating a vision is a key skill among individuals who are aiming to orchestrate the emerging ecosystem, as well as a key capability for orchestrating organizations (Dhanaraj and Parkhe 2006; Ritala et al. 2009). This future state transcends the boundaries of a single organization, leading to a higher-order collaborative intent, aiming at transitions of entire systems (Quist et al. 2011). In the case of a circular economy, this higher-order collaborative intent lies in designing out waste and regenerating natural ecosystems within economies (European Commission 2020; MacArthur 2013).

A vision can be developed through joint workshops and activities with relevant stakeholders, and requires interactive and creative elements like storytelling, or drawing (Wiek and Iwaneic 2014). It may align differing perspectives and reveal what different stakeholders find important about the future. Different narratives about a circular future may emerge in this process (Bauwens et al. 2020). Recognizing different viewpoints, acknowledging them, and negotiating different elements of a future vision are important aspects to legitimate the birth of an ecosystem and to arrive at a framing that can gain traction among various stakeholders (Wiek and Iwaneic 2014).

In the case of Unwaste, this vision is about eliminating the word "waste", about creating a world in which waste is seen as something beautiful. Its vision reads as follows:

> We cross out the word waste. Literally: ~~waste~~. The Dutch language does not yet have a good term for the way Unwaste looks at human-produced waste streams. Well, except for 'human-produced waste streams'. But that is not only very abstract, but also much too long to put on our packaging, for example. That is why we stay close to a word that many people know, but also makes our vision clear: ~~waste~~ is too beautiful to throw away.

Similarly, the vision of the Circular Footwear Alliance is about a future without waste. It reads as follows:

> The future is circular. Together we can make great strides. We believe in a future without waste. A future in which resources and raw materials are continuously recycled and reused. A circular future, to be precise. Together, we will bring this future closer. And we'll start at your feet…

In the case of Clean Water, the vision of the collaborative project is the following:

> Collaboratively transforming the supply chain of water and minerals in a European Port Area.

Developing a vision is an often underestimated but crucial part of developing an ecosystem for circularity. For innovators and managers, it is crucial to dedicate time and effort to joint workshops and opportunities for potential partners to engage in shaping the vision. In addition, it is important to check quality guidelines for a vision (Wiek and Iwaneic 2014). For example, visions should not be abstract statements, but tangible, measurable, and time-bound statements about the desired future.

4.4.2 Design an Ecosystem Value Proposition and Outcome

Another set of activities relates to the design of a tangible ecosystem value proposition and outcome, often put forward by the ecosystem orchestrator (Adner 2017), but developed and legitimized in a discursive and performative process among all ecosystem actors (Thomas and Ritala 2022). This should be built on the collective drive and motivation put forward by a shared vision (Den Ouden 2012). Ultimately, the shared vision should be transformed into a customer-facing value proposition and clear ecosystem outcome; this requires a lot of work in terms of designing, iterating, and communicating different aspects of the value proposition among ecosystem actors.

As perceptions of value are subjective, an ecosystem value proposition needs to integrate the value notions of various stakeholders. This can take place by critiquing existing institutions, i.e., widely shared norms, beliefs, rules, and values (Scott 2008), to open up space for new discussions, and to reshape these institutions. Part of this reshaping involves the joint development and acceptance of new symbols, a new language, and physical objects (Vink et al. 2021).

In a circular economy, where institutional drivers and barriers play a key role (Ranta et al. 2018), institutions can be reshaped around the ideas of reuse and repair, and waste as a resource (Konietzko et al. 2020b). New symbols like loop diagrams and graphics that portray the circular flow of resources, a new language around “waste as a resource”, a life-cycle perspective, and regeneration can stimulate the design of an ecosystem value proposition. Core to the idea of a circular economy is that resource efficiency and product life extension can be aligned with business and financial incentives. That is why the customer-facing offering is an important element of an ecosystem value proposition for a circular economy.

In the case of the Circular Footwear Alliance, the ecosystem outcome is the recycling of safety footwear. EMMA Safety Footwear, one of the initiating companies, realized that it could not achieve this alone. It calculated that it needed around 250,000 pairs of shoes to establish the business case for recycling, i.e., to make it financially viable and operationally feasible. Therefore, the company partnered with its competitor, Allshoes Safety Footwear, to generate the needed volume, and to encourage other actors to send back old safety footwear. The value proposition was framed for their customers who need to send back the old footwear. They could get help in improving their carbon emissions and waste metrics, as well as exchange knowledge on how to design the footwear for circularity, for example in terms of easy disassembly and mono-material components. In addition, the customers realized that joining this initiative could help them mitigate future regulatory cost around waste disposal.

Similarly, Unwaste makes products from recovered materials. The company has assembled an ecosystem of actors around it – waste management firms, office spaces, processing plants, and personal care product manufacturers – to enable the circularity of wasted orange peels and coffee grounds, to turn them into new products. It aligns the different actors around the following customer-facing value proposition:

> Waste is too good to throw away. It doesn't even need to exist. Because if human-generated waste is always relevant, then there is nothing left to throw away. Unwaste takes care of that. We give waste a new function in our care products, so you can experience its beauty every day.

The ecosystem value proposition to the customers of Unwaste taps into the emotional value of doing something good for the environment, and to be part of a changing mindset that sees waste as a resource. In general, an ecosystem value proposition for circularity communicates both emotional and functional value to the end customer, as well as the systemic outcome that is achieved by delivering the value proposition. This is an iterative process and requires careful validation of the systemic outcome that can be achieved, as well as the value perceptions of different stakeholders and the end customer.

4.4.3 Identify and Engage Relevant Actors

The ecosystem value proposition needs to be broken down into single independent modules that are contributed by different actors with defined roles and responsibilities (Lingens et al. 2020; Vink et al. 2021). Before engaging other actors, the orchestrator needs to be clear on its own role and position in the aspired ecosystem (Bosch-Sijtsema and Bosch 2015; Dedehayir et al. 2018). We assume here that the ecosystem is initiated by the ecosystem leader or orchestrator, which is typically the case. The role of the orchestrator is best performed by a start-up-like organization that can develop products fast, is agile and flexible. If the founding organization of the ecosystem is a large multinational, consultancy, a political, or an academic institution, it makes sense to consider founding a spin-off or external organization (Lingens et al. 2020; Gastaldi et al. 2015). On the other hand, an established and well-known orchestrator can bring the necessary legitimacy and related resources for the new ecosystem (Thomas and Ritala 2022), which shows, e.g., in the well-known circularity initiatives by multinationals such as IKEA and H&M. Once the orchestrator's own role is clear, the actor engagement strategy requires identifying and engaging relevant external actors (Dedehayir et al. 2018).

Actors can be identified based on prior collaboration, as well as based on the need to involve the right representatives who bring in key capabilities (Cobben and Roijakkers 2019; Overholm 2015). This may or may not include competitors (Ritala et al. 2013; Almirall et al. 2014). If uncertainty is high, less actors can help to limit the attention on core actors. If uncertainty is low and the path is clear, more actors can be included (Lingens et al. 2020; Bosch-Sijtsema and Bosch 2015). In the context of circular economy, it might be necessary to involve relevant actors from different parts of the value chain early on (see also Ritala et al. 2013).

Once actors are identified, the engagement strategy requires clear incentives for others to join and a clearly articulated vision and ecosystem value proposition that others can identify with, see value in, and are willing to commit to (Dedehayir et al. 2018). Initial engagement can then happen through joint meetings and activities to develop shared goals and a common point of departure. To attract new actors, an ecosystem needs to build an ecosystem identity that new actors buy into, which can happen by leading the discourse on new ways of doing business in a circular way and by showing an exceptional performance in delivering an ecosystem value proposition (Thomas and Ritala 2022). This can happen through forums, associations, meetings, and other communication channels. Developing an engagement strategy for all the partners that are expected to contribute to the ecosystem also requires ongoing negotiations to accommodate different needs (Overholm 2015).

In the case of the Circular Footwear Alliance, for example, EMMA Safety Footwear decided to partner with its competitor in a cooperative alliance to generate the needed volume of old safety shoes to make recycling viable and feasible. It also partnered with two recycling companies that could support the sorting, separating, and recycling of the shoe material. Further, the Alliance partnered with FBBasic for software that could help identify shoe material and organize the reverse logistics. FBBasic also helped to provide a dashboard for participating companies so that they could showcase the impact of returning and recycling old shoes in terms of CO_2 savings.

In the case of Clean Water, a scientist and innovator drove multilateral efforts for creating the foundations of a collaborative business aiming to put back on the market minerals recovered from wastewater. To this end, a large supplier of demineralized water based in the European Port was engaged to provide infrastructure and wastewater streams for the recovery of the minerals. A firm that might commercialize such minerals was also included in the consortium. A leading European University was included to provide technological expertise needed to separate minerals from wastewater in an energy-efficient way. Other research institutions and multiple technology suppliers were also included for the design and implementation of the Clean Water innovative wastewater treatment system. Eventually, this led to the creation of a Clean Water consortium, with complementary expertise coming from 22 academic and industry partners based in different European countries.

As these two examples show, the exact engagement strategy depends on the context and may be born out of the need to join forces and maximize impact and achieve feasibility, or because of personal contacts that people have, to help build the required network around an ecosystem vision for a circular economy.

4.4.4 Develop an Initial Governance Model

The governance model defines the roles of the actors and their intended interactions, and the openness, for example in terms of data and information sharing (Almirall et al. 2014; Bosch-Sijtsema and Bosch 2015; Dedehayir et al. 2018; Wareham et al. 2014).

In terms of roles and interactions, the governance model needs to find a balance between the stability and evolvability of the ecosystem (Wareham et al. 2014). On the one hand, the ecosystem needs to be stable enough to deliver quality and ensure that the investments of complementors will pay off (on the role of stability in networks and ecosystems, see also Dhanaraj and Parkhe 2006; Ritala et al. 2009). On the other hand, the governance model needs to allow for evolution in how complementors operate and adapt to changing environments, and the related changes in the governance mechanisms implemented by the orchestrator.

An important first step in establishing a governance model is therefore to identify important tensions and find ways to address them (Wareham et al. 2014). These tensions can be found in a potential disbalance on two spectra: (1) between standards and variety of ecosystem outputs, and (2) between the individual versus collective identity of participating actors. To govern an ecosystem, the outputs need to be standardized over time to ensure efficient processing and delivery. But there also need to be incentives for variety to bring in novelty, and actors should feel encouraged to innovate. Similarly, the individual identity needs to be balanced with the collective ecosystem identity, where the former leads to variety in behavior and more innovation, and the latter ensures a consistent ecosystem outcome (Thomas and Ritala 2022; Wareham et al. 2014).

These tensions can be governed depending on the power and influence of the orchestrator to steer the actors in a common direction while ensuring variety. The governance model can be based on a more hierarchic model, where one stakeholder has the power to lead and coordinate others, or on a more horizontal model, where there is no formal decision-making power on the side of the orchestrator (Kapoor and Lee 2013; Williamson and De Meyer 2012). Formal governance mechanisms include contracts and intellectual property regimes (Ritala et al. 2013), informal ways of governing an ecosystem include trust building, a clear business case, and a growing positive reputation (Bosch-Sijtsema and Bosch 2015).

Oftentimes, there is a need for data and knowledge sharing to enable the delivery of the ecosystem value proposition. Thus, the governance strategy also requires a negotiation and decision on the degree of openness, for example by creating the terms for data sharing and standardizes protocols that are needed to deliver the ecosystem outcome (Almirall et al. 2014; Konietzko et al. 2020b).

In the case of the Circular Footwear Alliance, the tension between standards and variety showed itself in the variety of safety footwear that was sent back and the challenges in ensuring an effective sorting and separation process for recycling. To ensure standards, the Alliance asked its partners to incorporate more circular product design principles in the shoes they manufacture to facilitate recovery. Similarly, the collaboration with the recycling companies required experimentation to find an effective and efficient processing of the old shoes into new raw materials, which led to new intellectual property on the recovery of shoes, which is shared with new entrants to ensure the scalability of the ecosystem.

In the case of Clean Water, a governance model was essential to steer and coordinate the collaborative efforts of all the partners involved. The governance model was initially sketched in the grant agreement between consortium partners and the funder, namely the European Commission. In this document, roles and responsibilities of the partners were clearly defined, specifying that the leading European University would orchestrate the collaboration. To this end, the university appointed an executive project coordinator, who was eventually flanked by a technical and scientific project committee meeting on a monthly basis. Furthermore, an external board of advisors was also established. This was essential to keep track of progress, ensure coherence across intra-firm activities performed by the partners and solve related challenges.

4.4.5 Develop Fair Value Capture Mechanisms

Another set of activities relates to developing fair value capture mechanisms to incentivize actors to engage and to stay engaged (Brown et al. 2021b; Den Ouden 2012; Williamson and De Meyer 2012). This is important for a healthy and a sustainable ecosystem. How much value is captured by whom depends on the negotiation and on the power and influence of the ecosystem leader, as well as the abilities of different actors to differentiate their value capture opportunities (Lavie 2006; Ritala and Hurmelinna-Laukkanen 2009). A benevolent leader will ensure fair value capture, a dominating one will try and vertically and horizontally integrate to capture most of the created value, which may compromise the longer-term health and sustainability of the ecosystem (Dedehayir et al. 2018).

An effective governance model ensures that actors have clear incentives to join, and can answer the question of "*what is in it for me?*" for each participating actor (see also Ritala and Hurmelinna-Laukkanen 2009). Ideally, this includes short-term gains that keep actors engaged and long-term benefits, for example in terms of recurring revenue streams enabled by the participation in the ecosystem (Ritala et al. 2013). Depending on the needs of the actors, this can be made explicit through formal contracts and intellectual property models, or it can be negotiated more informally and based on mutual trust (Holgersson et al. 2018; Leten et al. 2013).

The participating recycling companies in the Circular Footwear Alliance capture value through the viable recovery of materials that can then be sold on to other suppliers. Other participating stakeholders who send in old safety footwear capture value by showcasing the carbon emission reductions on their website through a dashboard that the Circular Footwear Alliance provides. They also benefit from the developed knowledge around the recovery of the shoes, which can be used to improve the circular product design and technology of their shoes. Overall, in this case, the whole ecosystem can increase its value capture opportunities via the increased legitimacy in the eyes of the external participants (Thomas and Ritala 2022), providing more transparency in terms of circularity, and resulting benefits in consumer trust, brand recognition, and stakeholder perceptions.

Value capture, in the case of Clean Water, represented a challenging aspect, considering the large number of partners involved, their different typology, size, and core business, naturally resulting in disparate innovation goals and approaches. In principle, the idea was to allow the supplier of demineralized water to capture value through a more energy-efficient solution for its wastewater treatment process, which would also provide additional value by recovering some minerals to be reused within the process itself. Those minerals that could not be reused internally would allow another firm to capture value through their sale on the market. Finally, technology suppliers would capture value by being able to sell their solutions through Clean Water, while research institutions would benefit through the production of scientific knowledge. To test whether all of this would be technically feasible and financially viable, a large-scale demonstration was conducted in the European Port. Results evidenced the need for further development, strengthening the business case, before being able to capture monetary value while operating commercially at full scale.

4.4.6 Keep Track of Environmental and Social Impacts

To track progress toward the circular economy vision of the ecosystem, it is important to keep track of both environmental and social impacts (Baldassarre et al. 2019; Manninen et al. 2018). The circular economy has often been criticized for ignoring the social side of sustainability (Schröder et al. 2020). Impacts on workers, human rights, and product responsibility, for example, should be considered in the context of a circular economy, to prevent negative social externalities (Padilla-Rivera et al. 2021).

In the case of the Circular Footwear Alliance, a dashboard was created that shows the number of collected pairs of shoes, the weight of the total material, the carbon emission reductions, and the number of participating actors.

In the case of Clean Water, for example, the environmental impact was analyzed using life cycle assessment (LCA). As part of this method, several environmental indicators (e.g., CO_2 emissions, freshwater eutrophication) were selected and used to quantitatively measure the impact of implementing the wastewater and resource recovery technologies, in comparison to a baseline scenario in which the technologies would not be implemented.

To prevent rebound effects – when good intentions for environmental impact reductions lead to a net increase in impact – the value proposition might have to be reconsidered and adjusted along the way to ensure optimal environmental outcomes (Bocken et al. 2019). The cases in our chapter exemplify that circular economy innovation also tends to exclude social impacts in practice.

In general, newly emerging innovation ecosystems for circularity should aim for positive value and impact across the social, environmental, and economic dimensions. Recent developments on company pledges for net positive outcomes on sustainability — like storing more carbon than is emitted or replenishing more water than is consumed — go in the right direction, to aim high and motivate an emerging ecosystem to join ambitious efforts. It is imperative that newly founded ecosystems aim at net positive impact, rather than just aiming at creating something that is less bad. Making such aims concrete is essential, which highlights the importance of assessing, measuring, and reporting impacts.

4.5 Discussion and Conclusion

Ecosystem-level innovation is perhaps the most complex of the different types of circular economy innovations (material, product, business model, etc.), involving different actors, high circular economy ambitions, and potentially complex governance models as a result (Konietzko et al. 2020b; Aarikka-Stenroos et al. 2021). It is therefore unsurprising that, despite many successful industrial symbiosis networks that we have witnessed in practice, our understanding of circular ecosystems and their innovation potential is still in its infancy.

This paper has contributed to nascent research on circular ecosystem innovation by conceptualizing – based on Ron Adner's work on innovation ecosystems (Adner 2012) – a framework for a Minimum Viable Ecosystem for Circularity (MVEC). This framework is based on literature and three emerging circular ecosystem cases. The framework boasts 6 core steps with a typical sequence: (1) Put forward a circular economy vision, (2) Design an ecosystem value proposition and outcome, (3) Develop an actor engagement strategy, (4) Develop a governance model, (5) Develop fair value capture mechanisms, and (6) Keep track of environmental and social impact. We expect these steps to capture the essential aspects required in setting up an ecosystem that aims at circularity as the ecosystem-level outcome, and at a viable business case for all involved actors.

Given the contextual heterogeneity of our cases and the inherent organizational complexity of ecosystems (Phillips and Ritala 2019), the steps in our framework should be treated as iterative and interconnected dimensions, rather than linear roadmap that is suited to all context as is. Therefore, several limitations and further research directions should be highlighted. First, by nature, the Minimum Viable Ecosystem for Circularity provides only high-level steps and guidance. More research is needed to understand the precise intricacies of each step. Second, the study is limited by three cases, which were all about the closing of resource flows. More research is needed to understand the types of ecosystems emerging that use and combine different circular strategies like narrowing, slowing, and regenerating resource flows. We suspect that organizations will often engage in several circular ecosystems that cater to different aspects of the business and that cover different life-cycle trajectories for products, components, and materials.

More research is also needed to investigate the growth and successful scaling of circular ecosystems, similar to former research on industrial symbiosis networks (Boons et al. 2017). Third and finally, there is ample opportunity for inter and transdisciplinary research, to learn from adjacent fields like "circular cities", circular economy policy, but also engaged research with circular economy innovators. Another interesting avenue is to further investigate the relationship between the literature on ecosystems from strategic management and the literature on transitions (Quist et al. 2011). This chapter purposely did not include this stream of literature, because transition theory is mostly directed at policy and civil society, and therefore provides limited guidance for business. Nonetheless, the multi-level perspective, which forms part of transition theory, is crucial to understand the external viability of emerging circular ecosystems (Walrave et al. 2018).

With this chapter, we contribute guidance for innovators that want to tackle systemic problems like waste, greenhouse gas emissions, and pollution. Next to material, product, and business model innovation, the Minimum Viable Ecosystem for Circularity provides guidance for the broader, inter-organizational dynamics that need to be addressed to move toward successful systemic change.

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Chapter 5

Organizational Practices, Values, and Mindsets as a Basis for Circular Economy Transition

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Abstract The circular business environment is complex. Incorporating circular economy (CE) requires changes in organizational culture while relying on innovative organizational practices. These practices, by significantly influencing the business' performance, can provide guidelines for implementing CE principles. Organizational values, for example, influence innovation and performance while seeking the alignment of the values shared among leaders, employees, suppliers, partners, consumers/users, and society. Furthermore, behaviors and mindsets dictate a positive predisposition toward CE offerings, determining, for instance, consumers' acceptance and adoption of circular products or services. Hence, the organizational need is urgent to evaluate its adherence to these innovations brought by CE to improve their performance, prevent obstacles, and overcome barriers. This can be achieved by combining circular practices, values, and mindsets and associating them to maturity levels, which is supported by a systematic and collaborative view, considering the whole business ecosystem, which allows the increase of responsiveness, flexibility, and resilience in the organization. Therefore, this chapter

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aims to propose a pathway based on a circular business system perspective to support the organizational transition journey toward CE, associating, at maturity levels, practices related to circular ecosystems, human and organizational competencies, circular business models, resources and their flows, and support activities, also considering the relevance of organizational culture change and consumer mindset.

Keywords Circular economy · Circular business model · Organizational practices · Change management · Organizational values · Consumer behavior · Performance indicators · Business ecosystem

5.1 Starting the Pathway Toward a Circular Business System

The transition toward the circular economy (CE) goes beyond transforming an organization itself; it represents a transition in society with a socio-ecological approach. This transformation needs structural changes in multi-level dimensions, including technology, business, economy, culture, and society. Therefore, it requires the current system to change its cultural and normative values for radical innovations (Geels 2012), and drives change to a circular view at a landscape level, through investments, technologies, and collaboration of all stakeholders (including those who do not carry out specific activities in an organization's core business, but who are affected positively or negatively by it) (Bertassini et al. 2021a).

The transition toward a CE presents a collective purpose and requires multi-level transition approaches, in which non-linear processes are determined by niches (focal and radical innovations) that influence socio-technical regimes (practices and rules that structure existing systems) and exogenous socio-technical landscapes (Geels 2004). Therefore, issues related to CE and sustainability, such as the regenerative flow of materials, the co-creation of values, and the generation of social and environmental benefits involve socio-technical worldwide changes.

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These changes require emerging technological innovations, changes in values, and knowledge that create new behavioral patterns and cause systemic changes with a common purpose. Collective joint causes, collaboration, and integrative actions have defined organizational roles, conflict, and competition management to drive the transition toward CE and sustainability (Farla et al. 2012).

From the perspective of organizations, a transition toward a sustainable CE, according to the socio-technical perspective, implies the need for transformations in sectors with large inertia to change, such as manufacturing, food, energy, and transportation (Geels 2011). In other words, a CE transition is complex and systemic and depends on the transformation of many stakeholders and their respective ecosystems.

Conceptually, ecosystems are the alignment structure of a multilateral set of partners that need to interact for a focal value proposition to materialize (Adner 2017), in which interdependent actors play complementary roles (Aarikka-Stenroos et al. 2021). They are characterized as: actors' heterogeneity as they are not limited by national barriers and can embrace public and private companies, as well as for-profit organizations and NGOs; actors' interdependence for materializing the collective and systemic output, which could not be delivered by an actor individually; and organic governance, based on more informal and dynamic relationships instead contractual and strict ones (Thomas and Autio 2020).

Organizations and stakeholders can play a few roles in an ecosystem, depending on its strategic position and their complementary role to generate the collective output. Some roles as niche players work in technological issues, narrowing expertise by leveraging complementary resources from other actors. They are responsible for most of the innovation in the collective output and work in the keystone shadow (Iansiti and Levien 2004). In turn, organizations with the keystone role, also named orchestrators, are at the center of the network or ecosystem. They are responsible for the health and productivity of the ecosystem. They orchestrate the network according to the collective output and collective value proposition, enhancing technological innovation and stimulating reliable behavior within the actors. By doing that, keystones not only pursue a thriving ecosystem but also guarantee their prosperity (Iansiti and Levien 2004).

In a circular ecosystem, keystones are crucial for maintaining circular values and principles, addressing collective value creation, retaining relationships within actors, and prioritizing transparency and collaborative links through the ecosystem. In contrast, niche players can innovate on cleaner inputs, regenerative flows, and circular business models. Thus, the circular ecosystem perspective brings relevant innovation related to orchestrating ecosystem value proposition and configuration (Gomes et al. 2023), especially with high diversity, the long-term value proposition for positive impact to all. Thus, understanding how the stakeholders in an organization behave is essential to implement and maintain CE, as it is possible to adjust organizational practices to satisfy stakeholders' needs and expectations while sustainability is reached.

Ecosystems can adopt the CE or even emerge circular by creating a shared, system-level goal related to long value for all from circular business models (CBMs) (Aarikka-Stenroos et al. 2021). Usually, CE solutions are implemented by thinking or rethinking organizations' BMs in order to capture circular values that can be distributed to a variety of stakeholders (Bertassini et al. 2021a) in their business ecosystems, positively impacting all actors considering a long-term perspective. Thus, the ecosystem view can stimulate and drive changes in CBMs, enabling the creation of relationships and social, economic, and environmental benefits for stakeholders that are the pillars for value proposition, value creation, value delivery, and value capture (Bocken et al. 2018).

Companies with CBMs are internal vectors in the organizational society that force change from unilateral and linear production patterns to an innovative and sustainable way of planning production (Schaltegger et al. 2016). However, for the socio-technical regime to be influenced and the mainstream to be modified, CE innovations (niches) that establish circular practices are needed. Specifically, the effects of maintaining new circular niches in the environment are determined by some conditions, as when consumption modes, consumer behavior, and some usual practices are modified, different action patterns are spread and old practices at the consumer level are eliminated (Jurgilevich et al. 2016).

Innovations toward CBM are implemented through Organizational Practices (OPs), which represent the typical procedures adopted by members of an organization (Verbeke 2000). The OPs are learned through socialization in the work environment and are rooted in individual and organizational values (Karahanna et al. 2005). In turn, the OPs and the organizational and individual values are shaped by the organizational culture (OC).

Culture provides stability to the organization, and it is the force that keeps leaders stuck in the old ways of conducting business or drives them for change (Napier et al. 2020), ensuring the success of the organization and its business ecosystem. Companies that join successful ecosystems do not hesitate to look for new partnerships that bring resources and capabilities, they have a well-designed alignment framework that reflects the agreements between ecosystem partners (Frishammar and Parida 2021), and are able to scale their business quickly.

In addition, consumers and users are driving forces to promote and magnify circular initiatives (Geng et al. 2019) and to promote changes in consumption behaviors. Consumer circular mindsets, as individual predispositions to behave circularly, can guarantee, for example, the perception of value to be captured across a product chain (Zacho et al. 2018) and even the involvement of consumers in sharing-based BMs (Barbu et al. 2018).

Despite what has been exposed so far, there is still a gap of pathways and references that summarize these contents in order to guide organizations in the process of CE transition and in the implementation of CE principles, in which the use of maturity levels is an alternative to help in this journey. In this context, circular maturity levels indicate whether an organization, its units, and/or business models have the main characteristics and resources (values, practices, mindsets) to achieve a mature circular business operation.

Scholars have developed maturity models with a focus on specific sectors and circularity at the organizational level (Pigosso and McAloonen 2021), mainly at the operational level (Sacco et al. 2021). However, there are gaps at a strategic level, resource management, and related to the influence of internal structure on external structure. Some advances such as those made by Uhrenholte et al. (2022) explore at a strategic level the assessment of circularity following more systemic dimensions considering value creation, governance, people and skills, supply chain and partnership, operations and technology, and product and material as building blocks.

This chapter enhances the strategic level contribution on CE, as it includes a pathway suggestion besides the circular economy maturity level analysis. Also, it includes the cultural dimension and is based on Circular Business Models from an ecosystem perspective. This research, therefore, aims to answer the following question: "How circular economy practices, values, and mindsets can guide companies transitioning to a circular economy based on circular business models from an ecosystem perspective?"

Thus, this chapter proposes a pathway based on a circular business system perspective to support the organizational transition toward the CE. This research intends to contribute to the field of circular economy transition by considering circular business model innovation and maturity levels from an interdisciplinary and ecosystem lens. The pathway presented takes into consideration the organizational aspects concerning the CE transition (e.g., values and mindset) and the firm's efforts toward the development of competencies, the establishment of partnerships, the creation of value, and the optimization of resource use, among others. Therefore, it presents a theoretical contribution of a systematized framework for a CE transition, as well as a practical guideline to improve the maturity of companies in their ecosystem.

5.1.1 The Organizational Journey

The steps for a CE transition can be translated into a circular roadmap. This roadmap could be an effective tool for organizations to understand more clearly the steps and activities that can lead to a circular transition, that is, to provide a strategic and detailed plan on how to become a mature circular organization considering the whole business ecosystem in which the company is involved (Fig. 5.1).

Based on the experts' experience, it is suggested that a roadmap for an organizational transition to a CE should consist of six cyclical main phases, including an objective, inputs (information needed to achieve the objective), and outputs (outcomes of each phase). Through these inputs and outputs, goal-oriented activities, their respective tasks (detailing what should be done) and appropriate tools to support the development of each activity can be proposed, making the roadmap more robust and suited to the reality of each organization.

The main phases of the roadmap and its objectives for a CE transition are: "Diagnosis" which aims to map the current organizational context and define the scope of the roadmap (i.e., delimit the BM and the maturity level of the circular practices); "Awakening and Identifying Opportunities" aiming to identify opportunities based on the analysis of the diagnosis and understanding the concepts and importance of the CE for the organization and its stakeholders, as well as seeking

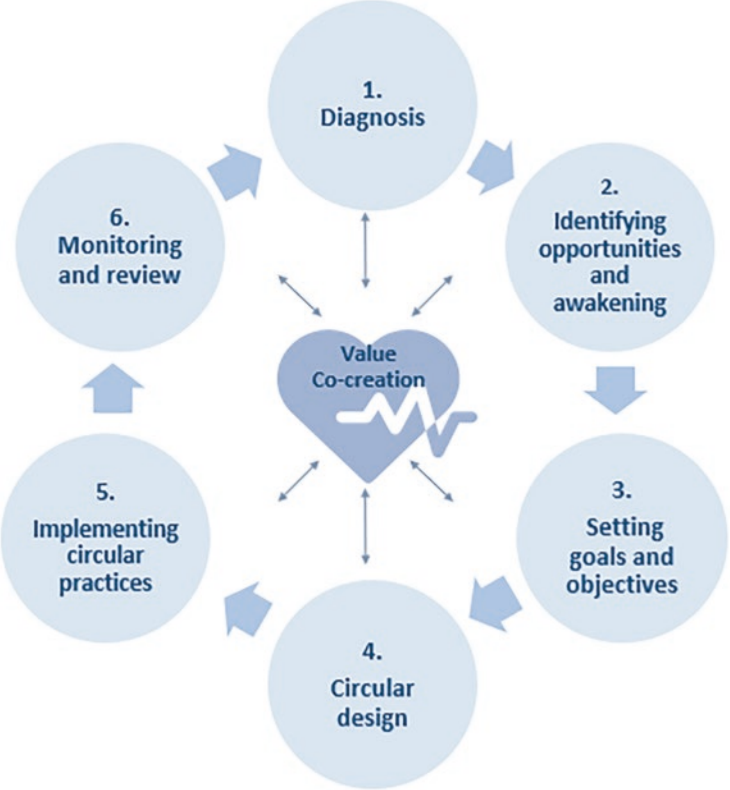

Fig. 5.1 Walking the journey: roadmap for an organizational transition to a CE in the context of circular business ecosystems. (Source: Authors)

alignment between opportunities and business strategy (general guidelines); "Setting Goals and Objectives" related to the definition, based on the opportunities raised, of direction, boundaries, business units, and (measurable) indicators aligned with the organization's goals; "CBM Design" which aims to plan the implementation, monitoring, and review of circular business practices (taking into account the strategic, tactical and operational aspects of the BM transition process), establishing the necessary course of action to achieve the organization's objectives; "Implementing Circular Practices" referring to the implementation and building of the necessary capabilities for the development of circular business practices and models, managing resources, orchestrating stakeholders and managing changes, if they occur; and "Monitoring and Review" in order to monitor and measure performance of what is being implemented, review and adjust what is not working, reinforce good practices and expand circular practices for the next cycle. There is also a "Checking" phase, which is an iterative and transversal process for analyzing and reviewing the adherence of the results of the activities (carried out at each phase) to their respective objectives, making, if necessary, incremental adjustments.

Finally, it can be said that the roadmap points out a way to implement a CE, through circular practices supported by the development of organizational and user values and mindsets, which the authors of this chapter understand as the foundation for long-term circular changes that will bring positive impacts to all actors in the circular ecosystem.

5.2 Organizational Values and Organizational/Consumer Mindsets: Enablers for a Circular Economy Transition

Sustainable circular innovations applied to products/services, processes, BMs, supply chains, and ecosystems and the implementation of new technologies are considered essential for the transition toward CE. However, cultural and behavioral aspects must be directed toward a sustainable CE, so that organizations have the necessary support to propose such innovation in a way that is lasting and actually transmits CE concepts.

The OC determines, through beliefs, values, and norms, how companies do business which is essential to support changes toward CE. These changes should occur at the individual, organizational, and societal levels, considering the interrelationships between individuals and systems. Thus, an OC oriented toward CE should be able to influence the behavior of consumers and other stakeholders, and organizational values, as the "heart of the culture of an organization" (Posner 2010, p. 536), are the basis for integrating essential performance and operational requirements into a results-oriented structure (Lagrosen and Lagrosen 2019).

Organizations that are more innovative cultivate values that motivate and inspire individuals to face challenges, seek new opportunities, and take risks in unknown environments and scenarios, such as ambition, creativity, agility, proactivity, flexibility, and audacity. Organizations seeking to implement CE should nurture, share, and communicate to its entire ecosystem a set of values that fit with their circular orientation. Examples of circular organizational values are system thinking, effectiveness, long-term thinking, and value creation (Barboza et al. 2020).

Organizational values for the CE transition need to be able to develop a specific awareness involving socio-environmental responsibility shared among all stakeholders, inspiring good practices, behaviors, and mindsets. The alignment of organizational values across the entire ecosystem can enable the trajectory toward the CE, generating positive impacts for the ecosystem (Bertassini et al. 2021a) by influencing circular mindsets. Culture and values are built through time and they can have the subtle power to make the entire ecosystem rethink their role in sustainable development. Combined with the organizational values, organizational and consumer mindsets are essential to promote a sustainable CE.

Mindsets, combined with organizational values, translate aspects that shape the organizational identity and behavioral characteristics (Bertassini et al. 2021b). Mindsets are "people's lay beliefs about the nature of human attributes" (Dweck

2012, p. 625) and they can be fixed or growth. A growth mindset encourages curiosity and risk-taking attitudes, while a fixed mindset focuses on continuing through the traditional and known path. Mindsets are the assumptions we hold about the way the world is, are things we take for granted, and are often invisible and difficult to change (Bertassini et al. 2021b). When aligned with circular organizational values, mindsets can determine how the organization will interpret and respond to situations during the transition journey toward CE (Bertassini et al. 2021b).

Circular organizational mindsets reinforce the need to inform stakeholders about the need for a more sustainable world and their role in contributing to achieve this. Circular mindsets enable the change of behaviors to implement strategies and business goals with focus on the future seeking to achieve multi-dimensional prosperity in environmental, social, and economic terms (Velenturf and Purnell 2021). In addition, circular-oriented mindsets are needed to move away from producer-driven consumerism toward a system-of-provision that enables responsible consumption, demand-driven resource use, and experience-based consumption.

Developing new values and mindsets that foster CE implementation requires a high level of managerial commitment to enable managers to spread the circular culture to the whole organization (Centobelli et al. 2020; Moktadir et al. 2020; Sharma et al. 2020). Implementing a CE-oriented culture is a task in which managers must provide their employees with the values, standards, and principles that govern the organization (Bertassini et al. 2021b). This implementation of CE-oriented culture can be boosted by developing mindsets according to which circular blocks an organization wishes to mature.

However, the success of a CE-oriented culture depends on the likelihood of consumers and users behaving according to CE goals (Daae et al. 2018). Consumers and users are key elements of the CE and act, across the circular model, in different functions, by purchasing, using, maintaining, repairing (etc.) products and components. Moreover, what shapes and guides consumer circular behavior? The mindset, as the positioning from which individuals act and express themselves (Dweck 2017), can be extrapolated in a consumer/user circular context as the predisposition that the consumer or user has when engaging circular products or services. In other words, their involvement with circular offerings and their value perception of these products/services. Consumer circular mindsets express psychological motivators to perform circular behaviors (Calvo-Porral and Levy-Mangin 2020; Russo et al. 2019), they envision, through these circular behaviors, benefits for the environment, economy, and society (Muranko et al. 2018), they are disruptive, offering new ways to consume and use resources (D'Agostin et al. 2020), and they are based on CBMs, that is, they depend on the value proposition, creation, delivery, and capture. A circular consumer/user mindset can emerge from the awareness of the ineffectiveness and burdens of the production and consumption models of the current linear economy, expressing a desire to solve environmental and social problems, or even the alignment between personal values, such as biospheric and altruistic, and the CE principles. Either way, mindsets provide a bottom line to perceive the processes of consumer behavior change.

As the organizational mindsets, the promotion of consumer circular mindsets can support the implementation of a CE-oriented culture, while encouraging current and potential clients to adopt products and services offered through the CE model (Box 5.1).

Box 5.1: Circular Mindsets in the Apparel Industry

The apparel industry is responsible for several negative environmental and social impacts, especially when associated with fast-fashion practices. Changes in this sector, such as the transition to a CE, must be disruptive to achieve a genuine transformation. This transition encompasses more than the adoption of a closed-loop system, it relies on the implementation and promotion of circular organizational and consumer mindsets.

A European denim brand has been expanding the frontiers of the circular apparel industry by developing strong organizational mindsets. This brand is aware and concerned about the impacts of the textile sector, which is communicated internally and among their stakeholders, and they take responsibility for their role in this system. Moreover, the brand embraces challenges and innovation, and by adopting a circular business model, they involve their suppliers, consumers, and other stakeholders in a new circular ecosystem. Their clients are also instigated to develop new mindsets. By promoting the leasing of daily garment items, such as pairs of jeans, this brand encourages valuing access instead of ownership and favoring leasing options. Furthermore, by reducing the input of virgin materials, this denim brand promotes the acceptance and use of recycled and remanufactured clothing and the participation in take-back systems.

The literature of socio-technical transitions, ecosystems, business models, organizational culture, and consumer behavior brings the most important aspects that are related to the transition toward CE. Based on an in-depth study of that literature, the authors of this chapter have proposed five spheres of analysis, called “blocks”, that are enabled by mindsets and comprise practices that should be put under organizations’ attention to advance in their journey toward CE.

These five blocks represent focal points that are relevant for a circular transition and business operation, namely: People and competencies, Ecosystem, Business model, Flow of resources, and Support. First, the “People and competencies” block represents the practices and mindsets that nurture the development and implementation of capabilities and competencies related to human resources, culture, and values. “Ecosystem” brings the practices and mindsets related to the construction and management of the stakeholder relationships and the co-creation of value. The “Business model” block is about the practices and mindsets that have influence on the creation, capture, and delivery of circular values. The “Flow of resources” block shows the practices and mindsets that encourage diversity and the optimization of the use of resources. Moreover, the last block, “Support” presents the practices and

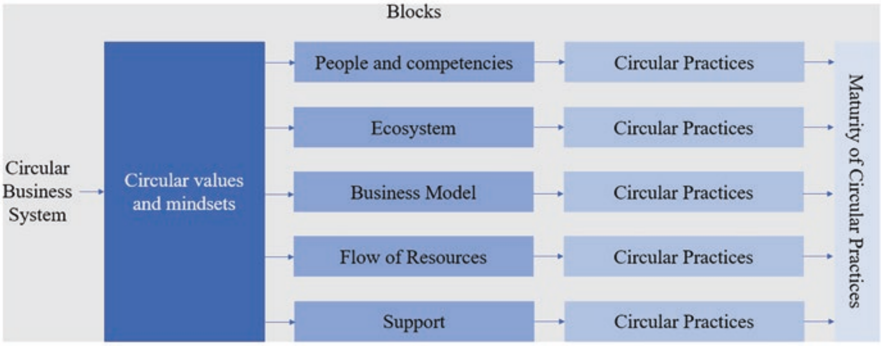

Fig. 5.2 Proposing a pathway to a circular transition: diagnosis. (Source: Authors)

mindsets that indirectly guide the implementation of the practices and mindsets present in the other four blocks.

The "People and competencies" block is directly related to the components of the CBM proposed by Lewandowski (2016): key partners, value proposition, relationship with the consumer, and factors related to intangible resources, because to design these components, the organization must interact intensely with people, for example, customers, employees, suppliers, etc. The CBM is part of an ecosystem; thus, all its components are related to this block. The "Flow of resources" is directly related to the channel components and take-back system, as they define the purchase, distribution, and return routes of resources. Furthermore, the "Support" block is directly related to the component referring to intangible resources, as the values and culture of the organization that will support the implementation and maintenance of a CBM.

These blocks are enabled by circular values and mindsets (presented in this section), encompass circular practices (see Sect. 5.3), which can be classified into maturity levels (see Sect. 5.4). By aligning and combining these concepts (Fig. 5.2), organizations that wish to start or continue their journey toward a circular economy can be diagnosed, that is, the first step of our cyclical roadmap. Thus, this chapter will present in depth the elements involved in the "Diagnosis" step of the proposed roadmap.

5.3 Circular Organizational Practices

When an organization implements the CE principles, it has the opportunity to rethink how they do business and embrace new business opportunities, not only internally but also across the value chain (BSI 2017). Depending on the position of an organization in the value chain, the opportunities of implementing CE principles are different, as well as the principles that better fit the business context.

The CE principles, at an organizational level, consist of a set of practices, some essentially circular, others not necessarily; some exclusive to a single principle, others shared. The fact is that there is no preset rule on which practices might be implemented to adopt specific principles, so mapping and understanding what works better for the organization and its ecosystem is a key factor for a circular transition.

Regarding the definition of "practices", Reckwitz (2002) describes them as routinized behaviors formed by interconnected elements – such as know-how and motivational knowledge, among others. However, there is no common definition for this term, and generally each author has their own use for it, which makes progress in this field hard to conquer.

Practices can be an umbrella term for different praxeology approaches, and some of them take the day-by-day use, considering practice as an activity or a behavior (Schulz et al. 2019) and they have the function of changing structural forms, whether by transforming, constituting or reproducing networks, markets, and production systems, among others (Jones and Murphy 2011). Therefore, practices go beyond an individual or an organization, they require collectivity, coexistence, and collaborations between all the related parts (Schulz et al. 2019). Collaborative practices also have the potential to cause fundamental changes (Schulz et al. 2019).

OPs, on the other hand, can be defined as the particular way to conduct an organizational function (Kostova 1999). They evolve over time, are influenced by the organization's culture, reflecting the knowledge and the competence of the organization, as well as varying on scope, formalization degree, content, and focus, reflecting the core competencies and values of the organization (Kostova 1999).

In this study, practices are defined as the usual way an organization performs certain activities, and also how the individuals behave considering the ecosystem they are part of. A practice is not determined only by the organization, nor by the individuals. The individuals are part of the organization, and the organization has its culture just as the individuals have their personal manners. But when both are connected in a common ecosystem, working together to achieve common goals, they will determine the practices adopted.

Considering the above, *Circular Organizational Practices (COPs) can be defined as the set of operational and management activities that contribute to implement one or more processes in multiple organizational areas, incorporating and/or employing CE principles*. The core circular practices are described in Table 5.1.

To facilitate the application and understanding of circular organizational practices, they can also be organized into the five circular blocks mentioned throughout this chapter.

"People and competencies" practices refer to organizations' soft skills on the value chain and external relations. These practices encourage the development and the implementation of human resources, culture, and values capabilities, and its relevance lies in the organization's needs in enhancing their values and practices based on CE's principles, internal and external ways, and spreading them to their stakeholders.

Table 5.1 Core circular practices, its definitions, and related blocks

Practices	Definition	Block
Assume a commitment	The organization is committed to generating positive long-term impacts for all the ecosystem actors by implementing CE principles, such as value optimization, transparency, collaboration, systemic views, and innovation	People and competencies
Increase effectiveness	Increase the organization's capacity to generate social and economic benefits while respecting the ecological flows during all its production processes	Business model; Flow of resources
Assess resources availability	The organization identifies, analyzes, and evaluates the resources needed to deliver the proposed value, considering the actors, factors, and conditions that enable co-creation of circular value	Flow of resources
Collaborate with stakeholders	The organization collaborates with its stakeholders to co-create value, aligning expectations and efforts applied to materialize the value proposition and generate positive impacts for everyone involved	Ecosystem
Share	The organization shares experiences, assets, responsibilities, knowledge, and information with their partners, eliminating resource waste and encouraging strong and resilient learning and relationships	Ecosystem
Communicate	The organization establishes communication channels, and feedback analysis and flows seeking to co-create value with the ecosystem. Thus, stakeholders are able to understand the organization's circular values clearly.	People and competencies
Promote user awareness	Encourage conscious consumption by informing users about the environmental and social impacts, positive and negative, resulting from the use of the product/service offered	People and competencies
Use of circular design	Design processes, products, and services in a way that makes it possible to maintain resources and components at their highest level of value and usefulness	Flow of resources
Provide services and offer support services	Recognize business opportunities in offering the product's functionality and utility, and offer technical support, consulting, installation, maintenance, and other services to extend useful life of the product	Business model; Flow of resources
Engage the ecosystem actors	Engage ecosystem members to empower their roles and impacts on society, recognizing the struggle of social minorities and the plurality of the population	People and competencies

Establish circular partnerships	The organization prioritizes relationships with partners who share circular values, aiming at value co-creation based on CE principles	People and competencies; Business model; Ecosystem
Extend product life cycle	Manage the product life cycle, planning its design and manufacture, and actively monitoring the use and post-use phases together with stakeholders, so that the product has greater durability	Flow of resources
Manage stakeholders	The organization understands the ecosystem in which it is inserted, as well as the roles and responsibilities of the actors who interact directly or indirectly with the organization, managing and articulating the relationships of interested parties	People and competencies; Ecosystem
Implement material management	Develop actions aimed at the search for systemic and circular solutions considering the political, economic, environmental, cultural, and social dimensions suitable for waste management	Flow of resources
Implement reverse logistics	Implement activities and procedures that enable the recovery of resources for reuse within the product's life cycle or in other production cycles, contributing to the value chain	Flow of resources
Measure effectiveness	Monitor and measure the effectiveness of circular actions qualitatively and quantitatively, based on the creation of economic, social, and environmental benefits	Support
Innovate	The organization is constantly innovating its business model, intending to create, deliver, capture, and regenerate circular values	Business model
Prioritize regenerative production systems	The organization uses circular inputs and plans and develops regenerative processes that aim to preserve ecological diversity and the health of the environment and human beings	Business model
Realize upgrade/update/upcycling	Carry out actions on the product to update it to perform new functions, increasing the added value of materials, components or products and extending its useful life	Business model; Flow of resources
Regenerate	Enable natural resources regeneration after use by pre-selection of renewable materials (non-toxic and compatible) and by processing/recovery, use, and logistics processes that are suitable for the entire ecosystem	Flow of resources

(continued)

Table 5.1 (continued)

Practices	Definition	Block
Remanufacture	Remanufacture the product so that it recovers its function after the use phase through an industrial process of the manufacturer itself	Business model; Flow of resources
Rethink value chain	Redefine the value chain, from its conception to its return to the product cycle, with processes and activities based on CE principles	Business model
Return revenue	Create positive monetary impacts on the organization and share them with its stakeholders	Ecosystem
Reuse	Reuse products, resources, and supplies, keeping their use, quality, and value as long as possible	Flow of resources
Select circular resources	Use criteria consistent with the CE to select resources effectively and safely in their acquisition, prioritizing resources from circular sources (renewable, biodegradable, natural, non-toxic, returnable, etc.) that respect the standards of ecological flows and generate economic benefits and social	Business model; Flow of resources
Establish management systems and labeling programs related to circularity	Establish a management system and/or formal labeling program that have objectives and goals that demonstrate the differentiation of the characteristics of the organization, service, or product in relation to environmental awareness and circularity	Ecosystem; Support
Adopt long-term view	Implement and internalize the concept of longevity, systemic view, and future in the dynamics of the business model for the transformation of circular value	Business model
Adopt cascade use	Optimize resource use when returning products, parts, and materials to the value chain after their use, keeping their quality, value, and lifetime levels as high as possible	Flow of Resources
Use innovation and process optimization concepts for circular purposes	Internalize concepts and technologies available and applicable to the business focusing on innovation, improvement, and process optimization to circular purpose	Support

Source: Authors

COPs in the “Ecosystem” block refer to an organization’s relations with stakeholders and shared value creation. This block focuses on the organization’s ecosystemic scenario for collective and circular value creation and how it can operate and influence its stakeholders to adopt circular values and CE-based practices. These practices also embrace the situation of a keystone orchestrating an ecosystem with the CE principles at its core. As in “People and Competences”, “Ecosystem” practices demand transparency with their stakeholders to really develop products and innovate on the CE’s principles and influence their ecosystem to do so.

The “Business Model” block approaches practices that relate to the way organizations can implement CE’s principles in their business for value creation, capture, and delivery. These practices refer to the implementation of CE in the way the organization builds its business, especially by covering partnerships and supplies, thinking how developing CE’s principles in their business model can enhance value, innovation, and return internal and external benefits.

The “Flow of resources” practices relate to the product’s life cycle and its return to the supply chain. These practices seek to extend the valuable time of the products, delay products disposal, enable material regeneration and multiple reuses of resources, and attend other features in business models such as dematerialization and servitization.

The “Support” block does not closely relate to CE, but these practices can improve circular strategies or other practices already in action, in management and innovation areas.

Some practices can fit in more than one block. When this occurs, the practice should be analyzed according to the block’s context. Taking Select Circular Resources, for instance, we have to think about what it means when it is in the “Business model” block, about how the organization will create value on that, and what it means when it is in the Ecosystem block, about how to pursue these resources in the ecosystem.

On the whole, the listed practices below seek to enhance CE’s development on organizations and its stakeholders, and more often, CE’s effectiveness, not only decreasing negative impacts but also improving positive impacts, on economic, environmental, and social spheres.

Examples of circular organizational practices already implemented can be seen in the automobile industry (see Box 5.2).

Box 5.2: Circular Practices in the Automobile Industry

An example is implementing CE principles through diverse and complementary circular practices in the life cycle of their product. In vehicle design, there is a priority to replace virgin raw materials with recycling materials, in addition to the application of a circular design, which promotes the development of vehicles that are repairable, easy to dismantle, and with recyclable or recoverable materials. Within the company, there is also the reuse of parts from its end-of-life vehicles, reconditioning or remanufacturing of collected used parts, which come from a

(continued)

Box 5.2 (continued)

sales network, factories, or suppliers in a specific and affordable after-sales offer. The service for end-of-life vehicles is interesting for their customers when the vehicle repairs are not economically viable with new pieces. This process demonstrates an application of one of the CE principles mentioned above, the value optimization. The company creates a "short recycling loop" that brings recycled materials into compliance with automotive industry specifications. An example of this application is copper recycling, in which the wire is purchased from end-of-life vehicle disassemblers and the recovery process is carried out.

As part of promoting a more sustainable future for cars, the business group in question has a project to build a factory, creating an ecosystem favorable to the CE principles, including: complementary areas that include the reconditioning of vehicles for versions with lower carbon emissions and manufacture of rare parts by 3D printing; energy storage and management, which will seek to optimize battery life and the second life of used batteries; optimization of resources for recycling, with dismantling of end-of-life vehicles, remanufacturing of parts, reuse and recycling of materials; and, finally, an area that promotes innovation and knowledge sharing related to the CE (Renault Group 2017, 2021).

OPs reflect the knowledge and skills shared by the organization, being implemented and disseminated differently across organizations. Therefore, the implementation of several practices significantly influences the organization's performance, and the COPs provide guidelines to implement the principles of the CE in organizations.

As stated by Kostova (1999), organizational practices can be easily identified, and when this is possible, the change is already external to the organization. Generally, when the circular practices are visible to others, especially in the ecosystem in which the organization is embedded.

Change management is the process of guiding the organization through a transformation of values, strategy, or BM, that is, the change of the core (Prosci 2018). Its stages are dynamic and unfold in: identifying the change point (the sooner the better); disseminating the conception and preparing a clear plan about what and how will change; and finally, the resolution. Basically, it is to move from point A to point B, while the guidance process has to ensure the organization's resiliency. Identifying the change point is facilitated by organizational maturity. The higher it is, the easier it is to make a statement.

5.4 The CE Transition Pathway

Considering the changes in values, culture, mindsets, and practices (mentioned above) that organizations will have to face to go through a process of transition from a linear to a circular economy, it is possible to say that these companies will need a structured path to guide them and support this journey. Thus, in order to facilitate the determination of focal points to lead to a change that will carry the organization to a more solid and lasting result in the sphere of the circular economy, concepts and outputs related to maturity models can be used.

Maturity models (MM) are a measure used to assess an organization's resources, implying an evolutionary process that varies from an initial phase to the desired scenario (Reis et al. 2017). These models cover different levels of maturity that reflect the evolutionary path of a given area or process, which supports organizations to assess their current situation and determine the desired state, of better quality and effectiveness, based on the consideration of a series of predefined items (Marx et al. 2012). It also enables a better assessment of skills, the level of capacity, and the sophistication of associations (Liker and Morgan 2011). MM can be used for three main purposes: analyzing strengths and weaknesses (of a particular area or process of the organization), developing a roadmap for future improvements, and evaluating the company against the standards and best practices of other organizations (Pigosso et al. 2013).

In the CE transition, maturity levels can indicate if an organization or its business units have the key characteristics and resources to achieve a mature circular business operation. As a process, it is crucial to establish a group of strategic, tactical, and operational activities related to COPs to implement circular principles in the transition to a CE in the context of circular business ecosystems. Circular practices, in turn, can only be effectively implemented if the organizational values and mindsets are aligned with circular principles. Thus, change management has a fundamental role in this process, as each organization can be at different levels of circular maturity, which are evolutionary stages of the processes. In this sense, to respond to the latent organizational need to evaluate its adherence to the innovations brought by the CE to improve its performance, prevent obstacles, and overcome barriers, a tool to assess the circular maturity levels of organizations' practices is proposed. This tool is configured as an association of circular practices (mentioned in Table 5.1) with their corresponding maturity levels, based on stage models presented by Serrano and Pereira 2020.

Thus, the way in which the circular maturity levels were proposed allows organizations to identify if they present circular practices and which are their maturity levels. Moreover, this tool provides insights on the paths they should follow to increase their responsiveness, flexibility, and resilience in the context of transition to a CE.

At this point, it is important to emphasize that the aforementioned tool is being evaluated by companies and other specialists, so that it can be further improved based on their feedback. Therefore, what is presented here is part of a wider project that has the circular practices assessment tool as the core of a robust process, which aims to facilitate the organization's journey toward a CE.

Assessment of the maturity of organizational circular practices is divided into the five circular blocks presented earlier. These blocks group circular practices, which can be classified into five maturity levels, varying from fully immature (level 1), in which an organization still operates linearly, does not formulate strategies to enhance resource efficiency, and does not position itself as an active part of the environment and society, to fully mature (level 5), designing its business model as circular, taking advantage of nature-inspired strategies, and orchestrating its value chain and business ecosystem (see Table 5.2).

Table 5.2 Maturity levels for organizations' circular practices

Level		Description
1	Immature	The organization has a narrow understanding of its business model and does not formulate or engage with strategies that increase resource efficiency or activities that improve its performance toward a CE. The organization designs obsolescent products and aims only at minimizing costs and maximizing profits. The organization does not recognize its role as a social actor, nor map or identify the needs and expectations of its stakeholders; therefore, it does not implement activities that generate positive impacts to the surrounding community
2	Basic	The organization establishes strategies to use resources in the best way possible, however, it does not implement activities that enhance their production processes. The organization identifies and acknowledges business opportunities within the CE, however, does not engage in complex and systemic processes, such as take-back systems. The organization selects suppliers that prioritize non-toxic, biodegradable, and renewable materials, but does not yet exclude suppliers that do not fit these conditions if they offer better prices. The organization establishes partnerships with their stakeholders to share assets, inputs, information, and responsibilities, but still explores opportunities without taking into consideration value co-creation according to CE principles
3	Intermediary	The organization and its collaborators have full knowledge of CE, its principles, practices, and values. The organization rethinks its processes, projects, and products based on patterns inspired by nature, and offers support services to align its business models to the product life-cycle extension. The organization maps and establishes relationships with stakeholders that can help it transition to the CE
4	Advanced	The organization employs strategies that allow it to achieve resource-efficient processes and activities. The organization designs its products to use only circular resources, influences its value chain to rethink its products and services, implements circular practices from design to post-use phases, and incentivizes conscious consumption. The organization takes responsibility for the impacts of its products in the environmental, social, and economic spheres throughout the product's life cycle and multiple cycles after use. The organization collaborates with its stakeholders to reduce the use of natural resources, carrying out a complete assessment of the product's life cycle, and also implements waste and energy recovery measures, as well as reverse logistics processes
5	Mature	The organization clearly understands its circular business model and makes long-term growth projections, implementing, monitoring, and reviewing, through quantitative and qualitative indicators and assessments, the business model's components integration. The organization establishes nature-inspired strategies to increase effectiveness and maximize product value. The organization orchestrates its value chain, influencing its partners in the development of circular practices and value co-creation and co-capture. The organization is committed to generating positive long-term impacts for all actors in the ecosystem through the implementation of the circular principles and promotes shared responsibility among all actors throughout the product's life cycle. The organization maintains effective communication with all stakeholders and influences their practices and perceptions on practices and mindsets

Source: Authors

The assessment of the maturity of organizational circular practices can be carried out by any collaborator who has enough knowledge about the organization and its specificities. It is recommended that people from different organizational areas contribute to this, thus generating a robust profile of the organization. Furthermore, the determination of the respondents and the environment in which the assessment will take place relies on the organization's strategy. That is, the assessment can be done individually and then compiled to generate the organization's profile or, for example, during a workshop with simultaneous and collaborative involvement of key organizational actors.

The tool is simple and is based on a binary questionnaire with yes/no answers. Each respondent will have to evaluate if the question provided for each circular practice, related to each circular block context, is true or not for that organization. Each practice, in each circular block, is evaluated according to the five maturity levels, that is, when the respondent answers that their organization implements a circular practice as described in the questions, it will automatically open a new question concerning the same practice at a more mature level, until it reaches the last level (fully mature).

For example, the assessment of the circular practice "Establish circular partnerships" within the "People and competencies" block is based on questions about the organization's partnership with stakeholders, which starts by recognizing the need to share value, information, and risks (immature) to prioritizing partners who share circular values for value co-creation in the context of CE (mature). On the other hand, the assessment of the same circular practice within the "Ecosystem" block is focused on the prioritization, integration, and influence of the stakeholders on the values shared by the company in the context of its circular ecosystem.

Thus, each positive answer receives a score depending on whether organizational practices are immature, basic, intermediary, advanced, or mature for the CE, and if it is a negative answer, the organization does not score on that question. In the end, a sum of the assigned weights can be performed to assess the organization's circular practices maturity level. An example of mature organizational practices can be seen in the steel industry (see Box 5.3).

Box 5.3: Maturity of Organizational Practices in the Fertilizer Industry

The initial focus of a Canadian company was to handle pipes, pumps, and water treatment plants to other players in order to meet regulatory requirements. However, 5 years later, the company realized the potential of recovering nutrients (phosphorus, nitrogen, and magnesium) from wastewater and, in partnership with a local university, innovated its BM by developing new nutrient recovery technologies.

Nowadays, the company is a world leader in nutrient recovery and innovative crop nutrition solutions, (Ostara Nutrient Recovery Technologies Inc 2021) providing sewage treatment solutions for cities, farms, and industries through a customizable and modular system. The recovered nutrients are transformed into

(continued)

Box 5.3 (continued)

commercially viable agricultural fertilizers of superior quality than conventional ones, as they are released when the roots of growing plants secrete active acids, a sign that they need the nutrient. This creates a more effective system as it works on the demand from the crop and prevents nutrient loss.

Thus, by implementing COPs as “use innovation and process optimization concepts for circular purposes” and “collaborate with (new) stakeholders”, the company achieved a much more mature and circular BM, which puts their practices in an “advanced” maturity level (compared to the previous one which was just “immature”). To do so, they also used COPs as “prioritize regenerative production systems” in order to provide innovative circular products and services to a wider range of customers, “promote effective waste management” in collaboration with its stakeholders, as well as “adopt a long-term vision” being possible to co-create and share value in its ecosystem.

Finally, this case is also an example of upcycling (included in the COP “realize upgrade/update/upcycling”), which sees the potential of waste (in the case of effluents) as nutrients, making it possible to close the phosphorus cycle, purify water, regenerate the biosphere and increase agricultural yield.

Applying the proposed Framework, it is possible to have greater clarity to direct and prioritize the next steps of the CE transition, based on the organization’s goals, current circular practices, and maturity. Thus, the pathway that each organization will use to achieve its transition, as well as the other tools it will be necessary to enable a continuous and consistent evolution, will depend on its capability, viability, and strategic priorities.

5.5 Final Remarks

This chapter proposes guidelines to guide organizations in the transition to a CE based on the ecosystem view, the co-creation of values, the development of mindsets that support changes to circularity, the implementation of circular practices that will increase an organization’s circular maturity levels, and circular business models. Thus, we can conclude that the ecosystems approach and circular business model are crucial for transitions to circularity. The ecosystem perspective considers organizations and stakeholders as an aligned structure of the multilateral set of partners, which interact and create a focal value proposition with a system-level goal related to resource circularity, circular economy knowledge, or circular economy business. In addition, CBMs include circular values in strategic plans and operations and enable the implementation of all circular principles in practice.

Organizational values and organizational mindsets have an important role in the transition to a CE. They give support to organizations to develop their behavioral/

soft side in parallel with their technological side. Without the support of organizational values and mindsets, the circular technical innovations would not work in the long term. Thus, organizations may acquire technical knowledge to implement CE innovations, but may also develop circular organizational values and mindsets that support these technical innovations.

Circular consumer and user mindsets are also essential for a successful transition to CE. Consumers and users are important actors in the circular ecosystem, which enable the flow of products and services. Therefore, understanding their predispositions and behaviors concerning the acceptance of circular business models and adoption of circular products and services must be seen as a fundamental step in the design and implementation of circular businesses. Willing consumers/users, in addition to acquiring circular products/services, engage with maintenance services, repair activities, take-back systems, and other circular practices, realizing the value embedded in these circular organizational practices and individual behaviors.

Given this context, this chapter aims to bring together and point out paths for an organizational transition to a CE based on the ecosystem view. Figure 5.3 represents a conceptual framework about co-creation of values, development of mindsets that support changes to circularity, and implementation of circular practices. In this sense, the circular ecosystem brings relevant considerations related to the alignment of strategies between organizational groups, to the importance of diversity and

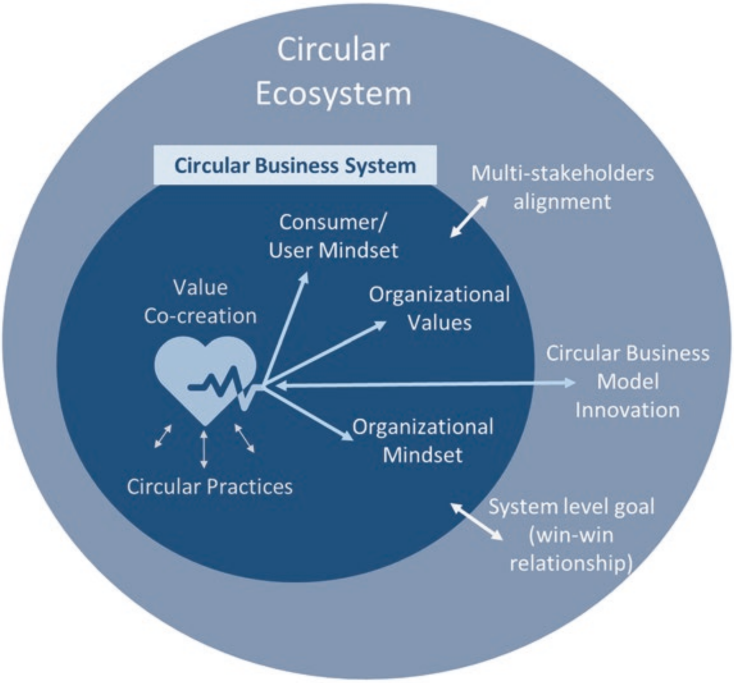

Fig. 5.3 Basis and correlation between a CBM and the circular ecosystem. (Source: Authors)

complementarity in a value proposition, being able to establish circular practices in mainstreams, modify consumption modes, consumer behavior and values, and create new products with high relevance to the market. In turn, the implementation of a CBM should be based on the ecosystem view, on the co-creation of values, on the development of mindsets that support changes to circularity, and on the implementation of circular practices.

In conclusion, the co-creation of circular values with multiple stakeholders that generate positive long-term impacts, the adoption of systemic effectiveness, the development of circular organizational and consumption mindsets, and the implementation of circular practices are the paths pointed for an effective organizational transition to a circular economy. This roadmap brings not only eco-efficiency which means increased value with reduced use of resources and environmental impacts, but mainly eco-effectiveness based on systems thinking and positive impacts.

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Chapter 6
From Socio-technical Innovations to Ecological Transitions: A Multilevel Perspective on Circular Economy

Ken Webster and Stefano Pascucci

Abstract This chapter promotes pluralism in the discussion of a circular economy, contrasting existing use and innovations with a systems perspective. The authors argue that the strength of a circular economy lies in changing perspectives on production, consumption, and exchange, enabling a participative economy based on capital management. It aims to resolve the tension between the circular economy as a 'toolbox' and a 'framework for thinking', subsuming the former under the latter. Evidence suggests that a circular economy offers three key insights: gathering principles from other schools of thought to inspire policy actions, evoking a socio-technical transition into multiple regimes, and contributing to environmental and economic sustainability through eco-effectiveness. The EU supports this through its Circular Economy Action Plan as part of the European Green Deal. The chapter emphasizes the deeper idea of using insights from living systems to design eco-effective systems, reflecting the perspectives of original circular economy writers. Implementing eco-effective approaches may be challenging due to the current linear system's lock-in. The concept of eco-effectiveness shifts thinking towards positive footprints and rebuilding capitals, encouraging an ecological transition. However, this approach is still little discussed scientifically. The lack of economic discussion may stem from the existing economic system's focus on creating and maintaining scarcity for economic rents. Moving towards eco-effectiveness requires a policy shift that engages participatory stakeholders. In conclusion, the circular economy is practical and engaging as a heuristic, but it also carries the potential for a new

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economy based upon feedback-rich complex systems. This aligns with the complexities of real-world systems, necessitating a focus on enduring participatory systems and expanding all capitals as solutions accessible to the majority.

Keywords Circular economy · Ecological transitions · Multilevel perspective · Eco-effective

6.1 Introduction

> *Circular Economy has to be seen as an instrument for delivering decoupling of economic growth from resource use and environmental impacts and as a part of the bigger economic picture of economic, societal, and cultural transformation needed to deliver Sustainable Development Goals*. (Janez Potocnik, co-director at SYSTEMIQ)

This chapter is a position paper designed to promote pluralism in the discussion of a circular economy (CE). It contrasts the existing use of the term and associated socio-technical innovations with the greater depth and significance which comes from drawing on a neglected systems perspective present in many original writings. The authors argue that the strength of a circular economy lies ultimately in the unfoldment of these insights into a coherent framework for an economy which a) changes perspectives on production, consumption, and exchange to enable a more participative economy at all scales and b) to one based on capitals management rather than throughput. The chapter illuminates the main contours of this broader but more intellectually satisfying context and the prospect~~s~~ for the future of a circular economy. It might possibly resolve the essential tension between the CE as a ‘toolbox’ and as a ‘framework for thinking’ by subsuming the former under the latter (Alexander et al. 2023).

We begin with the evidence that currently a circular economy offers three key insights: first, to understand CE as gathering principles of other schools of thought and elaborating them in a narrative able to inspire policy actions (Borrello et al. 2020a). Second, interpreting CE as field of practices evoking a socio-technical transition into multiple regimes in which societal and material needs are fulfilled by innovative industrial systems (Alexander et al. 2023). Finally, looking at CE as a contribution to the environmental and economic dimensions of sustainability by means of an eco-effectiveness approach to industrial systems. In sum, it is essentially a heuristic around an ecomodernist agenda – the aspiration for jobs and growth which tries to decouple resources to a greater or lesser degree. A CE is addressed to policymakers and to business, primarily – as long-time advocate Prof Walter Stahel has claimed – as *an economic opportunity driven by innovation* (Stahel 2019), although primarily in the global North. A vivid example of this view is given by the EU support to a CE agenda through its latest Circular Economy Action Plan (CEAP) issued in March 2020, as part of its European Green Deal (EGD). The CEAP looks at CE mostly from a materials flows perspective, given that materials are also a large part of an expanding EU agenda around climate change. These, we suggest, comprise some of the targets that engage 'toolbox' elements, e.g. the business models, materials innovation, and waste management/recovery techniques, within mainstream business and economic frameworks (Dzhengiz et al. 2023).

Even so, significant 'resonance' exists around the deeper idea of using insights from living systems to design eco-effective systems and create, in effect, a 'nutrient economy'. Although long exemplified by the likes of McDonough and Braungart's 'cradle-to-cradle' initiatives (Braungart and McDonough 2009), most original CE writers [e.g. Amory and Hunter Lovins, Janine Benyus, Gunter Pauli, Thomas Lyle and especially those in the field of industrial ecology] reflect this shifted perspective (see also Saavedra et al. 2018). They are consciously taking insights from living systems and by extension insights from complex dynamic systems.

A great deal might depend upon whether CE participants have absorbed this perspective when considering design, production, the rest of the value chain, etc. At present, the evidence is generally patchy since it implies designing to fit a system which has not yet been born – we are locked into a linear system based on 'scale and sale' with regulatory incentives in this direction too. Something like an eco-effective approach is more difficult to imagine or do compared to ameliorating existing conditions through, for example, waste management or eco-efficiency. However, following Dana Meadows's work on interventions in a system (Meadows 2008), the notion that much change has its roots in those who can move us from the 'impossible to thinkable' (a paradigm shift) is important when contemplating an economic transformation. Following an *eco-effective* – as opposed to an eco-efficient – orientation does move thinking away from 'do less harm' to a positive footprint and towards the possibility of rebuilding capitals, creating abundance not just sufficiency. This ambitious and systemic approach has been core to Cradle-to-Cradle (C2C) work for above two decades and yet in practice is often hard to implement. Using an explicit systems perspective also reveals the role of structure in systems and specifically it's the interplay between efficiency and resilience which marks out 'eco-effective', yet this scientific insight is as yet little discussed. This may be related to what is implied by the word. 'Effective' is always framed in terms of questions around purpose. Eco-effective also points to *systemic* health, taking in all scales of course, allowing for nested systems and multiple capitals (financial, natural, social, manufactured, and human). It is, unsurprisingly, capable of being described as an 'ecological transition'. This is beyond an ecomodernist agenda – where the tools are what are needed *since the aims and purpose are given*.

Perhaps a lack of discussion in an economic context is because it points in the opposite direction to that of the existing economic system, which is concerned, as Brett Christophers has documented in his book *Rentier Capitalism*, with securing economic rents (unearned surplus) based on creating and maintaining *scarcity* (Christophers 2020). Perhaps it is because an 'ecological transition' mandates reaching all parts of the economy and enabling in a fuller sense both the demand and supply sides; participatory or 'empowered' customers, producers, and certainly citizens. This would, in turn, mean something very different on a policy level. It also tells us something about different scales. If the use of living systems analogues is useful, then the work of Gunter Pauli is instructive when he speaks of 'adding value with what we have and circulating locally' (Pauli 2010). It is also something showing up in business texts/commentary (e.g. Roger L Martin *Why More is Not Better*), i.e. the necessary pulling back from efficiency and towards effectiveness. This is all redolent of an economy of competition *and* cooperation a more circulatory, 'scale sensitive' rather than extractive monopolising exercise. It is also significant in its orientation to a productive rather than to a financialized economy.

In conclusion, CE is practical and engaging as a heuristic. It overwhelmingly gets attention from business and policy and is open enough to be a toolkit. However, it also carries the seeds of a new economy in its evident feedback-rich complex systems orientation. This chimes with the times for many, given that scientifically speaking almost all real-world systems are complex adaptive systems and interdependent. Perhaps this means there is authenticity in going beyond just materials and energy, beyond products, components, and materials to building eco-effective and enduring participatory systems where all capitals are maintained and expanded as stores of wealth and stocks of potential solutions accessible to the majority.

The chapter is organized as follows: first, we discuss CE as a system design strategy mobilizing different worldviews (Sect. 6.2), and particularly eco-efficiency and eco-effectiveness. We explore the key levels where these different narratives unfold, questioning a circular economy and the degree to which it is focused on ownership *or* access to resources, scale *or* scope, and finally efficiency *or* resilience (Sect. 6.3). The fourth section is dedicated to envisioning a multi-level perspective to undertint CE transitions or transformations while Sect. 6.5 focuses on a circular economy becoming a nutrient economy, inspired by living systems and celebrating participatory and reciprocal relations of competition and cooperation. We conclude by reflecting on limitations and future research avenues.

6.2 Circular Economy as a Set of Different Worldviews

Circular economy (CE) has been recognized as an emerging field of inquiry and practice able to stimulate novel approaches to socio-ecological changes, innovation, and business transformation (Fischer et al. 2021). CE had been framed mostly about enabling businesses, policymakers, and practitioners to simultaneously manage natural resources and achieve sustainable development goals – SDGs (Ludeke-Freund et al. 2019; D'Amato et al. 2019). Scholars and practitioners have often depicted CE as a 'vehicle' to stimulate socio-technological and organizational innovations with system-level sustainability (Alexander et al. 2023), for example by: (i) designing products for slowing, narrowing, and closing loops of resource use (Webster 2013; Bocken et al. 2016; Geissdoerfer et al. 2018b; Borrello et al. 2020b); (ii) delivering performance and functionality rather than ownership (Tukker 2015; Stahel 2016; Geissdoerfer et al. 2018a). According to this view, CE creates the potentials to change frames and perspectives on how we organize production, consumption, and exchange of resources, goods, and services, and how we can create a more participative economy at all scales (Moreau et al. 2017; Borrello et al. 2020a;

Ferasso et al. 2020). However, after almost a decade in which CE is structuring as a field of inquiry and practice, a number of critical tensions and ambiguities seem to be emerging as well, and particularly whether we should see CE as a 'toolbox' or more as a 'framework for thinking' (Morseletto 2020; Webster 2021; Alexander et al. 2023).

Borrello et al. (2020b) have unearthed and discussed these tensions, particularly looking at how scholars and practitioners position themselves in their understanding of circularity and circular economy. They propose to unify a circular economy agenda through three key insights (Borrello et al. 2020b): first, to understand CE as gathering principles of other schools of thought and elaborate them in a narrative able to inspire policy actions. Second, interpreting CE as field of practices evoking a socio-technical transition into multiple regimes in which societal and material needs are fulfilled by innovative industrial systems. Finally, looking at CE as a contribution to the environmental and economic dimensions of sustainability by means of an eco-effectiveness approach to industrial systems. In essence, from this perspective, CE is a **heuristic** around an 'eco-modernist agenda', inviting us to create jobs and economic growth, while **decoupling resources use** to a greater or lesser degree.

In this mode, a CE offers a 'digestible' narrative to policymakers and to the business community, to soften the contradictions of combining the reality of a world made of finite resources with the capitalism aspiration of continuous and infinite economic growth. Hence, while often presented as a 'framework for thinking', CE has been implemented as a 'toolbox'. For instance, the current dominant approach to operationalizing CE is full of discussion of waste minimization, resource-efficiency, new technologies and techniques, LCAs, and so on: lowering the cost of access and ownership of resources is key in these narratives (Stahel 2019; Camilleri 2020).

The EU, particularly, has moved into the CE agenda and shaped the recent Green Deal around these frames and narratives, and created operational tools to translate them into a series of interventions for practitioners entailing waste management (e.g. smart re-cycling), resource efficiency, impact-assessment and methodologies, to carefully reduce the negative impact of the European industrial economy on the environment, support a climate-neutral and SDGs oriented agenda (Ganzevles et al. 2017; Hartley et al. 2020).

Despite this acceleration towards making the CE transition possible, scalable, and implementable, supporting the idea of using CE as a toolbox, there is still a significant 'resonance' around the deeper idea of using insights from living systems to design eco-effective systems and create a 'nutrient economy' through circularity (Webster 2021).

Long exemplified by 'cradle-to-cradle' initiatives and ideas, as well as by Biomimicry, Blue Economy and Industrial Ecology (Ludeke-Freund et al. 2019; Borrello et al. 2020a, b), whenever scholars and practitioners engage with a 'living systems' perspective to understand and implement CE they immediately create an opportunity to shift towards a more disruptive, imaginative and future-facing CE narrative, which works more as 'framework of thinking' than just a toolbox

(Pascucci 2020; Gümüsay and Reinecke 2021). This narrative, by its nature, is prefigurative and dealing with imagining futures that do not exist yet, aiming at designing an economy which has not yet been born, and thus becoming more difficult to implement, enact, and facilitate if compared to a 'toolbox' readily available to ameliorating existing conditions. However, designing an economy through a perspective of living systems is important when contemplating an economic transformation rather than transition, and how to move from the 'impossible to thinkable'. During the last two decades, the idea of developing a transition towards a CE as a nutrient economy has been somehow side-lined by the discourse of waste minimization and resource-efficiency, often referred to as an eco-efficiency approach to circularity (Borrello et al. 2020b). As indicated in the cradle-to-cradle design thinking (McDonough and Braungart 2003) rather than eco-efficiency, we need to follow an eco-effective orientation in order to move into a 'nutrient economy', moving our thinking away from 'do less harm' to a positive footprint (Pascucci 2020). This points towards the possibility of rebuilding capitals, towards abundance not just sufficiency and facilitating the interplay between efficiency and resilience which marks eco-effective (Webster 2021). An economic transformation inspired by principles of eco-effectiveness and living systems also entails the operation at different levels and scales, as indicated in frame-building approaches such as Biomimicry, the Blue Economy, or Industrial Ecology. This shift is also suggesting an economy that uses redundancy and circulation, rather than scarcity and extraction to build ***relations of competition and cooperation***, as Adam Smith had already recognized, an economy oriented towards the productive forces, rather than the rentiers (Christophers 2020).

In this chapter, we investigate and discuss the critical tensions characterizing CE, in its oscillations and contradictions between a 'toolbox', transitional, practical, engaging narrative that gets attention from business leaders and policymakers, and a 'framework of thinking', transformational, prefigurative, and imaginative narrative, inspired by eco-effective and living systems principles. We also reflect on whether the former is open enough to allow the latter to develop and become the seeds for a new ***nutrient-based and participative economy***.

6.3 How to Design a Circular Economy: Eco-efficient Networks or Eco-effective Ecologies

Since its inception, circular economy has been debated through the lenses of design~~ing~~ thinking for stimulating systemic and organizational change (Webster 2013; Stahel 2016; Alexander et al. 2023). Building upon the framing of different schools of thought like Cradle to Cradle (McDonough and Braungart 2003), Laws of Ecology (Commoner 1971), Performance Economy (Stahel 2010), Regenerative Design (Lyle 1996), Industrial Ecology (Graedel and Allenby 2003), Biomimicry (Benyus 2002), or the Blue Economy (Pauli 2010), practitioners and scholars have been creating narratives inspiring practices of change and innovation (Geissdoerfer et al. 2018a; Borrello et al. 2020a, b). However, these narratives have been spinning around a few unresolved ambiguities (Morseletto 2020), without addressing the tensions between a scholarly and scientifically grounded circular economy opposed to an ad-hoc heuristic based on few design principles and 5–10 business models and case studies to create 'economic opportunity' (Bocken et al. 2016; Borrello et al. 2020a, b).

In our view, these ambiguities and tensions root back to the design principles informing the two narratives resulting in the polarization of a circular economy understood as a 'toolbox' for incremental changes, opposed to a circular economy understood as a transition towards an economy-inspired and aligned with ecological processes. Nylén (2019) insightfully noted that a circular economy potentially 'changes the logic of the economy'. The question is how exactly this happens. For instance, is this change happening by re-designing existing industrial systems in a more resource-efficient way? Using closing loops and minimizing waste? Or, alternatively, is this change happening through a more profound re-engaging process dealing with the complexity of ecological relations?

While all these questions relate to systemic changes in an economy, resource efficiency and waste minimization follow the current approach of seeing the economy as a system dominated by 'laws' and 'norms' not too different from what govern physics and chemistry. An ecological approach to redesign an economy, instead, produces circular economy narratives and practices attempting to set a more disruptive pathway to identify a new economy framework, a system design inspired by 'insights from living systems'. Based on this background in this section we discuss the key differences of these two approaches: on one hand, an eco-efficiency-oriented CE that works to mitigate and reduce the negative externalities of current economic models and industrial systems, through careful 'pipework', enhancing efficiency through optimization of resource use. On the other hand, an eco-effectiveness-oriented CE that works to enhance the quality of the natural environment and is based on regenerative cycles. This difference is quite profound as the former legitimizes efficiency since physical/natural capital is assumed to be fixed and can only degrade and substitution from technological capital (knowledge) will be key, while the latter assumes that natural capital can increase and abundance not scarcity is the keynote, and it is not driven by scarcity or limited technology, but instead by designing and applying appropriate system conditions.

6.3.1 Building an Economy on Eco-efficient Networks

The pipework narrative builds mostly upon the idea of eco-efficiency, based on the notion of economic efficiency (Braungart et al. 2012). Efficiency is essentially the relationship between input and output, in colloquial terms the search for 'getting the most from the least'. It can be translated into a strategy of 'doing more with less'. Accordingly, eco-efficiency can be achieved through three practices: (i) increasing product or service values; (ii) optimizing the usages of resources; and (iii) reducing environmental impacts (Braungart et al. 2012).

The framing of eco-efficiency evokes a narrative of minimizing negative impact from the economy on the environment, and namely considering eco-efficiency as 'being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earth's carrying capacity' (WBCSD 2006, p.3). Despite various definitions, the core of the eco-efficiency concept can generally be understood as '**more product or service value with less waste, less resource use or less toxicity**' (Braungart et al. 2012). From a system design perspective, eco-efficiency can be said to build upon a core set of principles such as:

- Dematerialization
- Increased resource productivity
- Reduced toxicity
- Increased recyclability (down-cycling)
- Extended product lifespan

Each of these practices starts with an assumption of the linear, cradle-to-grave flow of materials through industrial systems (Braungart et al. 2012), a system of production and consumption that transforms resources into waste and the Earth into a graveyard (Borrello et al. 2020b).

Practices of dematerialization and increased resource productivity seek to achieve a similar or greater level of product or service value with less material input. With cradle-to-grave material flows as a background, strategies for generating increased recyclability and extended product lifespan seek to prolong the period until resources acquire the status of waste, for instance by increasing product durability or reprocessing post-use material for use in lower value applications (Braungart et al. 2012. Though recycling strategies begin to approach eco-effectiveness, the large majority of recycling actually constitutes 'down-cycling' because the recycling process reduces the quality of the materials, making them suitable for use only in lower value applications. Some materials still end up in landfills or incinerators (Braungart et al. 2012). Their lifespan has been prolonged, but their status as resources has not been maintained. Though some have commented that zero emissions cannot be achieved through the practice of eco-efficiency, parallels certainly exist between eco-efficiency strategies and the zero-emission concept. Both strategies concern themselves directly and primarily with the reduction of waste, and neither focuses directly on the maintenance of resource quality and productivity. This, however, is a necessary characteristic of eco-effective industrial systems.

In the short term, eco-efficiency strategies present the potential for tangible reductions in the ecological impact of a business's activities and an opportunity for (sometimes significantly) reduced costs (Braungart et al. 2012). In the long term, however, they are insufficient for achieving economic and environmental objectives on several accounts (Braungart et al. 2012):

1. Eco-efficiency is a reactionary approach that does not address the need for fundamental redesign of industrial material flows.
2. Eco-efficiency is inherently at odds with long-term economic growth and innovation.
3. Eco-efficiency does not effectively address the issue of toxicity.

Moreover, as a relationship between input and output and its impact, eco-efficiency remains essentially bound by a mechanistic or at least throughput-orientated worldview. It is mechanistic in the sense that the activity assessed through eco-efficiency is abstracted from the environment in which it sits and receives limited feedback and certainly not in the way complex systems work. It is also conceived of as an approach which defines boundaries to allow us to understand, predict, and control the process while (hopefully) minimizing negative externalities. It fits within an economic system also narrowly conceived as tasked with producing more and that 'more' is inherently a good thing.

Confusing 'more' – a quantity – with 'better' – a qualitative judgement – is at the heart of attempts to carry through a mechanistic approach to physics into economics and thus politics (Ormerod 1995). Eco-efficiency strategies focus on maintaining or increasing the value of economic output while simultaneously decreasing the impact of economic activity upon ecological systems. Zero emission, as the ultimate extension of eco-efficiency, aims – at least notionally – to provide maximal economic value with zero adverse ecological impact and true decoupling of the relationship between economy and ecology. Eco-efficiency begins with the assumption of a one-way, linear flow of materials through industrial systems: raw materials are extracted from the environment, transformed into products and eventually disposed of. In this system, eco-efficient techniques seek only to minimize the volume, velocity, and toxicity of the material flow system, but are incapable of altering its linear progression.

6.3.2 Eco-effectiveness for an Economy Mimicking Living Systems

In contrast to this approach of minimization and dematerialization, the concept of eco-effectiveness proposes the transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth. The goal is not to minimize the cradle-to-grave flow of materials, but to generate cyclical, cradle-to-cradle 'metabolisms' that enable materials to maintain their status as resources and accumulate intelligence over time (upcycling). This inherently generates a synergistic relationship between ecological and economic systems and a positive recoupling of the relationship between economy and ecology.

An eco-effective approach contrasts with zero emission strategies in that it deals directly with the issue of maintaining (or upgrading) resource quality and productivity through many cycles of use, rather than seeking to eliminate waste. The characteristic of zero waste (no production of negative side products) arises as a natural side-effect of efforts to maintain the status of materials as resources but is not the focus of eco-effective strategies. The maintenance of a high level of quality and productivity of resources is, by contrast, not necessarily a side effect of zero-waste approaches. This difference in focus between the concepts of zero waste and eco-effectiveness is reflected in the array of strategies which they employ. The zero-waste concept encompasses a broad range of strategies including volume minimization, reduced consumption, design for repair and durability and design for recycling and reduced toxicity. Whether changes are made in product design, manufacturing processes, consumer behaviour or material flow logistics, reduction and minimization remain a central component of the zero waste concept. In contrast to this, eco-effectiveness emphasizes strategies such as cradle-to-cradle design and intelligent materials pooling, which deal directly with the question of maintaining or upgrading the quality and productivity of material resources. Eco-effectiveness does not call for minimization of material use or prolonged product lifespan irrespective of their functional value.

Cradle-to-cradle prefers to speak of defined product lifetimes. In fact, it celebrates the creative and extravagant application of materials and allows for short product lifespans under the condition that all materials retain their status as productive resources and energy inputs come from renewables. Even the application of toxic materials is acceptable as long as it takes place in the context of a closed system of material flows and the quality of the material is maintained. In the context of eco-effectiveness, strategies of reduction and minimization are not even steps in the right direction unless they contribute to the ultimate aim of achieving cyclical material flow systems that maintain material quality and productivity over time.

Given this background, we suggest to further explore the contentious and still ambiguous relationship between an eco-effective and eco-efficient circular economy, but not rejecting one for the other, since there are approaches to a successful synthesis available through the identification and use of the common structures displayed within effective living systems to develop a richer and perhaps more inclusive and multilevel perspective on CE. This perspective, in our view, can be further elaborated as presented in the next section of this chapter.

6.4 Developing a Multi-level Perspective: Which Circular Economy?

The emphasis about the differences between ecological efficiency and effectiveness has been mostly debated at product and material design thinking level (Webster 2013), probably following the influence of Braungart and McDonough framing of cradle-to-cradle and close-loop design thinking (McDonough and Braungart 2003). Instead, as indicated in the previous section, the relation between efficiency and effectiveness is relevant particularly when thinking about the sustainability of large systems and in the context of transforming our economies, for example through the lenses of ecological relations (Lietaer et al. 2010). This invites an understanding of CE through a multi-level perspective, in which these two narratives, and set of practices, should not be seen as mutually exclusive alternatives, but rather as part of a wider and more satisfying picture. If we take seriously an ecological view of socio-economic relations, we can look at an economy as a web of structural and systemic relations, similar to the notion of an ecosystem. In an ecosystem, sustainability is ensured by balancing out *efficiency*, i.e. the system's capacity to perform in a sufficiently organized and efficient manner so as to maintain its *integrity* over time, and *resilience*: the system's reserve of flexible fall-back positions and diversity of actions that can be used to meet the exigencies of novel disturbances and the novelty needed for on-going development and evolution (Holling 1973, 2001; Lietaer et al. 2008). Hence, a ***window of viability*** and sustainability for organisms as well as ecologies depends on the interplay between efficiency and resilience (Fig. 6.1).

When this approach is applied to 'dynamic flow systems', for example the human body or the circulatory system, as well as flows of data, energy, money, or materials in a socio-economic system, too much efficiency in the flow would lead to *fragility* through brittleness. A shock to a system characterized by few nodes and connections can bring it down much in the way a blocked or ruptured artery is often fatal, whereas too much *resilience*, diversity or redundancy (many nodes and connections) can lead to stagnation or sclerosis. If we again think of the blood systems in the human body, the damage to peripheral blood systems might ordinarily lead to just a bruise, but poor circulation can have serious consequences too, via tissue

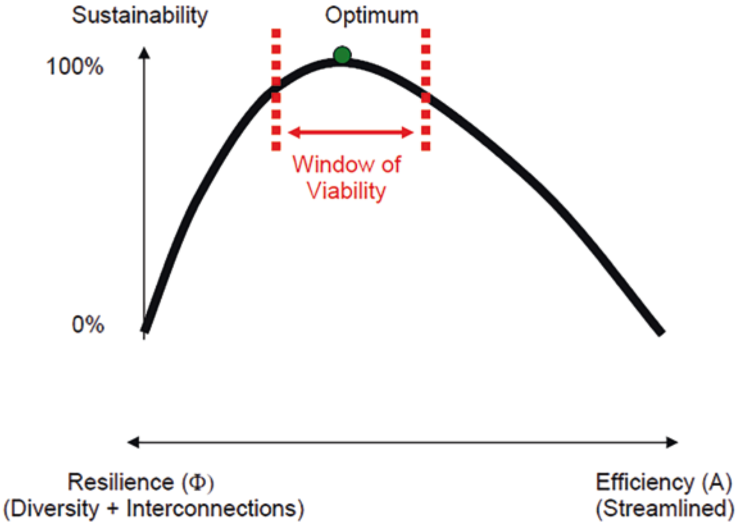


Fig. 6.1 'Window of viability' in the systems balancing efficiency and resilience. (Source: Lietaer et al. 2008)

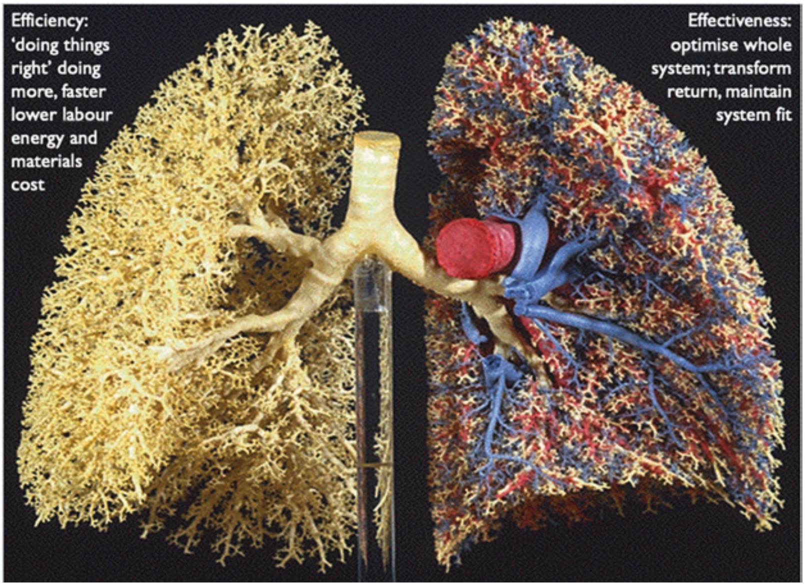


Fig. 6.2 Efficiency and effectiveness in living systems. (Source: Authors' elaboration on photo courtesy Ewald Weibel, Institute of Anatomy, University of Berne)

necrosis. Another analogy is with the way the lungs work (Fig. 6.2). Major airways facilitate volume, but the dominant part – alveoli and a network of tiny blood vessels, the capillaries, facilitate exchange and have a role in the resilience of the lungs as a whole due to them being able to bounce back from shocks/insult or have some redundancy built in.

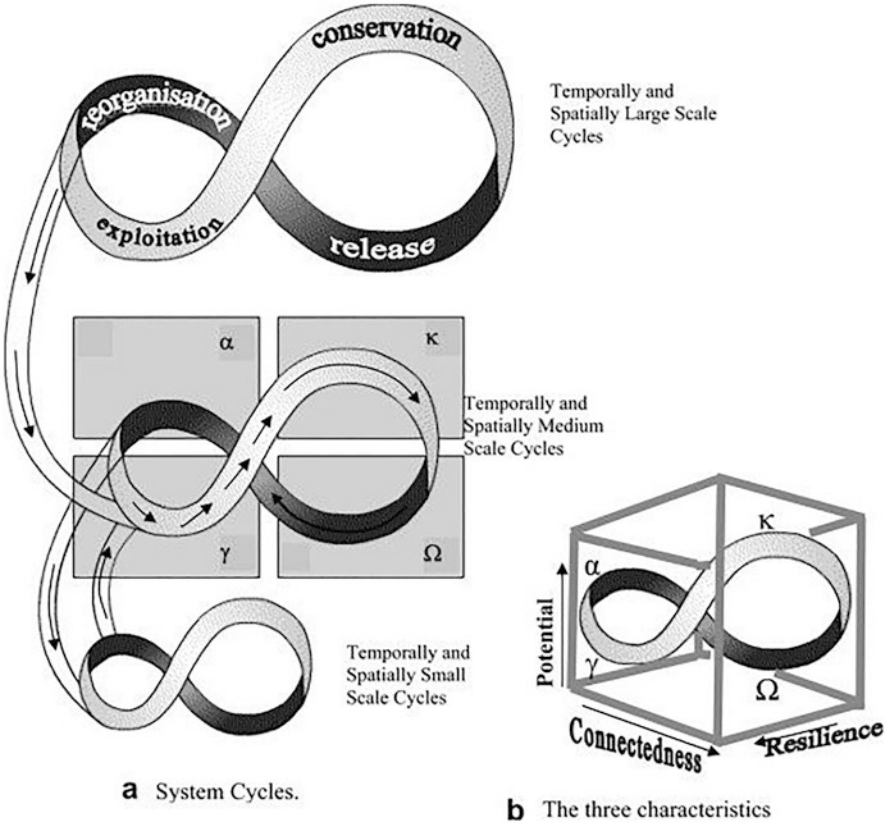
When applied to a socio-economic system, we surely need to recognize the differences between designing and operating it as an over-simplified system, for example with limited or extremely time-lagged feedback, and a non-linear (circular) system, with feedback-rich interdependencies, and 'patterned' in non-deterministic relations. Hence, if we use the same approach to relate CE to a biological/ecological system (e.g. living systems) then the existence of both the *larger scale structures,* which make flows efficient (e.g. fewer nodes and connections) must of necessity work in relation to those aspects of the system which facilitate *exchange and resilience* (e.g. more nodes and more connections).

As an example, an efficient large-scale infrastructure to manage data or materials would help a multitude of small and medium organizations to organize locally vibrant activities, supporting the circulation and re-circulation of the data and materials. High level of centralized efficiency at infrastructural level will be balanced by high level of diversity and interconnectedness in the peripheral systems, making the system more effective. In fact, it is when the two dimensions of efficiency and resilience/diversity are in dynamic balance that the system is in a state of viability or sustainability. Not one, too efficient, or the other, too resilient or diverse, but of necessity both together result in an eco-effective system.

The same applies to monetary or data flows. If biased towards efficiency, these systems are ‘brittle’ and the periphery functions degraded, e.g. small or nascent businesses might not be able to access financial means (e.g. money) or information or knowledge (e.g. data). If, instead, overly biased towards resilience these systems are in danger of stagnation – too little change and core functions inadequate. Clearly, coherence and change coexist in these feedback-rich systems over time and within nested systems at different scales and this deserves further examination.

The ability of living systems to endure and evolve over time through a process of renewal has been found to have fruitful parallels in socio-economic systems. We discuss this through the lens offered by *panarchy*, the identification that significant change can originate from any level of a nested system through feedback and also that these systems progress through four phases from growth (γ) through maturity (K) to collapse (Ω) and reorganization (α) (Fig. 6.3).

Interestingly, in addition to the variable loci of change, the cycle described relates to available resources: growth is based on readily available resources, maturity to those resources being locked up in the system and available energy is largely



a System Cycles.

b The three characteristics

Fig. 6.3 Panarchy in living and social systems. (Source: Holling and Gunderson 2002) maintaining the structure; collapse to the widespread release of resources and lastly reorganization – the potential for different organisms to thrive in a new growth phase.

Holling and Gunderson (2002) introduced the concept of panarchy, discussing changes and transformations of socio-ecological systems. They recognize that any change at a small level can iterate and cascade to overwhelm the bigger system, and not only the other way around, indicating the relevance of bottom-up changes and not only top-down processes, at least sometimes. They define panarchy as the alternating cycles of renewal and collapse in socio-ecological system characterized by nested and multi-scale/level sub-systems, where cross-scale relations are key to maintain the large system structure and dynamics, including resilience (Allen et al. 2014). In a panarchial system, stages of growth and accumulation will be always followed by stages of release/disruption and re-organization, within a sub-system and scale and between sub-systems and scales (Allen et al. 2014). An economy is a complex system of socio-ecological relations in which small and large-scale processes (flows) and structures (stocks) are deeply interconnected.

The role of diversity as a source of both resilience and creativity is clear from Holling and Gunderson's work (2002). It is rather myopic to conceive of any system of this general class as endlessly maintaining its growth and accumulation stages without any serious disruption or discontinuity. Only brittle systems are built this way and the size of the consequent collapse may be fatal. Overwhelmingly the historical record in socio-economic systems mirrors the alpha-omega process with our current economic situation indicative of late maturity (K) with constraints on new growth as the existing infrastructure demands more of any surplus since it is exceedingly complex (see for example Tainter 1988). Instead, accepting and managing – or at least systemically influencing – cycles of renewal and collapse will improve the chances of keeping the system, the economy, within the window of viability, at the highest level of ecological and social sustainability in each phase.

A number of characteristic 'traps' or limiting conditions found at different stages in this cycle are illustrated in the diagram (Fig. 6.4) but in all cases the interplay between large and small scale is a crucial dynamic in the outcome (Fath et al. 2015). Policy if it can be imagined within a wide appreciation of the existence of this cycle would surely help overcome the traps by judicious intervention. Current policy failures around longer term changes such as climate disruption, gross inequity, or soil quality do not bode well for influencing panarchical socio-economic systems. The difficulties do not negate the potential flowing from having a better sense of the workings of such systems, as we are working at worldview or paradigmatic levels for which Einstein's adage seems apt: 'the theory determines what we observe'.

Limiting Factors or Traps Which Might Be Found at Different Stages of the Cycle

r-stage 'poverty trap' 'The goal of the r-stage is growth ...but the trap occurs when a system cannot access enough activation energy to reach a state where positive feedbacks drive growth internally' (Fath ibid).

(continued)

K-stage ‘rigidity trap’ ‘K stage is about controlled development and ‘making a transition from quantitative increase to qualitative indicators’ (Fath ibid). The dangers include overshoot (where positive feedbacks still dominate negative) and a rigidity trap: There is little room for further innovation as there is a ‘high concentration of influence’. Brittle systems are vulnerable to collapse but the exact timing of this is unknown.

Ω-stage ‘dissolution trap’ Ω stage is about the capacity to survive in the face of extreme disturbance. A system must maintain vital functions throughout the crisis and will probably draw on reserves of resources created in the r and K stages. Failure to maintain leads to the dissolution trap – very degraded systems.

a-stage ‘vagabond trap’ A reorientation stage which might well draw on system memories to help point towards the next r-stage but will be very free flowing. If reorientation is impossible, the system will be ‘circling compassless’ (Fath ibid) and enter the vagabond trap.

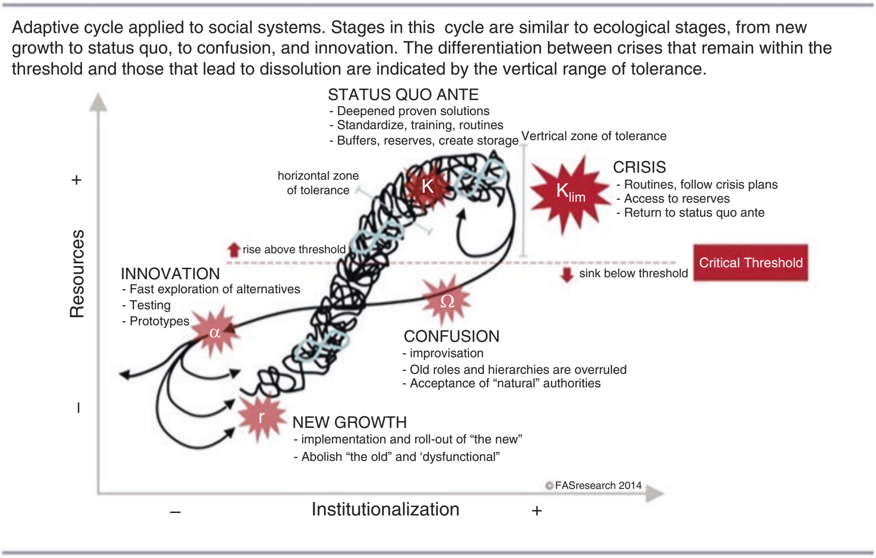


Fig. 6.4 Panarchy applied to the socio-economic field. (Source: adapted from Fath et al. 2015)

Hence, a multi-level, scale, and ecologically grounded CE recognizes the necessity of moving more decisively into a panarchy of socio-ecological relations, in which an economy is balancing efficiency and resilience by enhancing diversity in at least some of its subsystems. This idea is aligned with the mantra ‘Celebrate diversity’ introduced in the cradle-to-cradle design thinking by McDonough and Braungart as one of their three main principles alongside ‘waste = food’ and shift to renewables (McDonough and Braungart 2003). In their view, diversity is a source of resilience

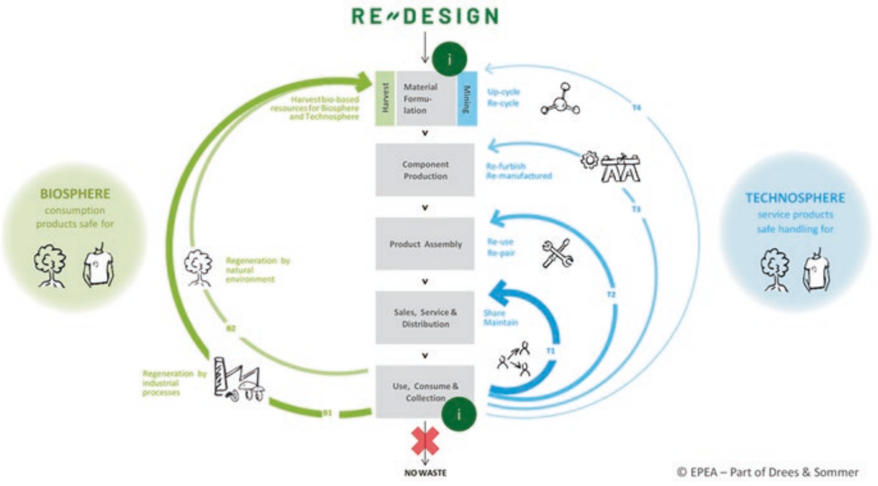


Fig. 6.5 Biological and technical nutrients within the biosphere and technosphere. (Source: Dreso.com 2020)

(or systemic strength) and creativity, some of it protects the system integrity – its ability to bounce back- and some of it potentially overturns the system at some level. Similarly a CE can be used for building socio-ecological systems as panarchies, through a conscious design and implementation of cycles of resources, or 'nutrients', organized in biological and technical metabolisms. These metabolisms can follow cycles of destruction and release of 'nutrients', not just reducing waste and so-called 'leakages'. This would represent an enrichment of the CE represented in the so-called 'butterfly diagram' (Ellen MacArthur Foundation 2013) where the interplay between **biological and technical nutrients** is conceptualized as two distinct material flows in which key assets are restored (technical) or regenerated (biological), but without conceptualizing or representing cycle of release and re-organization for example. In the next section, we discuss how to move from a stock and flows representation of CE to a panarchy of resilient and efficient socio-ecological relations (Fig. 6.5).

6.5 From a Circular to a Nutrient Economy: Centralized or Distributed?

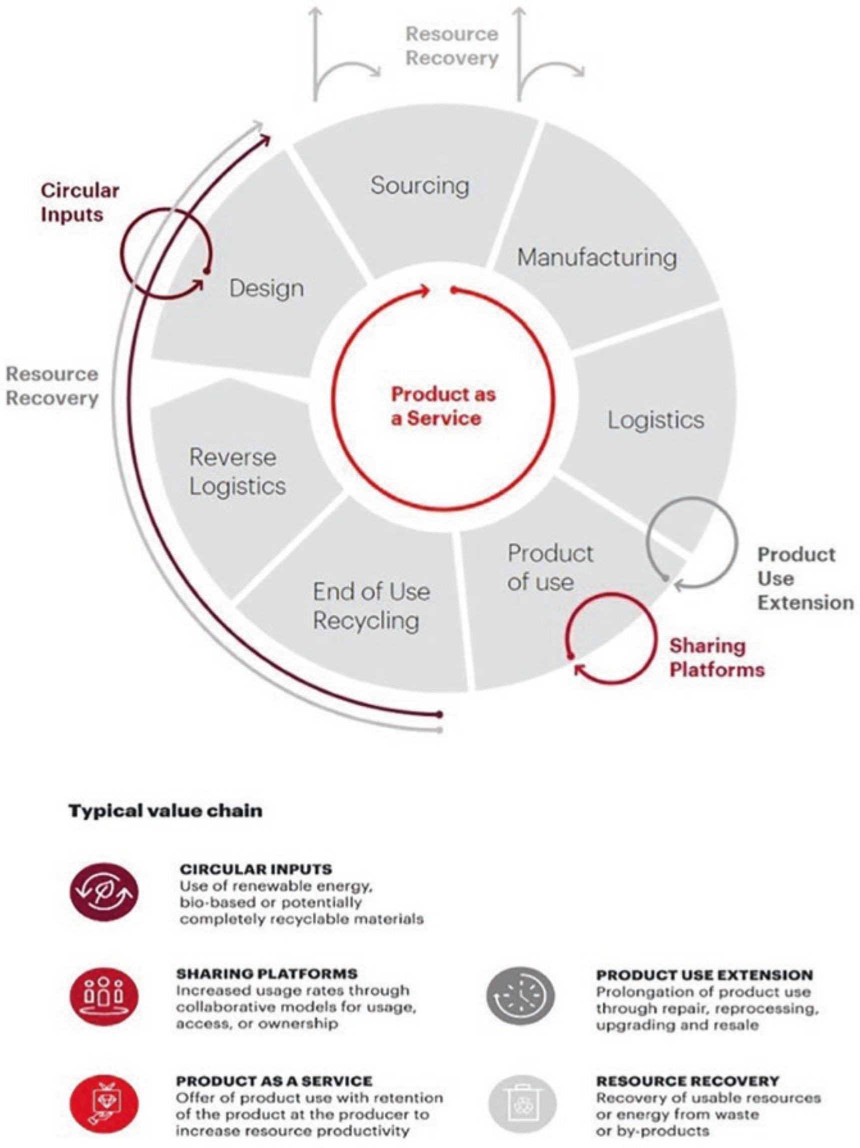
Conceptualizing and operationalizing a circular economy as a system of 'closed loops' made of structures and flows is very different from a circular economy that works as a panarchy of socio-ecological relations. The former relates more to the mechanistic conceptualization CE as materials 'pipework'; very much in parallel with the traditional engineering diagrams created by Samuelson in his textbook *Economics* to illustrate money flows (and repeated ever since) (Samuelson and

Nordhaus 2009). This then fits with CE operationally as a 'toolbox' of business models and technologies (and business-friendly policy adjustments) to profitably fix or reduce the leaks. This has an 'efficiency is the name of the game' assumption we have discussed in the first part of this chapter, since it is what falls out of the pipework analogy.

The latter more clearly relates to a new 'framework of thinking' inspired by an ecological worldview of an economy operating analogously as a living system. As indicated in Fig. 6.6, the pipework narrative builds upon the notion of a system in which slowing, narrowing and closing loops of critical resources will define a state of high efficiency, or an optimal ratio of inputs and outputs. This efficiency is achieved by enabling five key socio-economic strategies also defined as circular business models, such as resource recovery, sharing platforms, circular input design, product use extension, and product as a service (Bocken et al. 2016; Ranta et al. 2018).

In this approach, all five strategies lead to a circular economy that moves towards a socio-technical transition in which efficiency is achieved by scaling structures over flows through social and technological innovations. For example, to make sharing platforms more efficient, economically and technically, systems of sharing relations need to be scaled to involve as many users as possible while reducing the level of (resource/service) diversity to be managed through processes of standardization. Closing loops of resources by feeding back to large-scale manufacturers or switching to products of service and extended product life feels also as the most efficient step to make in moving from a linear to a circular economy. Similarly, designing materials, modules and products for sharing, closing loops and extended service use can accelerate this socio-technical transition. Therefore, a circular economy organized in biological and technological cycles aligns with all these strategies where resource flows (cycles) are embedded in emerging structures (e.g. institutions and organizations) that tend to increase in size and scale to increase the efficiency of the system. Hence, when moving from a linear to a circular economy (Fig. 6.7), in all these strategies an initial stage of re-organization, where distributed use and access prevails, is followed by a stage of controlled and centralized organization. However, while this approach might be more suitable for technical cycles, where materials need to be 'curated' through maintenance, reuse and recycling, biological cycles might be more suitable to strategies where open and distributed loops seem to prevail, they can be designed as cycles of decomposition and regeneration. Hence, in a transition into a circular economy in which socio-technical innovations prevail, strategies and structures which have emerged in the technical cycles will, in the long run, shape the biological cycles too.

The open and distributed nature of biological loops and cycles will persist, since nature-based regenerative processes are the source of so many ecosystem services and a system without them is inconceivable; however, it is possible to expect economic dominance of a centralized and 'closed loops'-based system in key areas. The key role here may well be closing of the loop not only through imperfectly circular volume flows but firstly through the control of IP around not only key food crop seeds and chemical or biological agents – Roundup is only one, well known,



Typical value chain

CIRCULAR INPUTS
Use of renewable energy, bio-based or potentially completely recyclable materials

SHARING PLATFORMS
Increased usage rates through collaborative models for usage, access, or ownership

PRODUCT USE EXTENSION
Prolongation of product use through repair, reprocessing, upgrading and resale

PRODUCT AS A SERVICE
Offer of product use with retention of the product at the producer to increase resource productivity

RESOURCE RECOVERY
Recovery of usable resources or energy from waste or by-products

Fig. 6.6 Five strategies in a socio-technical circular economy. (Source: Accenture 2020)

example – but secondly with the investment currently going into Precision Fermentation and Cell Agriculture.

Think tanks such as RethinkX (2020) are making bold claims as to the rapid decline of conventional agricultural approaches in meat and dairy. In this type of circular economy, the socio-ecological system as a whole through simplification

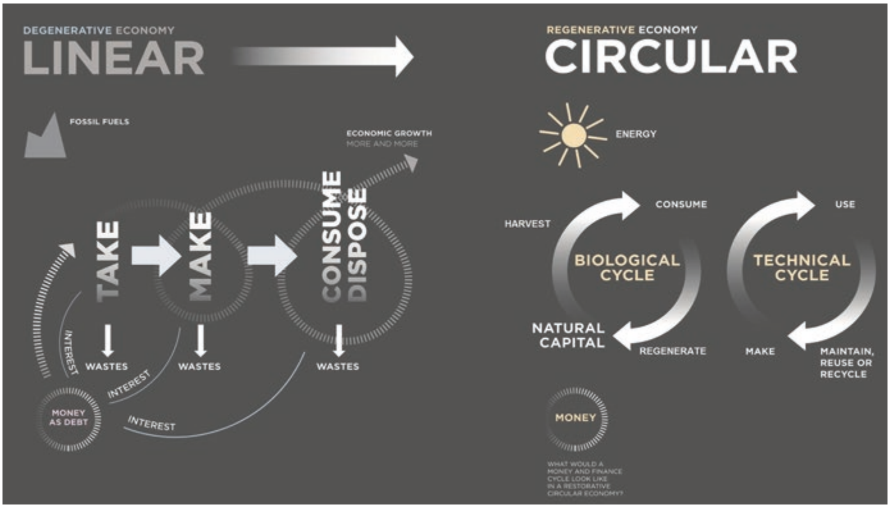


Fig. 6.7 Distributed and open financial, materials, and energy flows. (Source: Ken Webster (2021) based on Cradle to Cradle (McDonough and Braungart 2003))

and large volumes coupled with large-scale networked efficiencies and the control of IP and data platforms will reinforce the tendency to create economic rents (unearned or monopolistic surplus) which will be captured by relatively few actors. The loss of diversity and resilience in both technical and now biological cycles might keep the new system outside the window of viability, or at least reduce the range of that window. If loops are closed the first question is always around control and scale secondly around the consequences of creating a brittle system by focussing on efficiency and neglect of system fit. In any meaningful sense, these kinds of toolbox-orientated circular economy approaches fail the test of durability, from their inherent brittleness.

The alternative to this prospect might be represented by an **ecological transition** rather than a socio-technical transition. Following the metaphor of an economy working as a living system we can think of a more decentralized and open-access-based circular system. In living systems, in fact, sub-systems are nested within and without the main one, and they all have structures which support bigger flows down to the myriad cells and structures, networks or 'semi-lattices' which are there to allow the exchange of nutrients and the acceptance of a degree of damage or shock. As we have seen in the panarchy approach, efficiency interplays resilience in living systems, and so do structure and flows interplay with resilience and exchange, necessarily. In a circular economy functioning as an effective socio-ecological living system, maintaining and enhancing natural and social capital prevails over the ever-degrading natural and social capital processes of a linear economy, in which other capitals are converted into financial capitals or into waste.

In this reimagined economy, the achievement of effective system unsurprisingly comes from system conditions which enable but not determine the creation or enhancement of substantial nested hierarchies where energy, materials and knowledge cascade and, where appropriate, circulate into increasing social and natural capital (Fig. 6.5). As a highly devolved structure there is extensive competition and collaboration around accessible but defined commons (from forests to data platforms). We might substitute out ‘fossil sunshine’, finite and concentrated in ownership-based structures (e.g. multi-national petro-chemical corporates) in favour of distributed networks of producers and users of ‘current sunshine’, which is also endless and unlimited. We do it to avoid systemic collapse and in the name of justice for the very description ‘effective’ tells us much about purpose. And being clear about purpose is ground zero. If efficiency is doing things right then effectiveness, we reiterate, is about doing the right thing.

6.6 Concluding Remarks

In this chapter, we have examined how different narratives have emerged looking at CE as a framework for thinking or, alternatively, as a toolbox to minimize the negative impact of capitalism, and what we define as a linear economy. Often, toolbox approaches assume the character of an heuristic for socio-technological change. However, the ostensible narrative here is that many heuristic-driven approaches to circular economy, while having the strength to motivate and engage business, policy, and perhaps civil society do risk also falling into two other positions. Firstly, the effort is to apply a **toolbox of business models and technologies around resources**, leaving unexamined the overall **purpose of the system**, or rather it too easily falls in with the idea that it is eco-efficiency, which is primary. Since efficiency is inherently ‘a good thing’ – labour productivity in effect – when it comes to creating economic growth then it must be similarly positioned when it comes to resources. Secondly, the temptation to use circular economy tools – buoyed up by data and IT advances – to extend asset classes (IP, real estate, monopoly control, etc.) into products, components and materials is strong, since a predominately ‘pipework’ analogy for circular economy speaks to such control: preventing ‘leaks’, optimizing value extracted. This is circular economy as ‘business as usual with less stuff’ but very much out of kilter with what we do know of what real-world complex systems look like. It is unlikely to be sustainable, just or even stable.

The apparent opposite however of a devolved, distributed, more equitable arrangement is attractive to many, since the opportunity to take advantage of digital in terms of say, designing globally but making locally; of low-cost machines and techniques, of a variety of scales and diverse polities and means of controlling production (cooperatives, for example) couples with an ecological sensibility. This instead affirms that we can have a broadly regenerative, accessible and abundant economy based on insights from a ‘materials-as-nutrients’ inspired perspective. As a ‘fit the system’ and eco-effective approach is likely a given for the constituents of this group – a ‘green’ or participatory democracy element is also expected too, speaking of social capital building.

However, understanding systems structures and flows indicates that they are not opposites but compliments which do, however, have a number of internal, reinforcing relationships on each side which add to the sense of disconnection. Here are some suggested pairings (Fig. 6.8), where we present a continuum between each of the two opposites.

Looking down the left-hand column it is easy to see how a tendency for one aspect (for example scale) to mesh easily with 'efficiency' to mesh easily with enclosure. On the other side there exist similar reinforcing tendencies. It is not hard to see how two distinct approaches might appear to crystallize. However, using the necessary interplay of efficiency and resilience (of 'structure and flow' against 'resilience and exchange') inherent in these multi-scale complex systems we can ask instead: would it not be important to reflect on the existing arrangements and decide whether a readjustment of system conditions would bring us back into the 'window of vitality' of these systems.

Fath et al. (2019) proposed a number of measures of the health of such a system based on crossflow circulation but the purpose of this paper is not measurement, rather it is more conceptual. What do these systems look like and what follows?

This application of a multilevel complex systems perspective to the challenge of securing a way of discussing and making policy around an effective circular economy is, we believe, novel. It suggests further research on the interplay between efficiency and resilience in creating an effective stock maintenance approach to economic well-being. Inevitably this reaches into money stocks and flows and fiscal and monetary policy: it may be that the economy is extractive in both money and materials contexts with debt being the extractive driver much as cheap energy drives material exploitation. The connections between money and material 'cycles' are currently hardly explored in the circular economy field. This is a troubling gap in our collective knowledge. Given the assertion that we are experiencing a rentier capitalism then better management and control of products, components and

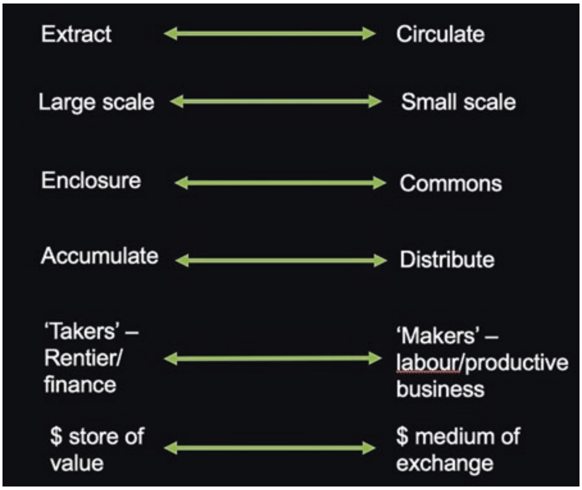


Fig. 6.8 Multi-level perspective of circular economy features. (Source: Authors)

materials speaks of creating additional asset classes, well suited to a financialized system.

The locus of further research might usefully explore system redesign which promotes effective but still dynamic systems. In this, how products, components, and materials, which benefit from very large scale, are technologically complex and need reliable IP protection to continue? However, the economic rents arising from this top-down ‘closed loop’ are captured. Alongside are the effort to capture resource rents, discourage carbon emissions, and let prices reveal their full costs thus making CE practices more competitive.

Secondly, research on how in the devolved, often biological cycle-based economy there might be interventions which lift the potential of local and regional businesses, most of whom are marginal businesses and short of capital. This might be explored by investigating the impact of deliberate infrastructure which promotes and facilitates added value: e.g. temporary storage, maker labs, local exchange platforms, community food processing and a local authority prioritizing local suppliers. It would be low cost to the user. The obvious circularity is in redirecting economic rents to this purpose and crucially the conceptual notion that *of necessity* effective systems have this strong and balanced interplay between structure and flow and resilience and exchange. The science of systems would be guiding economic policy choices in search of better system conditions for systemic health.

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Part II

Business Strategies, Processes, Practices, and Technologies

Chapter 7
The Importance of Circular Economy in HP Sustainable Impact Strategy

Paloma Cavalcanti and Ryan Kanzler

Abstract The circular economy is an essential part of HP's sustainable impact strategy. Through programs and initiatives such as design for circularity—which prioritizes modularity, reparability, and the use of recycled content and renewable materials—as well as the advancement of solutions (service-based solutions), progress is made toward the goal of reaching 75% of circularity by 2030. Innovative service solutions like HP's Device as a Service and Managed Print Services are integral to the strategy for minimizing environmental impacts. They promote extended device life, optimize device usage, and simplify device retirement. For products that reach their end of life, HP provides take-back programs in 76 countries and territories worldwide through a global network of reuse and recycling vendors. In addition, effective recycling programs, as well as social impact solutions that create a more inclusive circular economy are critical to enable and expand that impact.

Keywords Circular economy · Design for sustainability · Service-based models · 3D printing · Inclusive circular models

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7.1 Introduction

Electronic equipment is considered essential for modern cultures. This equipment can generate a waste stream at the end of use that contains valuable materials. In 2019, more than 50 million metric tons of electronic equipment were discarded worldwide. Due to the lack of reverse logistics and remanufacturing initiatives, less than 20% of these materials were properly collected and recycled.[1]

As a leader in electronics manufacturing, HP recognizes its responsibility as a manufacturer and engages in developing solutions for this challenge. Sustainability has been part of HP since its foundation and circular economy is part of HP's commitment to making a positive and enduring impact on the planet.

Product design plays a critical role in determining the environmental impact of equipment. Among HP's main design priorities are to increase the use of recycled and renewable materials and replace materials of concern; enhance repairability and modularity, and the continual improvement in product energy efficiency. Products are designed to last and be easy to maintain and repair.

Innovative service-based solutions, such as HP's Device as a Service and Managed Print Services are part of the strategy to reduce environmental impacts through extended life, device optimization, and easy device retirement. HP's Instant Ink program, as an example, is a service that anticipates when ink is running low and sends replenishments along with return envelopes for sending back cartridges for recycling. Recently, HP also announced a new goal to have 75% circularity on its product and packaging by 2030.[2]

With repair, reuse, and recycling programs HP helps to cycle products and materials back through the economy. This circular flow avoids waste and can give materials and products a renewed life. To enhance HP's commitment to sustainable impact it was necessary to move toward a more inclusive circular economy. In 2016, HP launched a program in Haiti in partnership with the First Mile Coalition and its suppliers to build an ocean-bound plastics supply chain. This opened a new market opportunity, providing a revenue stream for local collectors, enabling safer working conditions, and supporting local educational opportunities.

This chapter has the objective of showing how the circular economy has been playing a key role in HP's sustainability strategy, as well as describing each of the programs and initiatives that have been developed as part of that strategy. The main goals, accomplishments, and innovations are highlighted, and the last section is dedicated to demonstrating that circular economy is also about people's inclusion and economic well-being.

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[1] The Global E-waste Monitor 2020 (https://www.itu.int/en/ITU-D/Environment/Documents/Toolbox/GEM_2020_def.pdf)

[2] Percentage of HP's total annual product and packaging content, by weight, that will come from recycled, renewable and/or reused materials, products and parts by 2030.

7.2 HP Sustainable Impact Strategy and Its Circular Economy Centricity

Founded in 1939, HP's approach to business has consistently been influenced by principles such as legacy, global citizenship, and giving back to society and the planet more than it takes. The founders, Bill Hewlett and David Packard, were each advocates for social and environmental action and leadership. Responsibility has been a key tenet in the HP Way—the company's corporate culture—and the founders established global citizenship in HP's corporate values in 1957.[3] According to Hewlett and Packard, "a company that focuses solely on profits ultimately betrays both itself and society" (Hewlett-Packard n.d.) and that remains one of the bases for HP's corporate purpose, which is to create technology that inspires ambitious and meaningful progress.

Throughout its history, HP has encouraged employees to advance their social and environmental responsibility, and this commitment resulted in milestones such as the creation of a recycling program, in 1966, for HP's Palo Alto punched cards, which were one of the primary means of mass storage in the computer industry in the 1960s and 1970s. In the early 1970s, a manufacturing policy aiming to protect the environment was introduced and, in 1975, an HP team designed and installed a solar heating system at the Sunnyvale, California, site—securing HP's early adoption of renewable electricity alternatives.[4]

The company's commitment to make positive sustainable and social impact also resulted in its own hardware recycling program, HP Planet Partners for return and recycling of HP products, and the launch of the product-focused Design for the Environment program. Furthermore, HP has a long story of "firsts": it was the first to manufacture a hardware product with recycled plastic,[5] and became the first global company to publish a complete carbon footprint[6] and one of the first to publish a complete water footprint. Recently, also released the world's first display and notebook with ocean-bound plastic.[7] These efforts are complemented by a history of transparency and accountability: HP released its first Social and Environmental Responsibility Report in 2001 and has continued to report annually, raising the bar on disclosure for itself and the industry.

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[3] https://www.csrwire.com/press_releases/717876-empowering-cultural-shift-accelerate-more-sustainable-and-just-future

[4] https://www.csrwire.com/press_releases/717876-empowering-cultural-shift-accelerate-more-sustainable-and-just-future

[5] https://garage.hp.com/us/en/impact/closed-loop-recycling-printers.html

[6] http://web.worldbank.org/archive/website00818/WEB/OTHER/GLOBA-22.HTM

[7] https://press.hp.com/us/en/press-releases/2019/hp-launches-worlds-first-pc-with-ocean-bound-plastics.html

In 2021, HP announced its 2030 vision and goals,[8] bringing sustainable impact to the forefront of its corporate strategy and 10-year plan. The vision is to become the world's most sustainable and just technology company, with a primary focus on addressing the current most urgent issues of society regarding Climate Change, Human Rights and Digital Equity. Each of the three pillars encompasses goals to be met throughout the upcoming years, some of which are further explained below:

- Climate action: drive toward a net-zero-carbon, fully regenerative economy while engineering the industry's most sustainable portfolio of products and solutions. HP plans to achieve net-zero greenhouse gas emissions across its value chain by 2040, with a 50% reduction by the end of this decade. The company also pledges to reach 75% circularity for products and packaging by 2030 and is committed to maintaining zero deforestation for HP paper and paper-based packaging and counteracting deforestation for non-HP paper used in products and print services.
- Human rights: create a powerful culture of diversity, equity, and inclusion while advancing human rights, social justice, and racial and gender equality across the company's ecosystem. By 2030, HP is committed to achieving 50/50 gender equality in leadership and making sure that women represent greater than 30% of the workforce in technical and engineering roles. Across the company, HP intends to meet or exceed labor market representation for racial and ethnic minorities. And it also aims to reach one million workers through worker empowerment programs throughout the supply chain.
- Digital equity: lead in activating and innovating holistic solutions that break down the digital divide that prevents many from accessing the education, jobs, and healthcare needed to thrive. HP's goal is to accelerate digital equity for 150 million people by 2030. Part of these efforts is the HP Partnership and Technology for Humanity (PATH) accelerator program, focused on paving the way toward digital equity and inclusion in underserved communities around the world.

As illustrated, sustainable impact is inherent to HP's history, and embedded in this framework—that goes beyond just neutralizing and offsetting the impact—is the company's approach to circular economy in its product portfolio and value chain. According to the Ellen MacArthur Foundation, "a circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. Looking beyond the current take-make-waste linear model, a circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the

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[8] https://press.hp.com/us/en/press-releases/2021/hp-inc-announces-ambitious-climate-action-goals.html; https://press.hp.com/us/en/press-releases/2021/hp-shares-ambitious-2030-goals-to-drive-DEI-in-tech-industry.html; https://press.hp.com/us/en/press-releases/2021/hp-commits-digital-equity-150-million-people.html

consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital".[9]

Looking closely, initiatives as early as the punch cards recycling program and the manufacturing policy to protect the environment were already in line with the principles of circular economy, even if not yet formally identified as such. These and the other sustainability milestones achieved throughout the years make the foundation over which HP now stands and plans for the future. The vision is to become a fully circular company powered by multiple strategies that drive innovation in key areas, from product design, going through service models that consider all business units, to end-of-life options that ensure equipment is either repurposed for a second life or securely and sustainably recycled. To accelerate this move, which also encompasses low-carbon emissions and positive impact instead of just neutralizing impact, HP constantly challenges and rethinks processes, what materials to choose to make its products from and how to make them.

Reusing products and parts, for example, using only recycled or renewable materials in the products, and eliminating potentially harmful substances, are some of the actions the company is working toward. Already in progress are product life extension through maintenance, upgrades, repair, and service-based business models, and the efforts to reuse or recover all products at their end-of-life. Underpinning these, HP aspires to 100% use of renewable energy and zero waste processes in manufacturing, two other key premises of circular economy, as per the Ellen MacArthur Foundation.

Also, in line with circular economy principles are HP's service-based solutions, such as HP Device as a Service (Personal Systems), HP Managed Print Services (Print), and HP Instant Ink (Printing Supplies). Service models provide customers with not only business-related support, as all programs help to enable them to scale as their business needs evolve, but also with environmental sustainability support through the dematerialized services that allow the shrinking of clients' carbon footprint and help accomplish their long-term sustainable impact.

Finally, HP's efforts toward a positive impact, low-carbon, and circular vision are implemented not only through the design and delivery of products and solutions, but through global partnerships that are focused on strengthening natural systems. Through these efforts, HP is striving to transform how it functions as a business while enabling and encouraging other industries to eliminate waste and drive toward their own efficient, low-carbon, and circular value chains, altering industry business models and decoupling business growth from resource consumption.

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[9] https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy & https://www.ellenmacarthurfoundation.org/circular-economy/concept

7.3 HP Circular Economy Approach and Initiatives

HP's circular economy strategy—as shown in Fig. 7.1—is comprised of multiple strategies and programs to allow operations and the value chain to decouple growth from consumption, as well as to disrupt industry business models and digitize supply chain and manufacturing.

From the outer circle, HP is searching for solutions and innovations that allow closing the loop for the materials used in the products, starting with plastics, and already advancing for other streams like metals and glass. The goal is to have 30% of recycled content on the product portfolio by 2025 and 75% by 2030. Single-use plastic is being eliminated by 75% until 2025.

The second circle shows the strategy for reuse and refurbishment. Device Recovery Services are available currently for PCs in 27[10] countries. A third-party Life Cycle Assessment (LCA) shows HP device recovery service helps customers reduce their GHG emissions, decrease ecosystem impacts, and impact on human health.[11]

The third circle presents the strategy of shifting to product-as-a-service. This business model, already present largely for printing and personal systems enterprise customers (for print, the service is called Managed Printing Services—MPS, and for personal systems, Device as a Service—DaaS), is also available for consumers

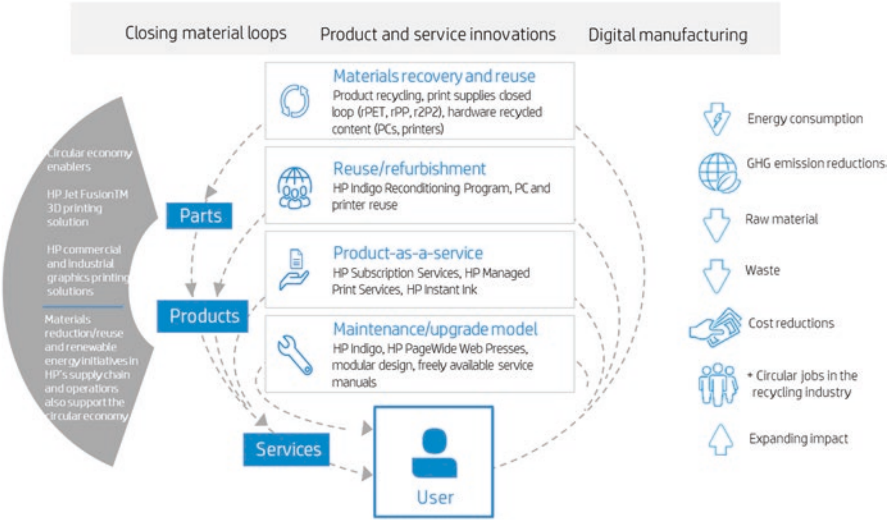

Fig. 7.1 HP's circular economy strategy

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[10] https://www.hp.com/us-en/services/device-recovery-service.html

[11] https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=c06646300)

with Instant Ink. This subscription service allows customers to receive cartridges at home before running out of ink and return old cartridges for recycling through mail envelopes.

The last circle allows products to last longer with the principles of repairability and upgradeability. HP provides free service documentation using its support channel and YouTube[12] for most products. Several HP personal systems products received high reparability assessment scores from the iFixit product repair site in 2020,[13] which considered easily removable key components, modular designs, labeling, and other features. In addition, some products such as certain models of desktops already allow upgradeability for the PC base and display. Another key element of this strategy is for products to be well rated on durability.

Additionally, HP's 3D printing technology acts as an enabler of circular economy for manufacturing and repair services. 3D manufacturing is often referred to as "additive manufacturing", a concept that encompasses manufacturing from the bottom up, with little to no waste produced. It allows more customized, localized, and accurate production of parts and finished goods.

All these programs will be further detailed ahead, along with some of the positive results and long-term value generation for HP and stakeholders. Overall, through this circular economy strategy, it is possible to decrease energy consumption and GHG emissions; the need for using raw materials is smaller, therefore decreasing impact in the extraction phase; and the generation of waste is also significantly decreased. On the other hand, positive economic impacts are also generated, with cost reductions and more jobs in the circular economy industry, especially from an inclusion perspective.

7.3.1 *Product Design*

When it comes to determining a product's environmental impacts, design plays a critical role. As stated by the Ellen MacArthur Foundation, decisions made in the design phase of a product can significantly influence how circular it is.[14] From an industrial system perspective, circular economy encompasses the concept of being restorative or regenerative by intention, shifting toward the use of renewable energy, the elimination of toxic chemicals, and the overall elimination of waste through a superior design of material, products, and services (EMF 2014).[15]

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[12] https://www.youtube.com/user/HPPrinterSupport/featured)

[13] https://www8.hp.com/h20195/v2/GetPDF.aspx/c07539064

[14] "Designing for reuse and circulation of products and materials" Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/assets/downloads/2_Products_Designing_Mar19.pdf

[15] "The benefits of a circular economy" https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Towards-the-circular-economy-volume-3.pdf

Accordingly, HP has and continues to strive to apply rigorous design principles to improve the environmental performance of products across their entire life cycle. The Design for Environment program was developed in 1992 to formally consider factors impacting sustainability performance throughout product design and development phases and, in response to technological and scientific developments, changes to the supply chain, and customer demands, the program has been renamed, now known as Design for Circularity. As a member of the Ellen MacArthur Foundation Circular Economy 100 network, HP also collaborates to drive industry-wide progress toward a more circular materials and energy-efficient future.

Internally, the company uses a science-based approach to evaluate products, identify, and prioritize improvement opportunities, and set goals. Also, in 1992, for example, the first Life Cycle Assessment was made on ink cartridges, providing insights into the product, and enabling a deeper understanding of what worked and what could be improved. Today, from a product design standpoint, HP is committed to designing waste out and responsibly using materials, aiming to:

- Increase materials and energy efficiency.
- Use more recycled content, tackling ocean plastic pollution as well.
- Replace materials of concern.
- Decrease product carbon and water footprint.
- Help to restore global forests through a Forest Positive framework that addresses printing value chain impact, including non-HP paper used by customers.
- Longevity of devices—maintenance, repairability, and upgradability.

To assess its own performance across the established circularity-related goals, HP uses the Ellen MacArthur Foundation's Circulytics tool, which goes beyond assessing products and material flows, revealing the extent to which a company has achieved circularity across its entire operations.[16] Through a wide set of indicators divided between enablers and outcomes, Circulytics analyses the submitted data and demonstrates strengths, highlights areas for improvement, provides optional transparency to investors and customers about a company's circular economy adoption, and delivers clarity about circular economy performance, giving visibility to new opportunities to generate brand value with key stakeholders.[17]

Through the Circulytics assessment, HP has been able to not only locate successful approaches and improvements needed in current focus areas, but also identify how to best move forward on its path to 2030, narrowing down and understanding which primary areas to focus on to achieve the company's circularity vision. Regarding product design, ahead are some initiatives and actions being taken by HP across the aforementioned goals.

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[16] https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity

[17] https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity

7.3.1.1 Increase Materials and Energy Efficiency

Now aiming to reach 75% circularity for products and packaging by 2030, to later become a fully circular company, HP is increasing its efforts to achieve energy and material efficiency.

In 2021, the company used 969,696 tons of materials in products and packaging, 3% more than in the previous year. This represented 39% of circularity by weight, achieved using 32,000 tons of recycled content in products and packaging, 105,700 tons of recycled fiber used on HP brand paper and packaging, and 227,800 tons of certified sustainably managed fiber. The company also achieved 4300 tons of recycled content metal used in HP products and 7200 tons of reused products and parts.[18]

As for energy efficiency, HP is working to increase it for products and services, enabling customers to reduce energy use with efficient product fleets. Certifications like eco-labels provide detailed information that enables and guide customers to make better product choices. In 2020, for example, HP announced the world's most sustainable PC portfolio, based on the criteria set out by EPEAT—a comprehensive, measurable, and transparent eco-label of the IT industry. Administered by the Green Electronics Council, the EPEAT program provides independent verification of a manufacturer's products based on sustainability criteria, including product energy efficiency. 77%[19] of all HP's personal systems products and 88% of printers shipped in 2021 were EPEAT registered.[20]

HP also has products recognized by ENERGY STAR®, a program run by the U.S. Environmental Protection Agency and the U.S. Department of Energy that promotes energy efficiency. As of 2021, 85% of personal systems products and 94% of printers shipped were acknowledged by the eco-label as having superior energy efficiency. HP itself was recognized as an ENERGY STAR® Partner of the Year in 2021, for the fourth year in a row (second for Sustained Excellence).

Furthermore, since 2010, the energy consumption of HP's personal systems products has dropped by 47%, on average. Printers that use HP EcoSmart black toner consume 20% less energy, on average than the previous generation.[21]

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[18] https://www8.hp.com/h20195/v2/GetPDF.aspx/c08228880.pdf, p. 67.

[19] https://www8.hp.com/h20195/v2/GetPDF.aspx/c08228880.pdf, p. 70 .

[20] EPEAT data for personal systems is for models registered worldwide and for printers, for models registered in the United States.

[21] HP calculations based on Energy Star® normalized TEC data comparing the HP LaserJet 200–500 series. https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=4AA7-8457ENW

7.3.1.2 Use More Recycled Content, Tackling Ocean Plastic Pollution as Well

Part of designing out waste and using materials responsibly are the initiatives to increase the use of recycled content, with a special focus on tackling ocean plastic pollution. Across its Print and Personal Systems products, HP is currently on track to achieve its goal to use 30% postconsumer recycled plastic by 2025. During 2021, 32,000 tons of postconsumer recycled content plastic were used in both lines of products, constituting 13% of the total plastic used.[22] In the personal systems portfolio, 8510 tons (14.9%) of the plastic used was postconsumer recycled content and in Original HP Ink Cartridges, it amounted to 53.6%.

For home and office printers, the number reached was 12,600 tons or 8.6% of the total plastic used. HP's Ink Tank printer, manufactured in Brazil, achieved 40% of recycled content in weight of plastic, exceeding the initial goal of 32% for 2020.[23]

On the ocean plastic pollution front, in 2019 HP launched the world's first notebook with ocean-bound plastics.[24] The HP Elite Dragonfly has more than 80% of all mechanical parts made from recycled material and its speaker enclosure component is made with 50% postconsumer recycled plastic, 5% being ocean-bound plastics. As of 2021 HP had sourced more than 1298 million pounds of ocean-bound plastic—more than 102 million bottles—for use in supplies and hardware.[25]

7.3.1.3 Replace Materials of Concern

HP has been continuously working so its products and operations use materials and chemicals that cause no harm. Manufacturing processes, packaging, and product design have been guided by the HP Materials and Chemical Management Policy, which helps specify materials and chemicals for use. It is noteworthy that this policy applies to all HP employees and businesses worldwide and extends to suppliers.

As part of the process of chemicals management, HP continues to gather chemical data from suppliers, and identify and confirm the implementation of corrective actions when needed. The company also has a full list of material restrictions and contributes to standards, legislation, and improved approaches to materials use in the IT sector.

In 2021, highlights of materials of concern reduction include the launch of five Elite Displays without the video cables and with a PVC-free power cord that uses GreenScreen Benchmark 2 or 3 flame retardants; 83% of personal systems product series as low halogen; the reduction of PVC usage through the manufacturing of

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[22] https://www8.hp.com/h20195/v2/GetPDF.aspx/c08228880.pdf, p. 90.

[23] Id., p. 7.

[24] Based on HP's internal analysis as of August 2019.

[25] https://www8.hp.com/h20195/v2/GetPDF.aspx/c08228880.pdf, p. 70.

inkjet printers without cords; and by December 2020, all HP workstation PCs, displays, and accessories switched from solvent-based to water-based paints.

7.3.1.4 Reduce Carbon and Water Footprint

As seen, the manufacturing, delivery, and use of HP products and solutions require substantial natural resources and energy use. HP's carbon and water footprints cover the entire global value chain, from suppliers to operations and millions of customers worldwide. In 2021 GHG emissions associated with product energy use equaled 8,700,000 tons of CO_2, 31% of our overall carbon footprint, representing a decrease of 11% in absolute emissions compared to 2020.

Specifically, in the print business, HP's Managed Print Services (MPS) offering is carbon neutral, in accordance with the CarbonNeutral Protocol,[26] with end-to-end solutions for HP-branded devices helping businesses reduce and offset the carbon impact of printing by, for example, estimating the total carbon emissions from HP-branded printing solution using HP's proprietary Sustainable Impact Reporting and Analytics tool and offsetting 100% of GHG emissions.

As for water, HP's 2021 water footprint equaled 146,756,000 cubic meters,1 8% less than in 2020..[27] This resulted primarily from a reduction in indirect water consumption from electricity generation and paper production associated with HP product use. Product energy use represented 54% of HP's water footprint, due to the water used for cooling during electricity generation. This indirect water consumption related to product use equaled 78,900,000 cubic meters, 19% lower than the prior year (2020), due to the same factors that decreased GHG emissions.

7.3.1.5 Addressing Impact Over Forests

As part of HP's efforts to minimize printing impact on forests, all HP brand paper, paper-based packaging, and wood in products must be derived from recycled or certified sources. The company gives preference to Forest Stewardship Council® (FSC®)-certified fiber where available and works with WWF's Global Forest & Trade Network—North America (GFTN-NA), FSC, and suppliers to continually improve programs related to the sourcing of virgin fiber and to increase the amount of certified fiber in products and packaging. HP also analyzes its supply chain to understand areas of specific risk (due to weak regulation or ecosystem vulnerability) and create specific strategies as needed.

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[26] Natural Capital Partners, The CarbonNeutral Protocol, 2020 edition, carbonneutral.com/the-carbonneutral-protocol

[27] The 11% decrease in the water footprint in 2020 compared to 2019, which contrasts a 4% decrease in the carbon footprint during that period, reflects differences in the two calculation methodologies related to the supply chain phase. Details are available in the HP water accounting manual and the HP carbon accounting manual.

In 2016, the company achieved 100% zero deforestation associated with HP-branded paper, with all of it deriving entirely from certified and recycled sources.[28] The goal was met nearly 2 years ahead of schedule, marking a milestone toward the vision for a forest-positive future. In 2019, the HP Sustainable Forests Collaborative was officially launched, aiming to restore, protect, and transition to sustainable management of more than 200,000 acres of forest. This amount of forest restored would address more paper than used by HP's consumer printers worldwide annually.

In 2020, HP achieved zero-deforestation also for its paper-based product packaging. And building on this progress, by 2030 HP will scale up investment in forest restoration, protection, and other initiatives to counteract deforestation for non-HP paper used in all products and print services.[29] HP is one of the few companies in the world to achieve a zero-deforestation goal for the sourcing of its paper and packaging and the only technology company to set a goal to address deforestation that goes beyond its own fiber sourcing to include the use of its products and services. As a result, in 2021 an expansion of the partnership with WWF was announced, pledging US$ 80 million to address that impact.

The carbon-neutral MPS offering and the HP Instant Ink, for home users and microbusinesses, which anticipates when ink is running low and sends replenishments and new recycling envelopes to customers' doors, are two examples of initiatives part of HP's Forest Positive Framework which also includes the NGO partnerships targeted to protect forests, improve responsible forest management, and help develop science-based targets in this area.

7.3.1.6 Maintenance, Repairability, and Upgradability

According to the Ellen MacArthur Foundation a modular design, or "modularity in design" is a design approach that subdivides a system into smaller parts, which can be independently created and then used in different systems. Such a design approach brings four areas of value creation: product life extension, once it facilitates maintenance, repairability, and refurbishment; creation of secondary component markets,

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[28] Per HP's definition of certified wood-based products, a certification label must be displayed on the pack. On average, less than 1% of HP papers annually by weight is unlabeled due to the incomplete chain of custody for some low volume products. To avoid deforestation, all of HP paper by weight originates from certified paper stock, and/or certified fiber, and/or wood that meets the definition of FSC controlled wood. In addition, on average less than 1% of HP paper annually by weight may be unlabeled certified due to obsolete or lingering regional inventories. Recycled fiber for paper products is included in the FSC®-certified volume.

[29] Fiber by weight will be (1) certified to rigorous third-party standards, (2) recycled or (3) balanced by forest restoration, protection, and other initiatives through HP's Forest Positive Framework. Paper does not include fiber-based substrates for HP industrial presses not listed in HP Media Solutions Locator catalogues.

as it requires the adoption of standardized components that can be reused in other applications; higher prices of materials waste streams, as the modular design allows for easier separation of materials, therefore higher purity of after-use materials streams; and reduction in dependency of raw materials extraction, once this process enables better recycling and recuperation.[30]

The potential benefits that a modular design brings include upgradability, maintenance, repairability, and recyclability. HP products are designed considering the entire lifecycle, using a science-based approach and the concept of modular design to develop its reuse, repair, and recycling programs, as well as to increase the upgradability of products.

HP also stands for the right to repair, making available free service documentation for most products, supplemented with service options and warranties. The HP Customer Self-Repair webpage[31] includes information in that area, and the HP Parts Store[32] sells PC and printer parts for that end.

Several personal systems products have received high reparability assessment scores from the iFixit product repair site in 2020, which noted easily removable key components, modular designs, labeling, and other features. Through the modular design, several printer models have also increased upgradeability and are easily disassembled for repair or recycling. Customers can exchange parts and have access to a range of repair options, either in the traditional transactional business model or in the managed printing services modality. In addition, printers also have spare parts available until at least 3 years after their production ceases.

Furthermore, industrial printers like HP Indigo and PageWide are major capital investments for customers and therefore are designed for upgradeability, repair, and refurbishment. Through firmware and component upgrades those printers can be kept updated. As an example, due to continuous upgrades of components and technologies such as printheads, electronics, software, and inks, customers who have acquired a PageWide T200 press in 2010 now experience more than twice the speed, with increased print quality and media versatility,[33] and Indigo presses are built to last, with some that have been working for nearly 20 years.

Lastly, one important effort to improve efficiency in repairability is being led by HP's area of customer services. The goal is to improve the non-recovered rate from spare parts from 40% to 10% by 2030 and have a 90% rate of repairable parts refurbished or reused by 2030. In 2020, 67% of total parts returned to HP were reused after refurbishment.

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[30] Modularity in ICT Paper. CE 100 - EMF, October 2017, developed in partnership with HP, Anteagroup, Ifixit, DLL, Orange and Granta.

[31] https://support.hp.com/us-en/document/c05348074

[32] https://parts.hp.com/hppartsIGSO/Default.aspx?mscssid=]~{{{{{{{{{{{{{{{&from=ERP

[33] https://www8.hp.com/h20195/v2/GetPDF.aspx/c07539064, page 82.

7.3.2 Product End-of-Life

As seen, there are multiple aspects to consider when building a more circular and low-carbon economy. The after-use phase also requires close attention so that electronic materials and products can either be securely repurposed or recycled.

HP has been engaging in recycling efforts since 1991, with the creation of its recycling program "HP Planet Partners". The program aims to make it easy and secure to recycle electronic equipment and printing supplies worldwide, from consumers and corporate customers and is present in more than 60 countries across the globe.

To provide product reuse and recycling services to customers around the world, HP works with a global network of vendors. As part of a diligent process to accredit these recycling suppliers, which includes third-party audits and setting strict parameters for disassembling and recycling, the company has a policy that nothing goes to landfill. Only a small percentage of the recycling process is sent for energy recovery, while most materials are either recycled and reintroduced in HP's supply chain or used in another chain, with open-loop solutions.

In Brazil, for instance, the creation of an ecosystem integrating reverse logistics and manufacturing capabilities is particularly seen as a worldwide case of the company's successful strategy from a supply chain perspective. 100% of the waste generated in the manufacturing process is kept out of landfills through the Zero Waste program, in which initiatives to reduce, reuse, and repurpose are designed to reduce waste. To achieve this, the company had to rethink the relationship with suppliers, continuously encouraging them to change processes and invest in new capabilities. The program engages more than 20 suppliers, from packaging and plastic molders to the manufacturing partner.

Similarly, efforts have been made in China, where HP was the first IT company to use pallets, which are made primarily from straw, with some bamboo fiber and small amounts of nonhazardous binder materials. The shift to these new pallets delivers several environmental, health, and societal benefits, in addition to reducing the pollution created by burning the straw. HP used 49,900 pallets made from 2500 tons of straw from China that would otherwise have been burned as agricultural waste, and expanded its recycled pallet program in North America, using 607,000 recycled pallets during 2020.

HP also set the goal to recycle 1.2 million metric tons of hardware and printer supplies by 2025. And by the end of 2021, it already had recycled 764,800 tons, over 63% of the target. In addition to the recycling efforts, programs have been set to recovery and refurbish devices. In 2020, more than 5.3 million units of hardware were repaired, and 1.28 million were remarketed and reused, reaching when combined approximately 4% rate in comparison with HP units of hardware sold worldwide. HP Indigo presses (large format industrial printers) refurbished reached a total of 14% of the total presses of this model shipped during the year.

Device recovery offerings are available for commercial PC customers. It is possible to recover equipment from any brand and this service that has been rapidly growing, with close to a thousand customers using the service in 2020. The service provided is transparent about environmental and financial aspects of devices being retired and a sustainability benefit report provides the savings of greenhouse gas emissions by giving those devices a second life.

A third-party Life Cycle Assessment (LCA) study sponsored by HP showed that the device recovery service for PCs can reduce GHG emissions by 25%, decrease ecosystem impacts by 28%, and reduce human health impacts by 29%. This is a very strategic effort for HP as it helps to minimize supply chain impacts for critical components that arise from shortages or disruptions like a pandemic**.**

7.3.3 Disrupt Industry Business Models

Service-based business models are another cornerstone of the circular economy, it allows for better management of the entire life cycle of products, maximizing its lifetime through appropriate maintenance, and recycling or repurpose when it reach its end of life.

Another aspect of shifting to services is from a fleet management perspective, which makes it possible to carefully choose devices that meet customer expectation while maximizing environmental benefits. This is very critical for large fleets, where choosing the appropriate products as well as capabilities can enable a considerable decrease in the footprint, up to 40% on printing services.[34] Solutions such as Managed Print Services (MPS) and Device-as-a-Service provide customers with access to the latest technologies, allowing them to scale up or down as their businesses evolve. From LCA studies conducted by third parties, product-as-a-service systems proved to be more efficient in lowering carbon footprint due to extended product life, usage optimization, avoided manufacturing, and material and transportation savings.

According to research provided by MarketsandMarkets, a B2B research firm that quantifies high-growth emerging market opportunities, PC-as-a-service market (PCaaS) alone will reach USD 141.6 billion by 2024 starting from a baseline of USD 15.9 billion in 2019, which represents an annual growth rate of 54.9%. This shows how much the business model is going to grow over the next years.

At HP, PC as a service is a growing revenue source. Not only do this service provide more value for customers, as they pay only for the services they need rather than the purchase of hardware and materials, with this they also achieve proven environmental benefits as well.

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[34] Estimated energy and paper savings based on analysis of select HP Managed Print Services customers' imaging and printing operations using data gathered on devices and paper consumption and comparing with post-MPS actuals or projections. Results depend on unique business environments, the way HP products and services are used, and other factors.

HP uncovered this significant finding via three studies it commissioned in 2019 and 2020 of its "Product as a service" offerings: HP Device as a Service (DaaS), HP Managed Print Services (MPS), and HP Instant Ink (cartridges consumer subscription service). Those third-party experts conducted a LCA ISO-compliant assessment,[35] with the objective to compare whether the contractual services models have more environmental benefits than their conventional transactional counterparts.[36]

Those studies revealed that HP's service-based solutions have better environmental footprint in areas studied (global warming, water, human health, ecosystems, and resources). These results are significant not only to HP, as it was possible to accumulate empirical evidence that the service models are powerful routes to decoupling society's impact on natural resources and climate change.

From a DaaS (Device as a Service) perspective, the results were that the service model can reduce GHG emissions by 25%, resource efficiency by 28%, ecosystems impact equally by 28%, and human health by 29%, when compared to the traditional transactional business model. Overall impact reductions range between 25% and 30% compared to the linear model and this is mainly due to keeping PCs in use for multiple life cycles, which avoids the highest impacts on the manufacturing and raw material extraction side.

From a MPS (Managed Print Service) standpoint, when compared to traditionally purchased multi-color function LaserJet printer, the service model reduces GHG emissions by 12%, improves resources efficiency by 13%, decreases ecosystems impacts by 12%, and reduces human health impact by 10%. Overall impact reductions range between 9 and 12% compared to the linear model. This gain is allowed mainly due to more efficient product use and reduced waste generation during the life cycle of the printer.

7.3.4 *Digitize Supply Chains and Production*

Taking advantage of its long presence in the graphics printing industry and a portfolio of large format printers that were already allowing a shift from an analogic to digital printing, HP launched its first 3D printer in 2016, with the promise to solve some big issues of the 3D printing at that time—speed, cost, and reliability. A new business unit dedicated to additive manufacturing was launched.

Additive manufacturing (AM) is considered an essential component of Industry 4.0 that integrates intelligent production systems and advanced information technologies, such as 3D print, which streamline the prototyping process, improves the

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[35] The LCAs HP commissioned of its circular PaaS solutions are full comparative LCAs, completed in accordance with ISO 14040 and 14,044. The assessments analyzed 20 environmental impact categories.

[36] https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=c06646300

economics of short-run manufacturing, and reduces waste and the need for physical inventories of thousands of parts and products.[37]

This type of manufacturing is designed with little to no waste production, as a shift from analogical printing to a digital solution allows customization, tailor-made products, as well as producing only what is necessary, when necessary. The on-demand printing helps better match supply and demand when manufacturing spare parts or finished goods while lowering the use of raw materials, energy, costs, and emissions. This will reduce waste generation, allow a production closer to consumer markets, and consequently avoid impacts associated with transportation, as well as the need for physical inventories of thousands of parts and products that are stored for later use—or worse never used at all.

The adoption of 3D printing and its ability to reduce waste and promote a circular economy changed the global manufacturing paradigm. The transformation that digital manufacturing enables is a requisite for success in modern marketplaces. The 3D printing has revolutionized manufacturing, quickly enabling responses to customer requests as well as to the needs of new industrial, medical, and dental ecosystems.

Another benefit 3D printing can bring as an enabler of a circular economy is that it allows manufacturers to offer a repair service that extends the lifetime of their products, by bringing new repairability models. Manufacturers can also learn from their repairs and rapidly iterate and improve design details after the product is on the market. It is possible to illustrate some examples from HP customers that start using digital printing technology. One publisher between 2009 and 2013, by better matching demand and supply was able to reduce inventory by 28%, warehouse space by 19%, and title obsolescence by 73%.

To further test and assess the benefits derived from the adoption of 3D printing, HP was able to incorporate some printed parts into its own products, as well as fiber packaging. Taking one example, from a traditional aluminum traditional machine design, HP started the test first with a solid printed block design, evolving for a light design and arriving at a topological design (Fig. 7.2), that was 93% lighter than the aluminum one, 95 times lower in terms of carbon footprint and 50% cheaper.

Similarly, it was possible to produce more efficient manufacturing aids: the drill extraction shoe is a device used during the manufacturing of HP printhead nozzles to remove the silicon sludge and water from the machining process. It essentially enables a more efficient laser drilling process. Consolidating the design from seven parts into one 3D part it was possible to achieve 95% cost reduction and 90% weight reduction versus the original assembly with Aluminum-machined parts (Fig. 7.3).

Lastly, during the pandemic, HP has collaborated with partners to produce face shields, nasal swabs, and hands-free door openers with 3D printing technology. More than 50 partners and customers joined the efforts, and more than 15 new applications were developed, designed, and made freely available on the internet.

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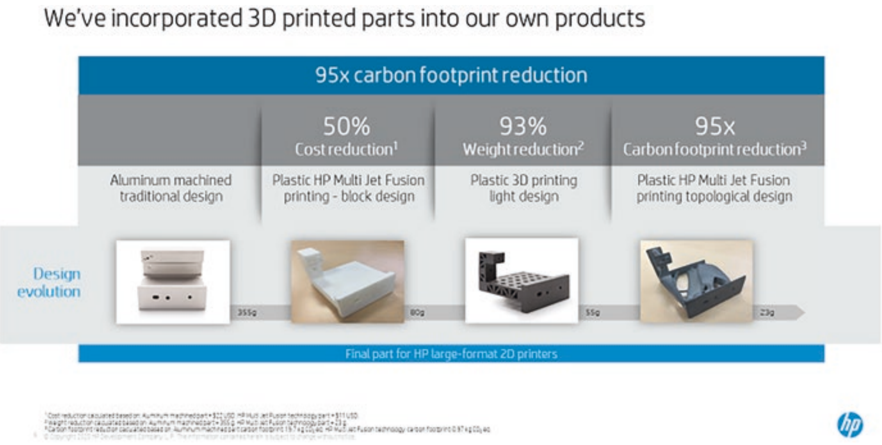
[37] https://www.sciencedirect.com/science/article/pii/S2351978917303529

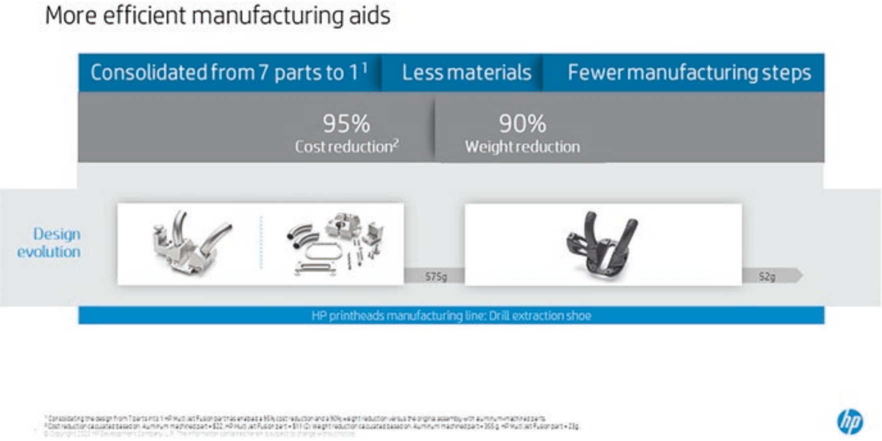

We've incorporated 3D printed parts into our own products

95x carbon footprint reduction

Aluminum machined traditional design	50% Cost reduction[1] Plastic HP Multi Jet Fusion printing - block design	93% Weight reduction[2] Plastic 3D printing light design	95x Carbon footprint reduction[3] Plastic HP Multi Jet Fusion printing topological design

Final part for HP large-format 2D printers

Fig. 7.2 Example of process to incorporate 3D parts into HP products


More efficient manufacturing aids

Consolidated from 7 parts to 1[1] | Less materials | Fewer manufacturing steps

95%
Cost reduction[2]

90%
Weight reduction

HP printheads manufacturing line: Drill extraction shoe

Fig. 7.3 More efficient manufacturing aids

7.4 Advancing Toward a More Inclusive Circular Economy

According to the International Labour Organization (ILO), across the world, many workers are involved in the informal waste sector, being usually excluded from labor legislation and social protection, working under poor conditions, and having low and insecure incomes (ILO 2014). Nearly 15 million people are involved in waste management activities in the informal sector and, despite often not being recognized, its members contribute significantly to the waste management of cities (Gupta 2012).

In middle and low-income countries, the infrastructure for waste management is under development or absent, causing it to be in part executed by the informal sector.[38] These workers play an important role collecting, sorting, and even recycling, thus preventing waste leakage, and reaching areas that are not covered by the public waste management system.[39] The prevalence of informality along the recycling chain is directly connected with social and economic factors, often expressed by marginalized social groups looking for a source of income and survival in waste picking.

It is possible to highlight some aspects that aggravate this reality: first, the lack of environmental education and information of the consumers, usually unfamiliar with recycling practices. Plus, low investment in the recycling chain, which results in low formal infrastructure for waste management and recycling, in turn causes an excess of postconsumer waste that has economic value.[40] This last part is the main incentive for the informal worker to start in the recycling sector, especially e-waste, since its components have precious metals like gold, silver, platinum, and palladium, that can be sold back to the industry.

To support these workers, generate more qualified jobs, improve economic gains, and create better capabilities, HP's first program was launched in 2016, to also help tackle the growing challenge of ocean-bound plastics in Haiti, in partnership with the First Mile Coalition. After the earthquake in 2010,[41] the country's water system was affected, forcing the population to use exclusively plastic water bottles. Sewage systems of many cities were also destroyed, compromising street gutters. On top of the catastrophic consequences caused by the earthquake and the intensification of poverty in the country, Haiti still needs to deal with the challenge of plastic pollution. To help tackle this, HP built a self-reliant ocean-bound plastic supply chain that contributes to the circular economy and provides income and education opportunities locally.

Along with First Mile Coalition and supplier partners, HP is helping to create new jobs, health, and safety training, while also providing education for children that used to collect plastic waste to help with their families' income. At the same

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[38] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR)—co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

[39] Siddharth Hande, « The informal waste sector: a solution to the recycling problem in developing-countries », Field Actions Science Reports [Online], Special Issue 19 | 2019, Online since 01 March 2019, connection on 15 October 2019. URL: http://journals.openedition.org/factsreports/5143

[40] The informal economy of e-waste: The potential of cooperative enterprises in the management of e-waste / International Labour Office, Sectoral Activities Department (SECTOR), Cooperatives Unit (COOP)—Geneva: ILO, 2014.

[41] https://www.theguardian.com/global-development/poverty-matters/2014/jun/05/haiti-drastic-plastic-problem-help-vulnerable

time, HP purchases recycled plastic made with raw materials collected at the Truitier landfill[42] to reintroduce them in the manufacturing of new products.

The first ink cartridges made from Haiti's bottles started to be sold in 2017.[43] In 2020, HP invested US$2 million in a new plastic washing line in the country, expanding the ocean-bound supply chain.[44] The investment allowed the production of high-quality recycled plastic for use in products such as ink cartridges and PC portfolio, made in collaboration with Lavergne (plastics transformer), ECSSA (the local Haiti recycler), and STF Group (the manufacturer of the washing line). The project increased the value of plastic collected on the island and the prices that collectors receive and will add an estimated 1000 more income opportunities for adults in Haiti on top of the 1100 that have already been created.[45]

Since HP committed to tackle ocean plastic, other supporting initiatives came up: in 2018, the company joined NextWave Plastics, an initiative convening technology, and consumer-focused companies to develop a global network of ocean-bound plastic supply chains. In 2020, HP joined Project STOP, which collaborates with governments and communities in Southeast Asia to create effective waste management systems that eliminate plastic leakage into the ocean. HP is working to create a circular waste management system in East Java, Indonesia, where Project STOP is operating to build recovery centers that will collect, manage, and recycle plastic waste while providing income-generation opportunities, including in the informal waste sector.

In Brazil, another inclusive circular economy project is being developed along with cooperatives: The HP & Cooperatives initiative, established in partnership with iWRC—Inclusive Waste Recycling Consortium. To understand the relevance of this project in the country, it is important to highlight that, according to ABRELPE (Brazilian Association of Public Cleaning and Special Waste Companies),[46] after 10 years of the publication of the National Policy on Solid Waste, waste management structure is still incipient, while waste generation increased 19% during this decade. This combination, along with low incentives in the recycling chain, results in low recycling rates overall, remaining below 4% during this entire period.

The informal sector plays a key role in that equation, collecting 90% of recyclable waste in the country.[47] The scenario of waste pickers is part of the urban scene in Brazil, and most of these people work in this activity because it is the only possible or at least the most viable economic alternative, considering poverty and social exclusion that takes place in the country. Brazil, though, has a long history of

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[42] https://press.hp.com/us/en/press-releases/2016/hp-announces-commitment-to-create-sustainable-recycling-opportun.html

[43] https://garage.hp.com/us/en/impact/haiti-recycling-plastic.html

[44] https://press.hp.com/us/en/press-releases/2019/hp-expands-efforts-to-reduce-ocean-bound-plastics-.html

[45] https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=c07539064

[46] ABRELPE: Panorama dos resíduos sólidos no Brasil 2020 disponível em: https://abrelpe.org.br/panorama/

[47] IPEA, 2016.

promoting the organization of waste pickers into cooperatives, facilitating the development of capacity-building programs.

An issue arising from the informality is that many of the cooperatives collecting e-waste end up disassembling those, selling the valuable materials to scrap dealers, and remaining with the burden of less valuable streams that may sometime end in polluting the environment and generating health risks for members. This happens because some industries purchase recyclables in large volumes, generally obtained by scrap dealers, creating a chain of exploitation that leads the informal sector to remain vulnerable and obtain few gains (Barbosa and Cavalcanti 2016).

There is now a global challenge to connect the informal sector with the electronics industry, making it possible, at the same time, to maximize the role of this actor, reduce the negative environmental impact of incorrect disposal, and improve the industry's role in promoting recycling, while aligned with the principles of producer responsibility.

In 2018, HP started HP & Cooperatives, this pioneering project in the IT sector, to create an economic business model to integrate the informal sector into e-waste take-back programs and recycling chains. The focus is to include the informal sector through a scalable, digital, and multi-stakeholder platform in order to increase the feed stream for the closed-loop process. At the same time, the project aims to improve cooperatives' working conditions and revenue and to promote education, digital inclusion, and women empowerment initiatives, by supporting capacity building and recognizing their role as agents in their communities.

This collaboration turns out to be a win-win situation. Cooperatives can improve their working conditions and revenue, so far, more than 600 workers have been supported by the initiative, with 360 directly working with e-waste. Those individuals were also able to improve their income above the minimum wage. On the other hand, HP increases its closed-loop material feed stream: in 2021, 380 tons of e-waste were collected, and recycled plastics were reinserted into the production of printing parts.

Ultimately, as a result, these programs developed and supported by HP foster a more inclusive circular economy, addressing societal challenges and integrating the informal sector into a critical component of the company's circular economy strategy.

7.5 Final Remarks

The success of future generations is dependent on our ability to change the current economic model based on "take, produce, and discard". Companies like HP have a significant opportunity to stand up for this global challenge and adopt circular economy strategies as part of its sustainability investments. Circular economy models will ultimately allow HP to build more resilient supply chains and earn stakeholders' trust.

As circular economy principles are being integrated into different types of businesses, technology can help decrease their environmental footprints and support the innovations needed to achieve more circular supply chains. HP firmly believes that technology can help companies meet their sustainability goals, and this journey starts with the way products are designed.

Decisions made in the design phase of a product can significantly influence how circular it is, according to Ellen MacArthur Foundation. HP's strategy is to increase materials and energy efficiency, use more recycled content in products and packaging, tackle ocean plastic pollution, and design products to last longer, thus helping decrease product carbon and water footprints. This strategy is driven by goals and the ability to measure progress: in 2021 the company was able to achieve 39% circularity for products and packaging, by weight, from the goal of reaching 75% until 2030.

To enable those circular principles in the product design—closing the loop on materials, increasing the longevity of the products and repurposing devices—it is necessary to develop effective end-of-life strategies. Since 1991 HP has developed recycling solutions in more than 67 countries, aiming to make it easy and secure to recycle electronic products.

To fully help companies and consumers be more sustainable, it is equally important to take into consideration that businesses and society are also changing the way they consume. As-a-service brings a very important change into HP's business model and supply chain. While service-based solutions create a new stream of revenue and the need for reinventing customer services, it also allows a better environmental footprint, reducing GHG emissions by 12%, improving resources efficiency by 13%, and decreasing ecosystem impacts by 12%.

It is important to remember that designing effective circular economy strategies also has to do with economic well-being and inclusion. Supporting the development of projects that will enable jobs generation and capabilities improvements on waste management is one way of doing that, as illustrated by HP's efforts in Haiti, Brazil, and Indonesia.

Circular economy strategies can not only reduce the pressure on resource consumption, decrease a company footprint and its impact on the planet, but also present new business opportunities, and a way to build supply chain resilience. As demonstrated, HP's vision to become a fully circular company is powered by multiple strategies that drive innovation from product design, shifting to service models and the development of technologies that help minimize supply chain impacts. To achieve these goals, HP constantly challenges and rethinks processes, driven by the goal of having a net-zero carbon value chain by 2040, and the vision to become the world's most sustainable and just technology company.

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Chapter 8
Purchasing and Supply Management Journey into Unilever's Circular Economy Strategy

Fabio Ferraz de Arruda Pollice and Marcelo Scarcelli

Abstract The Circular Economy (CE) has emerged as an alternative to the linear systems. According to CE principles, the system designs out waste by intention. Biological materials are non-toxic and can easily return to soil by composting or anaerobic digestion. Everything is to be reused, repaired, and remade, maximizing the retention of value.

To operate in this new environment, Purchasing and Supply Management (PSM) organizations will have a crucial role in the redesign of Supply Chains to speed up the change from linear to circular industrial systems, in a completely different way of doing business with existing suppliers and also innovative start-ups to break down the current linear system.

A leading organization in this new way of doing business is Unilever. The launch of Unilever Sustainable Living Plan in 2010 started a journey to bring a net positive impact to the environment.

In the last 20 years, PSM has moved in Unilever from a local-led transactional role in materials and services management towards a more strategic role, aligned to this long-term business requirements.

Two key paths that are making PSM contribution unique in Unilever's Circular Economy are: the new plastics agenda and the sustainable sourcing strategy.

- One of the key initiatives for the new plastic agenda was developed in Brazil. PSM team led the development of a completely new ecosystem of partners, engaging with NON-TRADITIONAL suppliers, and defining a wider sourcing strategy that provided a cost-competitive solution and supply assurance for

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post-consumption resin (PCR), aligned to Unilever's vision of world in which everyone works together to ensure that plastic stays in the economy and out of the environment.

- It included automatized segregation and collection of plastic waste from landfields, partnership with selected segregation cooperatives, and a joint development of a PCR that would fit into Unilever's requirements with a start-up. Finally, a partnership with Marketing teams to engage consumers, promoting the return of used plastic containers at selected trade stores.

The second path is the sustainable sourcing. Sustainable oils are at the heart of Unilever sustainable sourcing program. Oils derived from soy and rapeseed are crucial ingredients in many Unilever brands. These crops are usually grown by family-owned farms, who sell them to the processors and suppliers who in turn sell them to Unilever.

PSM has led an agenda involving a set of new stakeholders: farmers, NGOs, suppliers, other agri-businesses and governments. In Brazil, more than 40 farmers have gained Round Table for Responsible Soy certification, boosting sustainable soy cultivation.

The sustainable soy oil is shipped to Unilever's Pouso Alegre factory and used as raw material to produce Hellmann's mayonnaise. Oil waste is turned into compost and the garden's harvest is consumed in the factory's cafeteria and part is given to a local community institution.

Both initiatives will allow a rich discussion on the additional strategic elements required to manage a new ecosystem of suppliers. And how value generation can be achieved for a new set of stakeholders.

Keywords Circular procurement · Circular supply chain · Procurement evolution · Sustainable procurement · Partnerships · Regenerative agriculture · Procurement skills · Procurement capabilities

8.1 Introduction

Circular Economy has recently emerged as an alternative to linear systems. The traditional "take-make-disposal" logic in value chains is increasingly exposed to higher raw material prices, disruption risks, and supply constraints (EMF 2013).

According to Circular Economy principles, waste doesn't exist and it intentionally excludes it in system designs. Biological materials are non-toxic and can easily return to soil by composting or anaerobic digestion. Everything is to be reused, repaired, and remade, maximizing retention of value (EMF 2013).

To operate in this new environment, supply chains need to be redesigned. Purchasing and Supply Management (PSM) organizations will play a crucial role in accelerating the change from linear to circular industrial systems, setting a completely different way of doing business with existing and new suppliers (Pollice and Battochio 2018).

The challenges for PSM coming into a Circular Economy ecosystem touch important elements related to the readiness of the existing supplier base in terms of quality, resources, and mindset. Additionally, it highlights the need of partnering with innovative start-ups to break down the linear system currently in most consumer goods companies (Pollice and Battochio 2018).

A leading organization in this new way of doing business is Unilever. Since the launch of Unilever Sustainable Living Plan (USLP) in 2010, the company has started a journey to bring a net positive impact to the environment (www.unilever.com).

USLP brought a major shift in the way Unilever uses to manufacture its well-known products, with several global brands such as Hellmann's, Dove, Axe, Ben and Jerry's, and Knorr.

USLP proposed a business strategy in which Unilever would decouple its growth from its environmental impact, achieving absolute reductions across the product lifecycle. The goal was to halve the environmental footprint in the making and use of Unilever's products.

Therefore, new raw materials sourcing strategies had to be developed and deployed, including sustainability objectives and targets aligned to the new company strategy. Procurement and Supply Management had to lead this transformation agenda, and PSM became a key player in this new journey to achieve USLP external and internal commitments.

In the last 20 years, PSM was part of several organizational changes. It has moved Unilever from a local-led transactional role in materials and services management towards a more strategic role aligned to long-term business requirements.

This transformation began with basic key performance indicators such as cost savings, quality, and service embedded in all sourcing strategies with the mandatory use of methodologies. It then evolved to consider broader impacts in the way of sourcing materials and focusing on positive impact, translating sustainability and social space into new metrics, such as sustainable source materials; deforestation-free supply chains; reduction, recycling, elimination of plastics; and adoption of living wages across the supply chain.

The mandatory methodology during the early stages of the journey included the famous Kraljic's matrix as a foundation, a tool to segment purchasing portfolios based on supply risks and business importance. First-tier suppliers are the main target of these analyses.

Kraljic's segmentation tool was presented in 1983 in a classic Harvard Business Review article. He said that in order to ensure long-term availability of critical materials at competitive costs, manufacturing companies would need to manage risks and complexities of global supplier markets, as well as uncertainties and interruptions in supply, price, and scale.

The model developed by Kraljic (1983) initially considers two critical factors in a matrix of four quadrants:

- Strategic importance of the purchase: added value by the product line, percentage of raw materials in the total cost, impact on profitability, and product quality.
- Complexity of the supply market: scarcity risk, conditions for developing alternative technology and materials, entry barriers, logistical costs, and complexity.

For each quadrant, different strategies are developed to minimize supply vulnerabilities and maximize the potential purchasing power of the manufacturing companies in question.

Items in the SCALE quadrant allow the buyer to exploit their full bargaining power; items in the NON-CRITICAL quadrant are routine materials, low value, and frequent orders in which high transaction value should be minimized through automation and electronic tools; BOTTLENECK items bring significant problems and must be mitigated through safety stocks, supplier control, and contingency plans. Finally, STRATEGIC items require more collaboration and synergy between buyer and seller (Gelderman and Van Weele 2005).

The conventional development of a sourcing strategy also considers a dyadic buyer-supplier relationship in which procurement managers develop their strategies based on consolidated tools. As an example, the 7 steps of strategy sourcing, a classic elaborated by Clegg and Montgomery (2005) and extensively used by AT Kearney consultants.

This 7 steps methodology has led the strategic thinking of buyers for more than a generation:

- Step 1: Define category profile.
- Step 2: Select sourcing strategy (using Kraljic's portfolio matrix).
- Step 3: Manage supplier's portfolio.
- Step 4: Define implementation plan.
- Step 5: Negotiate and select suppliers.
- Step 6: Integrate suppliers.
- Step 7: Check performance and make corrections.

None of these tools, however, would be enough to eliminate the challenges that USLP has brought into the PSM agenda. These were elements that helped in the initial steps, but have not been enough to land an ambitious transformation.

In the following sections we will describe two major transformational programs that exemplify not only the challenges faced by PSM team, but also the innovative sourcing strategies that were developed to deliver the goals. They will bring clarity onto the key elements that differentiate a circular sourcing strategy from the traditional approach.

These selected examples are making unique PSM contributions in Unilever's Circular Economy agenda: the new plastics agenda—which deals with the technical cycle of non-renewable materials, and the sustainable sourcing strategy—which integrates the biological cycle into the Circular Economy model.

As mentioned before, Unilever has a serious commitment to the new plastics agenda. Plastics are the workhorse materials of the modern economy, combining unrivalled functionality with low cost. While integral to the economy, their linear take-make-dispose value chains have significant economic and environmental drawbacks as most of the material ends up as waste (EMF 2016).

Unilever approach to products and packaging is changing, looking for solutions to fix the broken plastic system to protect oceans and marine ecosystems. Unilever is searching new ways for consumers to easily access everyday products with less plastic waste. The goal is to keep plastic in use for as long as possible in a circular loop system by collecting, processing, and repeatedly reusing it.

In order to achieve that, challenging targets were defined: to halve the amount of virgin plastic used in packaging, help collect and process more plastic packaging than sold, ensure that 100% of Unilever's plastic packaging is designed to be fully reusable, recyclable, or compostable, while increasing the use of post-consumer recycled plastic in Unilever's packaging to at least 25%. All these are to be delivered by 2025.

Support collection and processing infrastructure is key to keep plastic in use as long as possible in a circular loop system and repeatedly reusing it. Sourcing strategies for plastic resign start including post-consumer recycled (PCR) content. Around 11% of Unilever plastics footprint was from PCR by mid-2021.

8.2 Recycled Plastics Agenda: A New Sourcing Ecosystem to Develop

One of the key initiatives for the new plastic agenda was developed in Brazil. The PSM team led the development of a completely new ecosystem of partners, engaging with non-traditional suppliers and defining a wider sourcing strategy for a cost-competitive solution and supply assurance for post-consumption resin (PCR).

By bringing this package sourcing strategy development into Unilever's traditional 7-step approach, procurement managers focused their effort in understanding direct raw and pack materials as well as first-tier suppliers, also known as "convertors". These suppliers in general buy virgin plastic resin from big chemical companies and transform this input into plastic bottles, for instance. Second-tier suppliers (in this case, resin producers) are not touched by the traditional sourcing strategies.

Post-consumption resin (PCR) is a totally different market compared to virgin resins. Turning plastic waste into usable material relies on local collection and sorting facilities. Technical innovation and new solutions are needed in order to make collecting and reprocessing materials commercially viable.

Virgin resins are produced by big petrochemicals, which in several cases, is a local-level monopoly. The use of PCR helped to break this monopoly as a new source of raw material in a different ecosystem from the traditional virgin resins supply chain.

PSM's new challenge is to start understanding the recycling system in Brazil, a very complex and confusing network. It involves several new steps that buyers now have to have a deeper knowledge and expertise of:

- Collection of recyclable waste, in most of the cases done in a very informal way by collectors.
- Segregation done at cooperatives.
- Logistic system to ship the selected material from cooperatives to a new partner that will transform recycled bottles into PCR pellets, according to a specification developed by Unilever R&D teams.
- Logistic system to ship from the PCR pellet supplier to the final bottle convertor and then to Unilever factory.

It is important to mention that this PCR ecosystem was characterized by non-established governance mechanism and no clear leadership role to any company.

The procurement manager started developing a disruptive sourcing strategy, considering the sourcing not as part of a traditional supply chain, but as an element inside a major ecosystem.

The first task was a deep understanding of the recycling market, and that included not only the traditional collection and segregation systems with cooperatives, but also alternatives such as the development of private landfills for source material. The use of recycling machines that allows artificial intelligence (AI) to automatically identify and sort plastics for recycling was a key enabler in the strategy because it tackled one important strategic element: constant availability of PCR in the required volumes, which was not possible working only with cooperatives due to randomness.

Two main performance indicators defined the project success: assure PCR availability and purchases at competitive cost.

The second workstream dealt with process packaging partners that would receive de-segregated bottles from cooperatives and landfills, clean them up, mill them and reprocess them into PCR pellets that would meet compliance to Unilever PCR specifications.

R&D involvement in this circular product redesign was also fundamental. A series of new specifications needed to be developed and validated: PCR, PCR + virgin, and finally new bottles made from recycled resin. New packaging specifications were drafted and pilot trials were made. Several rounds of experimentation were necessary to have a sample with a good level of quality that could be presented to Marketing for approval. Marketing was as a key business partner in understanding the limits of the technology available that would affect product appearance, an important consumer quality attribute.

The PCR pellets would be sent to a bottle convertor that would mix it with virgin resin in order to achieve all the technical parameters new bottles need before being sent out to Unilever factory and be filled with products.

The third strategic element was related to the governance around this new sourcing model in order to keep PCR costs at a competitive level compared to virgin resign markets. Additionally our aim was to develop a plan for required PCR volumes and virgin resin on a monthly basis, as well as how deliveries would be set.

This is a very important element. Business systems are not developed to reflect this kind of sourcing dynamics, in which materials come from many different sources (cooperatives, dealers, landfill robots, recycling stations, and supermarkets), at different rates and quality (resin grades, shapes, colours). Spreadsheets were used at this stage to plan all the ecosystem volumes and parameters.

This first sourcing strategy developed for PCR has demonstrated that current strategy development tools are not enough to design a robust strategy in a Circular Economy system anymore.

Eleven success factors were identified in these initiatives: (1) Because buyers had full control, this category was able to do the required trade-offs in the portfolio to present a healthy business proposal; (2) The collaboration with non-traditional suppliers and establishment of long-term relationships in a brand-new ecosystem, totally different from the traditional buyer-supplier relationship for virgin resin; (3) Strong R&D involvement in a circular product redesign and complexity reduction; (4) Marketing acting as business partner; (5) Performance indicators not focused exclusively on material cost, but also material availability and recyclability; (6) Making the sourcing strategy and its execution more effective, with opportunities for a more systemic and resilient system being identified; (7) ERP (enterprise resource planning) needs to be adapted to the new sourcing reality; (8) A better forecast system is key to assure PCR availability; (9) Cooperatives professionalism is to be improved, which brings a social contribution to the system as well; (10) Market intelligence and feedstock management bring future cost visibility; (11) Ecosystem strategy and governance model needs to be developed by the orchestrator and contributors need to have clear roles, capturing and sharing value.

Finally, this is an example that demonstrates new requirements needed for developing sourcing strategies in a Circular Economy framework.

8.3 Sustainable Sourcing: Palm Oil Case

The second path is the evolution of sustainable sourcing (and the emerging concept of Regenerative Agriculture). It is another key strategic element led by PSM teams in Unilever's agenda, working with farmers and suppliers to drive up social and environmental standards in Unilever's supply of agricultural raw materials. To better understand this evolution, its implications, and the connection with Circular Economy, we look at another portfolio, moving from Plastics to Oils (from Packaging into Ingredients).

Sustainable oils are at the heart of Unilever sustainable sourcing program. The oils derived from palm, soybean, rapeseed, and sunflower are crucial ingredients for Unilever brands, such as Hellmann's Mayonnaise, Sunsilk and Dove Shampoos, and Lux Skin cleansing Bars. In 2020, Unilever committed to achieving a zero-deforestation supply chain by 2023 for crops with high deforestation risk (palm oil, paper and board, tea, soy, and cocoa). This means attaining a view of that crucial first mile—from where the commodity is sourced to where it is first processed. It also means increasing traceability and transparency through emerging digital technologies which empower farmers and smallholders while working with industry, NGOs, and governments. In summary, a big shift in the end-to-end way of managing sourcing activities. This big shift is simply not possible without a complete review of working processes and a refreshed scope for procurement professionals. To better understand the role of PSM and illustrate practical situations, we look at the specifics in one of the ingredients: Palm oil.

Palm oil is a highly versatile and productive crop. It has many different uses—like foaming, binding and stabilizing. It's the most land-efficient oil crop—with a much greater yield per hectare than other oils like sunflower, rapeseed, or soy. For these reasons, it's now the most commonly produced vegetable oil in the world. Palm oil has grown into a major global industry over recent decades. Farmers today produce over 70 million tons of palm oil each year—that's more than double than what they were producing just 20 years ago. The palm oil industry brings money, trade, and jobs to producing economies, and employs millions of smallholder farmers. To provide an idea about the size of its impact, 4.5 million people in Indonesia and Malaysia rely on the palm oil industry for their livelihood. It clearly demonstrates the importance and the impact of decisions on local economies and social development.

Palm oil, however, only grows in tropical regions which are also home to a number of local communities and a host of flora and fauna. Rising demand has meant that, in some areas, rainforests are being cut down to make way for new planting—driving climate change and biodiversity loss. The expansion of palm oil plantations has led to a range of human rights issues, including land conflicts between plantation companies and local communities. These are all major challenges to be addressed. PSM has led this agenda by involving a set of new stakeholders: farmers, NGOs, suppliers, other agricultural businesses, and governments.

To create this new ecosystem, Procurement established new ways of working and capabilities. It was a clear departure from the traditional supply management approach, which included new ways of engagement, huge use of technology, and the inclusion of different supplier profiles. No doubt an evolution from a transactional suppliers-buyers relationship into a regenerative-circular model.

Market Intelligence and New Suppliers Onboarding (Smallholder Farmers) In the previously mentioned 7 steps, market scanning and supplier integration are critical elements. This is not only from a sourcing execution perspective, but also capacity building, with an almost entirely new set of skills to be fully embedded in Procurement.

Around 40% of the world's palm oil is produced by smallholder farmers—which means smallholders are a key part of the puzzle to ensure the long-term future of the oil palm sector. A key part of Unilever's supplier sustainability program involves engaging with smallholders on the ground.

Unilever is supporting projects jointly with our implementation partners in order to help increase profitability and incomes for farmers, professionalizing smallholder farming businesses, and promoting RSPO certification. It is also using credits to incentivize independent smallholders and support their livelihoods by creating a market for smallholder-grown oil palm. Unilever has been one of the largest buyers of independent smallholder RSPO credits since 2017.

But, what if the market and suppliers are not ready or developed up to a point one can source new requirements directly? That's where suppliers' development activities play an important role. It happens via programs that help independent mills improve their practices and achieve certification. The combination of these activities is important because sourcing from independent mills is critical into transforming the supply chain and creating a positive impact in the fast-moving consumer goods industry, particularly for smallholder farmers.

Engagement and Development of Suppliers The engagement with suppliers has to be proactive and this relationship needs clear expectations (made via public policy document). It has four key principles that are required to all palm oil suppliers to adhere to throughout their operations and supply chains: (1) Protecting natural ecosystems from deforestation and conversion; (2) Respecting and promoting human rights; (3) Transparency and traceability; (4) Being a force for good towards nature and people.

The principles of our policy are also embedded in the contracts with suppliers, requiring an update in the way legal and commercial documents are designed, similar to what is seen in the Plastics space when developing new sources with new suppliers.

Traceability As mentioned before, traceability and visibility are key elements of a circular model. It is good for Procurement, good for the planet and more increasingly relevant for consumers.

The evolution into a zero-deforestation supply chain requires more selectiveness about suppliers and areas to source from. Unilever is working in parallel with systems and processes in order to be able to have this assessment translated into independently verified deforestation-free origins. It considers the monitoring of supplier performance through a combination of tools that include an independent verification mechanism, the use of traceability technology, and reporting tools such as the No-Deforestation, No-Peat, and No-Exploitation Implementation Framework. With all this considered, if traceability is so important, how is it to be set up?

- Tracing back to palm oil mills and plantations: Unilever can identify a universe of mills for 99% of its core volumes. Getting full visibility of the supply chain up to the smallest supplier will radically improve Unilever's knowledge of what is happening on the ground. Unilever can then monitor land use, manage risks and direct investment into sustainability activities. Unilever is already using satellite and radar technology to give early warning of deforestation.
- Partnership comes to the table again here: Unilever is partnering with technology companies to receive deforestation and conversion alerts, which are overlaid with the sourcing areas in our supply chain. To get a better view of this 'first mile' from the farm to palm oil mill, Unilever is running a pilot in Indonesia with a tech company that is specialized in geospatial analytics. Information is then

made public. Palm oil starts its life as a fruit in a tree—and its journey from the plantation to factories has many steps. It may change hands several times through traders before it gets to the refinery—where it is mixed together with other small batches to be processed. Only after this point does it enter Unilever's direct supply chain.
- Identifying key risks: Unilever works with expert partners to monitor environmental and social risks in specific mills, plantations, and surrounding areas—and take steps to help suppliers comply with our palm oil policy.

However, information and visibility without action do not drive impact. Unilever gets to know about serious issues, including human rights issues, which exist within the palm oil industry. So, as well as working alongside with suppliers to help them improve their standards, the company needs to respond whenever concerns about a particular supplier are brought to its attention—and to make sure the response is transparent and appropriate. Unilever wants to be the first to know and act when issues are identified within its supply chain. In order to assist with this, Unilever launched a public palm oil grievance procedure encouraging people to notify the company when issues arise.

Partnerships and the Evolution of Relationships tackling the complex social and environmental issues in the palm oil supply chain requires more than policy commitments—it requires the transformation of an industry. To do this, Unilever needs to go beyond its own supply chain. Through partnerships, advocacy, and committed work on the ground, Unilever is helping to lead real progress towards its vision of a supply chain in which sustainable palm oil is commonplace.

It is important to highlight those partnerships should not be seen only as a relationship or something to be built with suppliers—it requires the engagement of new agents such as NGOs. Unilever was a founding member of the Roundtable on Sustainable Palm Oil (RSPO) in 2004, a globally recognized certification standard to drive sustainable production in palm. The RSPO is made up of representatives from growers and buyers, commodity traders, non-profit environmental social groups, and other influential organizations.

The right balance between global scale and local intimacy: Choosing where to focus and where to allocate resources is also critical in order to establish successful relationships and new sourcing ecosystems. Unilever has committed to a jurisdictional approach to projects in various priority landscapes in Indonesia and Malaysia. That means not just working alone but aligning efforts with a broad range of stakeholders to pool resources, knowledge, and know-how in specific locations. This involves working with governments, businesses, NGOs, smallholder farmers and other stakeholders around shared goals of conservation, supply chain sustainability, and sustainable economic development.

A strong example of changes in the mindset and the different levels of interventions to for more circular supply chains is inside the factories. So far, the content has explored sourcing alternatives, but a new mindset is now increasingly infused over the entire process. For instance in one factory in Brazil: in order to close the biologic cycle loop after the use of sustainable soybean at the Pouso Alegre factory producing Hellmann's mayonnaise, the organic waste is turned into compost. The garden's harvest is used in the factory's cafeteria and part is given to a local community institution. This brings contributions to environmental and social agenda of the company.

8.4 Conclusions

Circular Procurement is a relatively new concept and there is no agreed definition on it. A good foundation lies on the concepts and practices already defined for Sustainable Sourcing practices. From initial focus on resource reduction, product reuse, and recycling (Carter and Carter 1998; Carter and Dresner 2001; Carter and Ellram 1998; Min and Galle 1997), it expanded to reverse logistics (Carter and Ellram 1998) and to a wider approach that explored the concepts of corporate sustainability and corporate social responsibility (CSR).

Leading countries in Circular Economy implementations have already developed Public Procurement (PP) initiatives faster than the industry and provided relevant insights for industry rollout (Circular Public Procurement in the Nordic Countries 2017; European Commission 2017).

From existing pilots and collective industry discussions, several challenges emerge and should be addressed with an end-to-end supply chain approach.

- Design of products that enable dismantling.
- Minimization of value destruction and maximum use of renewable resources.
- Increase raw materials and product cycling.
- Promotion of new business models, including co-creation with suppliers and customers.
- Increased intensity of goods and services.
- Communicate the benefits of adopting new formats and new products designs to consumers.

A Circular Economy approach can create new value for the organization (Weetman 2017). There are savings associated with a Circular Economy system by reusing resource inputs to the maximum degree. It is fundamental for increasing the rate at which their products are collected and reused, or components/materials are recuperated (Ellen MacArthur Foundation 2013).

Focusing on the upstream of the Supply Chain will require a new mindset for buyers and procurement professionals. There will be a need to design sourcing strategies in a much broader way, looking ahead of the current linear system. This is not about improving reverse logistics, waste management, or sustainable and green sources. This is about partnering with designers and developers in order to have materials that can be reused, repaired, and remade in several loops, including production and consumption. Developing strategic suppliers and customers that can provide and manage these material chains over time has to do with skills and strategic calls: in summary, these professionals develop the market for a circular demand. Circular supply needs circular demand, so buyers will also become sellers in the design of this new ecosystem.

It is important to highlight that a deep transformation requires incorporating these practices in day-to-day activities, not as a project, but as a way of running the supply chain. It is about having these circular procurement practices in the day-by-day activities of the PSM teams.

Circular procurement should provide a different way to think business models:

- Consider service instead of products. Business that are product-oriented are transitioning to a service-oriented model, but the success of this transition also implies that product-service-systems are designed to be circular (Michelini et al. 2017).
- Focus on product design, its use phase and end of life (considering waste hierarchy as reduce, reuse, recycle, and recover).
- Engaging with suppliers and the wider market to establish a dialogue and to identify circular solution.

Both Plastics and Oils (Packaging and Ingredients cases) illustrate, with clear link between theory and practice, initiatives that enable a rich discussion on the additional strategic elements and skills required to create and manage a new supplier ecosystem in PSM. It becomes clear that Procurement activities will require a focus that will be increasingly external, going beyond transactions in order to build new relationships and partnerships. Customers and consumers will require this evolution from the organizations, and Procurement can play a pivotal role on how value generation can be achieved for a new set of stakeholders.

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Chapter 9
Circular Economy in the Paperboard Industry: Ibema Cases

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Abstract Transforming the economy and industrial processes with a focus on sustainable development has become paramount given the ever-increasing critical state we find ourselves regarding the use of natural resources.

Companies need to be aware of their capacity to adapt and make the changes necessary. Circular economy initiatives are becoming more popular and call for well-defined players with motivation aligned with the purpose of circularity. Strategic orientation coupled with the definition of a consistent purpose are initial steps for identifying and building value paths that generate long-term results.

Aligning corporate values and organizational culture with a systemic vision of the circular economy allows for engagement of both sides and improves communication within a project. Once companies execute their actions and decisions based on circularity principles, it is possible to see results evolve more easily.

Valuing and further incorporating the use of renewables is a path that can help reduce society's current impact on the planet. Brazil is already a major global player

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in renewable energy generation and highly productive in the cultivated forests sector. This context provides even greater long-term growth potential for projects of this nature.

For Ibema, sustainability is already part of its DNA as the company is inserted in a market environment of regenerative value. Tree planting delivers a renewable feature through its very existence since part of the process is carbon sequestration, a positive social impact, as is the conservation of native areas and biodiversity. Additionally, the planted trees market is based on high-technology planting, management, control, and harvesting.

This chapter presents two Ibema cases. Pursuant to a systemic strategic vision, circularity is incorporated to further reveal the benefits of using materials and processes from renewable sources, based on the bioeconomy. As a result, it is possible to develop product and service solutions under more favorable conditions for society, with better use of resources and less impact on the environment.

In consonance with the business purpose and its values, it is possible to see strong determination to overcome the obstacles encountered during execution of the cases and that also helps give more importance to caring for the connections within the ecosystem where the players are fully engaged in the same objectives and, with this, walk hand in hand toward the evolution, continuity, and success of circularity-based projects.

Keywords Circular economy · Bioeconomy · Paper · Forest · Renewables · Recycling

9.1 Introduction

We expect for a growing transition movement from a linear economy to a circular economy, so that the planet's natural resources are properly used through new processes and economic models of production and consumption that are based on minimizing environmental impacts and promoting prosperity and longevity for everyone.

Worldwide, it is possible to see a timely and growing number of circular economy initiatives with new developments in terms of processes and products across regions. Throughout its history, we identify a constant desire in Latin America for economic and social evolution from the countries in the region (América Latina e Caribe lançam coalização de Economia Circular. Nações Unidas Brasil 2021). According to their local conditions and available technologies, they invest and grow in different ways, but all unanimous in being in tune with what is happening in the world. Countries seek their economic opportunities, develop their products and services, and wish to be part of the international trade community.

The situation in which the planet finds itself due to climate change, as studied by the IPCC and duly communicated by the UN (UN 2021), are already fluent topics within Latin American, and countries are already establishing government agendas and determining what can be done by companies, people and governments.

Mitigation of environmental impacts and carbon trade initiatives are examples of projects designed according to the regional potential of each country. Some regions have competitive advantages in energy generation, others in planting areas, others in the culture of consuming and reutilizing industrial or residential waste, and employing materials and energy from renewable sources.

Taking into account our business experience, the ultra-connectivity between people, societies, businesses, and nations accelerates the flow of information on multiple subjects in constant interaction, and that has led to a concrete understanding of how much we are interdependent from the internal environment to the external, with the dual ability to influence and to be influenced. Therefore, it becomes relevant for organizations to develop people and their teams for a culture where this systemic vision is fully understood and thus capable of supporting decision-making, demonstrating its ability to be relevant to society and its businesses.

In this chapter, we will have the opportunity to present two successful cases of a company that makes its commitment clear to this positioning. Ibema—Companhia Brasileira de Papel, is Brazil's third largest producer of paperboard for packaging, always working toward a healthy socioenvironmental balance based on a respectful presence and market performance through its products and services. "Ibema's purpose is to pack the future and for such we start out with our strengths, our high performance, highly efficient Turvo/Paraná/Brazil mill that produces paperboard from renewable fibers, and the Embu das Artes/São Paulo/Brazil mill, a wastepaper unit focused on recycling, which conserves carbon capture in the fibers, keeps waste from ending up in landfills and contributes to the circular economy," said Ibema's CEO Nilton Saraiva.

With this purpose in mind, the company's ability to generate long-term value is clearly understood given its relevant commitment and care toward improving a culture with a systemic vision, which is supported by its values of "Doing with tact," "Believing in the role of courage" and "Thinking outside the box," creating a unique identity and way of doing things, facing challenges that allow evolving together.

The world still needs to make profound changes in its economic models so that we can have a truly sustainable economy. And this will only be possible adopting the circular economy as a guiding compass, and the quality of life of the next generations as our north star. It is necessary to seek collective maturity so that our subsistence is not jeopardized, and our legacy is a world in balance between mankind and what it needs, and nature and its sustainability.

9.2 The Forest and Society

Society and forests are codependent. "The forestry sector stems from a very strong root with sustainability in its history," said Ibema's CEO Nilton Saraiva. It is a natural regenerative system, which is part of the company's DNA to maintain the ecosystem in balance with its biological cycle functioning properly, and promote the continuity of resources we need today and for future generations.

Natural and cultivated forests provide constant benefits to flora, fauna, and all living beings, allowing for a virtuous cycle of wood, water, and energy availability, establishing a constant source of renewable resources. Other added benefits are the recovery of areas, the protection of springs, the preservation of biomes and ecosystems, and the resulting reduction of pressure on natural forests (Indústria Brasileira de Árvores, n.d.-a).

Within the concept of being renewable, by its very nature, Latin America has planted forests for consumption coupled with the preservation of natural areas, promoting a sustainable and positive balance for society based on Bioeconomy. In Brazil and Chile, there are excellent plantation examples for pine (softwood) and eucalyptus (hardwood). With productivity above the world average, technical knowledge, and management care, the international certification of planted areas demonstrates the commitment and reliability regarding the origin of trees.

And since wood and its products are the main inputs for the paper sector, as is the case with Ibema, much has been done to prove this reliability to its customers and packaging users. 100% of paper-industry inputs come from planted forests. Once again, corporate awareness, together with non-governmental organizations, implemented the culture of Environmental Certification through widely disseminated and accepted labels like FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification). The adoption of efficient metrics through these globally respected certification programs and the awareness of managers across the business chain defined a highly responsible chain of custody that can be seen today in Brazil's paper sector.

With support from the world's leading brands and non-governmental organizations, certification programs are gaining global scale to demonstrate their commitment to origin. FSC forest certifications cover more than 215 million hectares, of which 17.2 million are in Latin America. PEFC forest certifications cover 312 million hectares, of which ten million are in Central and South America (Forest Stewardship Council (FSC) 2022; Programme for the Endorsement of Forest Certification (PEFC) 2022).

The guarantee of certified origin has made it possible to accelerate decisions in this regard through the establishment of policies for acquiring inputs that reduce the impact and favor the socioeconomic conditions of the reality of Latin American countries. Encouraging the use of recycled materials in conjunction with certifications has been the main recommendations of small, medium, and large companies for their packaging. This decision-making process is a key factor in leveraging sustainable development initiatives.

Certification labels can already be seen by consumers on products and packaging. For this to happen, all companies that participated in the production process were certified and complied with the strict criteria and principles established in the regulations. This process is called chain-of-custody certification. That is, in addition to trees and their products coming from a renewable source, they also possess internationally recognized traceability and reliability.

9.3 Planted Forests in Brazil

The yield of planted forests in Brazil, due to its climate, soil quality, and especially the techniques applied to improve the species used, is one of the highest in the world. According to Embrapa's Brazilian Forestry Research (De Araújo et al. 2017), the country exceeded the mark of 40 m^3ha^{-1} $year^{-1}$ for pine species, while Finland reaches yields of 5 m^3ha^{-1} $year^{-1}$, Portugal 10 m^3ha^{-1} $year^{-1}$, United States 15 m^3ha^{-1} $year^{-1}$, and South Africa 18 m^3ha-1 $year^{-1}$.

Embrapa (De Araújo et al. 2017) reports that the sector's productivity in Brazil is due to genetic improvements that allow selecting species that can produce higher yields across the country's different regions. In addition, the Brazilian timber process is based on high-tech planting, management, control, and harvesting.

The planted forest model adopted by the country, with 9.5 million hectares earmarked for industry and six million hectares for conservation, is capable of sequestering 4.5 billion tons of (CO2eq) from the atmosphere (Relatório Anual IBÁ 2021).

Brazilian Tree Industry (IBÁ) also reports (Indústria Brasileira de Árvores, n.d.-b) that, in addition to generating social value in Brazilian regions distant from large urban centers strengthening small producers, development programs benefited roughly 1.6 million people in 2019. "Labor skill-building, economic-financial development and partnership initiatives with small producers aim to improve the living conditions of this population. From the perspective of small rural producers, the possibility of increasing family income, coupled with production diversification, is a huge gain. And for the community, there's the perspective of new business opportunities and the creation of new work fronts. A total of 2256 municipalities were benefited in 2020" (Relatório Anual IBÁ 2021).

9.4 Renewables in the Process: Energy

The challenges are many in finding this balance of resources, and they are even more evident in developing countries, as is the case with Latin America. We have to be fully aware that the circular economy cycle only generates value when we efficiently address all stages of the process, which begins by defining the energy matrix for production, then the inputs obtained ecologically, the proper treatment of industrial waste, the packaging that houses products, the correct disposing by end consumers and re-entry of this waste back into the production process.

An overview of Latin America's energy matrix places us in a privileged position. A survey conducted by the Latin American Energy Organization (OLADE) reports that the energy matrix in Latin America and the Caribbean is among the best in the world, with approximately 60% of installed capacity coming from renewable sources (OLADE 2021). This is mainly due to the high share of hydropower and biofuels in several South American countries.

In addition, the region has significant potential for renewable resources (hydro, solar, wind, biomass, among others) that can help make this matrix even cleaner in the coming years. This is a major competitive advantage compared to global levels, where renewable energies account for 36% of electricity generation capacity (Balanço Energético Nacional 2021).

In Brazil's case, this advantage is even greater. According to energy research company EPE (Balanço Energético Nacional 2021) in its 2022 statistical electricity yearbook (base 2021), 83% of Brazil's installed capacity of energy is renewable, one of the highest in the world. It is then followed by Canada with 67% and Germany with 55%, while the world average is still only 36%. The largest installed capacity in Brazil is hydroelectric with 60.2% and wind with 11.4%.

Relative CO_2 emissions of each electrical system are evaluated by the amount of CO_2 emitted per MWh generated. In this regard, the same study shows that, in 2019, Brazil had 104 $kgCO_2$/Mwh, among the lowest impacts in the world. Compared to other countries, it emitted roughly 85% less than China with 698 $kgCO_2$/Mwh, 73% less than the United States with 387 $kgCO_2$/Mwh, and 63% less than the European Union with 285 $kgCO_2$/Mwh, to generate each MW.

As a nation, there is still much to be done. Transport modes are starting to shift to profiles that are less aggressive to the environment, but this is a long-term job. However, Brazil's industry is already reaping the rewards of the high investments made in energy capture that largely replaced fossil fuels, and the paper sector is a leading player in this scenario having contributed 51,711 GWh of energy from biomass in 2021.

9.5 Ibema Cases

At Ibema, sustainability took on a new look and created a specific study group to develop the subject with the participation of people working in a multidisciplinary way to develop activities for this sustainability to really happen based on a systemic vision integrated with circularity.

This circularity is only possible with everyone's understanding and participation in each stage. Consumers aware of their duties when consuming and disposing their waste, public authorities establishing efficient collection systems in all municipalities as well as incentivizing private initiative to generate economically and socially viable solutions in conjunction with teaching institutions, research centers, non-governmental organizations, media and press supporting and communicating effectively, and companies perfecting their products, processes and services in order to enable the reverse cycle or reuse all the way down to design. They are key connected players who, upon deciding on one path or another, can promote the loss of resources or the success of their effective recovery.

At Ibema, innovation is encouraged through people's freedom to capture insights from different players that make up this ecosystem and to evaluate implementing actions that build value-creation paths that are linked to the business purpose.

Given the challenges presented and the favorable conditions for paper production in Brazil, Ibema developed two cases in its product portfolio that show a very promising path to promote cultural changes in conscious consumption, and encourage end users to actively participate in the circular economy wheel, by reintroducing disposed packaging into the industrial cycle.

9.6 Royal Coppa

At present, Americans and Europeans consume at least 4 times more paperboard per capita than Brazilians. This is due to a long acculturation process, new consumption patterns, and the evolution of markets such as delivery and take-and-go, where practicality and speed are important elements in the accelerated routine of people.

Believing that these trends, along with other elements of the so-called green wave, would arrive in Brazil, Ibema decided to move forward with a paper cupstock project. Its biggest potential resided in substituting the use of plastic cups.

The paper cup market in Brazil had a typical linear-flow model. Paperboard was imported from Europe and the United States, shipped to local cup manufacturers, and then sent for consumption, in order to then be collected together with other contaminated materials and sent to landfills as wet or organic waste. In 2017, Ibema decided to launch a locally produced paper in Brazil to replace imports, becoming the first Brazilian paperboard company to have cupstock.

This product launch was based on trends identified by the Marketing department, which continually analyzes consumer behavior trends and industry production chains in other more-mature markets. Companies in Europe increased the supply of this material with new launches by different players, which ultimately proved to be a more environmentally responsible alternative than plastic and styrofoam.

In Brazil, the take-and-go consumer profile for coffee started to take off, with thousands of franchises now spread across the country, in addition to a greater number of delivery platforms.

Market opportunity combined with the cost opportunity. In 2016, when Ibema incorporated the Embú unit—which included a polyethylene extruder –, it allowed the company to produce internally with the necessary quality and cost competitiveness.

After the Royal Coppa launch, the company gradually started to win over customers and cup & container converters. As a result, between 2018 and 2022, product sales grew 190%, demonstrating the product's excellent acceptance. This success led the company to develop a capacity expansion plan to start-up in 2023 and consolidate Ibema as the #1 supplier of cupstock in Brazil.

Ibema's Royal Coppa paperboard, made from cultivated forests that provide a source of renewable cellulosic fibers, capture carbon from the atmosphere and forest management practices certified by international organizations, was offered to paper cup manufacturers in Brazil and gradually conquered space and replaced similar imported ones. Ibema was the first company to offer a product solution like this in Brazil.

Despite large multinational suppliers striving to continue being the main option for cupstock, Ibema managed to demonstrate the relevance of its locally manufactured option for the service offered and the product's good performance.

The project included an additional concept that totally set it apart from imports. Ibema demonstrated its ability to recycle the paper cups it manufactured and allowed for the development of circularity projects in Brazil.

This fact drew the attention of a big packaging brand, which together with one of their customers saw in Royal Coppa a product 100% integrated with its objectives and circularity goals. As a result, the first project to capture post-consumption cups in the city of São Paulo was born to be reutilized by Ibema at its Embu das Artes unit.

These recovered fibers can be reused in other products that require recycled fibers, such as Ibema's Ritagli. The technology used allows reusing fibers contained in the cups through a process of hydration and mechanical separation of materials, filtration, and centrifugation until the fibers are effectively recovered and separated from other contaminants.

There is currently a worldwide concern about the use of single-use products that use inputs from non-renewable sources. Royal Coppa's solution allows substituting these applications, contributing to a rapid reduction in the amount of plastic used and that in the very short term will be replaced by resins already being developed and commercialized in the market. These biodegradable resins with water, moisture, fat, and other barrier properties are the future of this market, completely replacing plastic, and it is in this technological direction that Ibema and other market players aim their compass at.

The contribution from using renewable materials to reduce the impact of replacing the use of fossil materials is still being evaluated in a broader scope, including the effects on oceans. Project marilca.org will make it possible to integrate the potential environmental impacts of marine waste, especially plastic, into Life Cycle Assessment (LCA) results. "This will lead to a more comprehensive picture of potential environmental impacts in order to identify tradeoffs associated with using plastic and other materials in a product system" (Marilca, n.d.) .

9.7 Ritagli

In Brazil and Latin America, consumers are not yet aware that products made from pulp are a reference in terms of low environmental impact and good sustainable practices. We have an outdated perception when compared, for example, to European consumers. This is due to an unawareness about production methods and especially how fiber is captured. People still believe that paper is made from cutting down native trees such as those in the Amazon.

In addition to the fact that all Brazilian paper is produced through planted forests and in their absolute majority certified forests (FSC), the substrates, paper, and paperboard have a recycling rate close to 70% in Brazil. The goal is to increase this figure to levels similar to those in Europe, 85%.

Recent studies in Europe have determined that paper fiber can be recycled up to 25 times (Eckhart 2021). Albeit some natural limitations of cellulosic fibers, the study demonstrated their easy reutilization and technical characteristics close to original fibers, allowing them to be reused in packaging papers. In addition to increasing the lifecycle of paper and keeping the carbon attached to the fibers, it reduces the amount of materials sent to dumps and landfills, allowing for the social and economic development of this sector.

There is still a lot to be done. According to Abrelpe (Brazilian Association of Public Cleaning Companies) (Abrelpe 2021), there are more 2.868 cities with irregular dumps or landfills in Brazil that emit roughly 27 million tons of CO_2 equivalent per year (CNN 2021). Hence, the circularity of paper and the increase in its recycling rate reduces environmental impacts.

The fact is that Brazil still lacks infrastructure, public tools, and formalizing this chain of collecting and selecting materials to be recycled. In other words, many materials that could be recycled are not being recycled due to inefficiencies in the disposing, collection, and selection of these materials. It is a huge economic and social challenge, and when it comes to selecting just paperboard material the challenge is even greater.

With the state not solving this problem, like in other countries, new laws began being studied and implemented, transferring responsibility to the private sector. Such is the case with the National Solid Waste Policy (PNRS) that is gradually being implemented and initially obliges CPG companies to correctly dispose of at least 22% of their packaging.

Understanding this regulatory movement, coupled with consumers leaning toward more sustainable packaging, and the trend of consumer packaged goods (CPG) companies making ESG commitments, all this creates the perfect storm for developing a product that helps to solve these three vectors.

And this is how Ibema's Ritagli paperboard came about, a solution designed to reduce the impact of landfill disposal and stand as an exemplary, structured, and integrated initiative together with several players in the chain (recyclers, start-ups, CPG companies, printing companies, and others) that also complies with the National Solid Waste Policy.

To overcome the obstacle of not having the infrastructure to supply this post-consumption material, it was necessary to establish partnerships to develop a completely new logistics system, training cooperatives to define a new standard of recycled material for commercialization.

Approaching recyclers, packaging manufacturers and consumer packaging companies was a key task to combine the motivation and purpose necessary to leverage a flow of material sufficient for technical and economic feasibility and thus ensure the project's viability.

During the initial period, with a volume of post-consumption waste collected still on a small scale, it took persistence to believe in the growing acceptance of the concept by clients and partners.

“As a paperboard with 50% recycled fibers, 30% of which being post-consumption fibers (soon to be 35%), Ritagli was a major challenge that connected us with recycling cooperatives and startups, and enabled us to work on projects such as the partnership with key market brands, encouraging the recircularity of packaging,” said Ibema’s CEO Nilton Saraiva.

Today, Ritagli is a reference in the use of pre- and post-consumption wastepaper in Brazil, allowing brands engaged with the circular economy to choose this material in their packaging.

9.8 Business Evolution

During the internal assessment process, it was apparent that the choice of actions carried out in these two cases was made truly respecting a long-term corporate strategy, allowing the projects to be executed with full support to overcome the obstacles faced, tolerance to learn from innovating and awareness that the company was contributing to something relevant to society.

People looked to establish new connections with different audiences, demanding rapid adaptability, build new ways of communicating and engaging, new technological processes with compatible feasibility, and a strong learning capacity in tune with the new environment, with empathy and a genuine willingness to contribute.

By believing that products of cellulosic origin have impressive regenerative capacity, such as carbon sequestration, tree planting, conservation of native areas and biodiversity and a positive social impact, the drive to innovate and propose solutions for products and services that create real value is leveraged by integration with the business purpose.

The business evolution observed during the implementation period of both cases reinforced even more the importance of preparing a business culture with a systemic vision and the importance of having a well-defined, clear, and transparent business purpose in the company and across the entire ecosystem in which Ibema does business and carries out its activities.

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Chapter 10
Circular Economy Principles in Urban Agri-Food Systems: Potentials and Implications for Environmental Sustainability

Martí Rufí-Salís, Susana Toboso-Chavero, Joan Rieradevall, Laura Talens Peiró, Anna Petit-Boix, Gara Villalba, Cristina Madrid-López, and Xavier Gabarrell

Abstract Due to urban population growth during recent decades, the food supply chain has become one of the key material flows in the metabolism of cities. Urban agriculture (UA) can be an alternative for mitigating food supply impacts. UA can provide environmental benefits, but current concepts and strategies do not reflect its full potential. The circular economy (CE) can contribute to this goal. The promotion of CE principles in UA can help mitigate the environmental impact generated by these systems and move toward circular agriculture, which extends the life of critical resources consumed in urban areas. However, it is important to identify whether the application of CE strategies in UA systems entails burden-shifting processes. The aim of this chapter is to outline and analyze the environmental implications of applying CE strategies in UA, such as the use of struvite, compost, rainwater harvesting, or water and nutrient recirculation. We conclude that the application of CE

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strategies in UA systems should always include a parallel environmental assessment from a life cycle perspective to assess potential drawbacks and burden-shifting processes and to ensure that circular economy principles and sustainability goals are aligned.

Keywords Circular economy · Urban agriculture · Life cycle assessment (LCA) · Environmental sustainability

10.1 Growing Importance of Urban Agriculture Systems

For the first time, in 2007, the urban population surpassed the rural population (United Nations 2014). Despite this increase in urban population, cities only occupy 3% of the Earth's surface area (SEDAC 2016). It is thus expected that urban populations will consume a vast amount of the world's resources (Seitzinger et al. 2012). The food supply chain has been labeled one of the largest contributors to global environmental impacts because it is long and inefficient (Spiertz 2010). As an example, some of the most reported impacts of the food supply chain are related to water depletion (Vlachos and Aivazidou 2018) or greenhouse gas (GHG) emissions (Foley et al. 2011). The rising demand for food has also increased the pressures on natural resources and land availability (Schade and Pimentel 2010). The Intergovernmental Panel on Climate Change (IPCC) quantified that agriculture, forestry, and land use contribute to 24% of the global GHG emissions (IPCC 2014). Data for the European Union (EU-28) show that agriculture contributes to nearly 10% of the overall GHG emissions (Eurostat 2011).

Considering both the current urban population and future urban population, it is unavoidable to allocate most of the impact of global agriculture on the food supply to cities. As cities rely on their hinterland to feed the urban population, understanding how to reduce the pressures arising from urban food consumption is critical (Lenzen and Peters 2010). Additionally, the COVID-19 pandemic exposed the fragility of urban food sovereignty and its dependence on external imports (Bakalis et al. 2020; Vittuari et al. 2021). In this sense, new approaches to mitigating these impacts focus on providing cities with fresh and local food (Brock 2008).

Urban agriculture (UA) systems are those located within or at the edge of a metropolitan or urban area (Smit et al. 2001) and, in a certain way, serve as an alternative to traditional methods of food production in cities (Specht et al. 2014). UA is a dynamic strategy that can be implemented in multiple forms, such as greenhouses, open-air systems, vertical farming, or building-integrated agriculture (Llorach-Massana 2017). In addition to food supply or environmental enhancement (Smit et al. 2001), UA provides other benefits that can be classified according to the three dimensions of sustainability: economic, social, and environmental (Specht et al. 2014; Thomaier et al. 2015).

From an economic standpoint, UA provides fresh food on demand to local markets (Despommier 2013). Moreover, UA has the power to contribute to the development of local economies (Lovell 2010; De Zeeuw 2011; Kortright and Wakefield 2011). Nonetheless, the promotion of UA, especially in rooftop areas, must compete with other novel urban uses that entail a higher economic revenue, such as photovoltaic panels (Thomaier et al. 2015).

From a social perspective, UA increases the resilience of food supply chains, contributing to food security in urban regions (Mok et al. 2014). According to Zezza and Tasciotti (2010) and Müller and Sukhdev (2019), UA may be associated with a more diverse diet, greater calorie availability, and healthier food provision. Additionally, UA can increase the feeling of belonging in urban areas, create new jobs, and promote social equality (Orsini et al. 2013; Ferreira et al. 2018).

The environmental perspective of UA is related to concepts such as urban resilience (Barthel and Isendahl 2013), ecosystem services (Artmann et al. 2018; Orsini et al. 2020), release of pressure to rural areas (Specht et al. 2014), reduction in transport distances (Jones 2002), sustainable cities (Taylor et al. 2012), resilience to climate change or the need to reduce water demand (Lin et al. 2015; Kalantari et al. 2018).

10.2 Potential of the Circular Economy in Urban Agri-Food Systems

Urban agricultural systems are characterized as highly resource-intensive, especially in terms of land (Seitzinger et al. 2012), water (Parada et al. 2021b), nutrients (Sanjuan-Delmás et al. 2020), and substrate materials (Parada et al. 2021a). The substitution of traditional UA by innovative, circular UA systems (Fig. 10.1) can ameliorate competition for land and resource uses in urban areas (Sanyé-Mengual et al. 2019; Rufí-Salís et al. 2021). In terms of nutrients, the linear nature of agricultural systems causes the loss of nutrients that are not assimilated by plants, either to be treated by wastewater removal technologies or to be percolated into water bodies (Garcia-Caparros et al. 2017; Rufí-Salís et al. 2020b).

Apart from the potential impacts related to eutrophication caused by nitrogen (N) and phosphorus (P) emissions, one of the main concerns of intensive agriculture is the inefficiency of P resources (Cordell et al. 2009; Rufí-Salís 2020). Currently, P is primarily obtained from phosphate rocks, with 80% of the available stock employed in the production of fertilizers (Shu et al. 2006). Considering that P deposits are renewed on a scale of geologic time (Childers et al. 2011) and that unlike N, P does not have a mechanism to move from marine stocks to terrestrial stocks (Elser and Bennett 2011), mineral P resources are likely to be depleted in the twenty-first century (Steen 1998). Thus, given the scientific consensus on the depleting nature of P (Rittmann et al. 2011) and the risks that this depletion poses to

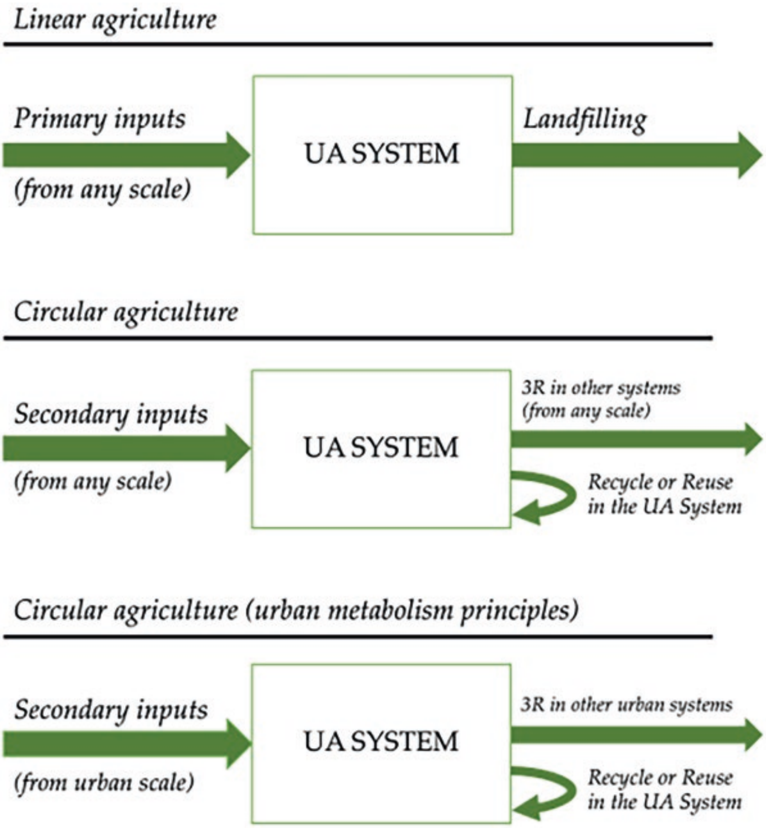

Fig. 10.1 Differences between linear and circular agriculture (with or without urban metabolism principles). Primary inputs refer to the use of virgin and raw materials, while secondary inputs refer to the use of recovered resources to which a second life is being given. *3R* recycle, reuse, revalorize, *UA* urban agriculture

food systems, sustaining P reserves has already reached the political agenda. For instance, in the EU, phosphate rock is considered a critical raw material (European Commission 2020a). In the period 2012–2016, the EU imported approximately 85% of phosphate rock (in P_2O_5 content) mainly from Morocco (28%), the Russian Federation (23%), and Algeria (13%) (European Commission 2020b). The supply dependence in the EU on producing food for cities could be alleviated by the use of secondary sources of P, mainly from animal manure, food waste, and wastewater (van Dijk et al. 2016).

In this sense, the application of CE principles can be a path to increase the efficiency of critical resources and to decrease the depletion of critical resources that are utilized in UA systems and the systems that can generate symbiosis at an urban or regional level (Fig. 10.1). As stated by Ferreira et al. (2018), "*agriculture is*

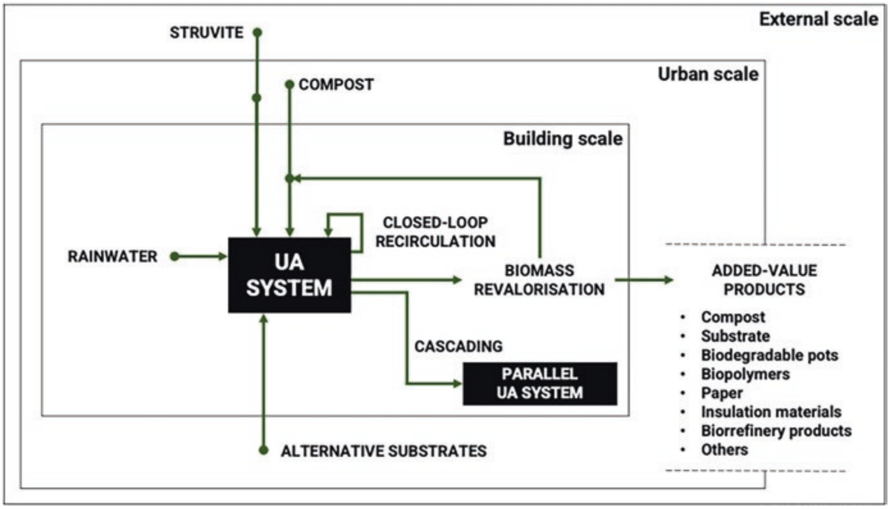

Fig. 10.2 Circular Economy strategies discussed in the present chapter. (Adapted from Rufí-Salís et al. (2021))

central to any territorial-based circular economy strategy". Along general lines and considering the EU context, Fig. 10.1 shows how the application of CE principles in UA systems is also a good strategy to reduce the import dependency of materials, such as P resources, from developing economies and to improve the internal EU market by moving away from linear agricultural production that consumes primary inputs and generates waste. This finding translates to a reduction in the dependency on external resources, especially regarding water as the main input of UA systems (Rufí-Salís et al. 2021). As exemplified in Fig. 10.1, moving from circular agriculture without a defined scale to circular agriculture that accounts for urban metabolism principles can ameliorate resource flows, such as virtual water, and the externalization of impacts at the expense of increasing locally reused water. However, we need specific strategies that focus on the enhancement of the UA system at different scales (Fig. 10.2).

10.3 Circular Enconomy as a Mean: A Life Cycle Perspective

Although the application of CE principles to UA systems may have apparent benefits, such as increasing the efficiency of water and nutrient flows and reducing direct emissions and wastes, to what extent these benefits compensate for potential tradeoffs should be quantified. This aim requires a broad environmental analysis of not only all the elements of the UA system under assessment but also all the life cycle stages associated with each of the UA elements involved: extraction of raw materials, processing, or end-of-life, among others. The use of life cycle assessment (LCA) can help to quantify to what extent the CE is a means to improve environmental sustainability (ISO 2006; Peña et al. 2020), since previous studies have indicated that closing loops are not always a means to improve environmental performance (e.g., Laner and Rechberger 2007; Humbert et al. 2009; Geyer et al. 2016; Rufí-Salís et al. 2020d). The application of LCA principles is vital to detecting weaknesses and environmental hotspots of CE strategies not only at the end of life through a redefinition of the waste hierarchy but also among different stages of the life cycle of a system. In this sense, a life cycle perspective is mentioned in the recent CE Action Plan from the European Union: "*this legislative initiative […] will be developed in a way to improve the coherence with existing instruments regulating products along various phases of their life cycle*" (European Commission 2020c). As expressed in the last Life Cycle Initiative's position paper titled "*Using Life Cycle Assessment to achieve a circular economy*", LCA should be applied as a methodology to promote more robust circular strategies that include all relevant resources and indicators, leading to better decisions for sustainability (Peña et al. 2020). Additionally, Zeller et al. (2019) state that "*whether the closing of material cycles at city level has environmental benefits compared to the national or global level, it needs to be further assessed based on comparative LCA studies.*"

10.4 Benefits and Trade-Offs: A Series of Cases

Given the potential of UA as an opportunity to utilize wastes as resources within city limits (Smit et al. 2001; Ferreira et al. 2018), the application of CE strategies in UA systems is a promising path toward not only circular UA systems but also a more circular urban metabolism (Fig. 10.1). In this section, we describe some of the most common CE strategies mentioned in the literature and discuss their potential benefits and trade-offs in terms of environmental sustainability. Figure 10.2 shows the strategies that will be described in the following subsections and classifies them into the scales on which they would be feasible. If a strategy is classified under the "building scale", it could be operational by using secondary inputs in the same building, including both the UA system itself and other waste-to-resource processes, such as organic waste generation. If a strategy is classified under the "urban scale", it could be operational using secondary inputs generated in systems that are often identified at a generic urban scale (including both city limits and urban/metropolitan region limits), such as municipal solid waste collectors and processors or wastewater treatment plants. Any strategy included in the "external scale" may not be feasible at the building and urban scales for a variety of factors, such as the nonexistence of recovery technologies in that specific city or the scarcity of secondary inputs.

10.5 Rainwater Harvesting

The use of harvested rainwater in the urban context can alleviate the limited water availability in these areas (Toboso-Chavero et al. 2018), especially for semiarid urban territories, where it can cause a significant reduction in water consumption, marine eutrophication and freshwater eutrophication impacts (Bonilla-Gámez et al. 2021). The use of rainwater at the building scale is a strategy that has been extensively investigated and is able to provide nearly 100% of the water for hydroponic cultivation (Sanjuan-Delmás et al. 2018; Parada et al. 2021b). However, concerns have been raised in the literature regarding the potential life cycle impacts across multiple impact categories (e.g., global warming or resource use) exerted by storage tanks in their extraction and manufacturing phases (Sanjuan-Delmás et al. 2018). In this sense, the parameter that can be modified is the size of the tank, accounting for local pluviometry conditions and water requirements of the urban agricultural system (Mun and Han 2012; Angrill et al. 2012). Software programs such as Plugrisost© are already available to model the decreased impact of rainwater harvesting systems while maintaining the benefit of reusing water (Gabarrell et al. 2014).

10.6 Closed-Loop Hydroponic Cultivation

The use of hydroponic cultivation in rooftop farming intrinsically improves water and nutrient supply efficiency by allowing for better control of plant nutrition (Christie 2014). Moreover, hydroponic cultivation also allows precise monitoring of the leachates and increases the flexibility of the UA system in managing the residual water and nutrient flows (Sayara et al. 2016). In this sense, different strategies are discussed in the literature to take advantage of these residual flows generated at a building scale. The recovery of valuable nutrients, such as P compounds, is being investigated and improved through different methods, such as chemical precipitation or membrane filtration (Rufí-Salís et al. 2020c). However, these technologies may require high investment costs, so they are only feasible given a considerable high residual flow (only reachable in large facilities) or by sending the residual flows to urban wastewater treatment plants. Accordingly, these technologies are usually related only to the removal of nutrients, with the principal goals of cleaning the water before losing it to water bodies and of complying with legal standards. Additionally, removal efficiency is still highly dependent on the degree of technological innovation (e.g., Piekema and Giesen 2001; Tchobanoglous et al. 2003; Royal Haskoning DHV 2019).

To ensure that all water and nutrients are recovered, the use of closed-loop hydroponic cultivation is reported in the literature (Agung Putra and Yuliando 2015; Bouchaaba et al. 2015), although limitations and potential trade-offs are also mentioned from studies that quantify environmental impacts. The recirculation of the drainage effluent in the same crop (thus classifying this strategy on a building scale) not only mitigates the eutrophication impacts from direct emissions but also directly diminishes the required inputs to agri-food systems (Parada et al. 2021b). However, potential limitations may arise if nutrient metabolism is not included in the analysis (Rufí-Salís et al. 2020d), since imbalances can negatively affect plant development and increase the environmental impacts due to a decrease in the quantity of the functional unit. Therefore, it is highly relevant to measure all nutrient flows within the system to maximize its efficiency. The use of drainage effluent in parallel crops in what are referred to as cascade systems is a potential way to overcome this limitation (Incrocci et al. 2003; García-Caparrós et al. 2016; Rufí-Salís et al. 2020c). Nonetheless, the largest trade-off detected is related to a potential burden-shifting in terms of infrastructure if the materials needed to implement closed-loop systems have a high environmental contribution (Rufí-Salís et al. 2020d; Parada et al. 2021b). This finding highlights the need for an extension of the assessment boundaries of CE strategies, sometimes narrowed at the end of life, to production and manufacturing considering eco-design principles, low-impact alternatives, and potential burden-shifting processes across life cycle stages.

10.7 Use of Recovered Resources: Struvite as a Secondary Fertilizer

As mentioned earlier in this chapter, phosphate rock, one of the main mineral sources of P, is considered a critical raw material in the EU. Identifying secondary sources of P, such as struvite, is a priority to make agriculture as self-reliant as possible. Additionally, the use of secondary fertilizers directly contributes to circular urban metabolism since it links two potentially relevant sources of impact in cities: wastewater treatment and agricultural production. Returning to the P case, a great example of industrial symbiosis in urban areas is struvite (Talboys et al. 2016). Struvite is a mineral composed of magnesium, phosphate, and ammonium in a 1:1:1 stoichiometric relationship that is accidentally precipitated in the ducts of wastewater treatment plants. Technologies aimed at removing struvite through induced precipitation to diminish maintenance and repair costs in wastewater treatment plants offer an unexpected opportunity. Struvite has been extensively tested in the literature, with results suggesting that higher production can be reached at a lower environmental cost (Linderholm et al. 2012; Amann et al. 2018).

The recovery of struvite in urban wastewater treatment plants and its reuse in urban and periurban agricultural production has already been quantified to be feasible at a regional scale (Rufí-Salís et al. 2020a), although P-recovery technologies should be implemented to avoid relying on struvite imports from other regions (External Scale—Figure 10.2). Thus, the next challenge is to quantify to what extent a regional CE plan for P is feasible in other key urban areas and to explore to which other linear flows the successful case of P can be extrapolated.

10.8 Use of Recovered Resources: Alternative Substrates

The use of stabilized compost from municipal solid waste, which comprises a tremendous flow at the building and urban scales, can enhance the resilience of nutrient supply chains and contribute to prioritizing composting processes over alternatives with less added value, such as incineration or cogeneration. The use of compost as a fertilizer can enhance production and have lower environmental impacts than commercial alternatives (Martínez-Blanco et al. 2009, 2011).

Apart from the use of compost as a nutrient supplier, recent studies have explored the use of this material as a potential substrate to displace primary materials such as perlite or rockwool, which are traditionally employed in hydroponic agriculture (Olle et al. 2012). Apart from being available from local markets, compost contributes to closing loops at a smaller scale, while the production of commercial alternatives is usually concentrated in specific countries, such as perlite in Turkey or Greece (USGS 2013). Nonetheless, CE strategies that are aimed at replacing conventional materials must always consider local characteristics. For example, hydroponic settings in rural areas may not have a large market for municipal solid waste as urban areas. Therefore, local alternatives such as sheep wool, dried moss, pine bark, or wood fiber can constitute a more resilient and reliable market for substrate provision (Barrett et al. 2016). In this sense, previous literature has demonstrated that dried moss might be more agronomically efficient than sheep wool (Dannehl et al. 2015). Therefore, it is also important to account for previous experimental tests and findings in the academic literature to plan the implementation of CE strategies in a specific region or agricultural system. As an example, Parada et al. (2021a, b) discovered that compost was a viable alternative as a hydroponic substrate, but its mixture with perlite provided more tolerance to temporary water restriction than perlite as a standalone substrate. This finding may be important in regions where compost and water are limited. Moreover, safety in use, for example, in terms of heavy metal content (Ercilla-Montserrat et al. 2018), is crucial to increase the acceptability of alternatives both to farmers and consumers.

10.9 Added-Value Secondary Products from Urban Agriculture

Considering the increasing spread of UA systems, insights into the main waste flows exiting these systems are critical to ensure that they contribute to a more circular urban metabolism. However, information about the quantification of waste flows from UA systems is lacking. A characterization of UA solid waste in the framework of the CE was performed by Manríquez-Altamirano et al. (2020). This study, which is based on a hydroponic system in a rooftop greenhouse, determined that each m^2 of crop annually generates 2.4 kg of inorganic waste and 6.6 kg of organic waste. Within this classification, inorganic outputs were mainly composed of substrate waste, while organic outputs were composed of branches and leaves (77%) and stems (23%).

Although inorganic waste represents 3.5 times the amount of organic waste, previous research that analyzes potential uses from the waste generated in UA has focused on organic outputs, more specifically on biomass reuse and recycling. The academic literature highlights the use of biomass waste as a substrate (Grard et al. 2018) and compost (Goldstein et al. 2016). However, recent studies have explored the use of biomass to create biobased, added-value products (refer to Figure 10.2). For example, Manríquez-Altamirano et al. (2021) discussed with a panel of experts three potential groups of biobased applications from tomato stems: fences, packaging and boards, panels, and blocks. Parallel research on recycling other parts of tomato plants has demonstrated the potential to create other circular bioeconomic products, such as biodegradable pots (Schettini et al. 2013) or biopolymers (Franzoso et al. 2015). By mixing tomato stems with other biobased materials, previous literature evaluated the production of paper (Üner et al. 2016) or insulation materials (Llorach-Massana 2017).

10.10 Circularity Assessment of Urban Agri-Food Systems: How to Link It with Environmental Performance

Unlike LCA, which is standardized through an ISO document (ISO 2006), the methodology for determining to what extent a system is indeed circular is still under discussion. Several indicators have already been reported in previous research, each of them with their own potentials and limitations. To ease the selection, reviews of indicators are provided in the academic literature (e.g., Haupt et al. 2017; Helander et al. 2019; Saidani et al. 2019a, b).

Not all indicators can be applied in all situations. Since a systems perspective is intrinsically associated with UA systems, scaling up indicators that are focused on products may entail a certain degree of uncertainty. Considering this point, reliable indicators for assessing the circularity of the agri-food sector are still lacking (Kristensen and Mosgaard 2020). In UA, where most of the foreground system is based on biological materials, an analysis of circularity may focus only on closing loops at the end-of-life stage via biological processes (i.e., composting and biodegradation). Other strategies, such as lifetime extension, repair, and remanufacture, may not be applicable to the foreground system of UA, especially if it is narrowed from an operational approach. However, if we want to link the circularity assessment with an analysis of environmental performance, the system boundaries must be comparable. As highlighted by Helander et al. (2019), the Material Circularity Indicator (MCI), which was developed by the Ellen MacArthur Foundation (EMF 2015), is applied across life cycle phases, rendering it complementary to LCA. In this sense, a dual assessment that combines LCA and MCI results has already been performed for UA by Rufí-Salís et al. (2021) but also for packaging by Niero and Kalbar (2019). These papers present different ways of coupling the MCI and LCA, either by multicriteria decision analysis to obtain a single factor or by developing a new set of indicators through environmental relative contributions. Apart from the potential discussion on the best way to couple circularity and LCA indicators, several limitations were reported.

Carbon fixed by short-cycle crops (labeled biogenic) or nutrient emissions to water without eutrophication potential are part of the flows that are not usually collected in LCA studies. However, these flows must be quantified in circularity assessments since they encompass mass conservation of all flows. Additionally, challenges may arise in assigning the terminology required for the MCI, such as virgin feedstock or unrecoverable waste, to specific flows (e.g., drained water or solid waste for which the next use is unknown).

Another potential limitation is related to the water flow. Water may hinder the results by representing most of the MCI total value, which is also reported by economy-wide material flows analysis (Eurostat 2001) and thus limits the assessment of additional flows with less mass. Other limitations highlighted include the omission of transport or energy processes (Rufí-Salís et al. 2021; Saidani et al. 2019a). Based on the complexity of integrating LCA and circularity indicators highlighted by previous attempts, maintaining the raw values obtained either through LCA or circularity assessment seems to be the safest and least uncertain way to proceed while standardization procedures are under construction.

10.11 Importance of Geographical Scales

The application of CE principles is not a standalone objective but a potential means to increase a system’s overall sustainability. Considering the three sustainability dimensions, locating circular strategies within a framework of different geographical levels can help contextualize broader implications than those captured by circularity indicators. As an example, Rufí-Salís et al. (2021) quantified 13 different circular strategies that could be applied to a hydroponic rooftop greenhouse, classified within building, urban, and national scales. Within the circular strategies analyzed, the use of compost as a potential substrate showcased how a geographical perspective may be important in quantifying the environmental sustainability of circular strategies. The use of compost presented limitations at the building scale due to the amount of biowaste produced but was feasible at the urban scale because of the amount of compost produced from municipal solid waste. Another potential example of the importance of a scale framework from the same study is the case of struvite. Although the potential struvite obtained from urban wastewater treatment plants has been demonstrated to be feasible at a regional scale for the Barcelona metropolitan area (Rufí-Salís et al. 2020a), the amount of struvite that can be obtained at the crop level renders it an inefficient method compared with other CE alternatives, such as direct recirculation (Rufí-Salís et al. 2020b). Thus, the conclusion is that the geographical scale needs to be considered to assess the feasibility of the development and implementation of circular economy practices.

10.12 Identifying and Addressing Environmental Burden-Shifting Processes

From a methodological standpoint, burden-shifting represents the major challenge in the application of CE strategies in UA systems from an environmental perspective. In this sense, LCA must be performed in a way that avoids solving one problem at the expense of another problem (Brandao et al. 2017). Three potential burden-shifting processes were identified in this chapter: between impact categories, between life cycle stages, and between systems, markets, or generations.

Burden-shifting between two impact categories was demonstrated to be quantified through LCA (European Commission 2013). For example, recirculation systems, one of the most common CE strategies in the literature, can potentially reduce the eutrophication potential of the system by avoiding nutrient discharge but may contribute to increasing the global warming potential due to additional materials required to adapt the system setup (Rufí-Salís et al. 2020d). The use of LCA is useful for detecting these weaknesses (Peña et al. 2020). However, LCA must be performed not only to quantify the environmental hotspots of the system in specific impact categories but also to design mitigation strategies (ISO 2006).

Burden-shifting between two life cycle stages is also quantified through LCA (Hauschild et al. 2017). As stated by ISO (2006), "*through such a systematic overview and perspective, the shifting of a potential environmental burden between life cycle stages or individual processes can be identified and possibly avoided*". However, the omission of specific life cycle stages in the assessment either due to a lack of data or low impact in the baseline scenario can decrease the efficiency of LCA in detecting these kinds of problems. To avoid this situation, it is critical that LCA accounts for all the impacts occurring throughout the entire value chain (Hellweg and Canals 2014). Using the previous example, if the study from Rufí-Salís et al. (2020d) had only accounted for the operational impacts of applying a closed-loop strategy (i.e., use and maintenance of the system), the potential environmental impacts from the manufacturing of the additional infrastructure required for the recirculation system would have been hidden in a blind spot. Therefore, the environmental assessment of the application of CE strategies should encompass all the life cycle stages and should not be limited to only the relevant life cycle stages for the baseline scenario, since unexpected hotspots may appear along the supply chain of the different inputs and outputs linked with UA systems.

Burden-shifting can also occur in terms of spatial and temporal resolution (European Commission 2013). However, burden-shifting processes among systems, markets, or generations seem unlikely to be detected from an attributional approach that establishes the system boundaries at the system level. The use of LCA from an attributional approach narrows the direct effects of a CE strategy to the system to which it is applied and the flows into and out of the system. In this sense, Schmidt (2008) states that modeling agricultural LCA from an attributional approach produces some blind spots. As highlighted by previous literature, avoiding the consequences from a market perspective, such as price fluctuations or rebound effects, can cause burden-shifting (Zink and Geyer 2017). In this sense, the use of consequential LCA (see Weidema (1993) and Zamagni et al. (2012)), which focuses on the consequences generated by a change in demand of the functional unit) has been labeled a powerful tool to avoid burden-shifting along the different supply chains linked to agricultural LCAs.

In a research paper on the mitigation potential of CE principles, Cantzler et al. (2020) highlight that a consequential approach is preferred over an attributional approach when communicating with policymakers. Taking into account that the CE has now reached the political agenda at different levels (e.g., People's Republic of China 2008; The White House 2012; European Commission 2020a, b, c), identifying the most accurate metrics to transition from linear behavior to CE strategies will continue to be a hot topic for a broad variety of stakeholders.

10.13 Final Remarks and Upcoming Challenges

This chapter has presented a summary of the current CE strategies applied to UA systems discussed in the literature and their contribution to environmental sustainability. From a system's perspective, three main challenges can be drawn from the analysis.

Standardization of CE definitions and metrics: not only the variability of CE definitions available in the literature (Kirchherr et al. 2017) but also the number of methodologies to measure circularity (e.g., Haupt et al. 2017; Helander et al. 2019; Moraga et al. 2019) makes it extremely difficult to compare the current works on these novel topics. Therefore, it is urgent to conceptualize a CE definition and the ways to measure progress toward it in every specific system. With a clear definition, the path to determine to what extent the application of CE principles in systems such as UA can contribute to environmental sustainability will be clearly defined for practitioners, decision-makers, and all relevant stakeholders. The development of the currently ongoing ISO standards on the circular economy by the ISO/TC323 would contribute to standardizing definitions and methods and therefore advance the assessment of current and novel strategies within systems (ISO 2018).

Accounting for all parameters that have a role: the environmental assessment of CE strategies in UA systems should account for not only all the relevant impacting items but also those parameters that affect the performance of the system, such as the nutrient metabolism or climatic conditions, to detect potential nutritional deficiencies or excessive evapotranspiration. When considering many parameters, the results might not be conclusive, but having more detailed information about the effects of changes in certain parameters would yield better decisions.

A system's perspective on the implementation of CE strategies and its assessment: applying a system's perspective to the implementation of CE strategies encompasses good knowledge about the system from the actor evaluating it: relevant flows, factors affecting its behavior, level of resilience, etc. A CE strategy that may improve the environmental performance in hydroponic systems might not be that efficient for soil-based setups. A similar situation can happen between open production systems and greenhouse production systems and with a great variety of different factors. Therefore, an in-depth analysis of how a system is designed and works on a daily basis is critical to planning the most suitable CE strategies not only for UA but also for all other assessable systems.

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Chapter 11

A Systems Perspective on the Industry 4.0 Technologies as Enablers of Circular Economy Transitions

Vinicius Picanço Rodrigues and Eduardo Zancul

Abstract A growing number of emerging Industry 4.0 technologies are claimed to be one of the most important enablers of the sought-after transition to the Circular Economy (CE). The technological aspects are of crucial importance for the establishment of CE as a solid paradigm. On the one hand, Industry 4.0 technologies can improve existing operations – thus enabling multiple CE strategies – while the development of new technologies and increased information sharing act as drivers for CE within manufacturing companies. On the other hand, the lack of adequate information and knowledge, coupled with limited technology adoption and technical skills, form strong barriers to the wider adoption of CE. In addition, Industry 4.0 technologies can profoundly influence the adoption of CE at different levels and forms, both in terms of product design and process management. This transition involves fundamental changes in various processes across the value chain, from product design and innovation to end-of-life mechanisms and business model innovation. Furthermore, the development of a CE requires both technological and sustainability perspectives to be fully realized, underpinned by a systems interpretation that captures the complexity and emergence of such phenomena. However, despite the increased availability and understanding of Industry 4.0 technologies and the ever-growing consolidation of the theoretical and empirical foundations of CE, there is still a lack of understanding of how these technologies can adequately

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support the transition to a CE. Based on a systems account of technological and sustainability transitions, this chapter reviews key CE strategies and Industry 4.0 technologies to provide a systemic framework and a selected set of cases that illustrate how Industry 4.0 technologies can be one of the key drivers of circularity across industries, sectors, and geographies.

Keywords Systems thinking · Digital technologies · Technological transitions · Sustainability transitions · System dynamics

11.1 Introduction

The Sustainable Development Goals (SDG) – proposed in 2015 by the United Nations – materializes a shared expression of the most pressing challenges in sustainable development (United Nations General Assembly 2015). The SDG represent a wide array of opportunities for both businesses and governments to tackle unmet needs and develop strategic partnerships with a large set of stakeholders (Muff et al. 2017; Rosati and Faria 2019a; Scheyvens et al. 2016). Commitments toward the SDGs include developing enhanced mechanisms for responsible and sustainable production and consumption, while building resilient infrastructure and fostering sustainable innovation (Rosati and Faria 2019a; United Nations General Assembly 2015).

The very concept of a *transition* toward the Circular Economy (CE) becomes critical as an alternative to the prevailing *take-make-dispose* logic (Blomsma and Brennan 2017; Ellen MacArthur Foundation 2015; Geissdoerfer et al. 2017; van Loon and Van Wassenhove 2020; Werning and Spinler 2020). Estimated benefits stemming from this transition in the European continent alone are around €1.8 trillion annually, which leads to a set of outcomes, spanning from enhanced industrial competitiveness to economic growth and job creation (Ellen MacArthur Foundation 2015; Werning and Spinler 2020). CE is claimed to be a new production and consumption paradigm (Lopes de Sousa Jabbour et al. 2018; Miranda et al. 2021) that pursues the safeguard of planetary boundaries (Steffen and Stafford Smith 2013). This is primarily attained by increasing the shares of renewable energy and recyclable resources, combined with an aggressive reduction of the use of raw materials and energy consumption (EEA 2016).

With a view to pursuing the benefits obtained from CE implementation, a growing number of manufacturing companies are actively engaging in the transition toward circularity (Homrich et al. 2018; Tukker 2015; Tura et al. 2019) as both a business strategy and a contribution toward the SDGs (Rosati and Faria 2019b). More broadly, the CE transition process can be understood and analyzed through the lenses of *sustainability transitions* (de Gooyert et al. 2016; Geels 2002; Geels et al. 2017; Markard et al. 2012). While these transitions directly threaten extant system configurations facing sustainability challenges (e.g. climate change, food scarcity, hunger, fossil fuels, pollution, overconsumption, etc.), they display opportunities for more systemic and accelerated change (Loorbach et al. 2017). This is, indeed, the expected endgame of CE: to represent a profound change of the production and consumption systems that leads to a sustainable future (Guzzo et al. 2021).

Within this context, the set of emergent digital Industry 4.0 (I4.0) technologies – such as Big Data Analytics (BDA), Cyber-Physical Systems (CPS), Additive Manufacturing (AM), Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain, among others – is claimed to be one of the most important enablers of the sought-after CE transition (Antikainen et al. 2018; Bressanelli et al. 2018a; Pagoropoulos et al. 2017; Rosa et al. 2019). Technological aspects play a crucial role in establishing CE as a solid paradigm. Digital technologies have the potential of improving existing operations, thus enabling several CE strategies. New technology development and increased information sharing act as drivers for CE within manufacturing companies (Tura et al. 2019). On the flip side, the lack of adequate information and knowledge, coupled with limited uptake of technologies and technical skills, configure strong barriers to wide adoption of CE (Adams et al. 2017; Jabbour et al. 2017; Tura et al. 2019).

Digital technologies can influence the adoption of CE in various levels and forms, both at product design (Linder et al. 2017) and process management (Bressanelli et al. 2018a; De los Rios and Charnley 2017; Ellen MacArthur Foundation and Granta Design 2015). However, despite the large set of assertions and solid foundation for taking digital technologies as a fundamental CE enabler, it raises the question of how to make this complex transition happen in a just and sustainable fashion (Adams et al. 2017; Moreno and Charnley 2016; Okorie et al. 2018; Tseng et al. 2018; Tura et al. 2019).

In this context, transitioning to a Circular Economy (CE) is inherently complex due to the numerous interdependencies among elements and stakeholders within the CE landscape. The transformation extends beyond mere technological development and adoption (Rodrigues et al. 2019; Miranda et al. 2021), demanding shifts in deeply rooted social, economic, and institutional structures, and transformation of business models. Therefore, a systems perspective is not just beneficial, but indispensable. It sheds light on the intricate network of relationships, highlights challenges and potential resistance points, and emphasizes the necessity for a multi-stakeholder approach. It also aids in designing effective strategies for this complex, challenging transition.

To address this gap, we adopted a systems perspective, anchored in the leverage points framework proposed by Donella Meadows (1999a, b). We applied this approach to analyze CE transitions, positioning Industry 4.0 technologies as critical enablers. This was accomplished by performing a content analysis of fundamental literature that describes Industry 4.0 technologies and high-level CE strategies. We established the relationships between these technologies and strategies, situating them within Meadows' leverage points, which were expanded by Abson et al. (2017) to include essential system characteristics, namely parameters, feedbacks, design, and intent. This chapter aims to illustrate the transition as a systemic shift and to outline various Industry 4.0 technologies that effectively enable CE at different stages of the transition. Our work enriches understanding and framing CE transitions by moving past the merely technological facet and exploring the profound implications of a systemic transition.

11.2 Circular Economy: A Systems Perspective

To set the desired CE transition in motion, society must identify and implement effective sustainability *interventions*, which can be defined as *"deliberate human actions targeting sustainability in a given system of interest"* (Dorninger et al. 2020). Therefore, one can see the implementation of I4.0 as a set of sustainability interventions conceived to support a broader transition toward CE. However, not all interventions are equal (Donella Meadows 1999a, b). While *shallow interventions* are often relatively simple to implement and visualize, they have very limited capacity to unlock systemic change.

Typical efforts include efficiency improvement and parameter optimization. These interventions are unlikely to underpin systemic transitions if other system characteristics remain unchanged (Abson et al. 2017; Dorninger et al. 2020; Leventon et al. 2021). As an example, the emerging rebound effects from efficiency improvements produce the reduction in expected gains due to behavioral or other systemic responses, weakening the positive effects of measures taken (Dorninger et al. 2020; Gürsan and de Gooyert 2021; Sorell 2010; Sorrell 2009; Sterman 2015). An analogy to understand rebound effects is when more driving occurs as a response to an automobile's improved gas mileage.

Conversely, *deep interventions* are less tangible and more difficult to implement, but potentially result in powerful, persistent change. Deep interventions are the ultimate drivers of CE transitions and might entail the social structures and institutions, along with the values, goals, beliefs, paradigms, and worldviews of actors within the systems under change. These deeper characteristics of systems under transition simultaneously shape and constrain other interventions at shallower levels (Dorninger et al. 2020; Leventon et al. 2021; Donella Meadows 1999a, b).

Examples of deep interventions can be found in the paradigm shifts occurring in the application of I4.0 technologies in energy and food systems. For instance, energy systems have been primarily optimized for efficiency over the years, while social and environmental aspects remain neglected. The shift toward higher uptake of renewable technologies is only possible thanks to a massive change in paradigm, which means that the aim of the optimization efforts is now encompassing environmental and social aspects (Kieft et al. 2020), giving rise to many CE strategies in the energy sector (Cainelli et al. 2020; Dalhammar 2016). As for food systems, several deep changes are also underway. For example, a major paradigm shift has put a lot of emphasis on the impacts of food production and consumption on environmental, social, and animal welfare aspects (Reis et al. 2020), pushing for the development of several CE practices and I4.0 technologies in food supply chains (Slorach et al. 2020). Shifts in the system's values and paradigms enable major movements toward plant-based diets and the development of novel cell-based technologies, catalyzed by I4.0 technologies (Rosenfeld and Burrow 2017; Sparkman et al. 2021).

To understand which types of interventions are likely to produce desirable results in CE transitions, we introduce the concept of *leverage points*. *Leverage points* was introduced by Donella Meadows in the systems literature (Meadows 1999a, b) and has been recently developed further by many authors under the auspices of the literature on transitions – see, for instance (Davelaar 2021; de Gooyert et al. 2016; Dorninger et al. 2020; Kieft et al. 2020; Leventon et al. 2021; Linnér and Wibeck 2021; Rosengren et al. 2020; West et al. 2020). Leverage points are particular points in a system where shifts (interventions) have great transformational power (Kieft et al. 2020; Meadows 1999a, b).

Meadows ranked 12 leverage points according to their effectiveness, from low (shallow) to high (deep) potential, in what she called "places to intervene in a system" (in increasing order of effectiveness) (Abson et al. 2017; Dorninger et al. 2020): **(12)** *constants, parameters and numbers* (e.g., subsidies, taxes, standards, etc.); **(11)** *size of buffers and stabilizing stocks, relative to their flows* (e.g., stock of physical capital and the rate of investments in new technologies); **(10)** *structure of material stocks and flows* (e.g., technology networks, population structures, etc.); **(9)** *length of delays, relative to the rate of system change* (e.g., technology lifecycle, development delays and time-to-market); **(8)** *strength of negative feedback loops* (e.g., corrective actions to reduce manufacturing carbon emissions); **(7)** *gain of positive feedback loops* (e.g., the reinvestment of profits generated by green technologies in the development of new green technologies); **(6)** *structure of information flows* (i.e., availability and transparency of information to key decision-making processes); **(5)** *rules of the system* (e.g., incentives, punishments, constraints – either physical or intangible); **(4)** *power to add, change, evolve or self-organize system structure* (e.g., rearrangement of physical capital, human capital and set of technologies in a manufacturing firm); **(3)** *goals of the system* (e.g., carbon emissions reduction or increase in the share of renewable energy); **(2)** *mindset or paradigm upon which the system arises* (e.g., linear industrial logic, or growth-seeking mindset); and **(1)** *power to transcend paradigm* (e.g., profound reexamination of extant paradigm, say linear industrial logic, and the ability to structure and pursue viable alternative paradigms, such as the CE).

We used Meadow's framework to analyze the role of I4.0 technologies as enablers of CE transitions, in a rationale depicted by Fig. 11.1. In the proposed analysis rationale, mapping I4.0 technologies is the first step to enable effective interventions based on leverage points to activate large-scale CE transitions.

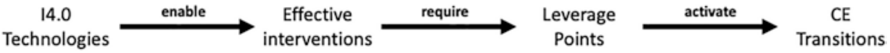

Fig. 11.1 Rationale linking the implementation of I4.0 technologies to CE transitions, using the concept of leverage points of complex systems

11.3 Industry 4.0 Technologies

Industry 4.0 has been strongly disseminated since 2011, referring to the fourth industrial revolution, characterized by increased digitization in manufacturing (Culot et al. 2020; Kagermann et al. 2011, 2013; Liao et al. 2017). I4.0 is not limited to technological aspects, as it also encompasses organizational, business, and societal impacts (Benitez et al. 2020; Kagermann et al. 2013; Nosalska et al. 2020). Nevertheless, at the firm level, I4.0 has been closely related to the adoption of key enabling technologies (Culot et al. 2020; Frank et al. 2019).

Due to the broad I4.0 scope, many digital technologies have been considered under the I4.0 umbrella. Thus, a frequent question for both practitioners and scholars is defining the range of technologies that should be regarded as part of I4.0 (Culot et al. 2020; Frank et al. 2019; Liao et al. 2017; Nosalska et al. 2020). A widely accepted I4.0 technological framework has not been yet established in the literature.

One of the first efforts to create a framework of I4.0 technologies has nine elements (Rüßmann et al. 2015): Autonomous Robots, Simulation, Horizontal and Vertical Integration, Industrial Internet of Things (IIoT), Cybersecurity, Cloud Computing, Additive Manufacturing, Augmented Reality, Big Data and Analytics. This framework has been extensively adopted, especially among practitioners. Later efforts established more sophisticated and well-grounded I4.0 technology frameworks, including other relevant I4.0 technologies, grouping technologies in clusters (Culot et al. 2020), and organizing them according to typical adoption patterns in the industry (Frank et al. 2019).

To analyze I4.0 technologies as enablers of CE transitions, we adopted a broader perspective to combine technologies from three relevant frameworks in one comprehensive set (Culot et al. 2020; Frank et al. 2019; Rüßmann et al. 2015). The terminology was standardized. Establishing the relationship between the existing frameworks also required equalizing technologies described in different granularity levels. The selected I4.0 technologies were organized according to the four categories defined by Culot et al. (Culot et al. 2020). Physical-digital interface technologies combine extensive hardware with connectivity to bridge the operational reality of machines and products with digital representations and data. Network technologies focus on connectivity and online functionalities. Data-processing technologies are mainly composed of software solutions to support processes and decision-making. Digital-physical process technologies include manufacturing equipment (Culot et al. 2020). Table 11.1 presents the categories, the resulting list of 21 technologies, and the source of each selected technology.

The listed technologies can be combined in application areas such as smart manufacturing, smart products, and smart supply chain (Frank et al. 2019). For instance, a smart product may combine several I4.0 technologies – e.g., IoT, Traceability, Cloud Computing, Big Data, Analytics – to provide product connectivity and optimization functionalities (Anderl et al. 2018; Pirola et al. 2020; Zancul et al. 2016).

Table 11.1 Industry 4.0 technologies

Categories (Culot et al. 2020)	Technologies	Culot et al. (2020)	Frank et al. (2019)	Rüßmann et al. (2015)
Physical-digital interface technologies	Internet of Things (IoT)	✓	✓	✓
	Cyber-Physical Systems (CPS)	✓		
	Visualization – augmented, mixed, and virtual reality	✓	✓	✓
	Traceability – final products and raw materials		✓	
Network technologies	Cloud Computing	✓	✓	✓
	Interoperability and cybersecurity	✓		✓
	Blockchain	✓		
	Machine to Machine (M2M) Communication		✓	
Data-processing technologies	Horizontal and Vertical Integration (ERP, MES, SCADA)		✓	✓
	Modeling and Simulation	✓	✓	✓
	Machine Learning and Artificial Intelligence	✓	✓	
	Big Data Analytics	✓	✓	✓
	Digital Platforms (internal, suppliers, customers)		✓	
Digital-physical process technologies	Additive Manufacturing	✓	✓	✓
	Advanced Robotics – autonomous robots, collaborative robots	✓	✓	✓
	Automation (sensors, actuators, PLCs)		✓	
	Virtual Commissioning		✓	
	Remote Monitoring and Operation		✓	
	Flexible Lines		✓	
	New Materials	✓		
	Energy Management Solutions	✓	✓	

11.4 Enabling CE Through the Adoption of Industry 4.0 Technologies

Once a comprehensive I4.0 technologies list has been established, we identified those with a potential to enable CE by improving existing operations (Kumar et al. 2021; Tura et al. 2019), increasing the shares of renewable and recyclable resources (Bassi and Dias 2019; EEA 2016), reducing the consumption of raw materials (EEA 2016; Hanumante et al. 2019), reducing energy consumption (EEA 2016; Tseng et al. 2020), and supporting the development of business models that drive enhanced use of resources (i.e., circular business models) (De los Rios and Charnley 2017; EEA 2016; Pieroni et al. 2019). Table 11.2 relates the identified I4.0 technologies with CE high-level strategies.

As an example, machines equipped with sensors and connected through IoT for remote monitoring may be optimized for improving operational conditions (Zancul et al. 2016), including energy efficiency. IoT also supports servitization through product monitoring (Durão et al. 2020; Pieroni et al. 2019). Additive Manufacturing may be applied to produce parts remotely closer to consumption sites (e.g., spare parts for maintenance), optimizing operations (Durão et al. 2016, 2017; Jiang et al. 2017; Khajavi et al. 2014). Moreover, the Additive Manufacturing layer-by-layer production process enables parts' geometrical optimization to reduce material consumption and weight (Thompson et al. 2016).

In Table 11.2, the intensity of the relationship between the I4.0 technologies and the high-level CE strategies varies quite significantly. This hints that different I4.0 technologies operate at different levels of effectiveness in terms of enabling CE transitions. For example, out of the 21 listed I4.0 technologies, four have no other impact than "Improving existing operations". These four technologies – Cloud Computing, Horizontal and Vertical Integration, Advanced Robotics, and Flexible Lines – appear to have less potential to support a CE transition significantly, therefore probably only supporting shallow interventions for CE. As a result, the remaining 17 technologies display wider impact on the strategies, hinting at deeper levels of intervention. To systematize the understanding of how these enabling I4.0 technologies can be used to identify and activate effective interventions toward CE transitions, we integrated the concept of leverage points into a comprehensive framework that simultaneously draws from the knowledge from I.40 technologies, CE high-level strategies, Meadow's leverage points and the classification of the leverage points into system characteristics (i.e., parameters, feedbacks, design, and intent) proposed by Abson et al. (Abson et al. 2017). Figure 11.2 displays the resulting framework, with the key links between these elements.

In the *parameters* category, the focus rests on modifiable, mechanistic aspects of systems, such as the physical elements and the taxes, incentives, and standards (Abson et al. 2017). Several I4.0 technologies might be applied at this level as they have been systematically developed to improve efficiency and efficacy of production and distribution processes (Bressanelli et al. 2018b; Culot et al. 2020; Pirola et al. 2020; Thompson et al. 2016). Examples include the deployment of combined Visualization and Remote Monitoring and Operation techniques and technologies with M2M Communication to collect and analyze production data to identify hotspots for improving production parameters (e.g., speed, throughput, leadtime, etc.) or reducing the consumption of resources (energy and/or raw material). These interventions are typically used to improve existing conditions to do less harm to the environment.

In the *feedbacks* category, we highlighted the interactions between the various elements in a production and consumption system, such as reinforcing or balancing feedback loops, and the information regarding specific outcomes. Many I4.0 technologies also operate well at this level, since the interactions between human,

Table 11.2 Industry 4.0 technologies relationship to high-level CE strategies

Categories (Culot et al. 2020)	Technologies	Improving existing operations	Increasing the shares of renewable and recyclable resources	Reducing the consumption of raw materials	Reducing energy consumption	Developing business models that support enhanced use of resources
Physical-digital interface technologies	Internet of Things (IoT)	✓			✓	✓
	Cyber-physical systems (CPS)	✓			✓	
	Visualization – augmented, mixed, and virtual reality	✓			✓	✓
	Traceability – final products and raw materials	✓	✓	✓	✓	✓
Network technologies	Cloud Computing	✓				
	Interoperability and cybersecurity	✓				✓
	Blockchain		✓			✓
	Machine to machine (M2M) communication	✓			✓	
Data-processing technologies	Horizontal and vertical integration (ERP, MES, SCADA)	✓				
	Modeling and Simulation	✓	✓	✓	✓	✓
	Machine Learning (ML) and Artificial Intelligence (AI)	✓	✓	✓	✓	✓
	Big Data Analytics	✓	✓		✓	✓
	Digital platforms (internal, suppliers, customers)	✓	✓	✓		✓

(continued)

Table 11.2 (continued)

Categories (Culot et al. 2020)	Technologies	Improving existing operations	Increasing the shares of renewable and recyclable resources	Reducing the consumption of raw materials	Reducing energy consumption	Developing business models that support enhanced use of resources
Digital-physical process technologies	Additive Manufacturing	✓		✓		
	Advanced Robotics – autonomous robots, collaborative robots	✓				
	Automation (sensors, actuators, PLCs)	✓		✓	✓	
	Virtual Commissioning	✓			✓	
	Remote Monitoring and Operation	✓			✓	
	Flexible Lines	✓				
	New Materials		✓	✓	✓	
	Energy Management Solutions				✓	

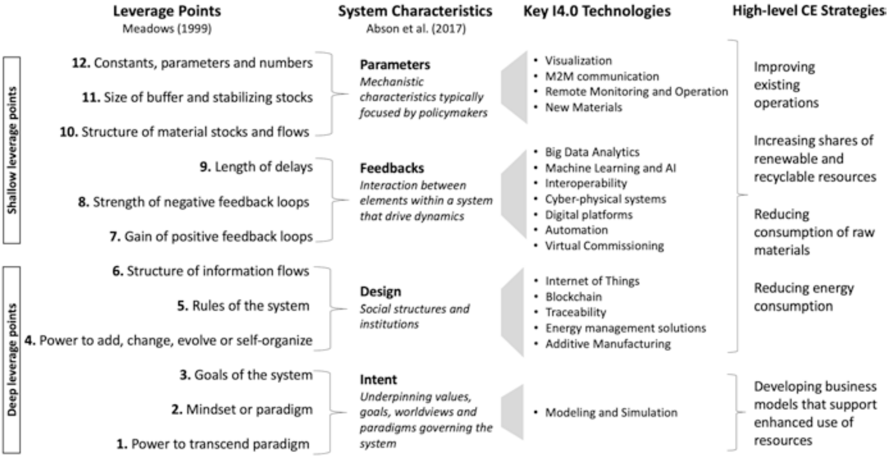

Fig. 11.2 Framework connecting a production and consumption system's leverage points (Meadows 1999a, b) to system characteristics (Abson et al. 2017) to key I4.0 technologies and high-level CE strategies.

physical, and intangible capital are often the focus of these technologies (Okorie et al. 2018). Examples in this category include adopting digital platforms and Machine Learning and Artificial Intelligence algorithms to enhance the connectivity, transparency, and visibility among the various players across the supply chain. This, in turn, might lead to the identification of innovative ways of reducing the consumption of resources, exploring potential co-use and co-development of renewables and recyclables by different players (elements) in the supply chain, or even the improvement of logistics and distribution operations to reduce environmental impacts and carbon emissions.

As for the *design* category, we emphasized the structure of information flows, the rules of the system, and its ability to add, change, evolve, or self-organize. Here, there are less potentially aligned I4.0 technologies, as we enter the realm of deeper interventions. Traceability technologies and new energy might seem to play a key role at this level of intervention. Technologies such as Blockchain, Additive Manufacturing, and Internet of Things allow a more profound development and rearrangement of structures and information flows, with enhanced ability to adapt to new configurations (Despeisse et al. 2017; Ivanov et al. 2019). Examples in this category include adopting blockchain to deeply redefine and rearrange the information and financial flows within and across different supply chains to support changes in the rules of a system and its flexibility to adapt and change. This redefinition might lead to several impactful CE strategies, such as less energy-intensive and material-intensive models, the sharing and tracing of innovative materials and energy systems, and the complete redesign of basic rules of operation, both for production and consumption.

Finally, in the *intent* category, the sole application of I4.0 has limited power. Intent is an emergent direction to which the production-consumption system is oriented, encompassing its goals, mindset, beliefs, and worldviews. Alone, I4.0 technologies cannot intervene in that, as these are essentially human endeavors. However, one category of I4.0 technology – Modeling and Simulation – might have a profound impact on designing high-leverage interventions toward CE. More particularly, modeling and simulation approaches and technologies are powerful tools for learning, testing assumptions, challenging mental models, and updating worldviews (Diehl and Sterman 1995; Gary and Wood 2011; Gary and Wood 2016; Sterman 2018; Sterman 2001; Sterman 1994). By asking different "what-if" questions and building scenarios, decision-making processes are significantly improved, since our mental models and reasoning capacities are limited (Guzzo et al. 2021; Lane 2016; Rodrigues et al. 2019).

Therefore, these technologies present a unique opportunity to challenge and adjust the goals of the systems and the underlying paradigms, allowing a major transition to take place. Concurrently, the adoption of I4.0 technologies also represents a transition. This technological transition presents several challenges for individual organizations and entire supply chains as the scope of implementations grows. These challenges refer to shifts in (un)employment as required technical skills evolve, lack of legal frameworks, lack of digital strategy and vision, poor data quality, and issues regarding inclusion and diversity (Ghadge et al. 2020; Haddud et al. 2017; Luthra and Mangla 2018).

A large area of concern over the I4.0 transition relates to artificial intelligence bias – including systemic racism, sexism, and discrimination – which has a far-reaching impact on individuals and society (Hong and Williams 2019; Ntoutsi et al. 2020). As the autonomous application of these technologies grows, we must ensure that innovative, emerging models of governance and deep scrutiny of algorithms, methods, processes, and data revert potential negative consequences (Fountain 2021).

Building on top of the previous categories and by using the discussed I4.0 technologies coupled with good quality data and strong ethical and social standards and strategies, future CE scenarios can be developed and analyzed to engage and persuade corporate leaders and policymakers to conduct the transition toward business models that support the enhanced use of resources.

11.5 Final Remarks

To support the transition toward CE and contribute to the SDGs and the global sustainability agenda, manufacturing companies and governments must be aware of the different levels of effectiveness when developing and/or adopting I4.0 technologies to inform their strategic decisions. As the concept of leverage points emphasizes, not all interventions are equal (Abson et al. 2017; Dorninger et al. 2020; Leventon et al. 2021; Meadows 1999a, b). By acknowledging and learning from the different potential implications of interventions enabled by I4.0 technologies in production and consumption systems, manufacturing companies and governments are better positioned to derive more powerful strategies to engage in the sought-after CE systemic transition.

As the different levels of aggregation for transitions proposed by Loorbach (Loorbach 2010) suggest, transition management cycles encompass strategic, tactical, and operational perspectives and activities. In this sense, I4.0 technologies are powerful mechanisms to articulate and implement effective interventions aimed at CE transition, starting at the operational (shallow) level, and progressively building competence, skills, and knowledge toward strategic (deep) and more advanced levels.

The key contribution of the framework discussed in this chapter is to provide a novel mapping of the relationships between I4.0 technologies and high-level CE strategies and apply that against a systems background to fully understand the dimensions of sustainability transitions implicated by CE. Manufacturing companies can use the framework to guide I4.0 implementation trajectories related to CE transitions. Policymakers might use the framework to design integrated public policies to incentivize the development and adoption of I4.0 technologies by organizations to accelerate CE transitions.

The framework discussed in this chapter also shows that I4.0 technologies alone may not be sufficient to formulate deeper interventions in complex production-consumption systems toward CE transition. Relying solely on specific technology may result in shallow interventions in lower-level leverage points, limiting their potential. Therefore, manufacturing firms should consider I4.0 technologies to be deployed consistently in a combined way - from shallow to deeper levels – to enable high-level CE strategies, including unlocking novel circular business models. This might generate an iterative process of implementation and learning that builds an improved feedback loop and creates unlimited opportunities for engaging in the CE transition.

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Chapter 12

Psychological and Systemic Factors Influencing Behaviour in Circular Consumption Systems. *Lessons from the Fast-Moving Consumer Goods and Apparel Industries*

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Abstract To address the pressing issue of waste accumulation and material intensity, there is an urgent need to introduce circular consumption systems, i.e., a combination of products, services and processes, which extend the utility of resources. The successful deployment of a circular consumption system is dependent on the consumer adopting a circular behaviour, such as *repair, reuse* and *recycling*. Circular behaviour is determined by various factors that are either psychological or systemic. Psychological factors relate to human psychology, a key influencer of consumer decisions. Systemic factors relate to physical and digital system elements such as products, infrastructure, instructions and incentives, facilitating the consumer interaction with the circular consumption system. Both sets of factors require close consideration when designing and implementing consumer journeys. Many of the existing circular consumption systems are novel and experimental and are not yet widely adopted by consumers. With circular consumption systems requiring the implementation of new behaviours, it is paramount that all key psychological and systemic factors are consid-

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ered and understood by businesses in order to improve the likelihood of achieving consumer-system interactions that foster a circular economy. Using the fast-moving consumer goods and apparel industries as examples, this chapter illustrates how the consideration of the psychological and systemic factors in the design of circular consumption systems can promote the adoption of circular behaviour. This chapter emphasises that both consumer psychology and the environment play a critical role in guiding consumer journeys through circular consumption systems.

Keywords Circular behaviour · Consumer journey · Behavioural influencers · Circular consumption systems

12.1 Introduction

Fast-moving consumer goods (FMCGs) are mass-produced products retailed globally to satisfy the ongoing needs of consumers (Zeeuw van der Laan and Aurisicchio 2019). FMCGs are predominantly single-use and disposable products, such as food, beverages, personal care and home care goods. In recent years the fast way in which we consume has been expanding to other product categories such as apparel (Kuzmina et al. 2019), increasingly described as fast-fashion. Apparel includes clothing, footwear and fashion accessories, which traditionally have been intended to satisfy consumer demand over multiple uses and for longer periods (e.g., several fashion seasons). However, with constantly changing fashion trends, apparel has become more affordable and lower quality and its consumption increasingly involves more frequent purchases and early disposal (Armstrong et al. 2018).

At present FMCGs and apparel are both largely based on a linear economy model, which involves exploitation of raw resources, turning them into products and disposing of them, often into landfill, at the end of life. This leads to resource overconsumption, waste generation and pollution to the environment (Lacy et al. 2020). An alternative to this linear economy system is a circular economy model whereby goods are manufactured using sustainable resources, their value is retained by enabling them to last in use for as long as possible, and at the end of life they are fed back into the system as products, components or materials for further use. This makes the circular economy a solution to the rising environmental impacts streaming from the unsustainable industrial activity and consumerism that has been practised to date, whilst enabling healthy societies and thriving economies (Murray et al. 2017).

In the FMCG and apparel sectors, the circular economy is increasingly implemented through circular consumption systems (Charnley et al. 2015; Ellen MacArthur Foundation 2017), i.e., networks of elements that interact with each other to achieve a circular flow of resources within the consumption phase (Zeeuw van der Laan and Aurisicchio 2021). The consumption phase is a time period during which the consumer makes important decisions whether or not to perform behaviours to *circulate* products, components or materials in the economy (Muranko et al. 2020). The consumer is, therefore, a *vehicle* to the movement of products, components and materials in and out of this phase. Consumer decision-making and behaviour is one of the key determinants of the successful uptake of circular consumption systems.

During interaction with a circular consumption system, the consumer embarks on a journey consisting of several sequenced and interdependent behaviours, here termed *behaviour chain* (Muranko et al. 2020). The behaviour chain begins in the moment in which the consumer makes the step to acquire a product, through to when they use it, up until when they depart from it, such as by disposing of it or passing it on for reuse. The interdependence between the behaviours in a chain means that if the behaviours are not completed according to specific sequences there is a risk that the circularity of a system is not met. This is because a broken and incomplete chain can lead to products being underutilised and prematurely or incorrectly disposed of. Therefore, when designing circular consumption systems and the journeys undertaken by consumers with products, it is important to account for every behaviour in a chain. This includes consideration of the *stimuli,* specifically consumer psychology and system factors, impacting the performance of a behaviour, with a view to facilitating the whole consumer journey and supporting consumers to ultimately transform their journey into a routine.

Building on past research on behaviour chains in circular consumption systems (Muranko et al. 2020), this chapter focuses on the topic of *stimuli in behaviour chains,* namely the intrinsic and extrinsic factors that influence human behaviours performed by the consumer throughout the interaction with a circular offering. Developing new understanding of stimuli in behaviour chains is critical to inform the design of circular consumption systems. Through the review of current theories and past research on consumer behaviour and by mapping example cases of consumer journeys, we aim to illustrate how the consideration of psychological and systemic factors in the design of circular consumption systems can promote their adoption by facilitating circular behaviours.

Section 12.2 provides insights into circular consumption systems, defines circular behaviour and explains the concept of a behaviour chain. Section 12.3 introduces types of psychological influencers of circular behaviour, such as values and perceptions. Section 12.4 introduces types of systemic influencers, including system elements that enable, instruct and nudge human behaviour. Finally, Sect. 12.5 draws conclusions on the two types of factors and emphasises their importance when designing circular consumption systems.

12.2 Consumer Behaviour in Circular Consumption Systems

There are several human actors guiding the resource flow. Each actor performs behaviours embedded within a system-wide behaviour chain. Individually or collaboratively actors enact behaviours that guide the resource flow through several consecutive phases (e.g., origin, production and consumption). Before a product enters the market, its flow is guided by actors involved in phases such as resource extraction, design, manufacture and retail. After a product is consumed, its flow is guided away from the market by actors involved in phases such as collection and value recovery. In these phases many of the ongoing behaviours of system actors are an integral part of established processes (Geng et al. 2019), meaning that they follow a protocol and therefore actors are less influenced by stimuli.

When a product is on the market, its flow is in the consumption phase and largely guided by one key actor – the consumer (Camacho-Otero et al. 2018). The consumer has the freedom of choice to acquire and utilise products in any way they wish or are able to, as they do not follow a protocol and are influenced by stimuli (e.g., intrinsic – psychology and extrinsic – system conditions). This means that behaviour chains in the consumption phase are less controlled and less predictable, with the consumer making key decisions about how they navigate the direction of resources.

Therefore, to establish a successful circular consumption system, it is important to design an environment that encourages and enables circular behaviours (Daae et al. 2018). Given that human behaviour is influenced by stimuli driven from intrinsic and extrinsic factors, having a perspective and good understanding of both is crucial.

12.2.1 Circular Consumer Behaviour

In consumption systems, the consumer typically has the role of moving products within the consumption phase and directing them out of it. This makes the consumer a key enabler of the flow of resources (Zeeuw van der Laan and Aurisicchio 2019). Ultimately, the circular flow of products relies on the consumer enacting specific behaviours.

There are several definitions of consumer behaviour in the literature (e.g., Solomon 1995). There is consensus that consumer behaviour generally encompasses a collection of actions related to a product or a service aimed at satisfying their needs, such as *choosing, purchasing, using* and *disposing* of products. However, in circular consumption systems specifically, consumer behaviour has an additional important role, which is to facilitate a circular flow of the resources embedded in products, namely by narrowing or slowing their pace and closing the loops (Zeeuw van der Laan and Aurisicchio 2019; Bocken et al. 2016). This behaviour, termed *circular behaviour*, consists of a single or a sequence of human actions to facilitate efficient consumption of resources, limit waste and pollution, and ultimately help regenerate natural systems (Muranko et al. 2018, 2020). Thus, circular behaviours promote the flow of circular value in consumption systems (Gomes et al. 2022) and are an integral driver of circular business models. Circular behaviour is an inherent component and driver of circular consumption systems in models such as reuse, remanufacture and recycling. Circular behaviours relevant to FMCG and apparel goods are, for example, *consuming food from reusable packaging* and *wearing second-hand clothes.*

12.2.2 Behaviour Chains in Circular Consumption Systems

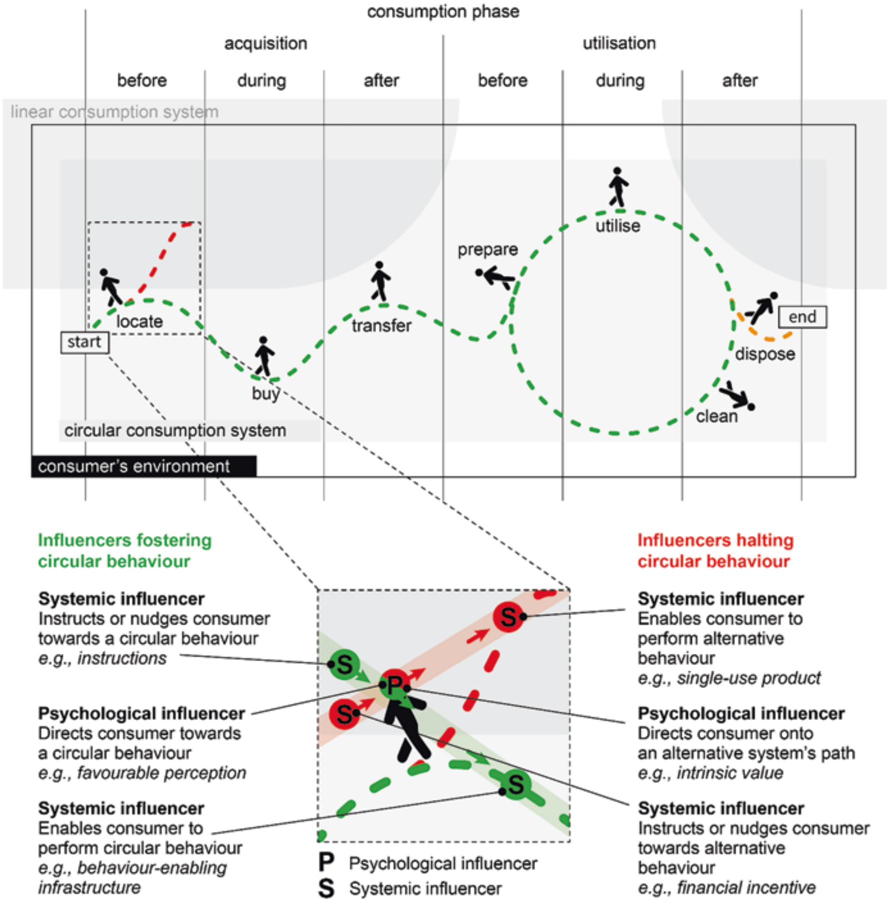
A behaviour chain is a sequence of interdependent behaviours (Cooper et al. 2020) performed by the consumer of a circular consumption system (Muranko et al. 2020). The consumption phase is the period during which the consumer interacts with the elements of a system (Zeeuw van der Laan and Aurisicchio 2019). This consumer-system interaction is executed on a continuum of events taking place before, during and after the acquisition and utilisation of products and services. Furthermore, the elements of the system are identifiable at a macro and micro level. At a macro level there are elements that business typically cannot modify or influence instantly, e.g., legislation and available technologies, but are required to consider and comply with when designing offerings. At a micro level there are elements that business can introduce in systems, such as products, infrastructure and instructions.

In a circular consumption system, a behaviour chain typically comprises various types of behaviours (e.g., *searching, refilling, purchasing, transporting, storing, utilising, maintaining, returning* or *disposing*) (Baier et al. 2020; Botelho et al. 2016; Gomes et al. 2022), with at least one of them being a circular behaviour. Behaviour chains have several attributes that define their structures, including path, behaviour, direction, level, dependency, performance indicator, locus and stimuli (Muranko et al. 2020). The consideration of chain attributes is an integral step in the process of scoping and designing consumer journeys. A behaviour chain allows understanding important aspects of consumer participation in circular consumption systems and how to influence them by system design. Ultimately, the successful uptake of a circular consumption system depends on the consumer: (1) engaging with the behaviour chain by undertaking the initial behaviour; (2) performing the whole chain correctly in order to achieve the goal of the system; and (3) returning to the beginning or specific segments of the behaviour chain to repeat it and ultimately form a habit.

Whilst a circular behaviour can be identified as a single action (e.g., *placing a recyclable bottle into a recycling bin*), this can also be broken down into its constituent actions (e.g., recycling behaviour can be defined as *understanding if a bottle can be recycled – transporting the recyclable bottle to a disposal area – identifying the recycling bin – placing the recyclable bottle into the recycling bin)*. Furthermore, a circular behaviour as much as other behaviours can either be performed solely by the consumer or collaboratively with other actors. An example of the latter is when a consumer purchases a beverage refill from a shop (e.g., coffee shop) and performs the refill behaviour with another actor, i.e., refiller (e.g., coffee barrister), which involves a series of micro-level actions shared between them (e.g., *consumer provides the vessel to the refiller – refiller replenishes the vessel using a dispenser – refiller secures the vessel to protect the consumable – refiller passes the replenished vessel to the consumer – consumer pays for refill).* In some circular consumption systems, a circular behaviour falls outside of the consumption phase and is performed by other actors in the system. Nonetheless, in those instances the actors (e.g., courier, cleaner, refiller) follow a well-defined protocol and their actions can, therefore, be interpreted as a process of planned operations rather than being performed freely and under stimuli.

12.2.3 Psychological and Systemic Factors Influencing Circular Consumer Behaviour

Consumer behaviour, whether *circular* or not, is influenced by both intrinsic factors such as human psychology and extrinsic factors such as system elements. Psychological and systemic factors act as *stimuli*, which direct consumer decisions throughout their journey in a circular consumption system (see Fig. 12.1). Having a holistic understanding of these stimuli is fundamental to ensure that we develop systems that can foster a circular journey, rather than halt it. Ultimately, the



Influencers fostering circular behaviour

Systemic influencer
Instructs or nudges consumer towards a circular behaviour
e.g., instructions

Psychological influencer
Directs consumer towards a circular behaviour
e.g., favourable perception

Systemic influencer
Enables consumer to perform circular behaviour
e.g., behaviour-enabling infrastructure

Influencers halting circular behaviour

Systemic influencer
Enables consumer to perform alternative behaviour
e.g., single-use product

Psychological influencer
Directs consumer onto an alternative system's path
e.g., intrinsic value

Systemic influencer
Instructs or nudges consumer towards alternative behaviour
e.g., financial incentive

Fig. 12.1 Psychological and systemic influencers in a behaviour chain circularity of an offering can only be achieved by ensuring that all the behaviours in a chain are performed so that the consumer performs the ultimate circular behaviour embedded within.

There are several schools of thought describing the types of psychological and systemic factors that play a role in influencing human behaviour. Psychological factors are human-intrinsic motivators and mediators of behaviour including, for example, *attitudes, perceived norms, perceptions, values* and *behavioural beliefs. Attitudes* are favourable or unfavourable appraisals of a behaviour (Ajzen 1991). *Perceived norms* are shared beliefs on how one should act, enforced by the expectations of a reward or threat of punishments (Ajzen 1991; Schwartz and Howard 1981; Stern 2000). *Perceived behavioural control* is the believed ease or difficulty of performing a behaviour (Ajzen 1991). *Values* represent the evaluation and influence of behavioural outcomes on an individual or what they perceive is important to them (Stern 2000). *Behavioural beliefs* are the subjective probability that performing a behaviour will lead to a certain outcome or experience (Ajzen 1991), e.g., *owning a reusable bottle* is believed to reduce waste (outcome), but may require effort in the *search of a beverage dispenser* (experience).

System design has a key role in ensuring that the performance of behaviours is possible and encouraged in order to facilitate consumer journeys that are completed and performed correctly. Systemic factors are consumer-extrinsic elements that function as enablers, instructions and nudges of behaviour in a chain. Systemic factors can be interpreted as elements of the macro-environment (i.e., global landscape) and micro-environment (i.e., consumer-immediate landscape). In the macro-environment, systemic factors (e.g., demographic, economic, political, ecological, socio-cultural and technological forces) play a role in shaping the design of business models for circular consumption systems. In the micro-environment, systemic factors (e.g., products, infrastructures, incentives and communication), instead, play a role in shaping an offering by strategically positioning enablers, instructions and nudges in the consumer's immediate environment to influence their journey.

Ultimately, circular consumption systems can be interpreted as *socio-technical systems. Socio-technical systems theory* postulates that systems are networks of interdependent elements, such as the interdependence between humans and the environment (Carayon 2006). This human-environment relationship is also described in *environmental psychology theory*, which proposes that human surroundings are complex and multidimensional, and comprise various human-extrinsic factors that impact human behaviour (Stokols 1995). This notion is also present in *behaviour settings theory* (Barker 1968), which highlights the presence of human-environment interdependence in systems, along with its impact on human behaviour. Furthermore, *choice architecture theory* (Thaler et al. 2013) proposes that designing environments that foster consumer choices (e.g., returning products for reuse in a reuse offering) is paramount to achieving system goals.

When designing circular consumption systems, consideration of psychological factors, such as values and perceptions, is crucial as it can help understand the types of consumers and their perspectives, to ultimately inform how to keep them engaged throughout their journey. There is a relationship between understanding both psychological and systemic factors. This is because psychological factors play a role in informing the design and positioning of systemic factors in the consumption phase, that not only enable behaviour but also instruct and motivate it.

12.3 Psychological Factors Influencing Circular Behaviour: Circular Apparel Consumption Systems

Various theories explain human behaviour. The Value-Belief-Norm theory proposed by Stern (2000) has been increasingly used in research to explain the psychological determinants of consumer behaviour, including circular behaviour performed to achieve pro-environmental outcomes. In the next sections, values and perceptions are discussed in terms of having an impact on consumer behaviour and contextualised in relation to *reusing* and *recycling* behaviours in the context of circular apparel consumption systems.

12.3.1 Understanding Consumer Types: Human Values

Rokeach (1973) defined human values as *"beliefs that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence"*. Schwartz (1992) describes human values as core beliefs, which act as guiding principles of a behaviour. Ultimately, values determine how people evaluate their behaviour, such as whether they believe it is good or bad, based on what they think is important. In the context of pro-environmental behaviours, including those that are circular, Stern (2000) identifies values as key influencers of other psychological factors that motivate human behaviour, such as perceptions, beliefs and personal norms. Circular behaviours can thus be understood as being indirectly guided by human values, whereas other psychological factors, such as perceptions, are considered to be directly influential in the decision-making process of the consumer participating in a circular consumption system.

It is common that certain values are shared among specific groups, for example, based on the same demographics, laws and cultures. Nonetheless, human values vary from person to person, depending on what they agree or disagree is important, which ultimately leads to diverse decisions they make in relation to performing a behaviour. Interestingly, when it comes to behaviours that are circular, particularly those that lead to environmental benefits, they are more likely to be adopted by people who hold *self-transcendence values* than those who hold *self-enhancement values* (Stern 2000).

There are various classifications of human values in the literature. Steg et al. (2014) propose four types of human values relevant to the uptake of environmental behaviours, namely *biospheric values* (e.g., environmental protection), *altruistic values* (e.g., social equality), *egoistic values* (e.g., power) and *hedonic values* (e.g., comfort).

Biospheric and altruistic values are related to self-transcendence values and describe a belief that collective well-being is important and must be cherished in the context of both society and the environment (Steg et al. 2014). The type of consumers who hold these values are likely to adopt a circular behaviour providing they hold a belief that through performance they can generate a greater good (Steg et al. 2005). Circular consumption systems inherently aim to achieve greater good in the social, economic and environmental contexts, thus can align with biospheric and altruistic values of consumers.

Egoistic and hedonic values are related to self-enhancement values and describe a belief that personal benefits are important and must be prioritised in decision-making (Steg et al. 2014). The type of consumers who hold these values are less likely to adopt behaviours for which they have to exert effort, such as performing new, complex and time-consuming circular behaviour, which can require change in their routines (de Groot and Steg 2008; van der Werff and Steg 2016). However, system elements can be added to a circular consumption system, enhancing the connection with consumers holding egoistic and hedonic values. For instance, thrift-shop consumers can experience resales as treasure hunting, consequently, being influenced by hedonic values.

Furthermore, Richins (2004) proposes *materialistic values* as another type that relate more specifically to consumption behaviour. The type of consumers who hold materialistic values believe that the possession of goods is important to them over other matters explaining the need for frequent purchase and ownership. There is an opportunity for some types of circular consumption systems to connect with consumers holding materialistic values, while enabling a more resource-efficient consumption. For example, *leasing* can offer the consumer an exclusive long-term access to a product, the length of which can resemble the time they would normally keep a product before disposing of it. On the other hand, *rental*, although typically short-term, can offer the consumer the option to wear a variety of apparel products over time, whilst aligning with their desire for frequent acquisition.

Overall, human values are core psychological factors that tend to change over time rather than instantly under stimuli. In decision-making, values can act as either enablers or barriers to consumer circular behaviour. Therefore, to target multiple types of consumers in the transition to a circular economy, there is a need to develop circular consumption systems with objectives aligned to both self-transcendence and self-enhancement.

12.3.2 Understanding Consumer Perspectives: Human Perceptions

Perception, as a psychological factor influencing circular behaviour, represents the beliefs that an individual can hold towards their surroundings, such as in relation to a problem, a behaviour itself, or a product or a service.

Relevant to circular consumption systems, one key perception held by the consumer is the *awareness of the impact* that their behaviour has (van der Werff and Steg 2015). For example, this awareness can correspond to the consumer understanding that apparel waste generates serious environmental problems leading to concern and worry. Awareness of these consequences raises attention to the fact that for behaviour to change, consumers need to be aware of and acknowledge the environmental problems caused by their choices and be informed about how they can contribute to reducing these problems.

Outcome efficacy depicts the perceived results of one's action or inaction (e.g., moral costs, social costs, or material costs to self or other actors; Schwartz 1977) reflecting the extent to which individuals feel that they can contribute to reducing negative environmental impacts or promote social benefits through adoption of circular behaviour. For example, outcome efficacy can involve the consumer rejecting the purchase of fast-fashion products and instead purchasing second-hand garments to improve environmental impacts of their consumption. Consumer perception of outcomes can be influenced through effective communication about the impacts of a behaviour, e.g., through awareness-raising campaigns.

Personal norms, also a perception-based psychological factor, are activated in specific situational conditions (Schwartz 1973) and can explain behaviours of individuals in the same situation. Personal norms combine two aspects, the conditions of a specific situation, as well as distinct norms at the individual level. The latter construct is attached to the self-concept and can be experienced as a sense of moral obligation to perform a behaviour. For example, a consumer apparel recycling behaviour may be motivated by their perceived norm and moral obligation to do so.

Perceived ability to perform a behaviour is another key determinant of human behaviour (Ajzen 1991) relevant to circular consumption systems (Muranko et al. 2018). Raising the awareness of the consumer about ways in which they can participate in a circular consumption system is an important stimulus of their behaviour.

In line with Stern (2000), consumers are likely to engage in circular behaviour when they feel morally obliged to do so (*personal norm*). These feelings are stronger when people believe that they can do something about environmental and social problems (*outcome efficacy*) and when they are aware of the consequences of their behaviour (*awareness of impact*). Still, in line with Ajzen (1991), consumers need to believe that they have the opportunity to enact a behaviour (*perceived ability*), such as by being aware of and feeling able to use the behaviour-enabling mechanisms present in the system.

12.3.3 *Psychological Factors in Context: Clothing Reuse and Recycling*

In the apparel sector, circular consumption systems include leasing, reuse and recycling of clothes. Companies operating in this space offer clothing lease (e.g., MUD Jeans), upcycled reusable apparel (e.g., Suave) and recycled textiles (e.g., Fibersort). These examples of circular consumption systems require the consumer to perform a variety of behaviours including those that are circular, such as the sequential acquisition of reused goods, product care aimed at prolonging lifespan and return for recovery (e.g., reuse and recycling).

Figure 12.2 presents two consumers (referred to as consumer A and B) and their journeys in circular apparel consumption systems to demonstrate how psychological factors can drive or hinder circular behaviours. In this example, both consumer A and consumer B hold strong biospheric values, meaning they are concerned about the environment.

In addition to biospheric values, consumer A holds strong hedonic and materialistic values. They are concerned about the environment, and at the same time they value experiencing the enjoyment of buying and the possession of clothing. Keen to limit the environmental impact of the apparel sector, consumer A performs circular behaviours at the point of purchase, as they acquire clothes made from recycled fibres, and at the point of disposal, as they take clothes to a recycling point directing them back into the system for recovery. Nonetheless, their desire for frequent buying means that they acquire clothing in high volumes. Ultimately, they continue to overconsume resources.

In addition to biospheric values, consumer B holds strong altruistic values. They are concerned and aware of the social impact of fast-fashion and linear apparel production. Committed to reducing the negative social impact of the apparel sector, consumer B acquires second-hand clothing. More so, aware of the impact of short product life cycles (e.g., waste accumulation), consumer B believes that they could contribute to developing a socially conscious system by properly caring and repairing clothes to prolong their life. At the end of the apparel life-cycle, consumer B's moral obligation to reduce the impact of disposal and their belief that they have an ability to prevent the accumulation of waste in the environment, leads them to direct clothes back into the system for recovery via a recycling point.

12.4 Systemic Factors Influencing Circular Behaviour: Circular FMCG Consumption Systems

Behavioural theories (e.g., Theory of Planned Behaviour; Ajzen 1991) advocate that having the *actual ability* to perform a behaviour is the primary indicator of its conduct and that this ability is determined by environmental conditions. Theorists (e.g., Thaler and Sunstein 2008; Nudge Theory) also draw attention to *nudges* as external

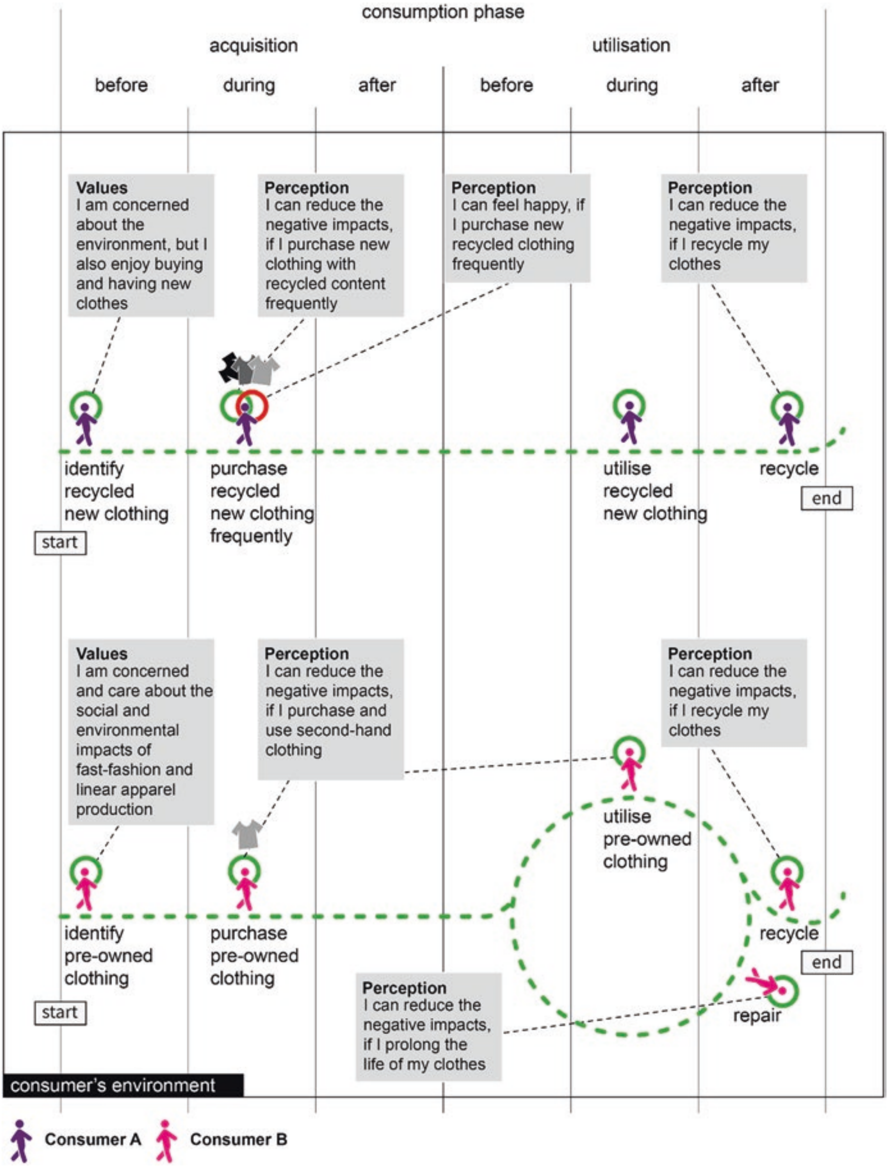


Fig. 12.2 Example psychological factors and their influence on the circular consumption of apparel: values and perceptions

forces, not necessarily needed for behaviour to take place, but important to guide consumer decisions in one direction or another, when they move through their consumption journey. Taking reuse as an example of a circular consumption system, the journey of the consumer involves them *interacting* with and *reacting* to several systemic factors that impact the direction and types of behaviours they undertake, ultimately resulting (or not) in the performance of the circular behaviour (Muranko et al. 2020, 2021).

In the FMCG sector, reuse models[1] have been distinguished based on consumer behaviour into exclusive and sequential reuse (Muranko et al. 2021). At a system level, reuse models are structures of interdependent elements designed into the consumer environment to facilitate recurring utilisation (i.e., reuse) of a product. Drawing insights from reuse models, three different systemic factors, namely *enablers, instructions* and *nudges*, are presented in the sections below.

12.4.1 Enabling Circular Behaviour: Products and Infrastructure

Circular consumption systems consist of elements positioned within the consumer environment (i.e., in the consumption phase of an offering) that are necessary to the performance of a circular behaviour. In this environment, the consumer (or a collective of consumers, e.g., in a household) is the main facilitator of a circular behaviour, such as reuse. The role of the consumer is to enact the circular behaviour, alongside several other consecutive chained behaviours. These behaviours are identifiable and can be defined at a level of either individual actions or segments of consecutive actions, all of which are embedded within a broader behaviour chain that unfold progressively towards and beyond the specific ultimate circular behaviour (Muranko et al. 2020). For example, in circular consumption systems such as reuse, once the consumer enters in possession of a reusable product, they are required to perform not one, but several key interdependent reuse-related behaviours which involve *preparing a reusable product for reuse, utilising a reusable product* and *recovering the reusable product for reuse.* These three key behaviours are performed in environments that contain various behaviour-enabling system elements, that are *circular products* and *infrastructure* (Muranko et al. 2021).

Behaviour-enabling *circular products* are designed to fulfil specific circular economy strategies such as reuse or recycling (Aguiar et al. 2022; Moreno et al. 2016). Reusable products that are durable equivalents of single-use and disposable FMCGs are an example of circular products. In circular consumption systems such as reuse, consumer behaviour is typically performed either directly or indirectly with the circular product. This is because the consumer can either have tangible interactions when handling the product (e.g., by utilising it) or perform behaviours in relation to it, but in its absence (e.g., by purchasing it online). To *enable* circular behaviours, in the first instance circular products must be present (i.e., available) in the consumer environment so that they can interact with them. Consumer access to

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[1] The first type is *exclusive reuse* systems, where consumers retain ownership and control over reusable products (e.g., Dopper – reusable bottles). The second type is *sequential reuse* systems, where consumers have temporary access and control over reusable products (e.g., Loop – reusable packaging).

circular products can be permanent (e.g., in an exclusive reuse model) or temporary (e.g., in a sequential reuse model). Furthermore, circular products must have the capacity to operate across cyclical processes, which is achieved for example, by designing them for longevity (Aguiar et al. 2022; Bocken et al. 2016; Bakker et al. 2014) so that they are able to withstand the environmental conditions set out in a specific system (e.g., exposure to the risks of material and structural damage in transportation, and handling).

Behaviour-enabling *infrastructure* consists of system elements that enable the performance of consumer behaviour in a given system. This typically involves the consumer interacting with infrastructure during different stages of a behaviour chain in order to utilise a circular product. This infrastructure can be either *consumer-operated* or *business-operated.* Interestingly, in the context of the infrastructure operated by business but provided as an enabler of consumer behaviour (e.g., a beverage cafe is available to the consumer to enable their refill behaviour), the infrastructure (e.g., dispenser located at a cafe) plays the role of an enabler alongside people who operate it (e.g., a barrister at the cafe). This highlights that in some systems the behaviour-enabling infrastructure is a system of products and people with whom the consumer shares the behaviour chain.

Ultimately, at different stages of the behaviour chain, circular behaviour is performed either with or without the assistance of infrastructure. For example, the behaviour of *consuming a beverage from a reusable bottle* is conducted in the presence of the product only. Nonetheless, it is a consequence of other prior behaviours that are prerequisite to its taking place. An example is *refilling a reusable bottle with a beverage* which relies on the availability of *reuse-enabling infrastructure* in the consumer environment to supply the consumable.

Environmental restructuring, i.e., changing the availability of behaviour-enabling products and services within the consumer environment, is one of the key aspects of designing systems that foster the adoption of new behaviours (Michie et al. 2011). When designing the consumption phase of a circular system, such as reuse, it is important to fully enable consumer participation all the way within it. Without this ability, there is a risk that consumer participation is incorrect or lacks at all, therefore leading to unsustainable consumption (e.g., by choosing to partake in an alternative linear system or adopting unsustainable behaviours within the circular system, such as when prematurely disposing of reusable products). Ultimately, providing the consumer with all key systemic enablers in the environment and throughout their journey in the consumption phase to facilitate all interdependent actions is paramount to the successful uptake of the circular economy.

12.4.2 Instructing Circular Behaviour: Education

Circular consumption systems are in the early stages of adoption. To date, the FMCG sector has predominantly focused on achieving circularity through circular consumption systems centred on recycling where single-use products have been redesigned to include recycled and recyclable materials and schemes have been implemented to recycle materials that are hard-to-recycle. However, there is also an increasing number of circular consumption systems centred on reuse (e.g., in-store refill systems) implemented with the aim of prolonging the lives of products (Muranko et al. 2021).

Circular consumption systems such as reuse are a new territory to the consumer. Whilst some of the behaviours are familiar or 'common sense', there are many instances where these systems require them to perform complex and unfamiliar behaviours. Ultimately, consumers have a limited or incorrect understanding as to what they are required to do.

Educating consumers is one of several behavioural interventions that can support decisions to perform certain behaviours in a system. Education-based interventions aim at increasing knowledge and understanding by informing, explaining and showing (Michie et al. 2011). Knowledge is a desired outcome of education and while knowledge is not enough to change behaviour, it is critical to explain to consumers why behavioural changes need to be made (Arlinghaus and Johnston 2017). Education-based interventions include *instructions* that can be designed and presented to the consumer to inform, explain and train them as to *how, when* and *where* they are required to act in a system. By including instructions in circular consumption systems and ensuring their effectiveness and visibility to the consumer at all key stages of their journeys, we can guide their behaviours across a chain. Furthermore, consumer perceptions about their ability to perform a behaviour is one of the key influencers of their intention to perform it (Ajzen 1991). Therefore, naturally, consumers can avoid the behaviours they feel are unable to perform. By instructing the behaviour, we can increase consumers' confidence to partake and avoid them performing alternative behaviours. Examples of instructions include information (e.g., visual, written and audio communications), channelled through products, infrastructure, or providers' websites and mobile apps.

12.4.3 Nudging Circular Behaviour: Persuasive Communication and Incentives

For the consumer to shift to circularity, they are required to change (either partially or completely) their linear consumption routines and adopt new circular behaviours required in circular consumption systems (e.g., from purchasing single-use FMCGs to *borrowing reusable* FMCGs). Circular consumption systems are typically offered concurrently with linear consumption systems, meaning that both systems compete in the same consumer environment. This environment, also known as the choice architecture (Thaler et al. 2013), can be modified by system design to increase the chance of the consumer choosing to perform one behaviour over another. Similarly to behavioural enablers and instructions, *nudges* can also be positioned strategically as system elements operating in the consumer environment to influence the choices that they make and direct consumption journeys.

Nudge interventions are, for example, persuasive communication and incentives. *Persuasive communication* are messages (e.g., visual, written and audio) intending to shape how people feel about a behaviour, by making it either more or less attractive to them (Miller 1980). Persuasive communication has been adopted in some successful marketing strategies used to change people's beliefs and behaviours (O'Shaughnessy and O'Shaughnessy 2003). *Incentives* (e.g., financial rewards) have a similar capability to change how people feel about and perceive the attractiveness of a behaviour, by generating an expectation (or avoidance for disincentives) of its outcome.

Both persuasive communication and incentives are designed to target psychological factors determining consumer behaviour and influencing their decision to perform it. For example, persuasive communication messages can be designed to target consumer values by highlighting how a circular behaviour can achieve outcomes that matter to them, in order to nudge them to perform it. Similarly, incentives can also be designed to bring out outcomes that the consumers find attractive (or not). For example, the consumer may be more reluctant to perform a behaviour if the associated financial cost is too high for them, and *vice versa,* they may be more inclined towards it if it involves savings or profit.

12.4.4 Systemic Factors in Context: FMCG Reuse

In the FMCG sector, circular consumption systems such as reuse include two types of models – *exclusive reuse* and *sequential reuse* (Muranko et al. 2021). *Exclusively reusable* FMCGs include consumer-owned packaging (e.g., Dopper reusable bottles), personal care products (e.g., Bloom and Nora reusable sanitary towels) and transit packaging (Onya reusable shopping bags). *Sequentially reusable* FMCGs include temporary-access packaging (e.g., Loop pre-filled reusable and returnable vessels), baby care products (e.g., Washcot reusable and returnable diapers) and transit packaging (e.g., RePack reusable and returnable mail bags). These examples of circular consumption systems require the consumer to perform a variety of reuse-enabling behaviours aimed at prolonging the lifespan of reusable FMCGs.

Figure 12.3 presents two consumers (referred to as consumer A and B) and their journeys in circular FMCG consumption systems to demonstrate how systemic factors can drive or hinder circular behaviours. In this example, consumer A participates in the exclusive reuse of a reusable food packaging and consumer B participates in the sequential reuse of a reusable and returnable food packaging.

The journey of consumer A involves them acquiring and reusing a product they own and have exclusive access to. The journey of consumer A is first *enabled* by the availability of reusable packaging that they purchase. However, later on the path, their immediate environment lacks refill infrastructure to enable them to reuse it, indicating a system design modification is needed to bring the refill infrastructure to

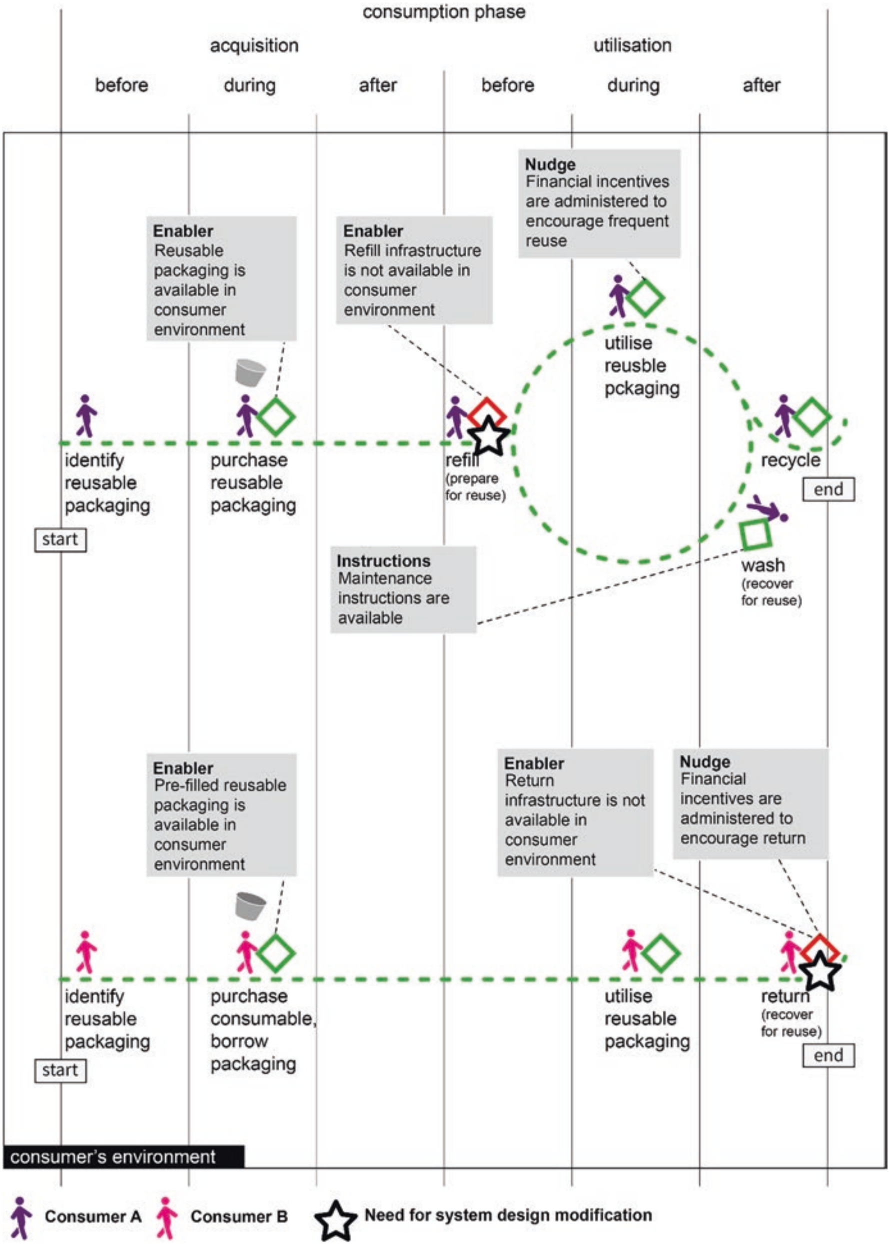

Fig. 12.3 Example systemic factors and their influence on the circular consumption of FMCGs: enablers, instructions and nudges

the consumer environment. Consumer A is also required to maintain the reusable packaging (e.g., it has to be washed at low temperatures and using mild detergents) to ensure it lasts for the maximum number of uses it was designed for – maintenance *instructions* are implemented on the packaging. The reusable packaging also requires to be used for a maximum number of cycles for it to be environmentally and economically feasible – *nudges* in the form of a financial incentive scheme are used to prompt the consumer to refill the reusable packaging, instead of buying single-use FMCGs each time they need to satisfy their needs.

The journey of consumer B involves them acquiring and reusing a product they borrow and have temporary access to, as the packaging flows in sequence from one consumer to another. The journey of consumer B is first *enabled* by the availability of reusable packaging that is pre-filled with consumables, meaning their reuse behaviour does not rely on the availability of refill infrastructure within their environment. However, their return behaviour, needed for the packaging to reach the recovery stage, can only be performed via in-store return at locations that are not within the immediate environment of the consumer, indicating that a system design modification is needed to make the return infrastructure available closer to the consumer. However, *nudges* in the form of financial incentives for returns (e.g., discounts or penalties) are implemented to potentially mitigate the effort that the consumer is required to exert to reach the return location.

12.5 Conclusions

The adoption of a circular economy requires consumer goods industries, such as the FMCG and apparel sectors, to develop new system designs that can foster the circular behaviour of the consumer. With the consumer being the critical actor who guides the flow through and out of the consumption phase, it is paramount to design consumption systems that (1) onboard the first-time consumer in the circular journey, (2) ensure the consumer performs behaviour chains correctly and completely in order to reach the specific objective of a circular offering, and (3) encourage the consumer to repeat behaviour chains, fully or partially depending on the system requirements, and eventually incorporate circular consumption in their daily routine.

Scoping consumer behaviour chains is an essential step in the process of designing circular consumption systems, as it can help identify and evaluate the types of psychological or systemic stimuli that are key to driving consumer behaviour. There is a relationship between understanding both psychological and systemic stimuli when designing circular consumption systems. Consideration of psychological determinants of a behaviour, such as values and perceptions, is crucial as it can help understand the types of consumers and their perspectives. This ultimately informs where consumers should be exposed to the appropriate enablers, instructions and nudges to be fully engaged (or have an increased opportunity to engage) with circularity.

Knowledge of these stimuli is particularly important for businesses that are looking to design new or improve the current design of existing circular consumption systems. Nonetheless, the process of designing these systems is complex as it requires consideration of human psychology, system element design, and understanding of the dynamics between them. Such offerings comprise a range of novel behaviours, system elements and processes not present in current linear consumption systems adopted in the FMCGs and apparel sectors. In these sectors specifically, manufactured goods are introduced in the market, and after the retail stage, providers (e.g., manufacturers, brands, retailers) rarely have a presence in the consumer environment to actively enable, instruct or nudge their behaviours, other than encouraging the recurring purchase of goods.

Nonetheless, the industry, prompted by environmental and legislative pressures (e.g., UK policies such as the Net Zero Strategy, Extended Producer Responsibility, the UK Plastics Pact), is increasingly exploring the circular economy, as demonstrated by the emerging activity of start-ups and large global brands innovating and trialling circular products, services and processes. In parallel, there are signs of consumer interest in the circular economy, as visible through their participation in reuse, repair and second-hand markets. These conditions now offer businesses an opportunity to collaborate with each other and innovate in circular consumption system design to build offerings that provide the consumer with more than products retailed in a linear way, by enhancing and extending to comprehensive multi-element system designs that foster circular consumption.

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