ROUTLEDGE ENVIRONMENT AND SUSTAINABILITY HANDBOOKS

The Routledge Handbook of Catalysts for a Sustainable Circular Economy

Edited by Hanna Lehtimäki, Leena Aarikka-Stenroos, Ari Jokinen, and Pekka Jokinen

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"For the last 50 years, we have come to realise that there are not only natural resource limits to our economic growth but that our extraction methods are – indisputably – responsible for global warming, ever-increasing levels of pollution, and dire health effects. However, despite all this data, we have been reluctant to act. In the last few years, circular economy initiatives and regulations have emerged as viable remedies to these calamities, but a deeper look often reveals a lack of a true systemic circular transition. This book is closing an urgent gap because it helps us understand the actual catalyzers of circularity and in so doing, once activated, long-term, sustainable change can finally take place."

Gordana Kierans, *EntrepreneurCircle.World, Croatia*

"An impressive array of experts masterfully help us to understand and expand the role of catalysts to help transition from linear to circular business models across industries, regions, and approaches. This handbook is both guidebook and playbook, and provides both sides of the telescope – informative zoom-ins, as well as insightful zoom-outs to help us take the necessary next steps to begin the transition in earnest."

Alon Rozen*, Dean and Professor of Innovation,*
École des Ponts Business School, France

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THE ROUTLEDGE HANDBOOK OF CATALYSTS FOR A SUSTAINABLE CIRCULAR ECONOMY

This groundbreaking handbook leads the way in accelerating the transition to a sustainable circular economy by introducing the concept of a catalyst as a positive and enhancing driving force for sustainability. Catalysts create and maintain favourable conditions for complex systemic sustainability transition changes, and a discussion and understanding of catalysts is required to move from a linear economy to a sustainable and circular economy.

With contributions from leading experts from around the globe, this volume presents theoretical insights, contextualised case studies, and participatory methodologies, which identify different catalysts, including technology, innovation, business models, management and organisation, regulation, sustainability policy, product design, and culture. The authors then show how these catalysts accelerate sustainability transitions. As a unique value to the reader, the book brings together public policy and private business perspectives to address the circular economy as a systemic change. Its theoretical and practical perspectives are coupled with real-world case studies from Finland, Italy, China, India, Nigeria, and others to provide tangible insights on catalysing the circular economy across organisational, hierarchical, and disciplinary boundaries.

With its broad interdisciplinary and geographically diverse scope, this handbook will be a valuable tool for researchers, academics, and policy-makers in the fields of circular economy, sustainability transitions, environmental studies, business, and the social sciences more broadly.

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During this project, we were able to engage with numerous people across the globe, and we would like to take this opportunity to take a short look back and express our thanks and gratefulness.

This book started as a quest to produce actionable knowledge for creating solutions to the environmental crisis of climate warming, biodiversity loss, and increasing pollution caused by our human activity. We came together to explore ways in which business studies and environmental policy frame circular economy as a response to environmental crisis. We introduced the concept of catalysts to our network and invited scholars from across disciplines and countries to examine what accelerates a sustainable circular economy.

We appreciate having worked with all the authors in a very co-creative process of looking at different fields and evoking the individual catalysts from various fields of research; we realised both how insightful the notion of a catalyst is, and how well the catalysts advance the circular economy in the many researched fields represented in this book. It has been an uplifting experience to work together, within a large community of authors, to bring the chapters together into the book you are reading now.

Throughout the process, we were assisted by Ida Parkkinen, Juha Kotilainen, and Kristina Leppälä. Their collaborative efforts in working with the authors, reviewers, and editors were invaluable during the entire process. We would also like to thank the anonymous reviewers for providing constructive feedback to the chapters as they were being developed.

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As editors, we are greatly optimistic for the future of the circular economy as it moves from a vision and ideal to an actualised phenomenon. As the chapters show, work is being done at all levels of society and all over the globe. We encourage and challenge researchers, firms, governments, and people from around the world to come together and work on this great challenge – this would be the greatest catalyst of them all.

1

INTRODUCTION

Circular economy catalysts in sustainability transition

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Introduction

The topic of sustainability transition and circular economy (CE) is of growing relevance in countries worldwide. Many environmental problems that contemporary societies are facing globally, including the biodiversity crisis, climate change, and resource depletion, are rooted in unsustainable production and consumption patterns. Many of our socio-technical systems, such as electricity, construction, and food, may cause harm to the environment and create negative consequences for the well-being of future generations. These exacerbating problems, which threaten economic stability and even human health, cannot be addressed only by incremental improvements and simple technological fixes. Solving the problems requires radical shifts to new kinds of socio-technical systems, which are called 'sustainability transitions' (Köhler et al., 2019; Elzen et al., 2004; Grin et al., 2010). The CE is one of these transitions. As a techno-economic and sociocultural model, it seeks to minimise the use of natural resources and waste creation, reuse material to sustain its maximum value, and recycle material efficiently (Grafström & Aasma, 2021). Ultimately, its aim is to change current production and consumption models (Hartley et al., 2020).

Governments, consultants, and think tanks in different parts of the world have promoted CE thinking. The Ellen MacArthur Foundation, a European consulting agency and think tank, has been influential in developing the CE concept, influencing legislation, and drawing large corporations into taking on the ideas of CE. In Europe, many organisations, from small companies to cities and states, have begun taking strategical steps towards a CE, believing that it can lead to positive environmental impacts while providing long-term significant economic advantages. Elsewhere, China has been driving CE development, driven by the massive environmental, social, and health problems within the country (Ghisellini et al., 2016). In North America, companies, third-sector organisations, and forerunner states such as California have advanced the CE movement. In the global South, the concept is gaining momentum among other sustainability developments, and due to the frugal economic conditions, CE is sometimes framed differently than in the global North. Overall, CE provides actionable solutions to green transitions of societies in the global North and environmentally and socially sustainable economic growth and urbanisation in the global South.

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In contrast to the earlier developments in sustainability transitions, the uniqueness of a CE comes from two interconnected ideas: the closed-loop economy and 'design to redesign' thinking (Murray et al., 2017). A closed-loop economy is a waste-free, economic model that aims to reuse, repair, and recycle resources; in other words, it effectively turns waste into a valuable resource. Design to redesign thinking aims to design out waste, return nutrients, and recycle durables using renewable energy to power the economy, and thus, makes the system restorative and regenerative in nature. Contrary to many other approaches, the scope of CE is on entire value chains or systems to address systematic problems, instead of its individual stages or components.

There is a strong sense of urgency with sustainable CE solutions. However, the challenge in sustainability transitions is that they are characterised by inertia and resistance (Markard et al., 2020). Even when progress is made, the change often feels slow due to fast global warming, biodiversity loss, and increases in harmful substances entering nature. As sustainability transitions are complex and consist of numerous variables, there is ambiguity related to which solutions are critical for the sustainability transition's success. To understand and influence the sustainable CE transition, we need new and continuously updated tools to ascertain how to accelerate the rate of CE transitions and to identify the critical variables and dynamic factors that can help us to accomplish this.

A catalyst is a new tool that can aid with the task of accelerating CE transitions. We consider catalysts as various factors, mechanisms, and forces of change that trigger, facilitate, and actualise transition processes and create a push for sustainable CE. Catalysts initiate, create, and maintain favourable conditions for complex systemic change in sustainability transition. They give an impulse to put systemic change in motion. To the extent the impulse leads to changes that advance the transition, the catalyst may create favourable conditions for complex systemic change and may even maintain the momentum of the transitional process. However, in all stages of transition, the core characteristic of a catalyst is that it is a trigger that kicks off the change either at the initial state of transition or at a later point when the momentum of transition should be strengthened.

The concept of the catalyst as a positive driving force for sustainability is a unique contribution to sustainability research. We introduce it as a third conceptual tool, complementing the concepts of *drivers and barriers* and *leverage points* that are commonly used in analysing and discussing sustainability transitions. The recognition for needing action concerning both research on transitions in general and the CE in particular has found academics analysing and discussing how sustainability transitions could be accelerated (e.g., Geels et al., 2019; Markard et al., 2020). To aid in this task, the past literature has utilised conceptual tools such as *drivers and barriers*, which refer to conditions that can either enable or hinder the process of transition (e.g., Hina et al., 2022; Khan et al., 2022; Kiefer et al., 2019; Lozano, 2015) and *leverage points*, which refer to critical points in a complex system where significant sustainability impact can be achieved with relatively small effort (Abson et al., 2017; Leventon et al., 2021; Meadows, 1999). The catalyst, however, considers the challenge of action in sustainability transitions with a focus on what initiates, creates, and maintains change in a systemic transition. Common to these concepts is that they all recognise the several simultaneous conditions that must be in place for a transition to occur.

In the specific context of sustainable CE transition, we suggest that the term 'catalyst' can be a useful concept in inducing, stimulating, nurturing, and accelerating various aspects of sustainable CE. Catalysts trigger, maintain, or establish favourable conditions for the CE via significantly varying applications, such as transition arenas (Hyysalo et al., 2019), different forms of collaboration (Hale, 2020), or as platforms for exchanging ideas (Pitkänen et al., 2022). A catalyst can be a sharp, small, single changemaker or a wider entity such as a technological advancement in some sector. Technological advancement is often counted among system drivers, but it deserves the status of catalyst when the contextual factors that make it catalytic are explicated. Whereas drivers are often understood as long-term carriers of system-changing processes, catalysts are seen as triggers. Also, catalysts can be used as tools for the intentional experimentation of system properties. In transitions, the routes to make progress may seem promising yet simultaneously insurmountable. Thus, catalysts for experimenting, trialling, imagining, and identifying where and when the first steps can be taken or how the momentum can be strengthened are needed. Catalysts help mutual learning, which is a necessary condition for a transitional change.

In this book, we have invited the authors of the individual chapters to identify and test the concept of a catalyst in varying contexts. The contributing authors present several conceptualisations of the catalyst, ranging from its metaphoric and analogical use in depicting change-initiating triggers, to specifications that aim to harness self-organisation in a systemic change. The catalysts discussed in this book cover the domains of technology, innovation, business models, finance, management and organisation, regulation, policy, product design, and culture. The authors show that a catalyst's target can be an individual behaviour, a city, an industrial sector, or even society. They direct attention to the right conditions, different technologies, process models, and individuals having a catalytic impact. Furthermore, the authors' contributions suggest that catalysing can occur at many levels, and it can be a specific tool for achieving a tangible change in the system, but it can also be a means to modify ways of thinking. The multiple insights lead to new understandings about the concept of the catalyst and, ultimately, its usefulness in sustainability research. The richness of the application areas for the catalysts provides grounds for future development of studying CE transitions with catalysts, and we offer some preliminary criteria to aid the process.

In this introductory chapter, we outline the conceptual underpinnings of the CE catalysts book and introduce the chapters in this book. Next, we will elaborate on sustainability transition as a systemic change and thus portray CE among the sustainability transitions. We will then provide an overview of the theoretical roots of CE and elaborate the concept of a catalyst. This introductory chapter concludes with an overview of all the chapters and explains the ways in which the different sections of the book increase understanding about catalysts and how they are transforming society from a linear economic model towards a sustainable CE.

Sustainability transition is a systemic change

The CE is a prominent example of sustainability transitions. The term 'sustainability transition' refers to systemic innovations towards more sustainable socio-technical systems (Hölscher et al., 2018). Essentially, sustainability transitions stand for moving to a more sustainable society, where the needs of the present are met without compromising the ability of future generations to meet their own needs.

Transition research started in the late 1990s, and these early studies mainly focused on the mutual shaping of technological and social change (Truffer et al., 2022). Since sustainability transition research (STR) is described as "broader and more interdisciplinary than many other sustainability approaches" (Köhler et al., 2019), there is not one group of disciplines forming transition studies. According to Zolfagharian et al. (2019), STR studies are rooted in system thinking and their main object is fundamental structural change. Other major intellectual roots identified for STR are comprised of evolutionary economics, the sociology of innovation, institutional theory, and governance studies, among others. However, and most importantly, the STR field has expanded and diversified when growing up by asking 'big picture' questions (Köhler et al., 2019;

Truffer et al., 2022). It is evident that sustainability transitions research continues to develop by building bridges, especially to social science theories.

Sustainability transitions are characterised by the complexity involved in the intertwined processes. They are multidimensional and multi-actor processes, which result in material, institutional, and sociocultural changes and, therefore, also include uncertainty and contested values (Zolfagharian et al., 2019). Guidance and governance play a particular role in sustainability transitions (Markard et al., 2012). Still, a controlled and well-managed systemic change has proven difficult to accomplish in practice, which is especially true if the introduced change is meant to fulfil genuine and strong sustainability criteria. This difficulty is the most critical challenge in the era of persistent and radical environmental problems that call for rapid decisions to ensure a liveable planet for future generations.

Why is sustainability change so difficult? Berninger et al. (2017) identified four reasons that make systemic change difficult. First, systemic change can be achieved only if there is a widely agreed-on need for change and there is a significant will to take the leap towards a new system. Second, prevailing and existing operation models create path dependencies, which hinder or even impede the required change(s). One apparent example of this is how existing traffic infrastructure can largely define the societal structure of the future or the modes of transportation. Third, forming a shared vision about the future is difficult and time-consuming, even if there is an agreement that the current system needs to change. This difficulty is because there are always numerous potential alternatives and timeframes, and decisions must be made with incomplete information. Finally, systemic changes often proceed unexpectedly and at unpredictable speeds, which potentially make managing them both difficult and unpredictable.

Consequently, as a form of sustainability transition, CE requires both top-down national and international policies and bottom-up company innovations (Ruggieri et al., 2016). Both top-down and bottom-up actions challenge and break prevalent practices, structures, beliefs, and assumptions that hinder renewal. The multi-level perspective (MLP) on transitions describes systemic change as an interplay between different levels (Geels, 2002, 2005). Yet, instead of describing transition as a simple vertical process, the MLP emphasises that systemic change is multidimensional and without a single, major driver. At the meso-level, the socio-technical regime accounts for stability of existing technological development and the occurrence of dominating trajectories. The micro-level of niches, consisting of protected spaces such as research laboratories, is the source for generating and developing radical innovations. According to the MLP dynamics, regimes resist niche innovations, but after a breakthrough of a successful innovation, major changes in the regime take place. The key issues brought up in recent transition studies are how the transitions can be accelerated and under what circumstances acceleration can occur (Köhler et al., 2019; Markard et al., 2020).

Circular economy as a sustainability transition

The CE is an economic system that seeks to reduce the use of natural resources, close material, energy, and nutrition cycles, and retain the value of products, materials, and resources as long as possible. The CE changes the production patterns from a linear take-make-waste model into loops of reduce, redesign, remanufacture, reuse, repair, and recycle (Kirchherr et al., 2018). These loops establish technical and economic cycles, minimise energy loss, and de-materialise production and consumption (Jaeger-Erben et al., 2021). Ultimately, the CE aims to decouple environmental pressure from economic growth (Ghisellini et al., 2016) and contrasts with the traditional linear take-make-waste economy that creates value on natural resources through extraction, production, and consumption, and destroys value through the disposal of the resources as they become waste. The vision with a CE is that we do not just repair what has gone wrong in the linear economy, but rather move to a regenerative economy to create value and well-being to both humans and nature within planetary boundaries.

The CE belongs to the same group of concepts on policy change as ecological modernisation, green economy, and sustainable development (cf. Meadowcroft & Fiorino, 2017). Despite their differences, all these concepts share the common ideal to reconcile economic, environmental, and social goals (D'Amato et al., 2021). Some scholars have questioned the compatibility of the concepts of CE and sustainable development (e.g., Schöggl et al., 2020; Nikolaou et al., 2021). Yet, others have argued for an integrated CE and SD benefiting both sustainability and circularity (Evans, 2023). Furthermore, the CE has been associated with several United Nations Sustainable Development Goals (SDGs) such as Sustainable Cities and Communities, Responsible Consumption and Production, and Climate Action (Nikolaou et al., 2021).

The origins of CE thinking go back to academic discussions in the 1950s on the limited resources on the planet, the ecological impact of human activity, and the planetary boundaries of consumption. The CE has several distinct roots in academic research. First, industrial ecology and ecological and environmental economics (Ghisellini et al., 2016; Murray et al., 2017) started to portray industry as a unified, large system rather than a set of independent inputs and outputs or single entity operations (Murray et al., 2017). This laid the groundwork for a systemic approach in CE. Later, in the 1980s, these areas of research started to highlight the environmental and social aspects of sustainability in industrial ecology and thus paved the way for deliberating CE thinking (Murray et al., 2017).

Second, the roots of CE can be found in waste management research. During its early developments in the 1960s, attention was paid to technological innovations related to waste management and recycling systems. Over the decades, researchers and developers started to consider waste as an input for other processes. Towards the start of the 21st century, related ideas, policies, and business models were brought together to connect the input and output flows in material cycles, and a comprehensive view on waste, resources, and energy production and consumption emerged (Calisto Friant et al., 2020). This comprehensive view explores CE as an avenue for energy savings, material efficiency and recycling, and improved waste management, and it highlights the important relationship between materials and energy.

Third, the roots of CE business research are in cleaner production (Schwager & Moser, 2006), sustainable manufacturing (Rashid et al., 2013), and resource efficiency (Schulte, 2013). In this line of CE research, value creation and capture in economic activity are of central interest (Geissdoerfer et al., 2020). Finding ways to reconcile economic and environmental value in business activities and to address the triple bottom line of sustainability has led to explorations of the CE business model innovations and business decision-making (Sarja et al., 2021). The business studies on CE are a broad field of research that include, at least, attention to closed-loop production, sustainable design of products and services, innovations on ownership and business models, and operating modes in CE ecosystems.

Fourth, a recent development in CE research has focused on cultural change and commitment and participation of societal actors in CE (Jaeger-Erben et al., 2021); this focus is on behavioural change that is needed to fully acknowledge the role of the environment in human economic activity. This line of research comprises studies on circular society, eco-cities, and collaborative consumption models. The interest lies in searching for ways to portray citizens and consumers as active participants in a culture of reduce and recycle, to decouple well-being from consumption, and to create socially just and inclusive economic models.

In terms of multilevel thinking and the vertical dimension of governance, the development of CE has quickly become a key policy objective of international and national agendas (e.g., Calisto Friant et al., 2021; Hartley et al., 2020). According to the attractive policy promises, CE development results in increased sustainability in various domains by cutting emissions, enabling the reuse of by-products, and stimulating economic activities (e.g., Morseletto, 2020). As an illustrative example, the European Union is pushing hard towards a CE transformation, including steering the member states (Calisto Friant et al., 2021; Mazur-Wierzbicka, 2021). However, policy studies have shown that, even though the CE discourse is rather holistic, so far EU policies have not succeeded in addressing the socio-ecological implications of a circularity transition, and therefore, the policies appear insufficient to support a sustainability transformation (Alberich et al., 2023; Leipold, 2021).

Though originally considering supranational and national challenges, the major benefits of circularity are ultimately materialised at a local scale. This means that the essence of CE is defined in the urban context (e.g., Savini, 2019). Many cities around the world have started to adopt CE as an important part of their sustainability agendas and action plans (Prendeville et al., 2018; Wolfram, 2016), and forerunner cities are defining themselves as circular cities (Fratini et al., 2019; Paiho et al., 2020; Williams, 2021). Urban policies may aim to integrate CE principles into existing urban structures and processes or to create entirely new physical areas that adhere to CE principles. Either way, the thought of a circular city is a promising concept due to its potential to localise and particularise the general notion of circular transition.

In addition to the multilevel governance approaches and directing attention to the vertical dimensions of governance as described previously, the CE is often analysed with horizontal approaches focusing on the linkages among industries, urban infrastructures, and policy-making structures (Ghisellini et al., 2016; Kirchherr et al., 2017). With horizontal approaches the interest lies in examining the CE at the micro-level with a focus on individuals, meso-level with a focus on organisations, and macro-level with a focus on societal structures. Micro-level studies typically pay attention to single companies and individual consumers, whereas the meso-level studies address industrial settings, public organisations, circular ecosystems, and collaboration for circular flows. The macro-level studies examine the shaping of social institutions, such as regulation, policymaking, and markets (Aarikka-Stenroos et al., 2021, 2022; Ghisellini et al., 2016).

Catalysing mechanisms in the circular economy

In contrast to the many other academic concepts, 'catalyst' is a word that is well established in common language and captures the imagination of a wide range of people from different backgrounds. The word has strong metaphoric aptness (Thibodeau & Durgin, 2011) –referring to something that sparks a reaction that can lead to change, to literally hasten it through a catalytic effect. As a conventional metaphor, catalyst is easy to understand without comparison-based processing between the source and target domains, which is the case with novel metaphors. Thus, people in practical, real-world contexts can intuitively recognise catalytic mechanisms in their organisations, political processes, or from their everyday life. In that sense, we find that catalyst has immense potential in transdisciplinary research that promotes systemic change in collaboration with practitioners and various stakeholders across society.

The catalyst is a multifaceted concept that can be used as an asset in sustainability research (e.g., Hale, 2020; Jensen et al., 2018; Lee & Waddock, 2021; Tozer et al., 2022; Waddock & Waddell, 2021). It is a metaphor for driving a positive force for sustainability. Like many other metaphors used in scientific research, a catalyst gains its tangible power from a source domain that is clearly different from the domain of application. Here the source domain is chemistry, which defines catalyst as "a substance that initiates or accelerates the rate of a particular chemical reaction without itself being chemically affected" (Nemeh & Longe, 2021, p. 837). Catalysis is the process in which the catalytic reaction takes place. We argue that 'catalyst' and 'catalysis' are particularly helpful metaphoric terms for sustainability research, including research focusing on CE transitions. The catalyst is one answer to the question presented by Sage et al. (2022, p. 3): Which metaphors will we need to address the deep era of transformation we are currently navigating?

In general, metaphors are essential for any scientific progress by providing inspiration for research ideas, methodologies, and theory building. For instance, the metaphors of machine and organism have been groundbreaking in the history of several scientific fields. They have created shared understandings of relevant scientific problems and worldviews and resulted in numerous productive research programmes. Currently, the use of metaphors is recognised to be increasingly important in sustainability research, as they enhance interdisciplinary understanding of complex sustainability problems. Metaphors are also needed because science alone cannot resolve wicked sustainability problems without engaging a wide array of experts, practitioners, and laypeople. Widespread metaphors make environmental problems and scientific concepts understandable for all participants and enhance collaboration among them (Niebert et al., 2012; Sage et al., 2022). The essence of metaphor is that it involves an implicit comparison between concepts that are unrelated but share some common characteristics. For instance, the following climate change metaphors create an instantaneous image of problematic gases in the environment: 'greenhouse effect', 'heat-trapping blanket', and 'osteoporosis of the sea' (Armstrong et al., 2018).

The productivity of metaphoric concepts in science depends on how they are used in actual research. Like some other authors utilising the concept of a catalyst, we see that a single catalyst is usually insufficient to cause a transformation, but catalysts need to be clustered or aligned with other actions to produce sufficient momentum for systemic change (Tozer et al., 2022; Waddock & Waddell, 2021). Catalysts are always bound to the context, that is, the surrounding conditions impact its effectiveness. This can mean that the idea of one CE catalyst cannot be effectively transferred to another state, city, or organisation where the socioeconomic or environmental conditions significantly differ. In a wrong context, a catalyst can become even an inhibitor, which ends up hindering the change and thus the wider transition. Legal frameworks, cultural traditions, or organisational structures can hinder or enhance the catalyst's impact. People who have a wide spectrum of experience in applying 'best practices' know this well: some practices are extremely sensitive to context and can be fruitless or even detrimental if applied at random.

Catalysts involve some degree of unpredictability, since social processes remain full of uncertainty and the contexts where catalysts are deployed, include unforeseen variables. In contrast to clinical laboratory conditions, it is hard, and often impossible, to control all the relevant variables in real-world situations. In catalysing social processes, any assumptions on causalities need to be considered carefully, to avoid false and simplified conclusions about impacts. An inherent assumption in catalysing is that a catalyst has a causal impact on something. However, it depends on our adopted systems thinking what types of causality we should think about (e.g., Voulvoulis et al., 2022). In general, sustainability transitions are complex, nonlinear systemic changes and break down the mechanistic thinking of linear causalities. A catalyst triggers and puts something forward, but at that moment we can see only probabilities of its systemic effects, and surprises are common. It might, thus, be better to depict how a catalyst operates in systemic reconfigurations and be reflective and analytical about the context. Such an approach accounts for the potential nonlinearity of catalysing mechanisms and still increases our understanding of the ways catalysts alter the interactions, components and structures that cause a system to behave in a certain way.

Overall, there is a need for a catalyst approach in sustainability research that complements the current lines of research. For instance, catalyst thinking helps transition management in tasks of putting change in motion and evaluating the probabilities of what happens next in the system, and which components of the system are reactive in relation to each other. Furthermore, metaphoric images evoked by the term 'catalyst' generate conceptual insights and theoretical ideas for catalyst-based research (see Cornelissen & Kafouros, 2008). However, before turning this possibility into systematic research, concrete experience and empirical research are needed that use the catalyst perspective in detailed knowledge production from multiple perspectives and across various cases in transitional processes and experimentations. This book serves as a collection of such work.

Overview of the book's chapters

In this handbook, we introduce a broad range of perspectives on catalysing sustainable CE from different disciplines and from different sociocultural contexts. Nearly 100 authors present theoretical insights, contextualised case studies, and participatory methodologies that are used in different countries in all continents to accelerate sustainability transition. The chapters in this book create a rich offering on the ways in which different catalysts work together in different contextual settings. Discussing sustainable CE within a variety of national, industrial, and cultural contexts provides for in-depth understanding of how sustainability and CE transition can be supported in different settings and through different catalysts. The chapters include aspects of sustainability and CE in multiple countries with different regional and urban contexts given the authors' varying economic, political, regulative, technological, and cultural backgrounds. In each chapter, authors explore how catalysts create and maintain favourable conditions for complex systemic change in sustainability transition. An increased understanding about catalysts helps us to understand the different aspects and dynamics of transformation from a linear to a sustainable CE.

Real-world case studies provide for cross-continent, cross-country, cross-industry, and cross-cultural comparisons that enable identifying different patterns of sustainability transition and relevant catalysts. By discussing the most impressive context of CE transition, cities, as nodes of change that are crucial for global sustainability, this book provides a novel contribution to existing CE literature. In addition, the variety of theoretical and practical perspectives deepens our understanding about ways to accelerate change across organisational, hierarchical, and disciplinary boundaries. The broad-based social sciences and business studies perspective on sustainable CE paves the way for further research on social and business innovation to accelerate the sustainability transition. These chapters invite readers who are interested in sustainability transition to join the authors in open dialogue and co-creation of knowledge to advance CE in business and society. To support learning about CE, the book has a glossary of key terms, and questions or points for further discussion on the topic are presented at the end of each chapter.

The book has four sections. The first section provides a rich contextualised understanding about the catalysts in different countries across the globe and in industries that are particularly relevant in sustainability transition. The second section presents an overview of the multitude of catalysts and the ways in which they operate in interaction with other factors in a CE. The third section presents actionable research methods for the catalysing forces. The central idea is to present actionable research methods that academic researchers, students, and practitioners need to find ways in which they can use their training and analytical skill to accelerate the transition. The fourth section provides views on future directions in sustainability studies and presents critical views on research on sustainability transition.

Contextualised understanding of catalysts

The chapters in this section examine different contexts of CE and the catalysts that enable and accelerate the sustainability transition therein. The contextualised understanding of catalysts increases our understanding about the ways in which catalysts mobilise assets and capabilities in different industries, sectors, regulatory contexts, and urban, national, and cultural contexts. A contextualised discussion of catalysts allows for readers to generate an in-depth understanding of the transition potential of CE conceptions, strategies, and practices. Furthermore, examining the catalysts of CE within a context-specific framework highlights the interconnections and dependencies of catalysts in the systemic change. The articles on CE catalysts in different countries and different industrial ecosystems and presenting empirical insight on CE companies varying from small-sized start-ups to mature large companies provide a rich elaboration of the dynamics of CE transition.

Chapter 2, "Catalysts for urban circularity: Reasoning by analogy approach" by Ari Jokinen, Pekka Jokinen, Leena Aarikka-Stenroos, Marika Kokko, Johanna Kujala, Hanna Lehtimäki, and Jere Nieminen, presents a detailed elaboration of analogies derived from chemistry to develop a catalyst approach for the research of urban circularity. Drawing on an empirical study of a city district, the authors elaborate on the ways in which policy, technology, and business as key catalysts were both selective and interactive in running the system towards a transitional change. The authors argue that stepwise mechanisms of a catalyst make a strong contribution in urban circularity.

Chapter 3, "Re-creating the construction sector for circularity: Catalysing the reuse of prefabricated concrete elements" by Satu Huuhka, Leena Aarikka-Stenroos, Jukka Lahdensivu, Paul Jonker-Hoffrén, Viktoria Arnold, Erik Stenberg, Rijk Blok, Kjartan Gudmundsson, Patrick Teuffel, and Angelika Mettke, examines the benefits, methods, and challenges of the reuse of concrete in the construction sector. The chapter examines the deconstruction and reuse of prefabricated concrete elements that were not originally designed for disassembly. The chapter provides insights on the interdependencies between technological and socioeconomic catalysts and the temporality of catalysts in facilitating reuse as an innovation that is to change the current business as usual in construction.

Chapter 4, "Catalysing the textile industry towards a circular economy: An ecosystem approach" by Olga Dziubaniuk, Leena Aarikka-Stenroos, and Eeva Pohls, maps the collaborative, multiple-actor ecosystem required for catalysing the CE in consumer textiles. The authors draw attention to technological competences, organisational and managerial practices, regulatory support, communication, and the ethical concerns of organisation managers as catalysts in the socio-technical transition indicated by CE in the textile industry. The chapter increases our understanding about the ecosystems of reusing and recycling of used textile products and highlights the importance of development in textile circular management.

Chapter 5, "A review of the circular economy in Nigeria: From rhetoric to enterprise development" by Muhammed Akanji, Nathaniel Amoah, Oreva Theresa Akpoveso, Oreva Atanya, and Chris Ogbechie, examines CE in Nigeria. The chapter presents a rich contextualised description of CE transition in a global South context. The authors provide insights related to the interplay of CE catalysts at the micro and macro levels of society. The micro-level catalysts include culture, passion, and attitudes while the macrolevel catalysts refer to government policies and infrastructures. The authors argue that catalysts at both levels are needed in advancing circular business models and supporting innovative companies operating in a CE.

Chapter 6, "Catalysts for transition to circular economy solutions in the biowaste management sector in India" by Bhavesh Sarna, Rahul Singh, and Pankaj Singh Rawat, examines CE in

India's energy sector. They report on their research on agricultural waste that is found in abundance and is a potentially important material for biofuel production. They elaborate on a broad set of catalysts that support agricultural waste management transition into bio-energy production.

Chapter 7, "Plastic waste and a circular economy in China: Current situation and future possibilities" by Jouni Havukainen, Mariam Abdulkareem, Yayong Yang, Mi Yan, and Mika Horttanainen, brings China's plastic waste challenges to the forefront and describes the transition to a sustainable and circular pathway from the waste management of plastic to plastic recycling. The chapter reviews the transition of plastic waste management towards plastic recycling from technological, regulative, and environmental perspectives. The authors direct attention to regulation and policies, on the one hand, to consumer behaviour, on the other hand, as catalysing mechanisms in dealing with plastic waste and increasing recycling of plastic.

Chapter 8, "The role of institutional environment in catalysing circular entrepreneurship: A cross-country comparison of Finland and Italy" by Beatrice Re, Kaisa Henttonen, Ville-Veikko Piispanen, and Hanna Lehtimäki, presents their study of Italian and Finnish regulative, normative, and cognitive-cultural pillars in institutional environments. The comparative study in two European Union countries shows that while CE start-ups create sustainability innovations to the market and society, they also catalyse change in the institutional environment through challenging the norms, culture, and the taken-for-granted behaviour and attitudes. The authors argue that both the constraints and the supporting factors operate as catalysing mechanisms for CE.

Types of catalysts

In this section, the chapters offer a variety of viewpoints to studying catalysts in sustainable CE transitions. The chapters present an in-depth examination of a variety of catalysts in CE policymaking and business. The chapters contextualise the dynamics of catalysts through empirical studies and provide literature reviews to present useful theoretical lenses for studying catalysts. The variety of catalysts discussed in this section provide insights on the diversity of catalysts, the bundles of catalysts, the dynamics between catalysts, and the chain reactions created by catalysts.

Chapter 9, "Regulatory catalysts for the circular economy" by Topi Turunen, Eleanor Reyes Mateo, and Joonas Alaranta, focuses on regulatory instruments as catalysts in changing production and consumption to achieve a CE. The chapter presents different regulatory approaches to CE and gives examples of regulatory catalysts from all around the world. The authors provide an overview of the ways of regulating the CE and discuss how regulation functions as a catalyst for the CE throughout a product's life cycle.

Chapter 10, "Mission-oriented policy as a catalyst for transition to a circular economy" by Lina Dagiliene, Jurgita Bruneckiene, Viktorija Varaniute, and Justina Banioniene, discusses mission-oriented CE policy as a catalyst. The authors present empirical research on Lithuania's CE transition and direct our attention to the readiness of public policy for a mission-oriented approach at the legislative level, co-creation principles in public policy, and a partner approach in policymaking to solve sustainability issues in business and society.

Chapter 11, "Information as a catalyst for the circular economy" by Nina Tura, Matias Ståhle, Tuomas Ahola, Jyri Hanski, and Pasi Valkokari, examines information as a catalyst for the CE. The authors present a model that emphasises the role of data, information, knowledge, and wisdom hierarchy, and the hierarchy's relations that enable efficiency improvements and cross-sectoral collaboration in circular business. The authors discuss the findings with four empirical case studies to elaborate on information as a catalyst for revising business models and accelerating wider system-level CE transitions.

Chapter 12, "Design as a catalyst for the circular economy" by Lykke Margot Ricard, Sofie Bach Hybel, and Sergio Jofre, examines design principles that are general to the practice of green engineering, eco-design, and cradle-to-cradle as catalysts for the CE. With an empirical study on solar cell panels, the authors direct attention to the role of design in enabling the reuse and recycle of materials at the end of a product's life cycle. The authors highlight the need for a change in mindset in designing products for full circularity and links this need to education, with a focus on the inner transition, where higher education plays a vital role.

Chapter 13, "Circular economy and finance: Either a straightforward relation or a virtuous loop?" by Claudio Zara and Luca Bellardini, examines the CE transition from a financial institution's standpoint and presents different views on finance as a catalyst. The authors argue that the existence of opportunities offered by a circular transition to the financial players is the crucial trigger for steering the financial services (FS) industry in supporting the CE. Furthermore, they highlight the importance of nonfinancial information and metrics on circularity for investors. The chapter brings forth interesting insights on the ways in which investing in companies that move towards circularity converge into a system-wide catalysing of the CE transition.

Chapter 14, "Core competences and core resources as catalysts for the design of circular business models" by Davide Chiaroni and Andrea Urbinati, focuses on business models as catalysts. The authors discuss the resource-based view of companies, a well-established line of research in strategic management literature, and use that to analyse the micro-foundations of the CE in business. The chapter focuses on core competencies, managerial practices, and resources as catalysts for circular business model design and capability building in a firm to create a sustainable competitive advantage in the market. The authors argue that a resource-based view of companies is a beneficial framework in CE studies that focus on circular business models.

Chapter 15, "Artificial intelligence as a catalyst in the circular economy transition" by Kang Li, investigates the role of artificial intelligence (AI) and machine learning (ML) as a catalyst. The chapter presents a systematic literature review and provides knowledge about how AI can be used to support the CE transition through advanced objectivity, accuracy, and cost-efficiency in implementing the CE principles in business. The results presented in this chapter help researchers, entrepreneurs, industry leaders, and policymakers to better understand AI and ML as catalysts in the CE transition.

Chapter 16, "Gamification as a catalyst to the circular economy" by Georgina Guillen, Marc Riar, Benedikt Morschheuser, and Juho Hamari, examines gamification as a catalyst in the CE. The chapter presents a systematic literature review of gamification and comprises perspectives on policymaking and managing CE transitions via gamification. The results show that existing research on the topic is firmly focused on end-of-life activities (e.g., recycling) whereas design, production, and use phases require more attention. Similarly, the authors show that there is a strong focus on operational tasks, although gamification for tactical and strategic efforts is less explored.

Methodological approaches for catalysing

The chapters in this section present methodological approaches to catalysing the CE. The methodologies include co-creation of new knowledge, processual research, practices of collaboration, design thinking, scenario tools, and future studies, to mention a few.

Chapter 17, "Mid-range transition arenas catalysts a circular economy" by Tatu Marttila, Jani Lukkarinen, Sampsa Hyysalo, David Lazarevic, and Helena Valve, introduces the transition arena (TA) as a knowledge co-production process to engage societal stakeholders to develop a future vision, pathways suggestions for policy actions, and experiments that cut across policy sectors. The authors show how the process has been used at national and regional levels of policymaking. The authors propose that the mid-range TA methodology offers a heuristic method to support CE policy development and catalyse the operationalisation of agendas and shaping ideas into action in collaboration with a variety of actors, organisations, and networks in specific spatial and temporal settings.

Chapter 18, "Design thinking tools to catalyse sustainable circular innovation" by Nancy Bocken, Brian Baldassarre, Duygu Keskin, and JC Diehl, presents an overview of how design thinking tools, skills, and methods can be used in catalysing sustainable circular innovation. The authors summarise design thinking phases and the principles of design thinking that are particularly relevant in tackling the complex CE innovation challenges. They show how to meet the criteria of desirability, feasibility, viability, sustainability, and circularity when seeking to catalyse sustainable circular innovation with design thinking and tools.

Chapter 19, "Scenario method for catalysing circularity and lowering emissions in the construction sector/real estate, Nigeria" by Olumide Ayanrinde and Jeffrey Mahachi, examines the use of scenario methods in catalysing a CE. The chapter inspires context-based sustainability thinking and shows how to approach the grand challenges of sustainability goals through locally based targets and measures. The authors present a case study to exemplify the use of scenario methods in estimating and validating decarbonisation with respect to energy, water, and material efficiency in a residential building pilot in real estate in Nigeria.

Chapter 20, "Digital affordances for a circular economy transition: A multiple case study of digital technology-enabled circular business models" by Outi Blackburn, Paavo Ritala, and Joona Keränen, presents digital technologies as enablers in circular business models and the ways to use digital affordances in assisting firms to overcome circular business model implementation challenges. Digital affordances refer to information provision, market intermediation, supply chain enhancement, and institutional legitimation. The authors provide practical implications for circular business model development and show empirical evidence for the benefits in circular resource flow strategies, namely narrowing, slowing, closing, and regenerating in socio-technical systems.

Chapter 21, "Accelerating the adoption of circular economy: An extended diffusion model for understanding consumer perceptions of CE products" by Jennifer D. Russell and Okechukwu Okorie, focuses on the perspective of the consumer to increase understanding about the ways in which the adoption of eco-innovation can be accelerated. They present an extended diffusion model for value-retention products that are remanufactured, refurbished, repaired, or reused. The authors highlight consumer education about value retention, acknowledgment, and mitigation of perceived risks associated with value retention and product differentiation as important in accelerating eco-innovations.

Chapter 22, "Co-creation art to catalyse competencies for a sustainable transition" by Juha Suonpää and Peter Sramek, shows how creative thinking skills and co-created art can be applied in learning processes to develop capabilities and problem-solving skills needed in a sustainable CE. The chapter reviews university learning models that are designed to lead to a fundamental ideological change required for achieving sustainable development and forming of CEs. Drawing on experiences of running a global initiative of the International Art Collaborations (INTAC), the authors present a collaborative methodological model in art making for producing instrumental and strategic skills that catalyse a sustainable CE.

Chapter 23, "Utopias as catalysts for a sustainable circular economy" by Marileena Mäkelä and Maili Marjamaa, examines preferable future images or utopias to provide new perspectives and agency to catalyse the CE. By providing insight derived from 61 interviews with CE experts in Finland, the authors elaborate on four utopias, economically sustainable CE, environmentally sustainable CE, socially sustainable CE, and culturally sustainable CE. The chapter shows how utopias can serve as mental models to inspire decision-making that catalyses the future development of sustainable CE.

Conceptual understanding of catalysing

The chapters in this section provide conceptual frames to support research on sustainable CE transition. The topics in this section include a discussion on temporality and dynamics of transition, critical views on CE, and the future of CE.

Chapter 24, "Towards a typology of circular economy agency" by Satu Teerikangas, Tiina Onkila, Katariina Koistinen, Antero Hirvensalo, Angelina Korsunova, Marileena Mäkelä, Milla Sarja, Mira Valkjärvi, and Noelia Reynolds, presents a typology of CE agency. The typology depicts active and relational agency at the individual, organisational, and interorganisational levels of analysis. The authors discuss circular transitions as structuration processes amid an ongoing tension between agency and structure. The authors emphasise that all actors have the potential to become CE catalysts, depending on the extent to which they recognise and exercise their CE agency.

Chapter 25, "Roles of virtual intermediaries in the transition to a circular economy" by Magnus Moglia, Christian A. Nygaard, Olamide Shittu, Tmnit H. Halefom, and Sean Trewick, discusses the roles virtual intermediaries play in facilitating a business ecology to a CE. The authors present three transformation arenas – market creation, the enabling environment, and organisational change – and examine the roles of virtual intermediaries in reducing transaction costs, overcoming inertia, streamlining and standardising, or facilitating systemic learning within and across the arenas. The chapter highlights the systemic realignment that is required for a sustainable CE transition to take place.

Chapter 26, "The assembling of circular consumption: A sociomaterial practice approach" by Elina Närvänen, Christian Fuentes, and Nina Mesiranta focuses on consumerism and conditions of sustainable consumption in CE. The authors present a conceptualisation of socio-material assembling of circular consumption and the role of the consumers in it. The chapter contributes to the literature on circular consumption and has practical implications for involving consumers as catalysts in a CE.

Chapter 27, "Catalysing a circular transition in Brixton" by Joanna Williams and Josefine Hintz, theorises on the circular urban transition process. The authors identify catalysts in a process of scaling up circular urban experiments. With an empirical investigation of Brixton, a community-led, circular transition process, enabled by tactical urbanism, the authors identify catalysts for circular activities. The chapter draws attention to a culture of activism, local symbiotic relationships, a positive narrative, and the availability of vacant land and property.

Chapter 28, "Regime-niche actors as catalysts in the transition to a circular economy" by Rachel Greer, applies the concept of catalysts as a mechanism of change. The chapter posits that innovative thinkers operating in a regime context are a prime example of catalysts in sustainability transitions. The author depicts such actors as regime-niche (R-N) actors and defines, describes, and exemplifies such actors with empirical analysis from the Dutch context. The chapter invites readers to ponder the impact of sociopolitical contexts and cultural differences on the potential of different types of actors to act as catalysts.

The chapters present a multitude of techno-economic and sociocultural perspectives on CE transition. Overall, this book paves a way to studying the variety of catalysts and catalysing mechanisms that accelerate the transition. In the final chapter, "Catalysts in sustainable circular economy: directions for future research", we reflect on the critique on CE and portray directions for future research on CE catalysts.

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PART I

Contextualised understanding of catalysts

2

CATALYSTS FOR URBAN CIRCULARITY

Reasoning by analogy approach

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Introduction

In sustainability research, it is important to know the forces that can drive systems and processes to sustainable paths. Research of urban sustainability transitions (Frantzeskaki et al., 2017) studies nonlinear and structural changes to identify pathways and solutions for desirable environmental and societal change. This chapter provides exploratory research to find dynamic features from chemical catalysis that have analogical similarities with urban systems transitioning toward sustainability. The purpose is to recognise the most relevant dynamic similarities for building an analogy model that can be used as a research tool for catalyst-based sustainability research. Thus, the analogy model utilises the well-known source domain, chemical catalysis, to provide new research perspectives to study the less known target domain, urban sustainability transition and its catalytic forces.

This research task has two parts. First, we make a systematic conceptual analysis between chemistry and sustainability transitions to identify the most potential analogies. Second, we conduct an empirical case study focusing on urban circular economy (CE) transition to demonstrate the selected analogies to find out their relevance, empirical credibility, and ability to bring out fruitful insights for sustainability research. The case study site is Hiedanranta, which serves as a district-level urban laboratory for CE transition in Tampere, Finland. In this case study, we focus on key catalysts and two research questions:

1. What kind of mechanisms give power to the catalysts promoting urban CE transitions?
2. How do the dynamic features of a transitioning urban system explain the systemic effect of catalysts?

The following choices make the case suitable for our empirical analysis. First, the studied key catalysts are policy, technology, and business. They carry the historical development of the idea of CE and frame the state-of-the-art research of CE transitions together with several other factors (e.g., de Jesus & Mendonca, 2018; Geissdoerfer et al., 2017; Kirchherr et al., 2018). While sustainability transitions are complex, multidimensional, multilevel, and multitemporal societal changes and should be studied from multiple perspectives (Frantzeskaki et al., 2017; Rotmans

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et al., 2001), the research focusing on these three key catalysts is particularly important in the initiation and acceleration of CE transitions. Second, the system studied is a case of urban regeneration. Urban regeneration is the core generator of sustainability transitions in cities (Wolfram, 2019). The experimental sites of urban regeneration are often conceptualised as urban living labs and can be studied, for instance, as urban CE ecosystems (Aarikka-Stenroos et al., 2021; Engez et al., 2021b). Thus, urban regeneration is a natural host for a multicausal systemic transition from a take-off phase (see Rotmans et al., 2001) towards urban circularity. During the process, the key catalysts of policy, technology, and business mutually shape one another and interact with other trajectories of change (Figure 2.1).

We utilise sustainability transitions research focusing on urban living labs as instigators of sustainability transitions (e.g., Florez Ayala et al., 2022; Frantzeskaki et al., 2017; Fuenfschilling et al., 2019; von Wirth et al., 2019) to recognise dynamic similarities between chemical catalysis and urban transitions. Context is essential: it makes no sense to study catalysts, system change, or urban regeneration without context. For urban sustainability, the defined place is a central contextual factor (Ghavampour & Vale, 2019), and we primarily conceptualise it as an evolving system property (Peris-Blanes et al., 2022).

Our research contributes to sustainability transitions research, particularly the research of urban CE transitions. We provide new insights of CE transitions by uncovering the mechanisms by which catalysts become influential both individually and in concerted ways to run urban systems towards transition. Moreover, our research provides inspiration for researchers to use catalyst-based approaches for sustainability research and to make these approaches more methodological. Thus far, the catalyst as a research term is in metaphoric use, and this use is basically communicative and expressive (Cornelissen & Kafouros, 2008). Accordingly, it evokes the research idea that catalysts for sustainability are increasingly important and points out the direction in which the most fruitful analysis of the catalytic mechanisms can be made. While the metaphoric use can be heuristic and generate promising inspiration for research, the catalyst itself as a research concept remains underdeveloped (for rare exceptions, see e.g., Lee & Waddock, 2021; Tozer et al., 2022). Analogy models provide one possibility to address this gap, and our research is a preliminary effort in that direction.

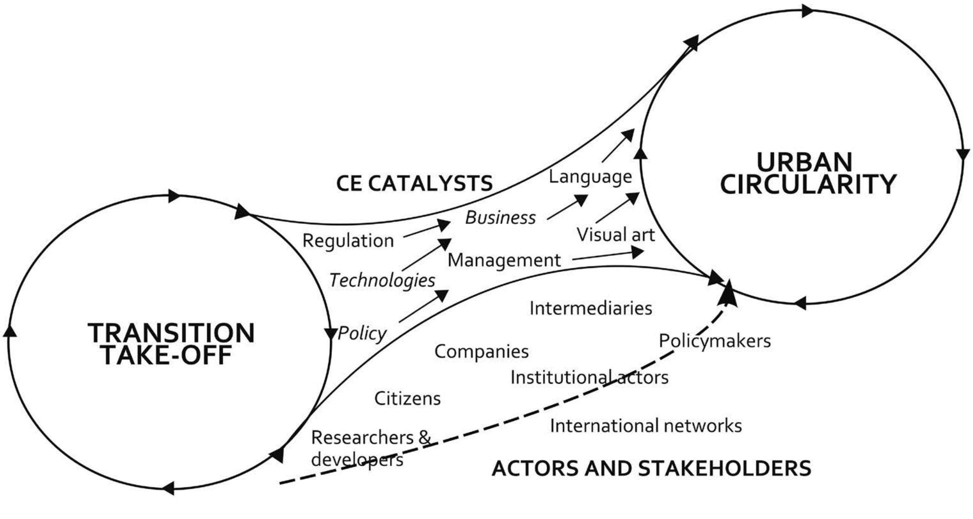

Figure 2.1 Catalysts accelerating the transition to urban circularity.

Source: CICAT2025 research project.

The structure of this chapter is as follows: in the next section, we implement our first research task by creating the theoretical basis of our approach by delving into conceptual identification, selection, and formulation of the most potential analogies between chemical catalysis and sustainability transition. This continues with a subsection in which we give some specifications of the catalytic nature of policy, technology, and business and formulate our assumption of the actualisation of this catalytic power. Then, we describe the empirical case study site of Hiedanranta, where we test the created analogies. In the results section, we uncover the catalytic mechanisms of policy, technology, and business as empirical research findings enabled by the analogy model. In the discussion section, we answer the second research question and present three dynamic features that characterised the transitioning urban system under catalytic forces. In conclusion, these results suggest that the analogy model has potential to be further developed as a research tool for sustainability research.

Building up the conceptual basis

Analogies between chemistry and sustainability transition

Analogies are used in research to make sense of and to produce new knowledge of complicated phenomena. Using analogies is based on the idea that there are certain aspects of the source domain similar with the target domain, which is the object of research. When the source domain is well-known, it is possible to create analogies that may significantly help understanding the unknown target domain. Analogies work if the similarities between the source and target are significant enough and provide fruitful results to increase the understanding of the target (Bailer-Jones, 2009; Haila & Dyke, 2006; Swedberg, 2014). Hence, a detailed mapping of similarities and dissimilarities is a major task in building a good analogy.

Catalysis is one of the most established areas of knowledge in chemistry. We use the chemical system of catalysis as a source domain to create an analogy model to study sustainability transitions, particularly focusing on a district-level urban system as a model case. Since numerous similarities between catalysis and transition can be found by examining these two systems, we made a systematic pre-empirical evaluation (Ketokivi et al., 2017) to identify the most relevant and helpful ones. For this purpose, we utilised our interdisciplinary knowledge, the basic textbook descriptions of chemical catalysis (e.g., Hanefeld & Lefferts, 2018; Nemeh & Longe, 2021; University of California, n.d.), and recent research of sustainability transitions in urban systems. In this iterative process, we examined chemical catalysis as a system of relations and whether these relations also hold in sustainability transition. The aim was to find the most relevant dynamic similarities between the systems because they are most helpful in analysing the real-life systems (Haila & Dyke, 2006).

After the first analogy, we constructed further analogies to get closer to our theoretical idea that system change in both domains depends on the catalytic mechanisms that push the system towards a transition state. 'Transition state' is a term in chemistry that describes the final stage of catalysis before the activated reactants convert into products. Throughout the chapter we also use transition state to depict the theoretical culmination point towards which an activated sustainability transition is moving during the phase of acceleration. During acceleration, change accumulates through positive feedback loops and the speed of change increases (Rotmans et al., 2001). By mechanism, we do not refer to its meaning in chemistry where it covers the whole pathway of the reaction that leads to catalysis, but as discernible factors that make the catalyst functional and keep it powerful. This means that the term 'mechanism' in our use covers the internal properties,

Table 2.1 Core analogies identified between the systems of chemical catalysis and sustainability transition. Grounds are the basics in catalyst thinking, and warrants refer to deeper system dynamics

Core analogy	*Potential value in model building*
1 Catalysts are selective and complementary.	Grounds
2 Catalysts increase the interaction of a system's entities towards a transition state.	Warrant
3 Catalytic pathways occur in a stepwise manner and overcome energy barriers.	Warrant
4 Catalytic processes are highly contextual.	Grounds

context, and trajectory of a catalyst. The focus on mechanisms helps us in our first research task to explicate the concept of catalyst but is necessary also for the second task to examine whether an analogy model is helpful in sustainability research primarily since it addresses the dynamic features of the studied system.

The following four analogies proved to be the most relevant to our research task (Table 2.1). For their tentative evaluation, we applied the idea of using the terms 'grounds' and 'warrant' presented by Ketokivi et al. (2017). We claim that the analogies 1 and 4 are necessary grounds for building an analogous model because they create the basis for catalyst thinking. They also present the novelty value of the catalyst approach, and it seems that they are at least invisibly present when the term 'catalyst' is used in metaphoric ways as a research concept. They become more explicit when the first ideas of an analogous model are outlined (e.g., Figure 2.1) but reach more depth only in model building. The analogies 2 and 3 can be considered warrants, because they are likely needed in model building if the goal is to develop a methodological basis for a catalyst approach. The cornerstone of all analogies is the catalyst as defined in chemistry: catalysts are substances that initiate or accelerate the speed of a particular reaction without undergoing a permanent chemical change (Hanefeld & Lefferts, 2018).

Analogy 1. *Catalysts are selective and complementary.* In chemical systems, in addition to a catalyst, the other substances participating in the reaction are called reactants, and they disappear when products appear as the result of the reaction. Chemical catalysts are usually selective, which means that they determine the product of a reaction by accelerating only one of several possible reactions that could occur. Catalysts complement each other because of complex chemical processes that require contribution by several types of catalysts. For a tentative analogy, catalysts in chemistry are selective and complement each other; this corresponds to the studied key catalysts of policy, technology, and business. Key catalysts are qualitatively different triggers, and they need to complement each other to initiate or speed up the system change towards a transition.

Analogy 2. *Catalysts increase the interaction of a system's entities towards a transition state.* Catalysts are needed in both systems to increase the interaction between the basic entities, which are molecules in chemical systems and entities like human actors, artefacts, institutions, and materials in sustainability transitions. In chemical systems, catalysts speed up the reaction by lowering the activation energy to achieve a transition state. The transition state is also changed with a catalyst, that is, the reaction goes through different pathways than without the catalyst. Transition state is an intermediate state during which the reactants are no longer reactants, nor are they yet products (Nemeh & Longe, 2021). While the time spans are different, a chemical system reaching its transition state resembles a sustainability transition approaching its turning point (Rotmans et al., 2001). In both transitions, intensive reconfiguration characterises the acceleration period during which the system becomes ready to change.

Analogy 3. *Catalytic pathways occur in a stepwise manner and overcome energy barriers.* This means that catalysts transform the system by creating stepwise pathways with lower energy demands. Chemical reactions can take place only when collisions between molecules occur with enough energy and proper orientation, and this threshold of energy is called activation energy. In chemical systems, catalysts reduce the activation energy and allow the molecules to achieve the transition state. Accordingly, it is understood in chemistry that catalysts accelerate the chemical reaction by allowing the reaction to proceed via the pathway that has a lower activation energy when compared to an uncatalysed reaction. However, catalysts do not affect the degree to which a reaction progresses but only the kinetics of the reaction. The overall change in free energy is not affected by the catalyst but is determined by the reactants and products. When catalysts decrease the activation energy and thereby accelerate the reaction, they create alternative pathways for the process. The catalytic cycle proceeds through multiple steps, from which the catalyst emerges unchanged that makes the sequence catalytic. A tentative analogy is that catalytic pathways require activation energy in both chemistry and sustainability transitions, and they are also stepwise, to avoid energy barriers of the system. Research focusing on sustainability transitions shows that steps are unavoidable in transition management (Frantzeskaki et al., 2017).

Analogy 4. *Catalytic processes are highly contextual.* Chemical catalysis requires suitable circumstances to speed up the reaction, such as temperature, pressure, energy, the presence of suitable catalyst and reactants and their dispersion and orientation, and the physical state and surface area of reactants. For instance, a higher temperature makes the particles move at a faster speed and collide with each other with more energy, and, therefore, they more likely reach the activation energy threshold needed for a chemical reaction. In systems where more than one reaction is possible, the same reactants can produce different products under different conditions. Because contextual circumstances are the necessary conditions for chemical catalysis to take place, we posit that also the mechanisms of sustainability catalysts are strictly dependent on contextual circumstances when triggering the system towards a transition.

As a result, these four analogies most faithfully respect the core dynamics of chemical catalysis and the CE transitions of urban systems and appreciate the most relevant similarities between the two domains. If this is correct, the four analogies we described can create novel ways to examine CE and other urban sustainability transitions. As we suppose, these analogies can be used for an empirical demonstration to examine how the structure of the chemical catalysis can be mapped onto the structure of the target domain. In the case study demonstration, we use the analogies to analyse the properties of policy, technology, and business as catalysts and how these key catalysts develop and interact in the studied urban system, and the mechanisms through which they run the system towards a sustainability transition. If the analogies fulfil empirical adequacy, factual validity, and structural soundness (Ketokivi et al., 2017), they give positive messages for further research to collect more empirical data for confirming, rejecting, or improving the analogy-based catalytic approach developed in this chapter.

The roles of policy, technology, and business in urban circular transitions

When we apply the analogies formulated previously to examine a transition towards urban circularity, we make the following assumptions of the key catalysts, causality, and the system under transition. Relationships, interactions, and interdependencies are crucial system properties in different approaches to transitional change. We assume that policy, technology, and business are continuously emerging catalytic triggers for urban change and thus evolve under particular circumstances. As key catalysts, policy, technology, and business are linked to the previously mentioned system properties and, therefore, can speed up a systemic change towards transition. This assumption of causality is our firsthand methodological guideline for the analysis. The assumption allows for detecting individual catalytic mechanisms and the connections between catalysts, and identifying how the mechanisms and connections accelerate the transition. At the same time, we acknowledge that various forms of causality and uncertainties arise from complexity. We can mostly observe only first-order mechanisms and can only study the most obvious catalysts at this time. The following specifications selected from previous research illustrate the catalytic potential of policy, technology, and business.

Perhaps most notably, policy catalysts refer to political institutions such as specific policies or programs, policy-making procedures, laws, and regulations that accelerate sustainability transitions (Patterson, 2021). Policy catalysts in CE transition are needed for creating momentum and circumstances for this new branch in urban environmental policy. Multi-level policy reforms and decision-making are needed by the EU, member state bodies, and city networks. Important policy issues include regulation, financial factors, and policy integration. City institutions must create policy catalysts to promote CE transition in issues such as local strategies for CE, institutional arrangements, land use policy and planning, public procurement, and new governance models while including stakeholder collaboration and experimentation for CE transition (Prendeville et al., 2017; Williams, 2021). Indications of catalyst thinking can be found from policy research. For instance, Johnson et al. (2005) have suggested that a catalytic change in policymaking employs a window of opportunity, is more intense than incremental change, and is also more fundamental in terms of implications. The concept of CE serves as a catalyst in policy processes (Nylén & Jokinen, 2022). Recent work on policy design and policy processes (Capano & Howlett, 2021) demonstrates how policy catalysts ('activators' in their terminology) trigger first- and second-order mechanisms in the studied system. Temporal issues, such as timing, sequence, and duration become important in these processes (Turku et al., 2022, 2023).

Technological evolution includes autopoietic mechanisms that lead to distinct stages in its internal development (Arthur, 2009). In our analysis, we examine these stages on a micro-level and call them as internal catalytic mechanisms of technology. Technology catalysts are crucial in urban regeneration because a fundamental infrastructural change is necessary when creating a new urban district based on CE principles (Dong et al., 2018). From a technological viewpoint, catalysts in CE transition involve, for instance, environmental, process and digital technologies that enable reduction, recycling, and reuse or sharing of resources. Novel technologies often trigger their adaptation and implementation (de Jesus & Mendonca, 2018) due to their enhanced efficiencies compared to technologies currently in use. However, to enable the transition towards a CE, technological solutions must be available, and the market, legislation, and other factors must support the implementation of the technologies (Aarikka-Stenroos et al., 2023). If these requirements are not met, a transition may be hindered. Other barriers may include the scarcity of large-scale demonstration projects and the lack of data on the impacts of technologies. However, according to Kirchherr et al. (2018), CE transition is not mainly hindered by technological barriers but by both cultural and market barriers. The technological catalysts entail innovative interaction between actors, employ material flows in the area, and thus mediate social and cultural aspects of CE transition.

The catalytic nature of business is studied indirectly by examining, for instance, the evolution of business models (e.g., Demil & Lecocq, 2010). In research on innovation ecosystems and business ecosystems, transition is understood as a dynamic change of evolution and extinction in a multi-actor network (Tsujimoto et al., 2018). In ecosystem literature, attention is paid to entrepreneurs, customers, users, public and private investors, policymakers, and technology actors who contribute as enablers or barriers in the dynamics of ecosystems. In urban CE transitions, the shift from innovation ecosystems to implementation ecosystems requires a value co-creating exchange between actors operating with different logics of value creation (public and private) (Aarikka-Stenroos & Ritala, 2017). The transition also requires that actors engage in the exploration of and experimentation with novel, value-creating opportunities for the different stakeholders who are involved (Tapaninaho & Heikkinen, 2022) and pay attention to the various interests that stakeholders have regarding the CE transition (Marjamaa et al., 2021). Business catalysts are needed to foster the shift from the current innovation ecosystem towards commercialisation of CE technologies, including profitable business models that can compete with current linear models, and with the practices that mitigate buyer risk when investing in novel technology (Lehtimäki et al., 2020). These catalysts employ the developing interdependences between companies and other actors. Aarikka-Stenroos and Ranta (2019) have distinguished five mechanisms of CE business catalysts: exchange, value creation, competence, business model, and collaboration mechanisms. Many of these mechanisms interact with other catalyst types.

To summarise, we assume that policy, technology, and business are intrinsically catalytic in transitions for urban circularities, but the full actualisation of this potentiality requires suitable circumstances. The context perspective is required to study the actualisation and its mechanisms. The activities of stakeholders, organisations, and institutions are essential contributors in these processes. Like catalysts in chemistry, policy, technology, and business maintain their core identity in transitions.

The case study for exploring catalysts in urban regeneration

In this chapter, we examine urban regeneration by adopting the case study approach. One recognised strength of the case study approach is that it provides for analysis of the interdependencies between actors and processes within their particular social settings. As shown next, we have selected a case that can be interpreted through its characteristics and then further theoretically examined in terms of key catalysts and their mechanisms.

The case we report on is the Hiedanranta district in the city of Tampere (235,000 inhabitants), the second most rapidly growing city in Finland. Hiedanranta is an old industrial area (pulp mill) under brownfield redevelopment for up to 25,000 new inhabitants. As shown in Figure 2.2, this process started in 2014, and the planning of housing for the incoming residents is ongoing at the time of publication. Enabled by the city, an entire series of experimental CE projects took place in the area between 2015 and 2020. Several companies, citizen groups, and research institutions carried out the CE projects in and outside of industrial buildings. These groups for instance, developed urban nutrient circulation by focusing on the following interlinked projects: source-separated sanitation, the cultivation of microalgae, composting, anaerobic digestion, developing methods for using urea for fertilisation, growing strawberries commercially by using LED lights and robots, experimenting with collective urban gardening, and creating waste and sanitation infrastructure for local treatment and nutrient recycling. In addition, pyrolysis and biogas plants were operated for local renewable energy. Another start-up innovation was to use overheated sand as an energy battery; the innovation raised international interest when the pilot was connected to a local district heating grid in Hiedanranta and elsewhere.

The city of Tampere's guiding strategy for the Hiedanranta area is to create a real CE city district in which residents, companies, and researchers are integrated to operate both together and separately. Hiedanranta is marked by its explicit place-based focus, and as an upcoming residential district it differs from isolated CE industrial parks commonly used for the promotion of CE in cities. The project is recognised in international city networks and is of strategic importance

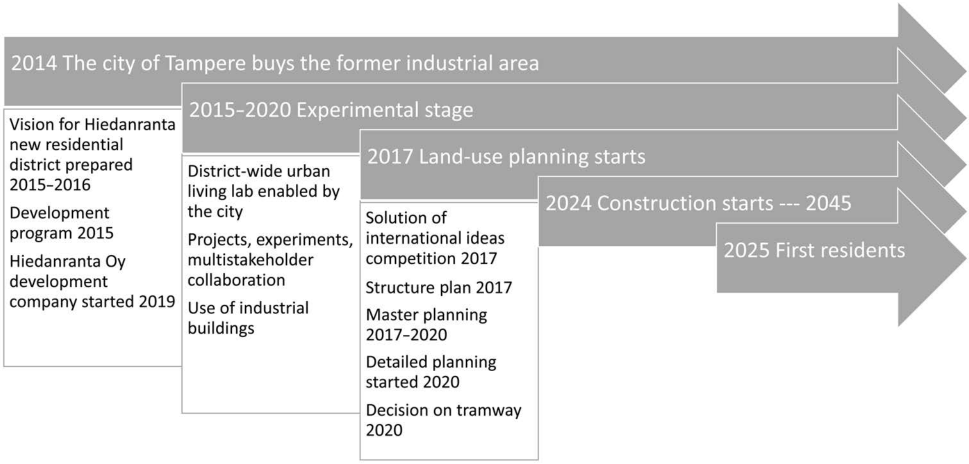

Figure 2.2 The timeline of developing Hiedanranta into a new CE district.

Source: City of Tampere, 2020, modified by the authors.

for the city. As a district-level urban living laboratory, its unique features include the intersection among the city, activist groups, businesses, and research; the generation of collective agency; the coexistence of diverse experiments; and local to transnational exchanges and connections.

The empirical case study work in 2015-2021 was based on interviews, group discussions, site visits, documents, and data created by observational and participatory methods. The primary aim of the analysis was to identify the most relevant socio-technical trajectories supporting CE practices in the area, exemplified by the 'zero fibre project' and the 'nutrient cycle project' described in the next section. The developmental path of each trajectory was followed and the mechanisms and interactions of key catalysts were specified and analysed. We made a distinction between (a) the policy catalyst creating an agenda and space for transition and keeping its momentum, (b) the technology catalyst necessary for CE innovations, and (c) the business catalyst enabling and boosting the commercial viability of CE innovations, leveraging their implementation and acceptance and thus the move of the CE transition.

While we particularly analysed technology-driven experiments for urban development following CE principles in Hiedanranta, we also considered the citizens, as they participated in many of these experiments (Engez et al., 2021a; Turku et al., 2022, 2023). Moreover, citizens were the primary actors in many other innovative projects in the area, focusing on the reuse of industrial spaces, new consumer cultures like do-it-yourself activities, and ideas for urban planning, including a new superblock implementable in the Hiedanranta area (Laine et al., 2017; Leino & Puumala, 2021; Sjöblom et al., 2021). Overall, the citizen activities significantly characterised the whole experimental stage of urban regeneration and created the spirit and preconditions for the urban CE transition in Hiedanranta.

Results

In this section, we examine the key catalysts taking place and reinforcing CE principles in the Hiedanranta development area and thus accelerating the CE transition in urban regeneration. While analysing policy, technology, and business as key catalysts each in turn, we aim to uncover the individual catalytic mechanisms contributing to circular urban development. In the final subsection, we analyse how the catalysts interact and accumulate, and how different catalysing forces amalgamate when enabling circular urban developments. Tables 2.2 and 2.3 summarise the empirical findings and complement the analogy model developed in this chapter.

Policy catalyst

In Hiedanranta, the policy catalyst emerged from the city's will, power, and leadership to enable a new kind of urban district and to keep momentum in its experimental development. This required a new mode of governance through which the city was able to harness multistakeholder capacities to collaborative urban development. The city's actions were decisive for the development of a CE as the guiding principle for the Hiedanranta district. The city had made a series of single decisions, but these decisions were not the only reason for the push towards the establishment of CE principles in the area. Rather, we found that the catalysing effect was evolving because of three interlinked mechanisms: the policy vision, the sequence of reflective decisions and plans, and space creation. The interaction of these catalytic mechanisms resulted in constant reorganisation of CE principles and activities in the area.

(a) *Policy vision of Hiedanranta.* In the vision, the city has launched the Hiedanranta district as the "City of the Future", referring to a district that supports "*the commercial and industrial progress, as well as the competitive strength, of the whole region, with emphasis on implementing a smart, adaptable and resource-effective city, based on a circular economy*" (City of Tampere, 2017). This vision is highly ambitious, reflecting the global inter-city competition over sustainability issues. Practically, it reflects the match between global policy models of urban sustainability and the local political and institutional receptivity, which always entails modification of global models into local circumstances (McCann, 2011). As a demonstration of global competition, the city has stated emphatically that "*the Hiedanranta district has a strong brand, because it is the first circular economy-based urban district in the world created by companies and citizens*" (City of Tampere 2018a, p. 7). This statement is a culmination of Tampere's urban development in recent years in terms of the adoption of low-carbon and other global sustainability targets in the city's strategy and strategic spatial planning (Jokinen et al., 2018). The strong position of a CE in the vision has its roots in previous works, such as the preliminary development vision for Hiedanranta made by local universities (Lehtovuori et al., 2016).

In 2018, there was an initial CE ecosystem comprising 25 operating actors (companies, associations, communities, entrepreneurs); collaboration with research and education institutes; 39 experimental research and development projects; and numerous events that annually attracted up to 40,000 visitors to the area (City of Tampere, 2018b). In short, typical of urban CE ecosystems, the collective goal was to produce sustainable urban amenities (Aarikka-Stenroos et al., 2021). Citizen activity had increased and developed diversely in the area, including many participatory elements (Laine et al., 2017; Leino & Puumala, 2021). The development in Hiedanranta shows that the vision had a quite strong catalysing power, but also required the support of technology and business catalysts and citizen activities.

(b) *Sequenced policy decisions.* Compared to ordinary urban development and the formal principles in planning and governance, the studied experimental period at Hiedanranta was quite different. The area was a free zone for actions where many formal rules had been loosened to enable attractive access to the area, interaction within and between diverse actor groups, innovation, and identity formation. The formal plans for land use only took place gradually, at the general level, and in the background. However, to support the vision, the city had to sharpen and

Table 2.2 Key catalysts along Hiedanranta urban circular developments from experimenting to implementation in the case of the urban nutrient cycle (P = Policy catalyst, T = Technology catalyst, B = Business catalyst; small letters indicate the catalytic mechanisms of each catalyst as presented in the Results section)

Components of the closed nutrient cycle	*Development of urban circularity*		
	Experimenting Years 2016–2018	**Intensification** Years 2018–2019	**Implementation** Years 2020–2040
	Stakeholders *interact* but experiments are mostly developed separately.	New *relationships* between stakeholders, experiments, and key components.	Further development towards a system of *interdependencies*.
Toilet	Source-separating dry toilets were permanently installed for 1,000 people in the Kuivaamo cultural venue.	New models of source-separating dry toilets were created; four vacuum toilets were installed in Kartano; systematic toilet testing.	New toilet solutions potentially implemented in the new residential district. Export potential of companies operating in Hiedanranta.
Catalysts →	Pabc + Tab	Pc + Tab + Bade	Pabc + Tab + Babcde
Technologies	Microthermal treatment of solid toilet waste and various treatment methods for urea were experimented to create fertilisers.	Microthermal treatment technique (DTS) was formally approved for food production; developing the old and testing new technologies for urea treatment; treatment of black water from vacuum toilets with anaerobic digestion.	Locally produced humanure products available for growing food and managing recreational green areas in Hiedanranta. Potential markets for DTS technique in Asia and Africa.
Catalysts →	Pabc + Tab	Tab + Babcde	Tab + Babcde
Local food production	Companies experimenting vertical farming and making soil improvers from biochar; collective gardening experiments by citizens and NGOs.	Companies creating innovations and international connections; diversification of collective gardening types; testing urea, humanure, zero fibre and biochar for soil improvement, fertilisation and food production.	Diverse communal and commercial food production in Hiedanranta supported by vertical farming techniques, biochar, biowaste recycling, and natural fertilisers and soil improvers. Export potential of participating companies.
Catalysts →	Pabc + Tab + Bcde	Pc + Tabcd + Babcde	Pabc + Tab + Babcde

Table 2.3 Catalytic mechanisms breaking the system barriers and creating push towards a transition state in Hiedanranta

	Origins of catalytic power		*Transitional setting*	
Key catalyst	**Mechanisms**	**Functional logics of the mechanisms**	**Principle of management sensitising to change**	**Energy barriers to be broken**
Policy	Vision Decisions Space creation	Successive mechanisms	Making urban regeneration in experimental ways	Locked-in institutional rules
Technology	Internal development Incomers Experiments Scope widening	Place-induced evolutionary mechanisms	Trialling potential functions of the place	Conventional urban developments
Business	Exchange Value creation Business model Competence Collaboration	Variational fit of necessary mechanisms	Reassembling the ideas of market actions	Linear economy

revise the policy decisions also during the experimental period. The development programme of the area was divided into three functional aspects: spatial land-use planning to create a new residential district based on a CE, Temporary Hiedanranta, and the Hiedanranta Innovation Platform.

The last aspect was crucial for CE development in the area, but also debatable:

> Some stakeholders were seeing this [Hiedanranta Innovation Platform] purely as a platform for accelerating business, some others as an area that resolves our sustainability challenges. In some way, these two views lead to quite distinct targets concerning processes, services, and actors they are employing. Then it was precisely outlined [in the meeting of Hiedanranta management group incorporating heads of city departments] that the innovation platform's main priority is to support the targets we have in planning and implementing this new urban district. This means, above all, that in the innovation platform we then promote collaborative knowledge generation by harnessing diverse expertise, and one aspect of this is that we provide space for companies in the area.
>
> (City official interview, May, 2019)

The three functional aspects of the development programme were helpful for the city because it had to make sequential policy decisions to support the vision, the principles of iterative governance and the modular ideas of urban development in the area. One of these checkpoints took place when the city shifted the name 'Temporary Hiedanranta' to 'Adaptive Hiedanranta' as a response to tensions between business-led and citizen-oriented urban sustainability (Turku et al., 2022).

(c) *Space creation.* The collaborative achievement of technological development and social innovations for urban circularity requires space for experimentation. Therefore, space creation is one of the catalytic mechanisms that can overcome barriers to circularity. In Hiedanranta, the city as the landowner was flexible in arranging space for projects, citizen groups, and companies to experiment with CE technologies and generate co-creative knowledge for sustainability. Space creation is a political act, because allowing space for certain kinds of actors and experiments, supporting tests for some solutions instead of others, and allowing certain project continuities are political choices between alternatives and between different interests among stakeholders. Space creation becomes more demanding over time when the CE solutions experimented with will be integrated into urban structures of the new district. The applied infrastructural solutions are new and space demanding in different ways, perhaps socially acceptable only by some parties, and make the city building more complicated. These challenges may be difficult to anticipate during experimentation.

Technology catalyst

Technological progress is necessary for urban circularity, particularly for transforming infrastructures to support sustainable urban development. As a former industrial area, Hiedanranta lacked most urban infrastructures but provided multifaceted physical environments for developing new kinds of infrastructures with field experiments. Several technological solutions were piloted and implemented in the area, and this was an opportunity for us to examine the contextual emergence and on-site evolution of the technology catalyst.

(a) *Internal mechanisms*. We first found that the catalytic effect depends on the general nature of technology. We use the term 'internal mechanisms' to catch the evolution in which each technology fulfils a human purpose and develops intrinsically in combinatorial ways (see Arthur, 2009). In the area, there were some innovative technologies, such as pyrolysis or vertical farming, where the technology and its future possibilities catalysed the further development and implementation of the technology on site. The combinatorial development can be seen in ways some technologies piloted in Hiedanranta were realised due to requirements generated by other technologies. For example, the use of source-separating toilets called for technologies that can be used to recover nutrients from new waste streams (e.g., source-separated urine) and that are rarely used on a large scale.

Second, we found three place-dependent mechanisms that catalysed technology particularly in the context of urban regeneration so that it fulfils the goals of the policy vision of Hiedanranta. The place-dependent mechanisms are discussed next in more detail.

(b) *Novel technologies as contingent incomers*. Since the development of Hiedanranta started, the aim of the city was to attract companies with suitable CE business ideas. The incoming companies integrated their activities with other local actors and old industrial buildings with the aim of promoting CE in the area. As a result, a unique, continuous pyrolysis plant operated in Hiedanranta since 2017 by a company whose aims matched with the city's plans for decentralised energy production. The pyrolysis plant produced carbon-neutral district heat since 2018, as well as biochar. Thus, while the technology acted as a catalyst to achieve renewable energy production with simultaneous production of biochar to be used locally (e.g., in organic food production), it crucially gained its catalytic power via the place properties. Another company started hydroponic vertical farming for strawberry cultivation in the area. The vertical farming promoted CE as it enabled the local year-round production of food as a part of urban agriculture by utilising LED lamps as the source of light. The first strawberries in the area were harvested in 2018. Both the biochar company and the strawberry company actively developed their own operations within the city's aim towards a CE, which supported the companies in expanding their operations elsewhere. It can be seen that the technology catalyst is formed by both contingent incomers and coevolution.

(c) *Technologies emerging from core experiments*. Source-separating toilets as a part of the sanitation infrastructure were created in Hiedanranta; this technological advancement has been described as "*one the most exciting developments in the area of wastewater treatment*" (Larsen et al., 2013, p. xxxi). It responds to urban nutrient wastage. Urine contains approximately 50% phosphorous, 80% nitrogen, and 90% of potassium present in municipal wastewaters in a small volume of 1–1.5 L per person per day (Chang et al., 2013), compared to 150–250 L of wastewater led to the municipal wastewater treatment plant per person per day. Thus, local nutrient recovery from urine provides an interesting opportunity, but it requires the development of novel technologies.

In Hiedanranta, the implementation of source-separating toilets was catalysed by the city's aim for closed water management cycles, and it further stimulated the piloting of other technologies on site, enabling nutrient recovery from source-separated urine or from the solid stream. Cultivation of microalgae in source-separated urine enables the algal cells to capture nutrients inside their cells, enabling nutrient recovery as a form of microalgal biomass. The cultivation of microalgae was piloted in 2017–2018 in a 2 m^3 raceway pond situated in a greenhouse in Hiedanranta (e.g., Chatterjee et al., 2019). Microthermal treatment of solid materials from the source-separating toilets were piloted since 2016–2017. The end material from the compost unit contains most of the nutrients present in the raw material. The plan to build a city district with specified CE targets has thus catalysed the experimentation with new technologies in ways that are compatible with place properties.

(d) *Technologies widening the scope of CE.* Hiedanranta is located on an old pulp mill site. The wastewaters from the pulp mill were piped to the nearby Lake Näsijärvi for decades, which resulted in the accumulation of circa 1.5 million m^3 of sedimented fibres in the closest bay. Similar areas around the world are often left untreated if there are no identified risks of environmental contamination. To improve the use of the bay area as a recreational area, the city of Tampere started to investigate the possibility of removing and treating the sedimented fibres. Three technologies were piloted for the treatment of sedimented fibres. One of these technologies was biogas process, where the fibres were biologically converted into biogas. This technology was first tested in a laboratory scale (Chatterjee et al., 2018; Kokko et al., 2018) and later piloted in Hiedanranta; this could enable decentralised energy production. In this case, a well-known technology was adapted for a new purpose. Biological conversion of the sedimented fibres into valuable chemicals with novel technological solutions and composting of the sedimented fibres were also piloted. In the pilots, the fibres as the most problematic persistent properties of the Hiedanranta brownfield made place an important constituent of technological development.

Business catalyst

When examining business aspects and commercial feasibility of circular solutions in circular development of Hiedanranta, we identified five major mechanisms of business catalyst. By 'business catalyst' we mean diverse business mechanisms that support commercial and business feasibility of CE transition and thus support diverse stakeholders' efforts to realise the desired CE shift (see Aarikka-Stenroos & Ranta, 2019). From the Hiedanranta case and among its diverse actors and stakeholders comprising of diverse businesses (e.g., dry toilet company, vertical farming, biochar production) and public actors (e.g., Tampere city), we identified the following catalytic mechanisms.

(a) Exchange mechanisms facilitate economic transactions and change between the customers and the solution providers. They were applied by employing pilots and experiments that enabled

risk-reducing trials of technology in the actual use context. For example, regarding source-separated sanitation and zero fibre processing, the city of Tampere enabled companies to experiment with their CE technology businesses in the Hiedanranta area. Such user and customer experiences can be developed into customer references for CE innovations and solutions to nurture further sales of solutions providers and they also serve risk-reducing customer testimonials for further potential public and private customers who seek similar solutions.

(b) Value creation mechanisms are formed around factors that enable and particularly enhance value creation between the solution provider and the customer; they boost value or extend what is perceived as valuable. In Hiedanranta, particularly stakeholder and customer involvement in the innovation process from technology development to commercialisation were applied to gather user experiences (e.g., from toilets). User experiences by the end customers were gathered and analysed to improve the customer experience of using circular solutions, and this feedback was then used to improve the value of such solutions. For example, the customer-citizens who visited different events in Hiedanranta provided valuable feedback that enables both developing the dry toilet tech solutions and the concept further, to make it more convenient to use and maintain, and thus creating more value for the involved stakeholders from the circular solution.

(c) Business model mechanisms refers to conventional business model elements, namely value propositions, value delivery, and value capture. This means that companies and city and other stakeholders can identify and propose attractive circular solutions (see Ranta et al., 2020), deliver them with their supply chain partners (Aarikka-Stenroos et al., 2022), and capture economic value to make the use and implementation profitable. In Hiedanranta, examples of identified business model mechanisms included the biochar company's attractive value proposal, as it provided not only a sustainable, circular product but also its production and value delivery were sustainable. Thereby its circular value proposition and value delivery also supported Tampere city's and Hiedanranta area's "business model" as those industrial companies' were in the Hiedanranta area. The business models manifested and actualised sustainability and CE, therefore supporting also the city's and the area's value proposition on novel urban district that was sustainable and circular, thereby increasing its value and attractiveness.

(d) Competence mechanisms are competencies that enable public and private organisations (both the city and companies) to design businesses, scale them up and grow, and strategize. Important catalysing competencies were to sense, identify, and articulate economic and environmental customer values of the CE solutions and thus induce and increase sales. These were applied, for example, as the Hiedanranta area was branded as a CE district by the city, and many activities were promoted successfully to increase the attractiveness and awareness of the area in the eyes of multiple stakeholders like citizen-inhabitants, businesses, and public actors.

(e) Collaboration mechanisms refer to factors and activities relating to how firms, cities, and other stakeholders in the business networks and ecosystems organise and reorganise to enable the circular loops or reduction of resources in a profitable or otherwise value-creating way (Tapaninaho & Heikkinen, 2022). This catalytic mechanism is manifested in Hiedanranta through many means; there has been considerable collaboration between small start-ups and the city. This collaboration has enabled small start-ups to test their technology businesses in the facilities owned by the city (linking collaboration mechanisms to exchange and value creation mechanisms) and the city itself to benefit from novel CE technologies at the Hiedanranta Kuivaamo venue (see Engez et al., 2021b). Furthermore, collaboration mechanisms enabled the city to build alliances, networks, and joint projects with companies, expert organisations, universities, and other stakeholders; such networking capability is often needed for the implementation of a circular business

model (see Aarikka-Stenroos et al., 2022). These collaboration projects served, for example, knowledge-sharing platforms that allowed the city of Tampere and Hiedanranta to process their initial experiences, including lessons learned with other large cities in Finland, and thus advance CEs via public–private interactions.

System changing dynamics of the catalysts

The three key catalysts analysed previously – policy, technology, and business – were decisive in turning the development of Hiedanranta towards urban circularity. The analogy model helped us to find and specify the catalytic mechanisms that created the transitional impulse. We summarise these findings by demonstrating why the four conceptually formulated analogies between chemistry and sustainability transition were empirically relevant to increase our understanding of the transitional process in this specific case. For this purpose, we utilise the case study findings comprehensively. We also illustrate the results by focusing on the closing of the urban nutrient cycle (Table 2.2), which was one of the main CE goals of Hiedanranta during the studied period. Next, we address each analogy in turn.

Catalysts are selective and complementary

The key catalysts in Hiedanranta were selective as they induced individual pressure towards a transitional change of the system. At the same time, the catalysts complemented each other, which was the necessary condition for a CE transition in Hiedanranta. Table 2.2 illustrates that during this complementary process, the key catalysts interacted and had a cumulative effect on the transition. The catalytic mechanisms had a double role in this process: they supported selectivity by serving as a specific source of energy for individual catalysts but also complementarity by creating a boundary surface for the interplay between the catalysts. Table 2.2 shows that usually at least two catalysts contributed to a key component of the urban nutrient cycle, and each catalyst had several participating mechanisms, which increase the probability of the interaction. Thus, these mechanisms were prone to support the interplay, but this took place only in particular situations. To summarise, the key catalysts were both selective and complementary at the same time, and these dynamics were dependent on specific mechanisms of each catalyst.

Catalysts increase the interaction of a system's entities towards a transition state

Through the mechanisms and interplay described previously, the key catalysts made the system's entities move and interact in oriented ways. The entities include human actors, institutions, material and intelligence resources, technical devices, and other system components participating in the constant reorganisation resulting from the catalysing effects. The number and variance of the entities and variance between them were high enough for self-organising processes after catalytic impulses. The mechanisms of catalysts gave iterative, partly contingent direction to these processes so that the main orientation of the system was towards a transition state. We call the emergence of a transition state as a result of *synchronisation* of the key catalysts. The analogy between chemistry and sustainability transition is based on dynamic similarities and applies despite the difference that a transition state in chemistry is instantaneous and very short, whereas in Hiedanranta, the transition state will take years, and possibly remains still partly open-ended. Its emergence is important for the next processes because it uncovers the potential for multiple sustainability paths (Turku et al., 2022, 2023).

Catalytic pathways occur in a stepwise manner and overcome energy barriers

The catalyst accelerates the reaction by reducing the required activation energy, and this takes place via a stepwise pathway. The catalyst enables a pathway where the energy demand is lower and thereby the catalyst speeds up the reaction. Our results underpin this analogy by showing that stepwise catalytic mechanisms promoted the transitional process in Hiedanranta. The steps could be perceived, for instance, as events, emerging situations, and change of rhythms. As presented in Table 2.3, each key catalyst pushed the process. First, through its single mechanisms that were essentially place-dependent; these catalyst-specific mechanisms complemented each other when giving activation energy and directionality of the process. Second, as the mechanisms worked as groupings that followed catalyst-specific functional logics and various dynamics, they gave distinct impulses for the process. Accordingly, the policy catalyst provided activation energy through sequential mechanisms that were intrinsically successive starting from the vision, but also shifting order could be recognised; the technology catalyst operated through place-induced evolutionary mechanisms that were both internally and spatially stepwise; and the business catalyst proceeded through a variational fit of necessary mechanisms that became successive at least when the change of business model required a specific order of the other mechanisms.

The functionality, directionality, and sequential order of mechanisms made the policy, technology, and business catalytic by increasing the kinetics of entities in the system. In addition, the mechanisms increased the mutual interaction and the cumulative effect of the catalysts (as described by Analogy 1), and this interaction pushed the whole transitional process into pathways with lower energy demands avoiding barriers. The progress of the whole transitional process was stepwise from experimenting to intensification to implementation because the catalysts took different complementary turns at each stage. A simultaneous part of this same process, and necessary for synchronisation, was that the mechanisms created coincident combinations across catalysts (Table 2.2). While the key catalysts of policy, technology, and business were parallel, interacting, and mutually reinforcing, they also conditioned each other in rejective ways. All these dynamic features of the transitional process break down the simplified image of linear order, in which policy creates a safety space for experimentation and innovation, technology brings content and form to renovations, and business makes them marketable.

When the key catalysts turned to reinforce each other, they sometimes accelerated change very tangibly. Digi Toilet Systems Oy (DTS) was a company established for experiments in Hiedanranta, and it finally succeeded in creating a usable product from humanure (human faecal material and urine recycled for agricultural purposes via treatment techniques). In 2019, the product gained formal approval from the Finnish Food Authority, a national regulatory body of the Finnish food chain, and now the product can be used as a fertiliser in growing food. This new technology bridges one of the gaps in the urban nutrient cycle.

Catalytic processes are highly contextual

The place-dependence characterised both the selectivity and complementarity of the key catalysts in Hiedanranta. As presented in Table 2.3, the mechanisms and how they grouped together made the place an integral part of the transitional process. The policy catalyst gained its power from successive mechanisms enabling the circumstances for a transition in this particular place; the technology catalyst from place-induced evolutionary mechanisms (meaning that the place is mediated into internal mechanisms of technological development by other mechanisms), and the business catalyst from the variational fit of necessary mechanisms that made the business to accelerate the transition in place-typical ways.

Discussion

In the first part of our research, we used detailed knowledge of chemical catalysis to formulate an analogy model for the examination of forces accelerating sustainability transitions. This pre-examination provided four potential analogies to be empirically demonstrated in a case study analysis of urban generation focusing on a district-level CE transition. The case study confirmed that the dynamic similarities we found between chemical catalysis and sustainability transition are empirically relevant and the analogy model provides new knowledge of the central problems of urban circularity and urban sustainability transitions. For the factual validity, the studied catalysts of policy, technology, and business fulfilled the basic definition of catalyst in chemistry and allowed an empirical analysis of mechanisms through which they initiate and accelerate a transition process. The results suggest that the dynamic similarities between chemical catalysis and sustainability transition can be a fruitful starting point to develop an analogy-based catalyst approach for sustainability research.

The empirical results produced new perspectives to understand the dynamics of urban CE transitions. We summarise the findings as follows: 1) policy, technology, and business are the key catalysts of urban CE transition and their *synchronisation* leads to the emergence of a transition state, 2) synchronisation requires that the key catalysts increase their processual power and mutual interaction through *stepwise catalytic pathways*, increasing the interaction among the system's entities and the directionality of the transition process, but 3) the initial roots of the catalytic force are *place-dependent mechanisms* that actualise the intrinsic but often hidden catalytic potential of the key catalysts (see the section 'The roles of policy, technology, and business in urban circular change') by making them accelerative in a particular context when the circumstances are favourable.

The previously mentioned dynamic terms can generate new conceptual ideas for further studies. Synchronisation is the precondition of the opening of a new phase in system development, transition state, in which several possible sustainability paths become available. The examination of these choices and probabilities of their realisation is important for the future development of urban regeneration, as we have done elsewhere (Engez et al., 2021b; Turku et al., 2022, 2023). Stepwise catalytic pathways refer to events and situations in which catalyst-specific mechanisms function in ways that overcome the energy barriers of the system and thus promote the systemic change (Table 2.3). As these events and situations take place between the intentional actions of human stakeholders and the self-organising system development, they can help transition management to identify critical points and catalytic chains for a change (Tozer et al., 2022). Finally, place-dependent mechanisms are crucial as they challenge the idea that place or land can be stabilised as circumstances where a transition takes place. Rather, when a catalyst reaches its functionality through place, it 'captures' the place for its functional property, as it were. Consequently, when place becomes a constituent of catalytic force, it means that any activity in policy, technology and business is simultaneously placemaking (Ghavampour & Vale, 2019), as well. This finding emphasises place-based conditions of transitions (Peris-Blanes et al., 2022) and suggests that placemaking can be a fruitful analytic lens to study urban CE transition in relation to other ideas of urban sustainability.

The analogy model allows various systems approaches to be adopted in research of sustainability transitions. Since the real-life systems are complex and dominated by nonlinearities, it would be relevant to include system parameters in the analysis, because shifts between variables and parameters are common during transitional processes (Haila & Dyke, 2006). For instance, the city-owned land in Hiedanranta can turn into a spontaneous catalyst or inhibitor and thereby radically change the system dynamics. Several tensions, including ‘zero fibre problem’, the limited urban space for CE solutions, potential land speculation in urban regeneration, and the dashed hopes of civic groups are creating pressures on land use since our intensive case study period.

We argue that the analogy model developed in this chapter has original value in sustainability research, including research focusing on urban CE transitions. We could illustrate only some aspects of its potential value in this chapter. The analogy model highlights the significance of catalysts in the acceleration of sustainability transitions, gives analytical depth to a catalyst approach, and can lead to novel conceptual insights in research. It also differs from two other models, the ULL and the urban CE ecosystems, that are used to study urban systems under sustainability transitions. An important point is that an analogy model works only situationally. Numerous other case studies with different ideas could be done by utilising the four-part analogy we developed in this chapter. How the analogies work and whether they provide fruitful results depends on the case. Taking this precondition into account, it may be possible to develop the analogy model as a methodological tool for a catalyst-based research approach. As presented by Ketokivi et al. (2017), this requires the accumulation of empirical evidence, critical evaluation of the results from internal and external perspectives, and a frequent emphasis on the model’s empirical adequacy, factual validity, and structural soundness.

Conclusions

The analogy model developed in this chapter to support the catalyst approach in sustainability research utilises the detailed knowledge of catalysis in chemistry. The empirical demonstration of the model in the context of urban CE gave positive results for its potential in the research exploring the possibilities to accelerate sustainability transitions. The chapter encourages researchers to develop the methodological basis of catalyst-based approaches in sustainability research. The findings confirm the view that it would be difficult to understand sustainability transitions without understanding the catalytic force that makes the system change towards a transition state. Vice versa, it would be difficult to uncover how catalysts work without an empirical examination of their contextual functioning in real-life systems. The chapter presents the claim that catalytic mechanisms do not refer to mechanical features of catalysts but dynamically developing contextual properties that make them catalytic. Like in chemistry, while catalysts may have intrinsic catalytic potential, only suitable circumstances can actualise this potential to support the contextual acceleration of a sustainability transition.

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Educational content

Urban sustainability transitions are diverse and are based on interconnected changes and shifting temporal scales. Due to complexity, several research approaches are needed to study them.

Analogy models can be used to study complicated research objects. In this chapter, the dynamic features of chemical catalysis were used to build an analogy model to study urban sustainability transitions and the catalysts accelerating them.

Policy, technology, and business were selected as key catalysts for empirical examination to study the emergence of urban circularities. This choice demonstrates the fact that analogy models are always unique, and they can be constructed for specified research purposes. In the studied case, the basic structure of the analogy model can be further developed by gathering more empirical evidence of its relevance and adequacy in sustainability research.

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3

RECREATING THE CONSTRUCTION SECTOR FOR CIRCULARITY

Catalysing the reuse of prefabricated concrete elements

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Introduction

This conceptual chapter discusses how the construction industry can transform itself into a circular and low-carbon sector. The construction sector is presently one of the largest waste-generating industries (O'Grady et al., 2021; Pomponi & Moncaster, 2017; Solis-Guzman et al., 2009) and producer of CO_2 emissions (Chen et al., 2022), and one of the largest consumers of raw materials and energy (UNEP, 2019). Even though it has been noted that the construction sector has a high potential for the use of circular economy (CE) principles and to create value by exploiting them (Smol et al., 2015), it is still at an early stage in the transition to CE (Hossain & Ng, 2018). The sector's impacts are not limited simply to construction activities but include upstream industries (raw material extraction and construction material manufacture) as well as downstream industries (the real estate and housing sectors). Therefore, transitioning the construction sector towards climate neutrality and circularity is focal for any society striving to transform its trade and industry so that the inflicted burdens do not exceed the planetary bearing capacity.

Moreover, this chapter investigates how circularity on a high level, that is to say the reuse principle, can be catalysed in the sector. In CE, solutions are favoured that preserve already extracted material resources in use, thus avoiding further extraction and waste generation. This can take place either through continued use or through the reuse or recycling of obsolete products. In Europe, the European Union (EU) has authorised a waste hierarchy stipulating that continued use should be prioritised over reuse, and reuse over recycling (European Union, 2008). Reuse is considered to create more value, since existing products and components are retained and put into new use via factory-refurbishment, remanufacturing, or redistribution; whereas in recycling, the product/component is reprocessed into a secondary material (den Hollander et al., 2017; Bocken et al., 2016; Lüdeke-Freund et al., 2019). However, in the construction sector, only a marginal proportion of construction and demolition waste (CDW) materials is presently directed at reuse as

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construction products in their original function (e.g., reusing a window as a window). Recycling remains the sector's business-as-usual modus operandi, and often results in downcycling, meaning that the recycled material will not be applied in structures and purposes equally demanding to those that the secondary material came from.

This chapter specifically examines the reuse of precast concrete elements. Most construction is made out of concrete globally, and consequently, concrete also dominates emissions of building materials and CDW generation. Concrete structures can be either cast in situ or precast in a factory and assembled on the site. As opposed to in situ casting, the prefabrication of elements results in components more favourable to reuse, even if most precast elements have not been specifically designed for disassembly. In Europe as well as in many other contexts, precasting in factories has been employed since the 1940s (Alonso & Palmarola, 2019). Consequently, countries have accumulated significant building stocks with panels and other prefabricated elements with the unlocked potential for reuse.

The purpose of this chapter is to present how, in the construction sector, the CE transition can take place by the increased adoption of the reuse principle, particularly the reuse of concrete elements in new buildings (Figure 3.1). Methodologically, this chapter is a conceptual one. Its insights are theoretical and originate from the planning of the Horizon 2020 project ReCreate, short for 'Reusing prefabricated concrete for a circular economy', which runs from 2021 to 2025. The aim of the project is to facilitate the deployment of the deconstruction and reuse of concrete elements as technologically and economically viable industrial processes. The focus is on elements that have not originally been designed for deconstruction. Therefore, this chapter discusses how the learnings acquired in planning and executing the ReCreate pilot projects in four European

Figure 3.1 Concrete elements deconstructed from the buildings behind them (left). Location: Finland. A new building made from deconstructed elements (right). Location: Germany. Photos: SH.

countries – work in progress at the time of writing – can help the construction sector to transition from a linear to a circular economy beyond the pilots themselves as well as beyond the borders of the project countries. The project and its approach are multi-, inter-, and transdisciplinary, covering not only construction and the related disciplines of architecture and civil engineering, but also the domains of demolition, materials science, environmental impact assessment, economics, the sociology of work, and regulation and public policy. This approach also allows the display and discussion of diverse technological, economical, and societal aspects that can catalyse the transition to a more circular modus operandi in the construction sector. Consequently, this chapter draws from various disciplinary vocabularies pertaining to the diverse disciplinary fields while still being positioned primarily within the construction sector research.

This chapter considers CE catalysts as factors enabling the implementation of the reuse to advance circularity and CE principles in the construction sector. The definition follows that of Cabell and Valsiner (2011), proposing that catalysts are positive 'helpers' that initiate and facilitate change processes. Focal catalysts encompass feasible deconstruction technologies and work processes, robust protocols for verifying the deconstructed elements' properties and quality, remanufacturing processes turning the elements into ready-for-reuse construction products, and regulation that acknowledges their recertification. It is also noted that key persons in stakeholder organisations, willing and positioned to ease this transition, can be considered catalysts in their own right. Moreover, it is considered that an extractable urban mine of a sufficient volume and a functional circular value chain, consisting of separate but connected operators, are also crucial for realising the upscaling potential of reuse. In brief, a wide variety of interlinked catalysts are required to operate simultaneously to facilitate a transition to circularity.

Background

Catalysing a technological transition

The ReCreate approach is inspired by Frank Geels's (2002) theory on technological transitions, which builds upon technology studies and evolutionary economics. Geels conceptualises technological transitions within the context of a multi-level perspective, consisting of a nested hierarchy of a socio-technical landscape, socio-technical regimes, and technological niches. Here, the landscape means a slowly changing context formed by a multitude of wider factors external to technology, such as (geo-)political, cultural, environmental, and economic structures and values. Regimes stand for the integrated configurations of routines, practices, and rules of individuals and organisations, pertaining to both engineers and other involved social groups, such as financers, regulators, and users of products, etc. The intertwined web of actors, products, and rules in these regimes create a kind of stability that constrains innovation on path-dependent trajectories, making any innovation incremental at best. Niches, on the other hand, are environments sufficiently protected from normal market mechanisms that can give birth to radically different innovations, which characteristically are expensive, low-performing, and unwieldy at first. They provide room for learning and building necessary social networks to support the innovations, such as value chains (Geels, 2002).

Niches are embedded in regimes and regimes in landscapes, meaning that novel technologies are developed in the context of the knowledge and capabilities arising from the existing framework. Often niches emerge from landscape developments to address problems within prevailing regimes. Geels suggests how radical innovation can break out of a niche into an existing regime via gradual niche cumulation, that is, by conquering one market or domain after another. For a breakthrough to successfully happen though, simultaneous developments in the regime and landscape are needed that reinforce the process. The landscape level, for one, may transform in a way that also pressures a regime to change. Tensions, such as differences of opinion, within a regime may weaken the regime's stability. In this way, windows of opportunity can open for new technologies to establish themselves within a regime. Mechanisms for this include technological add-on or hybridisation, where new technologies pair up with old technologies to form a symbiosis rather than present a direct challenge. Alternatively, new technologies can ride along the growth of specific markets in which the new technology is for contextual reasons a better solution than the existing one. Eventually, such changes can cascade and over time lead to an old regime reconfiguring into a new one in all of its dimensions (technologies, value chains, policies, markets, users, etc.) (Geels, 2002).

Catalysing circularity and the move from recycling to reuse in the construction sector

How then has the construction sector so far shifted towards more circular operations? The sector is very material intensive (Zimmann et al., 2016), so substantial material streams are both produced and consumed, and it also results in several side streams and waste generation. Therefore, the CE and more circular, resource-efficient operations implementing CE principles have been suggested for solving many of the sector's environmental problems (Hossain & Ng, 2018; Pomponi & Moncaster, 2017; Reike et al., 2018). However, the CE implementation in the construction sector is following the same biased patterns seen in society. Out of the hierarchical principles of CE – the so-called R imperatives 'Reduce, Reuse, Recycle' – the lowest-level option, recycling, dominates (see also Ghisellini et al., 2016; Ranta et al., 2018). It is often most easily applicable to the operators' own activities. This can also be seen to support Geels's (2002) argument about path dependency.

By harnessing the reuse principle in the construction sector and by reusing building components, it would be possible to achieve major environmental benefits (Zabek et al., 2017), such as lower CO_2 emissions (Çimen, 2021), but also create economic value (Hopkinson et al., 2019; Stahel, 2016). However, component reuse is a radical niche innovation, and as such it faces resistance from the construction sector regime. Component reuse triggers diverse technical, business, and societal challenges, such as rising costs, low market demand, and the need to develop reuse technologies (Densley Tingley et al., 2017; Hopkinson et al., 2019).

The literature has suggested diverse catalysing factors that could advance the implementation and adoption of the reuse approach in the construction sector. These factors range from the technical to the more societal: Densley Tingley et al. (2017) propose that digital solutions could be used to store and retrieve information from surrounding suppliers and reusable materials; market demand should be initiated, and training and guidance on material reuse should be provided as well as governmental influence could provide support. Also, many technological aspects, such as dismantling methods (Hopkinson et al., 2019) and tools for reusability analysis for different parts of the building (Akanbi et al. 2018), need further development to facilitate reuse in the construction processes. Solutions are also needed for transportation of the secondary products and materials (Gallego-Schmid et al., 2020). In addition to technical and economic factors, societal factors are crucial in advancing reuse in the construction sector, because stakeholders' perceptions of the risks of material reuse shape the reuse of building components (Rakhshan et al., 2020). It appears that currently, the implementation of reuse projects has depended on the vision of a few individuals in key positions in their organisations (Huuhka et al., 2019).

The ReCreate concept

Geels (2002) documented how technological transitions may occur with the use of a historical case study of the transition from sail ships to steam ships. His theory on technological transitions is used to explain how the ReCreate project approached catalysing future technological transitions. The ReCreate concept (Figure 3.2) is based on a multi-, inter-, and transdisciplinary approach focused on the collective problem-solving around real-life pilots, both for deconstruction and for reuse of deconstructed components. The 2021–2025 project takes place in four EU countries – Finland, Sweden, the Netherlands, and Germany – where at least some prior experience of precast concrete component reuse exists, and the project covers different building and element types, including residential, commercial, and industrial buildings and from panels and slabs to columns and beams. The pilots are deployed as a focal means to research and develop deconstruction and reuse in an operational environment to identify and work with key issues and to provide solutions, such as catalysts.

The approach is premised on the idea that the acts and business of construction are at their core human activities, even though technology is the foundation for human actions. Reuse in construction requires viable technologies enabling deconstruction, quality inspection and assurance, remanufacturing/factory refurbishment, efficient logistics, and redesign and reassembly. Nevertheless, we believe that for a wider deployment of reuse, it is important to tackle aspects pertaining to work, regulation, and business processes, such as acquiring new skills, having regulation that recognises and justifies (and even supports) reuse, and understanding the business determinants, and this will be even more important in the long run. In Geels's (2002) terms, the

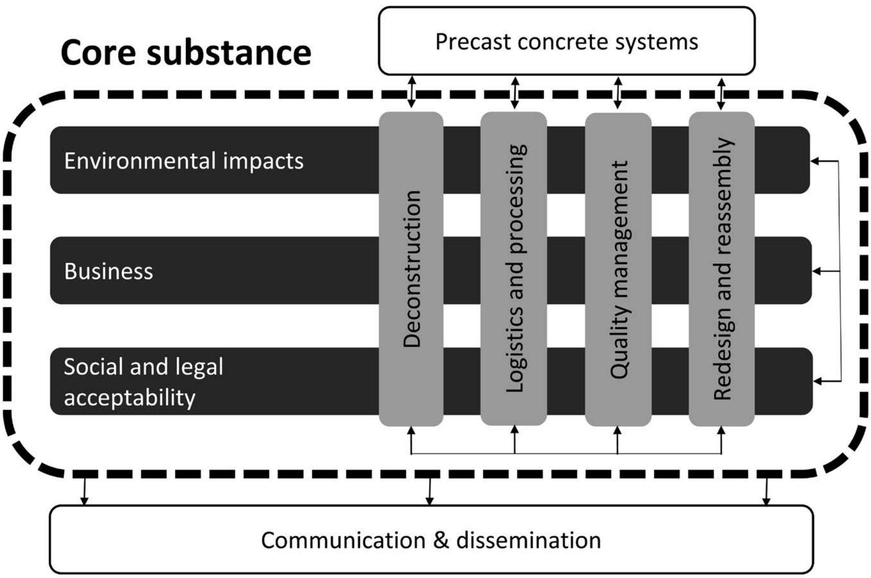

Figure 3.2 ReCreate's view on disciplinary expertise and the competences needed to transition the construction sector towards reuse. Socioeconomic perspectives (black horizontal) cross-cut technical perspectives (grey vertical). Existing knowledge on precast systems (white, top) feeds the research, but also draws from it when it comes to evaluating the business potential at large. The core substance – studied with the help of real-life pilot projects – is drawn also from for knowledge sharing (white, bottom).

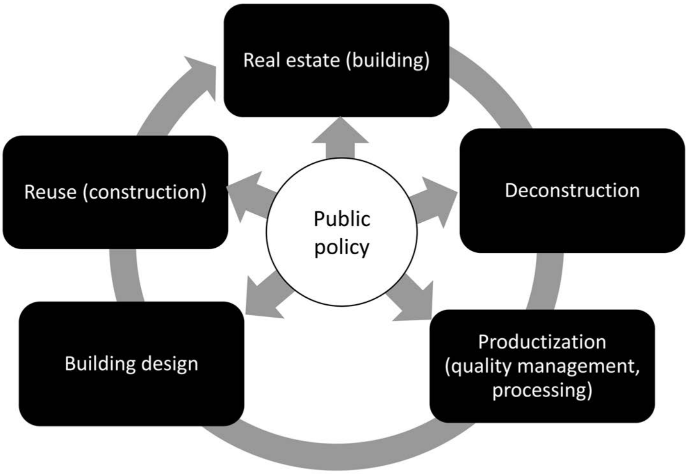

Figure 3.3 The circular value chain of reuse from (donor) building to (new) building.

former can be understood as developments within the niche, while the latter denote construction sector regime changes.

Thus, the next two sections of this chapter will cover both of these aspects. First, the section 'Catalysing the pilot projects' reflects how these pilots can be materialised and what kind of technological, process operational, and other considerations may come into play in the required technical activities of deconstruction planning, deconstruction, quality inspection, factory refurbishment, information management, building design, and reuse in a new building. Second, the section 'Catalysing wider adoption' discusses more societal factors focal for the upscaling of the novel reuse-enabling technical processes developed in the pilots in the wider construction industry. These factors include numerous socioeconomic factors, such as 1) learning novel work processes and skills throughout and at all levels of the value chain (Figure 3.3), 2) the acknowledgment of reuse in regulation, standards, and tendering, 3) business potentials and value creation and capture mechanisms in deconstruction and reuse, and 4) surveying the potential for reuse in building stocks. The next section discusses the role of landscape developments and their pressures on the construction sector regime in creating a window of opportunity for the reuse niche and the ReCreate project to emerge in the first place. In the concluding chapter, these factors are discussed as catalysts of different types and reflected on in more detail against Geels's (2002) theory of technological transitions.

Landscape developments and regime changes that catalysed ReCreate

The groundings for implementing the reuse principle in modern construction have long existed. The niche of deconstruction and the reuse of concrete elements has existed since at least the early 1980s, when the concept emerged nearly simultaneously in Sweden and the Netherlands (Huuhka et al., 2019). Deconstruction and reuse have been studied in Germany since the early 1990s, through the 'Stadtumbau Ost' urban renewal programme. The 2000s were a particularly active decade with several implemented deconstruction and reuse pilot projects. This created some sort of potential for a niche breakthrough in the German market, which did not occur. Activities in

Germany largely wound down by the late 2000s, but research in Finland kicked off at around the same time. In Finland, the first – and so far the only – Finnish pilot was constructed by 2010. As in Germany, its construction was connected to a mass housing renewal programme, but the focus was not yet on sustainable construction or CE.

The 2010s were not particularly active in terms of building deconstruction and reuse research, but towards the end of the decade, a substantial change in the socio-technical landscape became noticeable. In the EU, climate change and other impending global environmental crises came to the awareness of policymakers and the general public, giving rise to calls for low-carbon, carbon neutral, and circular industries. These calls were reflected in the European construction sector, which during the 2000s focused almost exclusively on the operational energy efficiency of new buildings. Towards the end of the 2010s, the industry became aware of the emissions 'embodied' in building products (i.e., emissions occurring in their raw material extraction and production), too (cf. Röck et al., 2020).

Presently, the pressure from the socio-technical landscape is changing the construction sector regime; new regulation, which requires lower-carbon and more circular construction is being put into place in the EU. We discuss these regulations shortly, but now point out that pioneering companies in the sector are establishing sustainability policies and programmes of their own, which reflects the linkages within the construction sector regime, even appoints towards a transition. The commitment to these sustainability policies is encouraging individuals in key company positions to become more open to change and to partner with research bodies to introduce radical innovation, such as deconstruction and reuse. With public funding, niche environments as projects can be created; these projects are protected from normal market mechanisms. It is here that the companies of the deconstruction-reuse value chain can establish relationships and obtain knowledge that is essential for scaling up from a niche. One example of such public financing is the EU innovation funding for ReCreate,

Catalysing the real-life pilots via technology (and process) development

Deconstruction planning and practical deconstruction

Donor building

The process aiming at reuse begins with identifying a so-called donor building, made from precast concrete elements and scheduled for demolition. From this donor building, elements can be deconstructed. Once a donor building is available, its analysis starts with a pre-deconstruction audit, under development in ReCreate, which differs from a conventional pre-demolition audit (European Commission, 2016) by having a specific focus on the reusable components and their extraction while still fulfilling the pre-demolition audit's requirements for waste management purposes. The pre-deconstruction audit is usable not only in identifying the potentially reusable elements of the donor building, but also in identifying the different potentials of structures and in directing them towards the highest-quality end-of-life alternatives. Elements or structures not deemed reusable can still provide high-quality mineral and other non-mineral secondary raw materials for recycling.

Pre-deconstruction audit

The pre-deconstruction audit can include an assessment of the available construction drawings and documents, a visual inspection of the building, on-site verification that the available documentation matches what was built, and a review of the connections between the elements based on the legacy drawings. An inventory of the numbers and types of distinctive elements must be made, either as a list or as an 'inventory model' in a Building Information Modelling (BIM) programme. When a BIM model is used, it can be populated with information gathered throughout the assessment process, as we will explain in more detail later. The audit may also want to examine how secondary fit-out materials are connected to the elements. Inspections to detect possible harmful substances and to survey the physical condition of the elements, as well as their material and structural properties, are vital parts of the pre-deconstruction audit (see the next section). In the case of missing or nonexistent construction drawings, the inventory can be complemented by digital building scanning methods, such as laser scanning or photogrammetry for the entire building, and by performing digital rebar scanning to detect the reinforcement layout of individual elements.

Deconstruction planning

Based on the inventory and an analysis of the building, structural and practical deconstruction plans will be made. The structural deconstruction plan addresses the order and sequencing of deconstruction, including (1) specific locations of cuts and drill holes to be made, (2) the type, number, and capacity of necessary lifting anchors, (3) measures needed to ensure the structural stability of the building frame, and (4) labelling the individual elements with unique identifiers to ensure full traceability of the elements once they leave the building. The practical work plan must state multiple factors: (1) the recommended and alternative methods of harvesting and handling the elements, including the equipment involved in the cutting, sawing, drilling, jacking, pulling, hoisting, and so forth, (2) the measures to ensure the health and safety of workers during each stage of the deconstruction, and (3) site logistics, such as the storage of elements on site, timing of the deconstruction and transportation, and the weather protection measures of the donor building and elements. In addition, the practical work plan must state the correct attachment of the physical tracing tags (see the section on information management), the unique identifier labels, to the elements; once the labels are attached, they must remain in place until the reuse process is completed. The execution of the deconstruction may include some on-site testing to see whether the planned deconstruction methods and handling work are as expected. If necessary, the deconstruction work plan can be revised.

Ensuring the health and safety of salvaged components

Quality management process

In new construction, there are established quality management practices for all building components and products. In the case of the reuse of deconstructed building components, the quality management process must be created. The quality management and authorisation process proposed in ReCreate consists of several steps (Figure 3.4). This process covers the whole value chain, starting from the pre-deconstruction audit (see the previous section), to condition investigation

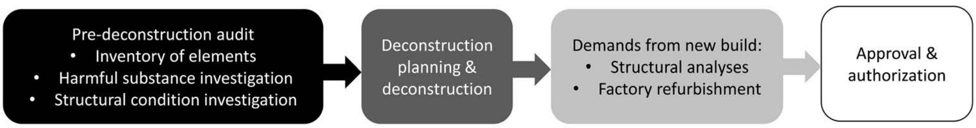

Figure 3.4 Quality control and authorisation process.

and deconstruction, to factory refurbishment/modification, testing, and reassembly (reuse). All the phases must be well-documented to ensure the quality of the reused building components.

While in use, construction materials and structures can deteriorate in several ways: they can be exposed to the outdoor climate, overloading, or harmful substances, such as asbestos. Damage to the components can also occur during deconstruction, transportation, storage, or reassembly. The possible presence and impact of deterioration and harmful substances can limit or prevent reuse and must therefore be determined before informed decisions about the deconstruction and reuse of building components can be made. This information will be acquired through a harmful substance investigation and a structural condition investigation. As much of the assessment and testing as possible should be performed before the deconstruction to avoid deconstructing components that have no residual value left. These investigations are considered an essential part of the pre-deconstruction audit.

Harmful substance survey

A harmful substance survey conducted according to standardised procedures (e.g., found in RT 18-103501, which communicates the industry best practice in Finland) will help identify the presence and amounts of polychlorinated biphenyls (PCBs), asbestos, absorbed hydrocarbons, lead traces from panel seam sealants, mould in the insulation, etc. The survey starts with tabulated information, given that the products used in the building can be identified and are well-known (e.g., certain asbestos-containing flooring and insulation products). Unknown materials and hygrothermally suboptimal structures prone to mould growth must be sampled and studied in an accredited laboratory. A risk assessment reviewing past functions of the building helps to identify potential contamination from the building's use, such as the risk of hydrocarbons leaked from machinery and absorbed into concrete during industrial use and is an aid in determining the locations and numbers of samples for laboratory testing. A similar procedure applies to mould growth–prone structures.

Structural condition investigation

A structural condition investigation, following current best practices (Lahdensivu et al., 2019), will help to identify the presence of weather or use-induced deterioration, and aids in the tracing of mechanisms behind deterioration. Typical deterioration of concrete structures includes carbonation-induced corrosion of reinforcements in structures exposed to the outdoor climate, and structural freeze-thaw damage, which can be found in cold climates. Moreover, chlorides in coastal areas and alkali-aggregate reactions may deteriorate concrete structures. The structural condition investigation will provide first, an estimation of the remaining service life of the structure under investigation in the present or planned new environment, and second, an estimate of the service life if different types of refurbishment measures are undertaken on the structure.

Factory refurbishment and legal confirmation

Material properties

In addition to damage and degradation, it is essential to uncover the essential material and structural properties of the elements to define their load-bearing capacities and other functional specifications as a part of the refurbishment process. The properties of deconstructed elements and their materials can be uncovered with the help of laboratory tests. Most of the tests are standardised (European or national standards) and can be adapted for this purpose. Construction materials are typically inhomogeneous, meaning that their properties can vary significantly. Therefore, the number of samples must be large enough to ensure that the components are safe to reuse. The planned reuse will influence which material properties of the elements should be studied. The tests will typically include the compression strength of concrete, E-modulus of concrete, E-modulus of steel bars, tensile strength of steel bars, freeze-thaw resistance of concrete, porosity of concrete, and carbonation depth of concrete.

Structural properties

Based on the material properties, the properties of the structures will be determined first by calculations and, if necessary, by testing a sample of elements on a 1:1 scale to verify the results of the calculations. The most relevant structural properties the calculations will determine are the bearing capacity of the structure, the durability properties (remaining service life) of the structure if the exposure class changes in reuse, functionality and bearing capacity of connections and lifting anchors, fire resistance of the structure, and cover depth of steel bars. In the case of virgin elements, testing standards often define how many samples should be tested. When such standards are applied to deconstructed components, the number of tested elements needs to be determined on a case-by-case basis according to statistical studies to reach a predefined safety factor (such as 95%).

Refurbishment measures

Structural elements may be damaged from overloading or become damaged during deconstruction and/or transportation. These structural damages are defects, and must be examined on a case-by-case basis as a part of the factory refurbishment process before the elements can be approved for reuse. Suitable examination techniques are strongly dependent on the type of deterioration of the elements. The simplest examination is a visual inspection of the element for cracks (width, length, and location in the structure) and based on these findings, deduction of the meaning of cracking, the need for repair, and viable repair techniques. Furthermore, there may be a need to resize the elements at the factory to the new, desired dimensions, to strip coats of paint off surfaces, or to retrofit new connecting devices if the original connecting devices have been cut during deconstruction. It may also be necessary to verify the performance of the new retrofit connections through 1:1 testing, in addition to calculations.

Legal confirmation

As the final step, the proposed factory refurbishment process encompasses a framework for legal confirmation that addresses the issue of liability. It builds upon existing construction product certification frameworks, such as the CE mark (Conformité Européenne), and associates the refurbished element with a quality class, which defines the element's suitability for different applications.

Managing information digitally in the reuse supply chain

Need for information management

As the previous sections illustrate, the deconstruction-reuse process is an information-intensive one. When compared to relatively homogenous virgin production, the required information is much more fragmented, and even element specific, since a singular element's location in a building may have influenced its current characteristics (e.g., via degradation). Thus, effective management of the information through digital workflows is essential to facilitate reuse. Ideally, BIM could be used in the future to create, store, and share structured data that various actors of the supply chain can use.

Building information modelling and digital twins

Design authoring software can be used to create templates for the digital models of the various types of building elements. The templates will define the necessary information regarding geometry, attributes, classification, and relations to other objects. The digital template can be used to create a digital instance, a digital twin, of a physical building element. This digital twin can be associated with data from the various stages of the supply chain, such as the pre-deconstruction audit, deconstruction, quality management, design processes, and factory refurbishment. The data may entail, for instance, measurement data from 3D scanning, data from material and structural testing, or environmental data related to the element's embodied CO_2. The data may also include historical information, such as building project-specific data or data from the original producer. The data will be of various formats from different software and may have to be captured with devices such as scanners, sensors, laptops, or mobile phones. Effective workflows for data exchange will require interoperability so that different actors and software can share data without the loss of information. Furthermore, it would be ideal if the data exchange would be automated as opposed to a manually uploaded and downloaded event. Workflows will also have to take into account the conversion of documents into structured and machine-readable data.

Data sharing requirements and current status

While proprietary software platforms will, in some instances, be necessary to create the digital twins of elements and the associated data, it is important that the information can be shared with a standardised data model, on vendor-neutral and open file formats, such as the Industry Foundation Class (IFC) format. Access to the data should be ensured with a common data environment (CDE) that is a central online data depository. The CDE should offer the possibility to control access to the data and authorisation to manipulate data while keeping a ledger of transactions. Construction sector CDEs can store any form of electronic data and are commonly equipped with special features for viewing 3D models and for the sharing of BIM models. In addition, a CDE for reuse must contain documentation of the donor building, including drawings, listings of relevant building codes and standards, and the documentation of design values, such as material and structural properties. As deconstruction and reuse increase as a practice, the CDE must be equipped to make the selected data available for real-time publication in existing and future digital marketplaces and material passport/urban mining portals. Today, these services often contain minimal product information on deconstructed components and lack details that are essential for reliable quality management and reuse.

Tracing

Either Radio Frequency Identification (RFID) or Quick Response (QR) is used to tag individual physical precast concrete elements and to connect each of them with their respective digital twin. The RFID or QR tag, attached to an element's fabric before a building's deconstruction, will help track the element throughout the logistic processes from deconstruction to reuse. It will also provide a link for up- and downloading data related to testing, refurbishment, and retrofitting processes into the digital model.

Designing and building with reused components

A reverse design process

The design of buildings and structures with reused elements turns the whole design process upside down. Conventionally, a design team of architects and engineers develops a building design, which fulfils the given boundary conditions for the building, site, and its use. Based on that design, all the required architectural and structural elements are made to measure. By contrast, to reuse deconstructed components, the redesign team must work with a given stock of existing building elements, which should be employed in the new building configuration. This new constraint will influence the scope of work and roles of the design team members and induce a greater need for collaboration.

Design parameters

To facilitate the reuse of existing elements in a new building design, a clearly defined framework of design parameters is necessary to support the design process. Apart from the most obvious, such as the geometry or material properties of the elements, there is a long list of more detailed essential technical information, including but not limited to the amount of steel reinforcement in the elements, the layout of the reinforcement, and potential degradation due to environmental exposure that a structural engineer will need to know. Based on these factors, as well as knowledge of the intended new use, the necessary factory refurbishment measures can be defined.

Connectors

An important aspect influencing the redesign process is the type of connections between the elements. Ideally, the existing connections between the elements can be opened and, given that their performance can be verified, used again to connect elements to one another. In reality, many connections may need to be cut or will be damaged during the deconstruction, so innovative connectors, preferably designed for disassembly (DfD), should be developed for future use and reuse.

Assigning existing elements to a new design

When a design team attempts to fit an existing stock of elements into a given new design, a perfect match is unlikely to occur. If needed, some dimensions of elements may be changed during the factory refurbishment process; for instance, hollow-core slabs may be shortened. Elements may usually not be substantially lengthened, though, and not all elements can be shortened, such as pre-tensioned elements. Thus, viable ways to compromise between the elements and the design are essential. Different design approaches will offer different possibilities, such as conventional tacit knowledge-based design, digitally optimised design using parametric modelling and BIM tools that draw element information from a digital database (CDE), and the application of artificial intelligence (AI) and neural networks in supporting the designers' decision-making process.

On the construction site

If the elements are factory-refurbished, the reuse may not differ substantially from building with virgin elements. In certain instances, larger tolerances between elements than in new production may need to be accepted. In other words, the dimensional deviations between individual elements may be greater than in virgin production, which may have a slight slowing impact on the assembly work.

Catalysing the wider adoption of reuse via societal and business development

Changing work processes need people to acquire new skills

Work as a material process

As described previously, building from salvaged elements differs inherently from producing, designing, and constructing with virgin materials; this difference is also reflected in human work and professions, as well as in work activities and methods. As the value chain is different throughout, so are the practical work activities within it; new professions may emerge, or at least the parties involved may need new or updated work skills. In sociology, the concept of 'work' can be defined as the activities that people undertake to achieve a goal; they do not just follow instructions, but the workers must use their judgement and skills to make decisions to take independent action (e.g., Wisner, 1995, as cited in Deranty, 2009, p. 70). This includes the interactions of the workers, such as the architect, engineer, or construction worker, etc., with objects, tools, machines, and technical procedures (Deranty, 2009). The translation of deconstruction and reuse from merely an idea into material work processes that are integrated and scalable is focal for the wider deployment of the ReCreate approach.

New tasks and processes for deconstruction

Deconstruction calls for new work methods because it is different from demolition and predesigned disassembly. Prior to deconstruction, a deconstruction plan must be accepted by a regulatory body that usually serves as the issuer of the demolition permit. As already described, this deconstruction plan details the phases of the process, including risks to work safety. Since deconstruction has implications for the structural integrity of the donor building, it may be necessary to provide additional calculations on the dynamic stresses that may occur during deconstruction. These can to some extent be nonstandard calculations, which may demand new or updated skills from the construction engineers as well as from the authorities evaluating the plans. When deconstruction and reuse are still at such an early phase, there may be differences in viewpoints between construction engineers and demolition experts. Since deconstruction is neither traditional destructive demolition nor pure construction in reverse, methods may need to be combined from both disciplines to successfully deconstruct a building. In principle, existing tools and skills can be deployed, but they must be reconfigured into new work processes that workers must learn. An inventory of a donor building's precast elements and an engineer's structural deconstruction plan are translated by the deconstruction firm into practical steps to retrieve the elements from the donor building, where the feasibility of the deconstruction and compliance with work safety regulations are assessed. This may also require the deployment of new tools or parts.

New workflows and data needs in building design

Similarly, redesign using salvaged prefabricated concrete elements is another part of the circular value chain that is affected. The tools used in building design are intended first, for designing building elements that will be made-to-measure, though following the manufacturers' guidelines for their characteristics, and second, for incorporating standardised, off-the-shelf building parts and materials into the design. Acquiring building elements through deconstruction can result in nonstandard dimensions and other characteristics of elements, even if the elements may be of sufficient quality and be shown to comply with regulations. Therefore, the digitalised workflows in today's building design call for accurate data of salvaged elements – such as the dimensions and results of the quality assessment of each individual element – to be available for use in the BIM tools. The circular value chain must be prepared to feed this information to custom BIM libraries of deconstructed and/or factory-refurbished elements in order to connect with the construction sector's digital planning environment. In a practical sense, this includes data for logistics as well.

Updating skills through education

Circular construction, such as the reuse of elements, may give rise to new or updated professions as construction education is reformed at all levels. These professions combine knowledge from various fields necessary to work in the circular construction industry. While new work processes in deconstruction and redesign can facilitate or improve one project at the time, education reform can have a generational effect. A further impact can be expected to take place in the labour market. In order to prevent a sharp division of workers according to circular skills or the lack thereof, practising construction workers should be encouraged to update their skills with the help of specific occupational schooling. This is crucial, as policy reports in various countries have identified shortcomings in human capital as a factor preventing the transition to CE-based construction (see Burger et al., 2019 for an analysis).

Recognising and justifying reuse in construction regulations, standards, and tendering criteria

Nexus of various regulations

The implementation of reuse in construction requires developments also in diverse regulations and standards, which shape how the construction sector can operate and what technologies, processes, etc. are considered appropriate. Deconstruction and reuse will have to operate in a regulatory nexus of work safety, waste, and construction regulations. In terms of work safety, present regulations will apply and good practices can be drawn from both demolition and construction. Waste regulation should not, as a rule, come extensively into play, since deconstructed elements are not waste but products to be refurbished and reused (Zhu et al., 2022) – though there may be regional differences in the regulations as well as their interpretation. Construction regulations are those most likely to be disrupted by reuse.

Focal construction regulations

Reusing components is in principle an act of new construction, so it must comply with construction standards and regulations that have been set, among other things, to ensure buildings are safe and healthy to use. In the EU, where ReCreate is located, some of this regulation is EU-wide, such as the Eurocodes (European Commission, n.d. a) for structural calculations and the European construction products regulation (European Commission, n.d. b), and some of it is national, regional, or even local, such as building laws and codes. In general, building codes in most places can be expected to contain some kind of special provisions that enable the development of and experimenting with new innovative solutions. While such provisions enable pilots to be constructed, it is essential that the solutions of circular construction, such as reuse, eventually become acknowledged in regulations, as perhaps different but equal (or eventually more preferable) to virgin material-based products.

Navigating construction regulations intended for virgin construction

There is no a priori reason why reclaimed materials and components could not comply with present standards and regulations. However, the fact that regulations have usually been written from a virgin material-based viewpoint may cause confusion about how reclaimed elements should be dealt with. It is fair to expect that additional testing and provision of extensive information may be required, as previously outlined, to evidence conformity with the requirements. However, in the absence of established and officially acknowledged standards and good practices for this process, individuals acting in the role of authorities may be reluctant to be among the first to clear such procedures for use. This is connected to the need to acquire new skills, as explained in the previous section, not only by the professionals in the deconstruction-reuse value chain that are producing the documentation about the elements, but also by the authorities that are tasked with evaluating whether the evidence is sufficient and convincing.

Construction products regulation

The European Construction Products Regulation (European Commission, n.d. b) pertaining to the CE mark is a good example of how the lack of acknowledgment of the existence of reused products and clear rules and processes fit with ensuring their characteristics can hinder the wider deployment of circular construction. The regulations, based on a European statute and European harmonised product standards, are intended to remove barriers of trade within the European Union. While the regulations are EU-wide and directly imposed, and as such in theory not subject to national interpretation, whether and how they apply to reuse has still been interpreted differently in different member states due to the fact that reuse has not been explicitly addressed in the statutes and standards written exclusively from a virgin production perspective. It is worthwhile noting here that construction standards and regulations are usually devised in collaboration with industry expert panels. While it makes sense to deploy the expertise of the sector in law- and policymaking, the practice can also become a hindrance to circular construction in that some of the sector's major players, which exercise primarily virgin material-based business, may be incentivised to obstruct the clarification of regulation.

Environmental assessment regulations

European standards, if not yet regulations, also exist for the evaluation of the environmental footprint of building products and whole buildings, as we will discuss in more detail in the next section. Presently, regulation is national (where it exists), so the form and requirements vary by country. The EU can nevertheless be expected to move in a direction where environmental requirements may eventually be imposed on buildings and building products at the EU level, even if only some of the member states, such as the Netherlands, have already enforced regulation at the national level. Stricter environmental requirements for building projects could be strong incentives for more circular construction, but robust evidence of reused components' environmental performance and rules of how to treat them in Life Cycle Assessment (LCA) should also be established.

Tendering criteria

In addition to regulations and standards, well-informed building owners and commissioners of buildings, both public and private, have the potential to encourage more circular practices with their tendering criteria. Quality-based tendering criteria can be devised both for demolition/deconstruction and construction bids to reward bidders who aim at higher reuse rates as opposed to conventional low-quality recycling.

Demonstrating the environmental benefits

Environmental benefits make up one of the most substantial arguments in favour of scaling up reuse. In previous projects, it has been demonstrated that the reuse of precast concrete elements, such as floor slabs and walls, can save energy by 93–95% and reduce greenhouse gases by 95–97% (Mettke, 2010).

Requirements emerging in regulation

The quantification of a building's environmental performance has so far been practised on a voluntary basis with certification frameworks such as BREEAM, LEED, BNB, etc. However, with the new European Green Deal growth strategy, the EU aims to transform into an economy with "no net emissions of greenhouse gases in 2050" where "economic growth is decoupled from resource use" (European Commission, 2019). The Netherlands has required environmental assessment in building permits since 2013 (Staatsblad, 2011). Finland, Sweden, and Norway will soon mandate submitting a whole-life carbon assessment with a building permit application as a part of their target to achieve carbon neutrality in the building sector by 2030–2035 (Kuittinen & Häkkinen, 2020). Germany aims to achieve this goal by 2045 (Bundes-Klimaschutzgesetz, 2019) with the help of a holistic sustainability assessment with not only ecological but also economic and social aspects (Bundesministerium 2019). The Netherlands has coupled CO_2 with circularity and, like the EU, aims at carbon neutrality by 2050 (De circulaire bouweconomie, n.d.).

Environmental assessment methods

The environmental impact of products, including buildings, can be measured in a quantitative and objective fashion with the help of LCA. The EU is presently developing EU-wide user-friendly tools for assessing the environmental footprint of buildings based on the LCA, such as the Level(s) framework (Dodd et al., 2017). A full LCA consists of "a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO-14040, 2006). The LCA relies on Environmental Product Declarations (EPDs). To conduct an LCA for whole buildings in the design phase, a database of the EPDs of the used construction products and materials is needed.

Environmental product declarations for reused products

Currently, there are no EPDs for reused products; their environmental impact is assessed on a case-by-case basis. The development of EPDs for the main range of reused precast concrete elements, which is a task within the ReCreate project, should be a catalyst for the implementation and acceptance of the reuse of such elements. The availability of the EPDs will demonstrate the benefits of reuse to clients, architects, and other professionals involved in the LCA of buildings that are looking for ways to lower their environmental impacts – not only energy and emissions, but also the use of virgin materials, natural land (especially gravel and sand extraction), and landfill land (by avoiding construction waste). An environmental advantage quantified with the help of an LCA, through EPDs, will result in higher scores in buildings' sustainability certificates, regardless of the certification system.

Uncovering the economic value of reuse for construction businesses

Creating and capturing economic value through business model and value chain development

While regulation, as discussed previously, can soon start to encourage reuse on an environmental basis, the ReCreate approach has also encouraged diverse companies to learn how to create and capture economic value and make business from the reuse of concrete elements. These may entail, for instance, putting the company's sustainability strategies into action, developing the business model to also include reuse-based services and/or products, strengthening brand value gains, as well as serving new sustainably oriented customer segments better. As construction-sector companies are networked and form value chains, companies can also perceive the economic value arising from the sustainability shift of the whole industrial value chain, where the projects and material flows are designed to be more resource saving and efficient with less waste and emissions. To encourage companies in this direction, it is essential to uncover what the business and economic aspects are that can catalyse reuse and particularly concrete element reuse in the construction sector, and what determines the economic value creation and capture (see Hopkinson et al., 2019).

Business potential arising from innovations

The novel technological methods for deconstructing, factory refurbishing, and building out of reused elements can create novel, innovative business potential for the diverse companies that are involved in ReCreate's pilot projects, as well as for potential new entrants. The business potential that drives change in companies' businesses is grounded in different types of innovation (Aarikka-Stenroos et al., 2021). The business potential can entail technological innovations, such as software for inventory modelling or hardware for deconstruction; product innovations, such as factory-refurbished elements that can replace virgin products; and service innovations, such as pre-deconstruction audits, quality assurance and certification services, or redesign services, just to name a few examples out of the value chain demanding expertise and competencies. In other words, the reuse of concrete elements necessitates diverse companies to operate in the circular construction value chain. However, it also requires substantial development, change, and innovation from them to enable efficient, safe, and functional flows of reused elements, which then enables the emergence of economic value. This implies both new companies, with new specified products and services that are needed along the reuse-implementing construction process, but also updating existing businesses, which can modify and even renew their way of operating in general.

Cost management in the value chain

Because the construction process with reused elements is still unconventional and not 'business-as-usual', cost management throughout the value chain is crucial for business to capture value and ensure optimal cost savings from reuse and to even create profits. From deconstruction to assessment to factory-refurbishment to reuse, process innovations can shape critically whether risks and costs are realised. For example, safe work methods can diminish risks and impact costs. Several factors, such as pre-deconstruction audit methods, inventory modelling of the donor building, efficient and smart deconstruction methods, and optimised storage and logistics for elements, determine how well the reuse process can be planned and optimised in advance and to progress as planned.

Ensuring economic benefits for all companies in the value chain

To capture economic value from reuse, the economic benefits should be aligned among all key actors/companies in the value chain. This includes, for example, the owner of the donor building, the deconstruction contractor; technology and design consultants, such as structural and environmental engineers and architects; the precast concrete manufacturer; the building contractor; subcontractors; and the client. Some tasks, such as deconstruction – implemented as planned in a controlled way – can determine the quality, amount, and type of harvested elements, thereby influencing how much economic value the other actors can capture after deconstruction and create out of the harvested elements. For one, the better the physical condition of an element is, the fewer factory-refurbishment measures are needed. Also, performing an inventory of the donor building using digital building information modelling may enable the whole value chain and its actors to do their tasks in a well-planned manner, which has direct implications for the value capture potential. For example, the quality of the data on the elements deposited in the donor building influences how fluently deconstruction, logistics, factory-refurbishment, and architectural and structural design can be planned and executed.

Different pathways to create economic value from reused concrete elements

The reuse principle can be implemented in different ways to create value from concrete elements in circular construction (Riuttala, 2022). First, concrete elements may be salvaged with the intention of reusing them in demanding applications, which require high-value components equal to new components. To correspond to the quality and safety requirements dictated by the design of the receiving building, elements must be carefully selected in donor buildings and factory-refurbished to the extent that they are comparable to virgin products, tested, and certified. This allows the building contractor to gain brand value and possible tax incentives from reuse without the risk related to product quality. Another value creation pathway builds on finding secondary applications for salvaged elements, such as in less demanding buildings or in infrastructure construction (e.g., noise barriers or retaining walls). Here, the key is to find a cost-effective solution for building contractors to gain use value from existing elements without needing to resort to heavy testing and validation processes. The owner of the donor building may also retain the elements for use on the same site, or the demolition contractor can choose to resell or donate them directly for reuse. In addition, reuse can be combined with recycling to strive for the highest achievable level of upcycling and material reutilisation.

Creating and sharing precast concrete knowledge

Building stocks as urban mines of elements

For companies to capitalise on the potential of reuse across the EU, there is a need to understand how large reserves of elements could be available in the 'urban mines' of building stocks. Although the global prefabricated housing production built during the post–World War II period has been estimated to contain 170 million flats with five billion square meters of space, there is no single and reliable source that has managed to collect and map the vast amounts of prefabricated concrete used in the European post–World War II period (1945–1989) or in the more recent past (1990–2020) (Alonso & Palmarola, 2019). Similarly, there are no reliable or unified sources identifying where these buildings are located in Europe. The documentation and historical records of the prefabricated concrete construction sector from the post–World War II period has proved weak or, in some cases, simply missing. Even if one had a more precise quantitative analysis of where, when, and how the precast concrete elements were built across the European continent, the possibility to apply the deconstruction and reuse methods created in one context in another depends on the types and details of the precast systems.

Classifying precast systems and elements

To meet the aforementioned challenges, ReCreate aims to create new, detailed, and integrated knowledge of precast concrete through an analysis and classification of past and present precast construction systems and their elements. Many different sources will be consulted, such as current historical research on the subject, literature, public and private archives, industrial partners' archives and employees, and building case studies. There are also regional differences that shape the business potential for concrete reuse, and it is crucial to capture this knowledge in order to increase the reuse of elements in all of Europe. Therefore, ReCreate's aim is to establish an open database, in line with the EU's goals for open data, for precast technologies (roughly from 1945 to today) to identify, order, and create a taxonomy of relevant building, component, and connection types.

Taxonomy and database to aid decision-making

The taxonomy and database can be helpful in upscaling the reuse of prefabricated concrete in that – much like a bird-watcher's guidebook –they can help spread general and specific knowledge of reuse potential to building sector professionals and so help them make informed judgments of singular buildings they may encounter. For example, contemporary planning processes do not take reuse into consideration and often, if not always, disregard the reuse potential in the existing buildings on the site. They are seen as refuse rather than a resource. The taxonomy can be helpful for planners by raising and answering the following questions: (1) Is the specimen in question a rare instance that needs to be protected? (2) Is it rather a well-documented, common building system that already showcases a track record of successful reuse? or (3) Does it contain elements that are likely to be constructed using nonhazardous substances and robust structural capabilities? For other professionals, such as structural engineers or architects that may be commissioned to inventory a donor building's elements, the taxonomy can provide a framework for the classification of the elements and, in the database, digital twins of the elements in 3D to ease the documentation process.

Appreciation generation through knowledge creation

By sharing precast concrete knowledge across Europe, ReCreate aims to promote a more positive understanding of the existing building stock from the post–World War II period. This era is largely misunderstood; its buildings are seen as something negative, even vilified. Presently such buildings are all too often slated for demolition far before their technical life has ended. A more widespread and better knowledge of their historical origins and contemporary reuse potential could help contribute to a more sustainable and circular construction sector.

Conclusions

This chapter proposed how the circular economy transition can be catalysed in the construction industry. This chapter has focused on a high level of circularity, that is, the reuse principle, using the deconstruction and reuse of precast concrete elements as its example. Drawing from the ReCreate project, the chapter has identified a spectrum of aspects that need to be catalysed to implement an industry transformation, ranging from novel technologies and processes needed in deconstruction and remanufacturing, reuse-oriented design, information management through digitalisation, to work and skill development, regulative development, and business model and cost management development. Conceptually, the chapter used Geels's (2002) multi-level perspective of technological transitions as a theoretical framework to discuss catalysing circular construction transition. Changes in the socio-technical landscape, mainly the political drive towards a low-carbon and circular society, have opened up a window of opportunity in the present time for reuse to break out of its niche, since there is pressure for the construction regime to change. Figure 3.5 illustrates these linkages.

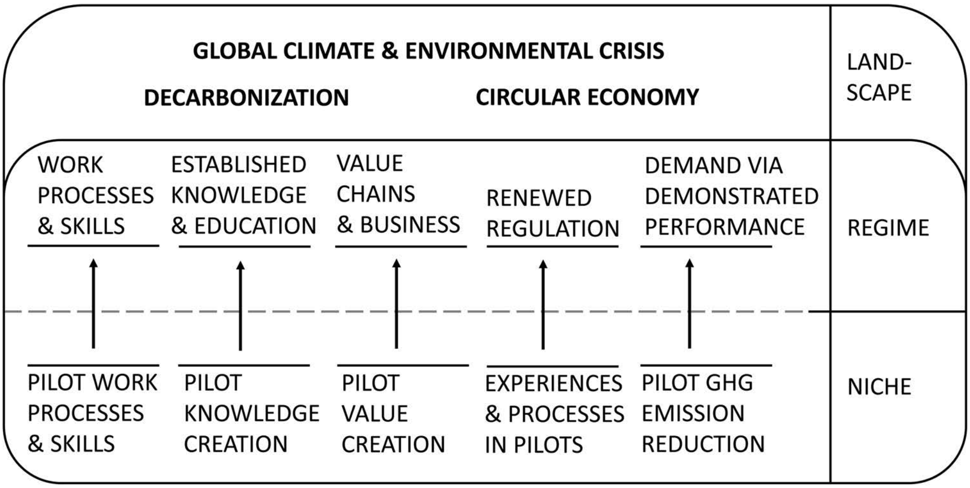

Figure 3.5 Catalysis of a reuse transition in the construction sector, conceptualised in Geels's (2002) framework.

Source: The authors.

This chapter first explained a wide variety of different aspects that need to be catalysed in order to make deconstruction and reuse happen in the context of pilots in the current niche, and second, needs for more general developments in the socio-technical regime to take place for the approach to spread and gain ground beyond the piloting phase. These needs entail not only key process steps and necessary tools and technologies, but also changes in behaviours and social institutions, such as knowledge, education, and regulation. Thereby, the key contribution of this chapter is in the analysis of the two main catalyst types, namely technological/design catalysts and societal/business catalysts, which interact in different temporal dimensions, the former being imminent targets and the latter more long-spanning goals of CE and here, in particular, circular construction. Figure 3.6 synthesises the various catalysts necessary for the sectoral change.

In terms of catalysts for pilots, manual tools are essential to make deconstruction and reuse feasible in practice, and digital technologies can be focal for ensuring a smooth and cost-efficient process. Nevertheless, the question is not of totally novel and unforeseen hardware or software. Rather, existing tools and technologies, developed for a different context, are applied on the deconstruction-reuse value chain in a novel process and adapted for this specific use. For instance, the quality inspection of elements can draw from the condition investigation of buildings; the deconstruction of elements is informed by the decommissioning of industrial production lines; and the logistics of elements can capitalise on the tracking of products in other industries, to name just a few examples. Making the existing tools even more suitable for deconstruction and reuse requires an evolution in practice. Building Information Modelling (BIM) is a good example: the existing BIM software is optimised for new production but could be adjusted for donor building inventory modelling and for design using reused elements with the help of add-on software and real-time object libraries available online. These notions match Geels's (2002) argument that regime transitions are rather gradual reconfigurations than sudden in nature.

Consequently, process innovations are at the core of the reuse transition, for both the pilot projects and the wider deployment. This includes not only practical design and production/construction processes and rules but also regulatory ones and how construction is managed as a business. Demolishers, architects, and engineers need to reconfigure their skills into novel work processes throughout the value chain in order for the sector to come up with new services, such as deconstruction, quality inspection, and design services out of reused elements. The same applies to element manufacturers and their new products, such as quality-assured factory-refurbished elements. The change of the socio-technical landscape is already manifesting at the regime level in building codes and company policies striving for carbon neutrality and circularity. Riding along this wave, there is now a chance to demonstrate the environmental benefits of reuse, have it acknowledged in legislation and incorporated in relevant education providers' curricula, and to uncover how to extract economic value from it. This applies not only in ReCreate's piloting countries but beyond them; necessary changes to the regime can be intentionally catalysed by sharing knowledge openly.

While ReCreate's pilots examine how to add on and hybridise with other sustainable construction methods, expanding into other markets beyond the project will be decisive as to whether, in Geels's (2002) terms, a successful niche-cumulation of reuse will lead to a transformed construction sector across Europe. The need for the construction industry to change is global, though. As concrete is the most used construction material in the world and the use of precast elements is also globally widespread, many practical contributions drawn from ReCreate's pilots will likely be applicable on other continents, too. Moreover, in contexts where other materials and forms of construction are more prevailing, the general framework presented in this conceptual chapter

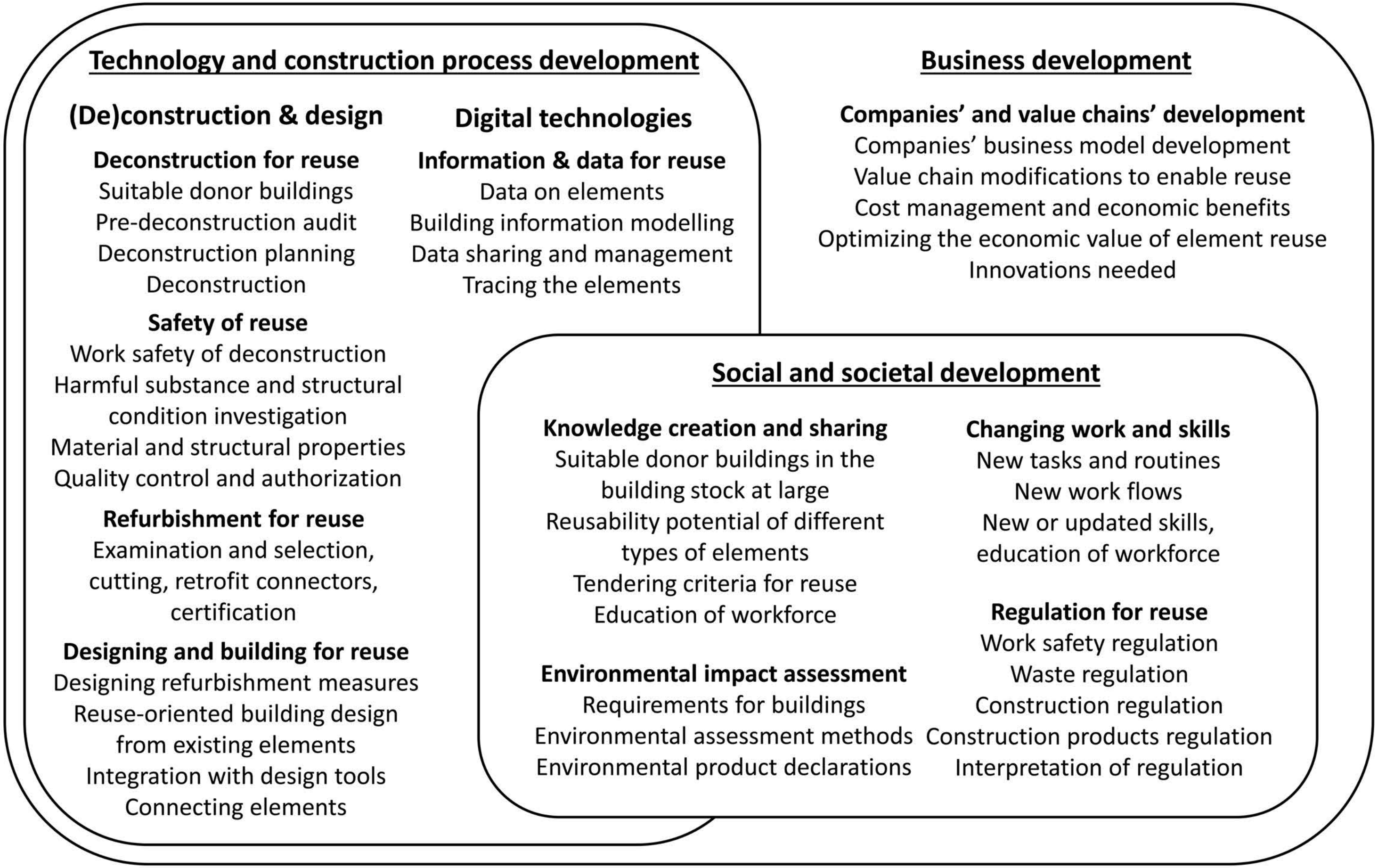

Figure 3.6 Diverse catalysts needed to transition the construction sector towards reuse.

Source: The authors.

may still be used as a tool for catalysing the construction sector's sustainability transition, even if other types and methods of circular construction are to be catalysed.

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Educational content

What categories of catalysts can be identified for a circularity transition in the construction sector? Name a few catalysts for each category and discuss their nature, role, and significance.

Considering the intertwined nature of factors in socio-technical regimes, such as the construction sector, reflect and elaborate on the potential linkages of a singular catalyst to other catalysts.

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4

CATALYSING THE TEXTILE INDUSTRY TOWARD A CIRCULAR ECONOMY

An ecosystem approach

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Introduction

'Circular economy' (CE) is an umbrella term and paradigm referring to CE models and circular processes in industrial structures that enable a reduction in the use of natural resources and the generation of waste by adopting the principles of recycling, reuse, and reduction to increase circularity (Geissdoerfer et al., 2017; Murray et al., 2017). High environmental impact industries, such as construction, textiles, and food have begun to initiate changes toward more circular operations (e.g., Fischer & Pascucci, 2017; Franco, 2017; Hossain et al., 2020). However, these changes can be difficult to implement as a rapid shift to circularity-enabling technologies and adoption of CE business models can disturb conventional business and operation processes, including related value chains, and demand changes in collaboration and competition (Aarikka-Stenroos et al., 2021; Ritzén & Sandström, 2017). Changes in industries frequently concern their whole socio-technical systems, including the regulatory domain (Geels & Kemp, 2007). Therefore, it is important to consider the entire industrial system and its actors, which can be conceptualized as an ecosystem in which diverse complementary, yet interdependent industrial and social actors share values, pursue system-level outcomes, and develop through coevolution (e.g., Aarikka-Stenroos & Ritala, 2017). When this consideration is applied to CE framing, such ecosystems can be conceptualized as CE ecosystems (CEEs) that seek system-level circulation of resources and materials through recycling, reuse, and reduction and involve companies, governmental organisations, regional bodies, policymakers, and consumers (Aarikka-Stenroos et al., 2021). Such CEEs facilitate collectively created sustainable value (Aarikka-Stenroos et al., 2021; Uusikartano et al., 2020). CEEs can focus, for instance, on regional or industrial circular resource flows (circular urban and industrial ecosystems) or a company's evolving relationships to drive economic value creation (circular business ecosystems) (Aarikka-Stenroos et al., 2021). In this chapter, we are particularly interested in a system of diverse actors enabling textile circulation and in identifying what could drive the textile industry towards increased textile recycling and reuse as a system-level outcome.

Research has paid increasing attention to the textile industry's pursuit of environmental sustainability through circularity (Filho et al., 2019; Franco, 2017; Hole & Hole, 2019; Moretto et al.,

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2018; Niinimäki & Hassi, 2011). Naturally, the textile industry causes an environmental impact since it represents a massive share of the world's manufacturing industries, and the production volumes of textile fibres have been increasing continuously in recent years (Bick et al., 2018; Ellen MacArthur Foundation, 2017; Textile Exchange, 2021). Global textile production in 2020 reached 109 million tons, of which 91.9% was virgin fibre feedstock (e.g., polyester, acrylic, cotton), and only 8.1% was recycled fibres (Textile Exchange, 2021). Textile production and fashion are now among the most polluting industries that threaten environmental and social well-being (Bick et al., 2018; Boström & Micheletti, 2016; Koszewska, 2018; McFall-Johnsen, 2020). Therefore, the industry is in urgent need of large-scale systemic changes in both production and consumption patterns to take a leap towards sustainability and circularity (Boström & Micheletti, 2016; European Environment Agency, 2017).

As the systemic shift toward circularity is arduous, there is a growing number of studies addressing drivers and barriers that enable or inhibit companies, industries, and countries in the move toward CE (e.g., Jia et al., 2020; Kirchherr et al., 2018; Ranta et al., 2018; Tura et al., 2019). The drivers and barriers are, for instance, technologies (De Jesus & Mendonça, 2018), consumer behaviour and adoption of CE principles (e.g., Singh & Giacosa, 2018), institutional and organisational drivers (Aloini et al., 2020; Jia et al., 2020), and industrial infrastructure (e.g., Fischer & Pascucci, 2017). However, these studies have made little contribution to uncovering the comprehensive set of driving catalysts that is needed for versatile actors to facilitate the circulating system. Hence, the current study aims to address this research gap by exploring the diverse catalysts for circularity as perceived by the ecosystem actors. To do so, we apply the catalyst conceptualisation, which refers to the mechanisms that drive or inhibit the change (Cabell & Valsiner, 2011). The concept of a catalyst (Cabell, 2010; Valsiner, 2013) is applied in this study as a metaphor for diverse enablers and conditions for CE in an industrial ecosystem.

To uncover circularity catalysing mechanisms in textile CEEs, and due to the pragmatic relevance of textile circulation from sustainability and business perspectives, we pose three research questions: (1) What ecosystem is needed for increased textile circulation within the textile industry? (2) What are the key catalysts for textile circulation? and (3) how do key catalysts enable and create favourable conditions for the textile CEE development? Empirically, this research is framed as a qualitative case theory (Gummesson, 2017) grounded on extensive data collected from the ecosystem actors involved in textile circulation in Finland. The Finnish context provides a fruitful background for our study as, within the past decade, the country has become a forerunner in industrial innovations in textile circulation (Kamppuri et al., 2021) in line with the European Green Deal (2022) policies that aim to tackle climate change issues and increase circularity. The European Green Deal mobilizes industries towards a CE and promotes circular design of long-lasting products that can be reused, repaired, and recycled. Special attention in the European Green Deal was directed towards the textile industry, as it is a resource-intensive sector.

This study contributes to the development of a novel categorisation of circularity catalysing drivers and a new understanding of how they can advance circularity among the actors of an industrial ecosystem. These contributions add to CE ecosystem research (particularly regarding industrial and business ecosystems), CE driver research, emerging research on CEEs and their transformation (Aarikka-Stenroos et al., 2021; Asgari & Asgari, 2021; Bocken et al., 2016; Parida et al., 2019), and general research on the CE in the textile industry. The contributions also provide pragmatic insights and guidance for business practitioners, companies, policymakers, and other public actors in their attempts to implement circularity and reorganize industrial value chains and social systems.

This chapter continues with a literature review on the circular textile industry emphasising the ecosystem approach and potential drivers. This section is followed by a description of the methodological approaches taken to the qualitative data collection and analysis. The results section presents diverse catalysts found in the Finnish textile industry and is followed by a section that summarizes and discusses the findings. Finally, a conclusions section summarizes the research contributions to the theory and practice.

Theoretical background

Textile industry to be catalysed toward the circular economy

The textile industry is recognized as one of the most waste-generating industries globally, and consequently research has indicated diverse rationales on why and how it could transform toward greater circularity (Filho et al., 2019; Franco, 2017; Hole & Hole, 2019). According to industrial reports in 2021, most textiles (73%) are produced for the fashion and clothing industry, followed by technical and household textiles (Grandviewresearch, 2021). The textile market is projected to grow by up to 4% in the period 2022–2030 (Grandviewresearch, 2021).

The typical linear life cycle of a consumer textile product consists of the following five steps: (1) naturally grown or manufactured fibres are spun into yarn, (2) yarns are constructed into fabric then treated with dyes, (3) fabrics are cut, sewn, and trimmed into a product, (4) finished garments are distributed to storage and retail stores and eventually sold to consumers, and (5) in the post-usage phase, textiles are discarded, used as landfill, or are incinerated (Ellen MacArthur Foundation, 2017). Textile production is far from being environmentally viable since it requires enormous volumes of chemicals, water, pesticides, and energy (Bick et al., 2018; Boström & Micheletti, 2016; Šajn, 2019). For instance, the production of petroleum-based polyester fibres utilizes fossil resources and large amounts of chemicals, causing significant carbon dioxide emissions (Bick et al., 2018; Šajn, 2019; Sandin & Peters, 2018). Pesticides utilized for cotton cultivation tend to cause soil depletion and they leak into the waterways, creating threats to freshwater bodies (Boström & Micheletti, 2016; Koszewska, 2018).

Due to the environmental impact of the textile industry, companies and institutional actors are increasingly attempting to transform the industry toward a more circular-operating mode (Filho et al., 2019; Franco, 2017; Moretto et al., 2018). An efficient system of textile circulation requires taking new approaches to textile design, prolonging the textile life cycle, and treating textiles as recyclable raw material instead of waste (European Environment Agency, 2017; Koszewska, 2018). Consequently, industry actors are searching for ways to increase circularity through the transformation of manufacturing operations that enable fibres and textiles to circulate as many times as possible, looping back to different parts of the value chain until the processes of reusing or recycling are no longer technologically, environmentally, or economically feasible (Kessler et al., 2021; Sandin & Peters, 2018; Snoek, 2017).

To address environmental goals and CE logic, a consumer can contribute to circularity by reducing the consumption of textile products through an extension of their lifetime (Levänen et al., 2021). However, worn-out textile garments need to be disposed of eventually. Textile circulation begins when a user places the textile product into a textile waste collection bin for reprocessing or donates it to a nonprofit organisation for resale (Fontell & Heikkilä, 2017). Textile reuse also prolongs the life cycle of a textile product, as the product finds a new user through secondhand boutiques, flea markets, online marketplaces, or renting services (Fontell & Heikkilä, 2017; Joung & Park-Poaps, 2013; Levänen et al., 2021). A crucial part of the textile circulation is a sorting process that determines whether the textile is reusable, nonreusable but recyclable, or no longer suitable for circulation (Fontell & Heikkilä, 2017; Karell & Niinimäki, 2019; Sandin & Peters, 2018). Textile recycling embraces processes from gathering and sorting used textiles to cutting them into fibre that goes through a mechanical, chemical, thermal recycling, or a combination of these processes (Piribauer & Bartl, 2019; Sandin & Peters, 2018). However, low-quality textiles that are not, for instance, suitable for mechanical recycling or cannot maintain their quality after recycling (Karell & Niinimäki, 2019), can create technological challenges. Even though textiles can pass through multiple cycles of remanufacturing, at a certain point, these textile fibres become unusable for recycling and are consequently discarded at municipal waste points (Kessler et al., 2021; Sandin & Peters, 2018).

From a value chain perspective, conventional textile production is shaped as a global supply chain with production outsourced to developing countries and most consumers in developed markets (Boström & Micheletti, 2016; Fontell & Heikkilä, 2017). The textile industry in developed countries is focused on localized production of high-quality products. However, within the past decade, European countries have begun to introduce manufacturing lines to reprocess used textiles locally due to high volumes of textile waste (Yousef et al., 2020), technological advancement (Franco, 2017; Jia et al., 2020), an issue of carbon dioxide emission during textile production and shipping used textiles back to developing counties for recycling (Moretto et al., 2018; Stanescu, 2021), and the consumer market demand for environmentally sound and ethically produced textiles (e.g., Desore & Narula, 2018; Ozdamar Ertekin & Atik, 2015). Besides the introduction of the European Green Deal (2022), the CE for textiles is actively promoted by the European Commission and the Parliament through its strategy "to achieve a carbon-neutral, environmentally sustainable, toxic-free and fully circular economy by 2050" (European Parliament, 2022).

Applying the ecosystem theory lens to understand circulation within the textile industry

The implementation of textile circularity requires the holistic involvement of various actors from businesses and society. The desired circular textile flow occurs in a complex industrial value chain and a system of networked business-to-business (B2B) companies that produce and supply textile-based products. However, this flow within the textile industry involves many other societal actors, such as nongovernmental (NGO) and nonprofit organisations, governmental institutions, consumers, and social activists (de Oliveira Neto et al., 2021; Fontell & Heikkilä, 2017; Rovanto & Bask, 2022; Staicu & Pop, 2018). Thus, it is relevant to consider all directly or indirectly involved actors on a system level (Parida et al., 2019). In this chapter, the textile industry is approached as an ecosystem of diverse actors who can contribute to textile circulation and whose actions need to be catalysed. The ecosystem approach allows researchers to examine complex industrial systems of interacting actors that are bound together through interdependencies and coevolutionary patterns (Aarikka-Stenroos & Ritala, 2017; Parida et al., 2019).

The CEE implies multiple complementary actors pursuing system-level goals of reduction, reuse, and recycling of materials (Aarikka-Stenroos et al., 2021). A CEE typically is composed of very diverse actors, varying from industrial actors (companies) and public and governmental actors, such as cities, municipalities, and ministries, to universities, nonprofit organisations, and citizen consumers (Aarikka-Stenroos et al., 2021; Staicu & Pop, 2018; Uusikartano et al., 2020). These very diverse CEE types differ regarding their actor setting and circularity goal (Aarikka-Stenroos et al., 2021). For example, circular industrial ecosystems refer to a regional community of hierarchically independent actors who sustainably produce industrial goods and services in symbiotic collaboration and resource use. Moreover, power is distributed differently in circular industrial ecosystems than in circular business ecosystems, where a set of actors enable the core company's business model implementation by collectively delivering a sustainable value offering by resource recycling, reuse, and/or reduction. Consequently, the structure and organisation of CEEs vary, as they can be either developed around a focal actor that orchestrates actions taken by other actors (e.g., a company managing its circular value chain) or organised among horizontally distributed actors (e.g., an alliance of textile producers seeking to manifest their circular processes) (Aarikka-Stenroos et al., 2021).

Regarding the textile industry, the CEE "aims to keep most post-consumed textile materials in the re-use cycles or recycle them instead of textile waste being incinerated or ending up in landfill. The key objective should be to use recycled textile materials for purposes that regenerate maximum value" (Fontell & Heikkilä, 2017, p. 18). Thus, facilitation of CEE for textile reprocessing requires the development of a network of interacting actors that enables, for instance, circularity of used textile products, information exchange, or facilitation of technological processes, at both national and international levels. The joint actions and system-level goals of the CEE in textile recycling may be focused on the following: (1) the flow of materials (cf. Joung & Park-Poaps, 2013; Levänen et al., 2021; Sandin & Peters, 2018); (2) the flow of knowledge, for example, how textiles can be technically remanufactured or how this process can be framed into a business model (Fontell & Heikkilä, 2017; Koszewska, 2018; Piribauer & Bartl, 2019); and (3) the flow of economic value, for example, profit generation from circulating textiles (Chen et al., 2021; Fischer & Pascucci, 2017; Rizos et al., 2016). Since we are interested in the actors and related catalysts that cause textiles to circulate, the driving catalysts and conceptual approach to their examination are discussed further.

Driving catalysts for the textile CEE

Most research regarding CE refers to the barriers and drivers that shape the boundaries of a system in different industrial settings (e.g., Kirchherr et al., 2018; Ranta et al., 2018; Tura et al., 2019). These studies indicate CE driving mechanisms for business model innovations, novel national and regional regulatory frameworks, consumer acceptance and awareness, and technological infrastructures (Aloini et al., 2020; Kirchherr et al., 2018; Ranta et al., 2018). As regards the CE in the textile industry specifically, drivers may include employees' initiatives (Jia et al., 2020), a favourable organisational culture (Rovanto & Finne, 2022), governmental incentives (Fischer & Pascucci, 2017), growing trends towards conscious consumption (Han et al., 2017; Salmi & Kaipia, 2022), consumer market demand for environmental solutions (Desore & Narula, 2018), and the ethical commitment of business leaders to sustainability (Niinimäki, 2010). In contrast, barriers to the CE in textile utilisation are more variable; there is a lack of clear corporate strategy and sustainability vision on the part of the supply change actors (Paras et al., 2018), financial challenges to making a change towards more sustainable production, especially for small-sized companies (Rizos et al., 2016; Snoek, 2017), insufficient enforcing regulations for the circularity of manufacturing processes (Perry et al., 2015), low technological capabilities or skills (e.g., Aloini et al., 2020; Rizos et al., 2016), limited availability of recycled materials and sustainable product design (Salmi & Kaipia, 2022), and consumer-driven barriers rooted in purchasing decision-making (Desore & Narula, 2018).

This chapter refers to a catalyst approach, this being a concept that embraces the systemic, developmental, and transformative nature of the processes and variety of the process results or outcomes (Cabell & Valsiner, 2013). Therefore, it is suitable to reflect complex and interdependent relations in the industrial ecosystem. A catalyst can conceptualize specific enablers and mechanisms that support a background ecosystem to create the conditions necessary to facilitate new processes within this system, its transformation, and other changes (Uriko, 2020). This chapter explores the catalysts necessary to enable textile and value flow in the ecosystem of textile recycling, reusing, and resale. The empirical case setting and research methods are discussed next.

Research design and data collection

This study is methodologically framed by case theory to address the complexity of the explored phenomenon. Case theory, in contrast to case study research (e.g., Yin, 2011), embraces an expanded version of the case study and explores a certain case to generalize to a broader scientific area (Gummesson, 2017). Case theory allows for both particularisation (understanding of a particular case) and generalisation (knowledge innovation that can be compared to other cases or create a background for theory generation) (Gummesson, 2017). We chose an extensive single case, namely the Finnish textile industry ecosystem pursuing circularity, as this design enabled us to map the relevant actors contributing to the circularity of the industry and identify catalysts for their contributions. Finland is a fruitful European context for the study of textile circulation, as it hosts several companies developing fibre innovations (e.g., cellulose-based fibres) and examining the commercial potential of recycled textiles (Pylkkänen, 2022). Additionally, Finland has set ambitious goals to begin the separate collection of consumer textiles by 2023 (Gädda, 2021), which can serve as a benchmark practice for other countries in Europe and globally.

Our research design allows us to address the complexity of the focal ecosystem of the Finnish textile industry by studying numerous involved actors and their links and interactions in a dynamic context to develop a theoretical understanding of circularity catalysts. A central aim of the data collection was to capture the multiple perspectives of the ecosystem actors involved (companies, research institutes, NGOs, etc.) and explore catalysts. Empirical data was collected from multiple sources during the period from March 2019 to September 2021. Table 4.1 provides a summary of the data set, ranging from workshops to interviews and media data.

Each interview lasted approximately 70 minutes. The interviews were recorded and transcribed with the permission of the interviewees. The informants were also able to check and validate their transcribed interviews afterwards. The interviews included questions concerning the four following key themes: (1) company or organisation activities and technologies enabling CE and their role in the national ecosystem, (2) partnering actors and their role and importance for the facilitation of CE processes as well as actors missing from the system, (3) challenges to and accelerators of CE implementation, and (4) specific enablers of and conditions aiding CE facilitation. The field notes included remarks made at workshops, webinars, and panel discussions, concerning, for example, the ecological and social impacts of linear textile production, organising sustainable textile production and circulation (e.g., end-of-life textile collection and sorting), and turning textile recycling and novel recycled or bio-based fibres into a business, as well as remarks about the technical processes showcased at the tours of processing premises. The interviews and textual data of the field notes were analysed through content analysis during which the key themes and expressions related to the research objectives were identified (Duriau et al., 2007; Zhang & Wildemuth, 2009). The data from each interview was examined to find details about the main actors, conditions, motivations, and enablers of CE implementation and compared across interviews and field notes. After comparison, concurring themes and similarities were identified, allowing for us to determine and categorize the key catalysts for textile circulation within the national ecosystem. For instance, interviewees' observations about organisational management and

Table 4.1 Empirical data sources and methods of data collection

Data types and methods of data collection	*Data sources*	*Description*
Interviews	Interviews with ecosystem actors ($N = 14$; lasting approx. 70 minutes each)	Ecosystem actors and interviewees • Municipal waste management organisation (Circular economy specialist) • Technical research centre, governmental nonprofit organisation (Senior scientist, project manager) • Non-profit organisation, consumer textile management (Workplace counsellor) • Textile collecting and reselling nonprofit organisation (Communication specialist and clothing collection manager) • Textile, fashion, and apparel industry employers' association organisation (CE specialist) • University of Applied Science A (Textile CE expert) • University of Applied Science B (Development manager) • University C (Project researcher, recycled textile fibre specialist) • Medium-sized textile manufacturing company (Corporate responsibility manager) • Small-sized textile manufacturing company (project and management representative) • Small-sized textile recycling, technology provider company (Research professor, founding member) • Small-sized textile recycling company (B2B) (Customer relationship manager) • Small-sized clothing rental company (Chief executive officer) • Small-sized CE textile solutions, closed-loop services (B2B) (Chief executive officer and marketing manager)
Field notes	Workshop	03.2019 Growth from the Circular Economy – a workshop for textile industry actors (VTT Technical Research Centre of Finland, Espoo, Finland).
	Webinar	14.05.2019 Telaketju webinar (Finnish network of textile industry actors promoting textile recycling).
	Panel discussions	09.2019 Oslo Innovation Week 2019. Panel discussion: 'Wood looks good on you': how to build a profitable business around fashion and recycling of textiles.
	Tour of the textile sorting line and fibre laboratory	08.2019 Textile material identification line, Lahti University of Applied Sciences, Finland.
Media data, marketing, and promotion materials	Websites of companies and organisations	Media and promotion materials of 14 organisations participating in the research.
Research reports and publications	Project reports	Fontell, P., & Heikkilä, P. (2017). *Model of circular business ecosystem for textiles*. VTT Technical Research Centre of Finland. Kamppuri, T., Kallio, K., Mäkelä, S. M., & Harlin, A. (2021). *Finland as a forerunner in sustainable and knowledge-based textile industry-Roadmap for 2035*. VTT Technical Research Centre of Finland.
	Press release	Šajn, N. (2019). *Environmental impact of the textile and clothing industry*. European Parliament.

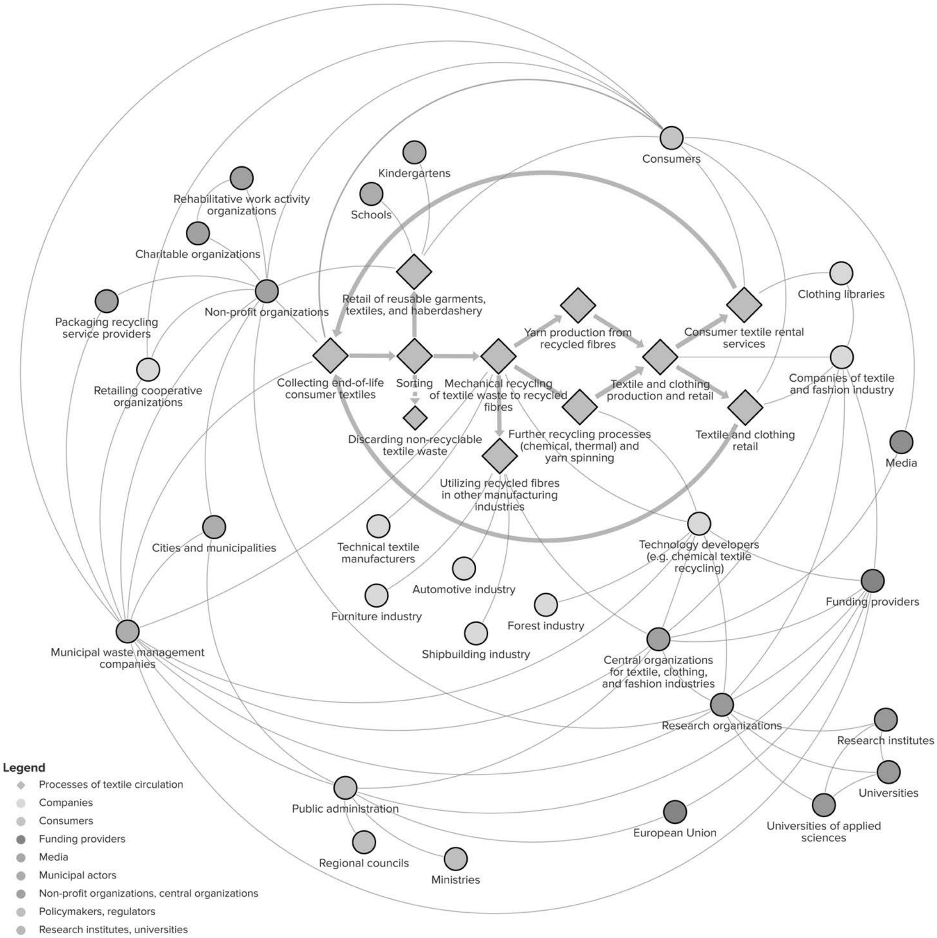

Figure 4.1 Industrial ecosystem for textile circulation: Actor types and relations.

Source: The authors.

culture were framed within the organisational catalysts category, and the technological capabilities discussed were framed within the technological catalysts category. Media and marketing data were used to gain additional insights into the ecosystem actors' roles, operations, and agendas, whereas reports and publications provided further understanding of the status quo of textile and fashion industries and textile circulation both nationally and globally. Our analysis resulted not only in catalyst categorisation, but also the map of the ecosystem actors (see Figure 4.1), depicted with the help of the Kumu.io online mapping platform provided by Kumu Inc., presented in the following section.

Results

Based on the study results, Figure 4.1 maps the CE textile ecosystem in Finland, actor types, and their roles and interconnections. The diamonds in Figure 4.1 depict the necessary processes for the circulation of consumer textiles, from collection and sorting of end-of-life textiles through recycling processes to manufacturing new textile products from recycled fibres. The circles in Figure 4.1

represent diverse actor groups in the ecosystem and both their mutual interlinkages and relation to the circulation processes, as described by the interviewees at the time of data gathering.

According to the empirical data analysis, six key driving catalyst types are perceived by the actors of the Finnish textile CEE are the following: (1) technological catalysts, (2) business catalysts, (3) organisational catalysts, (4) regulatory catalysts, (5) communicational catalysts (visual and linguistic), and (6) ethical catalysts. These catalysts are discussed next.

Technological catalysts

Several of the studied companies already have experience in textile recycling. Thus, diverse material processing as well as digital technologies were identified as technological catalysts enabling recycling or reuse. Modern technologies allow the use of mechanical and chemical recycling or a combination of these methods. For instance, one recycling company considered in this study was created around CE mechanical recycling technological advancement. However, the used textile collection phase remains challenging as it requires the presorting and collection of noncontaminated pieces of textile (e.g., articles without strong odours or mould). Manual sorting is also needed to select pieces that can be resold or have higher market value, such as vintage and branded garments. Several collaboration projects between companies and universities in Finland are working on the design of collection boxes, their strategic location (e.g., closer to consumers), and formulating clear instructions for consumers on the boxes to prevent them leaving textiles that cannot be recycled.

In preparation for recycling, textiles should be sorted into different fractions based on their fibre composition and transferred either to a warehouse or directly to a processing line. Mechanical recycling can be applied to textiles whatever their fibre composition. During mechanical recycling, textile waste is shredded into a processable fibre form that can be used to manufacture raw materials and for further chemical or thermal recycling or for yarn spinning. Mechanically recycled fibre has market potential even though the fibre length is shorter after each recycling process. Chemical recycling is applied when mechanical reprocessing alone does not result in high enough fibre quality, and it has even higher market potential. This recycling type is suitable for cellulose-based fibres and usually applied to cotton and viscose reprocessing. This method has already been tested as a pilot project but scaling up would require further technological development of recycling lines and, consequently, more investment. Implementation of chemical recycling can increase volumes of recycled fibre supplied to the market. This technology also provides significant logistic benefits: textile waste can be processed into the liquid raw material in one location and recovered into textile fibre in another.

Since textile manufacturing and circulation activities involve a tremendous amount of data, the handling of these data can improve the traceability of textile life cycles. The digital tools and software supporting these processes are still being piloted through partnerships between companies and universities. For instance, exploration is ongoing of the creation of a digital product passport that can contain information about materials, chemicals, and processes included in a product's life cycle and instructions for further recycling. Product traceability can allow a holistic approach to business model development whereby certain products circulate in small-scale closed loops, for instance in a B2B sphere. As the interviewed customer relationship manager of the textile recycling company has emphasized: "All kinds of digitalisation tools for identification and quality check of materials are needed. Quality check of fibre length, technical specification, laboratories, etc. This kind of digitalisation is needed in the future". Close collaboration with the software/hardware industry is also required to facilitate textile identification processes during the sorting of used garments. However, many such projects are still in the piloting stage. Digital catalysts are also needed for better online platform development for companies that rent out clothing for consumers and businesses (e.g., workwear). One example of a digital catalyst is virtual fitting for online stores and clothing rentals to reduce the amount of returned clothing.

Business catalysts

Previous research and the results of this study indicate an increased demand in consumer markets for sustainable solutions in the fashion and textile industries (Desore & Narula, 2018; Ozdamar Ertekin & Atik, 2015; Vehmas et al., 2018). This demand is driven primarily by the influence of the mass media, growing consumer consciousness, more responsible consumption, and trends towards the use of secondhand clothing. Modern consumers expect to donate or discard textiles for reuse and recycling. However, they also expect that organisations will collect used textiles at convenient locations. Sorting and collection of used garments are becoming the key processes that define future faith in textile waste. These activities need to be efficiently performed to demonstrate economic viability, offering an opportunity for business organisations – especially small-sized companies – to integrate sorting and collection into their value chains or develop new business models to manage the logistics of used textiles.

According to evidence generated by the companies participating in this research, the current textile production infrastructure can be modified to integrate textile recycling lines into existing manufacturing processes if the companies realize economic value. Since textile recycling is a relatively new business, companies can tackle the associated uncertainty through collaboration and involvement in projects with NGOs and universities to obtain technological solutions and financial support. Conventionally, such shared-purpose collaboration involves many business and institutional partners that not only share financial risks but also benefit from innovations, solutions, networking, and knowledge sharing (Ritzén & Sandström, 2017). Thus, changes in the textile circulation ecosystem may be accomplished only when multiple actors collaborate with the aim of redefining the value chain, as the corporate responsibility manager of the textile manufacturing company points out: "When you have four or five players, then it leads to an equal business ecosystem, and one must be always the leader". However, according to the current interviews, finding investors in Finland may still be a challenge for circularity businesses, although many projects find support from the government and international organisations. Thus, commercialisation of innovations and active promotion of recycled material usage across industries is required.

Organisational catalysts

Leadership and strategic management are among the drivers for sustainable innovations (e.g., Niinimäki, 2010). Business leaders and employees frequently take proactive roles in CE implementation, especially when their businesses are connected to the textile industry. According to the interviews, sustainable initiatives may impact the whole network of business actors when a strategically important company changes its business processes. A reactive response to market changes towards circularity may be caused by opinion leaders and institutional actors, for instance, input from universities. According to the interviews, Finnish universities attempt to disseminate knowledge on CE principles to business and consumer markets and to promote multi-actor projects and collaboration. Businesses benefit from this collaboration by retaining ownership of the innovation developed in the projects. Another role of the universities is to integrate knowledge of the CE into the curriculum of different subjects that are taught, thus leading to an increase awareness of circularity-enabling technologies and the CE in business and consumption.

Organisational culture also serves as a catalyst for circularity if it promotes open-mindedness and values environmental and social responsibility (Kwarteng et al., 2021), as many Finnish companies do (Koistinen et al., 2022; Rovanto & Finne, 2022). To promote innovations and initiatives in organisations, internal and external communications favourable to knowledge and the exchange of ideas need to be established. However, different countries have different attitudes toward circularity due to their culture, legislation, and business principles. Therefore, promotion of CE at the international level may be significant for international business and institutions to share best practices and knowledge.

Regulatory catalysts

Most of the interviewed research participants agreed that governmental regulations favouring circularity are a crucial catalyst, institutionalising and legitimising circularity. These may concern, for instance, collection of end-of-life textiles that can make a larger raw material flow for recycling. However, current textile CE legislation is based on waste management regulations, which is controversial considering that the CE aims to recover raw materials. For instance, as mentioned by the customer relationship manager of the textile recycling company, the reason that some recycling companies cannot deal with household textiles in Finland is "the law of restrictions related to waste management. Municipalities and the companies of regional waste management are responsible for household materials." Therefore, the waste status of end-of-life textiles should be changed to address this issue. Concurrently, this challenge is on the agenda at the EU level as an interviewee of the textile manufacturing company clarifies: "The EU is changing legislation for waste management, meaning all textiles in the European community must be recycled or collected separately so they will no longer be incinerated or used as landfill" (see also European Green Deal, 2022). Sustainable choices can also be promoted with tax regulation in both industry and consumer markets, for instance, by lowering the value-added tax of recycled textile and fibres.

Introduction of textile standardisation and labelling on the global level could enhance awareness of recycled materials and create a market for raw material with predefined classifications (e.g., origin of fibres, quality, etc.). Standardisation can tackle the challenge of material properties recognition across industries, where business actors can find various utilisations of recycled textiles, such as in the construction industry (Christensen, 2021). However, textile-to-textile recycling remains the key option, and this demands a specific approach to textile design that should align with the standards for the future recycling.

Regulations can also regard the import and export of textiles, their quality, and the data availability of products entering the EU. This global challenge may also concern the traceability of textile garments and brand protection. However, traceability raises the questions of what information may be included in a product passport and who can access it. Despite the benefits of standardisation and product quality criteria development in respect to circularity, such development may affect free trade and product movement across borders. Thus, these issues require deeper consideration at the international level.

Communication: Linguistic and visual catalysts

Our case analysis also exposed the importance of communication through visual images and aesthetics, as well as linguistic means that could all catalyse textile circulation. Mass media actively creates an awareness for consumers and B2B markets about CE in the textile industry by using understandable language, terms, and visuals (e.g., Han et al., 2017). For instance, the Finnish national news portal Yle has launched documentaries explaining and showcasing CE in different industries. According to our interviews, the efficient promotion of circularity depends on these media delivering a comprehensive message and using a common terminology. For instance, an interviewed representative of a clothing rental company suggested that terms such as sustainable or responsible garment can come across as vague and misleading, unless it is also clarified exactly which aspects of sustainability or responsibility are actualized in each product. Furthermore, the interviewees from nonprofit organisations emphasized that consumers frequently find it hard to understand the difference between donating and recycling textiles and may not be aware of what happens after a garment is placed in a textile collection box. This issue is important to address to ensure the efficient sorting and separation of clothing that is suitable for donation or resale and that which can be sent for recycling.

Interviewees emphasized that a common understanding of CE among business partners may serve as a catalyst for changes in the value chain. Communication is important in this case so that proactive companies can inform partners of CE opportunities and strategies (Paras et al., 2018). Companies such as the medium-sized textile manufacturing company that participated in this study can set a benchmark for further strategic development of circular processes. Information dissemination about CE in the business world can also be promoted through workshops and seminars for industry representatives, such as those noted in this research. Additionally, universities play a key role in CE knowledge transfer to students – not only through theory, but through research and projects with other institutional and business actors. Public speeches and lectures also increase public interest in circularity.

Diverse visual means were found to be important catalysts. These visual means include images, videos, and graphics that aim to explain technical processes, opportunities for business growth, or sustainable consumption habits (Han et al., 2017). Visualisation, besides delivering a marketing message, can make it easier to understand the number of resources used, processes behind recycling, properties of new products made of recycled materials, and so forth. Visual messages may need to be simplified for consumers that discard textiles. For instance, graphic instructions may be placed on textile collection boxes intended for recycling. However, it is still necessary to develop standardized symbols related to textile disposal across countries for consumers as well as for businesses.

Aesthetics also plays a role in perceptions of circularity (Jia et al., 2020). According to the interviews, conventionally eco-fashion has a reputation for being less visually attractive. New eco-brands aim to tackle this myth through unique design and quality products. The modern fashion industry offers a variety of sustainable clothing that may be desirable for its aesthetics and not only as a conscious consumption choice. Social media and image sharing are an effective means of popularising CE visually. Aesthetics also concerns designing secondhand shops as a point of sale in a way that shifts their reputation from 'flea markets' to 'vintage clothing stores'. The subjectivity of aesthetics may be challenging since the quality, look, and trendiness of donated, reusable garments can vary drastically due to differences in taste, perception, and sentimental value. However, as indicated by studies of Finnish fashion brands, durable, long-lasting clothes with a universal design can preserve their value on the secondhand market (Salmi & Kaipia, 2022).

Ethical catalysts

Catalysts in the circular textile industry may also originate from the ethical perspectives of consumers and business managers. Increased awareness of ethical consumption and recycling has created a market demand for sustainable solutions, where business organisations bear responsibility to produce environmentally and socially viable business offers. For instance, society has expectations that business and institutional actors will address the climate change issues that also concern fashion industry and textile production (Niinimäki et al., 2020; Peters et al., 2015; Vehmas et al., 2018). The ethical production of textiles and ethical fashion has become mainstream rather than an added-value activity carried out by companies (e.g., Brydges, 2021; Mishra et al., 2020; Perry et al., 2015). Pressure to find ethical solutions also originates from industrial ecosystems, where actors strive to take the leadership in addressing environmental issues, and competitors must follow business trends. Implementation of CE in the textile industry is becoming an ethical choice since the business mindset is also changing from satisfying shareholders towards achieving environmental, social, and economic sustainability. For some companies participating in this research, sustainability and business ethics are at the core of their business strategy, possibly explaining their longevity on the market.

The interview data showed that an efficient CEE is based on trust and transparency among its actors due to a need for collaboration and to follow common ethical goals. Trust development is especially viable for B2B interaction as some CE value chains may require new actors to enter the industrial ecosystems to facilitate infrastructure. Additionally, ensuring business activities are transparent increases the popularisation of circularity among business partners and manifests the trustworthiness of the company as well as strengthening its image. As was emphasized in the interviews, ecosystem actors need to realize common business and societal goals toward sustainability, otherwise the partnership cannot be fruitful.

The popularisation of conscious consumption influences changes in consumer behaviour and emphasizes the importance of individual choices, which make consumers a part of sustainable solutions (Desore & Narula, 2018). According to the interviewed nonprofit organisations and apparel industry employers' association representatives, consumers in Finland are keener to choose ethically produced textiles with sustainable features including the use of recycled materials. Although some misconceptions still exist regarding the quality of recycled products, these preconceptions can be overcome through the promotion of eco-fashion, design, and communication about fabric properties.

CE inhibitors

Although this research is focused on catalysts as positive drivers of circularity, our study also uncovered a set of the key inhibitors slowing CE development. First, technologies performing textile recycling have been introduced to the market only recently, and some have not yet reached an advanced level of technological readiness; they are still in the testing or piloting phase. Novel technologies cannot yet guarantee a high volume of recycling and flawless processes (De Jesus & Mendonça, 2018). According to the empirical data, technologies for recycling complex composition textiles, such as multilayered textiles, textiles with highly varying fibre compositions, or elastic knits are still in high demand for efficient recycling. Current technological imperfections require the manual sorting of textile waste, which further inhibits the CE as this is a work-intensive activity. This type of labour does not require specific training but organising this activity in developed industrial countries such as Finland is challenging due to high labour costs. Automatisation and digital support of sorting (robotics, AI and machine vision, and tracking), storing, and collecting information about textile articles would be a solution; no such solutions have yet reached a high level of technological readiness.

Legal regulations help to promote the circularity in business and consumer markets that forces companies to take proactive actions (Gädda, 2021). However, incentives are still lacking in this process. Companies may pursue CE implementation as forced changes in the industries but receive little support of the government with knowledge and finances. In this case, collaboration with universities and research institutions helps to tackle uncertainty and lack of knowledge, but financial incentives could make businesses more motivated toward circularity (Fischer & Pascucci, 2017). Lack of both knowledge and communication may also result in the misunderstanding of CE processes among value chain actors (Paras et al., 2018). As emphasized in the interviews, partnering companies may underestimate the opportunities of CE if they do not show immediate short-term economic results. Thus, the economic viability of CE should be viewed from a long-term perspective and considered in the future strategies of business organisations. Communication about circularity requires a stronger representation inside organisations and should be incorporated into organisational culture, as well. Ethical and moral motives may serve as enablers of change in the organisation towards more sustainability, but employees and managerial staff need to understand the reasons, motivations for, and benefits of CE.

Inhibiting factors related to the consumer markets may include the predominant assumption about the low quality of recycled or reused products. Additionally, a misunderstanding about the sustainable qualities of products can prevent consumers from purchasing. Thus, there is clearly a need for communication and information dissemination about sustainability in general, the issues circularity aims to solve, and how and where the recycled products are produced (Singh & Giacosa, 2018). Although conscious consumption is increasingly popular (Desore & Narula, 2018), companies should put more effort into emphasising the aesthetics and practicality of products with sustainable characteristics.

Summary and discussion

This study identified and conceptualized the ecosystem and driving catalysts needed for textile circulation. Table 4.2 summarizes the identified catalysts and also provides a brief overview of how they catalyse circulation. In addition to the catalysts, our findings showcase the interaction and complementarity of business, institutional, and public actors acting with the common purpose of reducing textile waste and maintaining the routine of textile recycling or reuse (e.g., Aarikka-Stenroos & Ritala, 2017; Aarikka-Stenroos et al., 2021; Fontell & Heikkilä, 2017; Uusikartano et al., 2020).

According to the findings, technological progress in the textile industry can be a driving force for new business models and changes in manufacturing processes. Many modern textile recycling technologies have been introduced in the EU to turn textile waste into raw materials (Franco, 2017; Koszewska, 2018; Yousef et al., 2020). Mechanical, chemical, and thermal recycling processes and combinations of these are among the most common technological activities enabling production of yarn and fibres from used textiles (Piribauer & Bartl, 2019; Sandin & Peters, 2018). Chemical recycling has more commercial potential as it can often produce yarns with a higher quality than those achieved with mechanically recycled fibres alone. Locating the recycling lines in the EU brings them closer to the consumer market and reduces distances for logistics aiming to tackle environmental issues (Boström & Micheletti, 2016; Fontell & Heikkilä, 2017). Location may affect textile waste and end-of-life textile collection as well as the sorting and delivery of used articles for recycling. Sorting is a crucial process in the value chain since not all textiles are recyclable (Karell & Niinimäki, 2019; Sandin & Peters, 2018). Digital tools could be helpful in monitoring the quality and properties of textiles. Digital solutions for information management about matters such as the usage (especially in the industrial sphere) and properties for recycling of textiles are at a development stage. Some digital platforms can advance clothing resale and renting services by placing points of sale online and introducing virtual fitting.

Although recycling technologies are a powerful catalyst, technology development cannot fully fuel the needed change in the textile ecosystem, and a combination of diverse, interlinked catalysts is needed. New technologies are associated with risks and unlikely to be implemented and commercialized without sufficient investments, regulatory support, or strategic leadership. Economic value can be a strong motivation for ecosystem actors to implement CE principles in

Table 4.2 Catalysts for textile circulation in the CEE

Catalysts for textile circulation		*Rationale: what catalysts do/how they catalyse*
Technological catalysts for recycling and reuse	Textile waste and end-of-life textile collection and sorting	Developing and serving collection points can be framed as a business model. Automatisation of sorting processes allows economies of scale to be achieved. The processes of sorting and identifying fibre types can be integrated into a business model.
	New textile recycling technologies and updates to existing production lines	Technological development will help improve recycling manufacturing facilities and the implementation of innovations in existing production lines. Different methods of textile recycling are developing and becoming more available for commercialisation.
	Digital solutions	Technical support for the processes related to recycling, renting, and tracking textiles is actively developing and requires more collaboration with the IT industry and new digital platforms.
Business catalysts	CE business models	The processes of resale, reuse, and recycling demand novel approaches to business model development.
	Changes to existing infrastructure	Companies can change their existing infrastructure to implement recycling processes that can add value to their business activities.
	Cross-sector collaboration	Since many business innovations in the textile industry are in the developing stage, more commercialisation of technologies and collaboration with business and institutional actors are required to develop sustainable solutions and share business risks.
Organisational catalysts	Proactive and reactive response to market demand	CE principles may be implemented following managers' initiatives for sustainability and/or as a reaction to market demand or changes in the business networks.
	Organisational culture	An organisational culture that promotes innovations and idea sharing can create favourable conditions for CE implementation in organisations.
Regulatory catalysts	International and national/regional regulations on textile reuse and recycling	Changes to local and international regulations towards CE in the textile industry support the strategic orientation of businesses towards circularity and influence consumer behaviour. The legal standardisation of textile characteristics labelling can simplify textile recognition for recycling but requires the development of international standards and labels.
Communication catalysts (linguistic and visual catalysts)	Linguistic: terms, words, and verbal discourse; shared understanding of words	Active communication and a common terminology for and understanding of circularity may increase collaboration between business and institutional actors for CE development.
	Visuals: figures, images, colours, symbols, logos, and other visual objects	A visual marketing message may be an efficient means to promote instructions about recycling and reuse of textiles. Visualisation is important for the aesthetic perception of eco-fashion and to enhance demand for recyclable products.
Ethical catalysts	Sustainability and ethics in business processes	Changes towards the CE may be based on ethical business practices and strategies to develop sustainable business solutions.
	Conscious consumption	The popularisation of conscious consumption and ethical fashion have become triggers for ethically produced textiles and increased consumer interest in recycling, reuse, and resale of garments.

the business processes (e.g., Aloini et al., 2020). However, engagement in the recycling business can be an answer to the consumer market demand for sustainable solutions (Desore & Narula, 2018; Ozdamar Ertekin & Atik, 2015). Companies can collaborate with nonprofit organisations and other institutions to share the risks of establishing new value chains. Such cross-sector interaction can be facilitated through collaboration with universities and research groups.

Favourable governmental regulations are among the key catalysts for the textile CEE. For instance, the European Parliament has introduced the European Green Deal (2022) aiming to address environmental issues, while the European Commission is promoting a CE strategy (European Parliament, 2022). Eventually, strategic regulations on the CE will become legislation at the local level (Gädda, 2021), forcing companies to start adopting new strategies to face future changes. Several companies dealing with textiles in Finland are already engaged in piloting projects regarding textile recycling to scrutinise business opportunities and correspond to regulatory changes.

The CE may be catalysed by a favourable organisational culture that allows the communication of shared values and understandings (Jia et al., 2020). However, changes such as the introduction of circularity may affect not only one business organisation but the whole network of involved actors, possibly causing a redefinition of the business network and the involvement of nontraditional actors such as universities, nonprofit organisations, and other institutions (Ritzén & Sandström, 2017). Failure to understand the strategic importance of circularity among the value chain actors may create a barrier to CE implementation (e.g., Paras et al., 2018). Communication becomes a necessary catalyst for these processes, since a common understanding and terminology of CE principles, knowledge exchange, and setting common goals are vital for managerial processes across the ecosystem. However, communication may involve not only B2B information sharing, but also address the consumer market by popularising circularity through marketing messages. The aesthetic approach to and visualisation of products made of recycled materials may appeal to conscious consumers and tackle the dominant assumptions about these products' quality (e.g., Singh & Giacosa, 2018).

Since the consumer market is seeing a rise in conscious consumption (Desore & Narula, 2018; Peters et al., 2015), companies are responding not only with sustainable solutions but by taking a proactive stance to manifest their sustainability and ethical approach (Niinimäki et al., 2020). Ethical (environmentally and socially sound) fashion is becoming a new normal and cannot be ignored by the textile industry, which is conventionally among the most polluting and unethical of sectors (Bick et al., 2018; Brydges, 2021; Koszewska, 2018; McFall-Johnsen, 2020; Mishra et al., 2020). Thus, circularity is an ethical approach to the management of business activities. For some companies, embedding business ethics in their management mindset may be a catalyst for CE since they attempt to balance economic value with environmental and social concerns. Disseminating CE principles across an ecosystem also demands actors' close collaboration based on ethical values such as transparency of business processes, trust, and shared ethical goals.

Conclusions

This extensive study explores diverse actors contributing to the circularity of the textile industry as a CEE and the key catalysts that facilitate and create favourable conditions for textile circulation. It uncovers a variety of perspectives and the voices of different ecosystem actors that allow us to capture and conceptualize six major catalyst types (technology, business, organisation, communication, regulation, and ethics) and explore how these catalysts act as mechanisms. Additionally, the findings allow us to map a CEE with complementary actors whose actions need to be catalysed to develop a more circular textile industry. Therefore, this study adds to the literature on

CEEs (Aarikka-Stenroos et al., 2021; Parida et al., 2019). Utilisation of the concept of catalysts has cross-disciplinary implications. The concept theoretically and metaphorically reflects enablers and conditions that aid in facilitating ecosystems (Cabell & Valsiner, 2013; Valsiner, 2013). Specifically, this study increases our understanding of the industry ecosystem and needed catalysts for textile circulation (Fischer & Pascucci, 2017; Franco, 2017). Contributions are also made to the studies focusing on drivers and barriers in CE (Kirchherr et al., 2018; Ranta et al., 2018; Tura et al., 2019). This study also has pragmatic implications for business managers, industry developers, nonprofit organisations, investors, governmental bodies, and regulators on how they can catalyse industry transformation toward circularity (Table 4.2) and whom they should involve (Figure 4.1).

We acknowledge that our study has several limitations. First, we examined the Finnish-based national textile-oriented actor ecosystem, although research on other industries and geographic and institutional locations may provide different results. This study also relies on a limited number of interviews. However, analysis of multiple data sources adds to the trustworthiness of the research findings. Finally, Figure 4.1 may lack some actors, but it represents the most prominent actors in the studied ecosystem at the time of data collection.

Regarding future research avenues, more understanding of the multiple-actor systems enabling circular or resource-efficient raw material flows is needed. Furthermore, research is needed to identify diverse driving catalysts for circularity that may be hidden in the international business and sociocultural settings.

Educational content

- A textile circulation ecosystem can be driven by technological, organisational, regulatory, communication, and ethical catalysts originating from business, institutional, and social spheres.
- The conceptualisation of a catalyst extends our understanding of CE drivers. In this case, catalysts embrace favourable conditions and enablers of the actors' ecosystem targeting CE implementation.

Discussion questions:

1. In what ways can the life cycle of textile fibres and consumer textile products be extended?
2. What measures can different actor groups take within a business or collaboration setting to promote circularity in the textile industry?
3. What are the major motivating factors influencing companies' proactive actions toward CE in the textile industry?

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5

A REVIEW OF THE CIRCULAR ECONOMY IN NIGERIA

From rhetoric to enterprise development

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Introduction

The process of shifting to a circular economy (CE), which is commonly described as a combination of reducing, reusing, and recycling operations, differs for emerging economies. In the northern hemisphere, notably in Europe, there is a broader knowledge of circular processes supported by well-documented case studies of multinational corporations. Furthermore, CE discourse in the Global North focuses mainly on waste reduction, cost savings, product reinvention, and new business models (Desmond & Asamba, 2019). CE implementation in the Global North emerged from a top-down strategy beginning with policies to shape sustainable development and safeguard the environment from further degradation (Ghisellini & Ulgiati, 2020). In Germany, the concept of CE was adopted via a bottom-up strategy that began with a ban on waste dumping intended to encourage eliminating landfills by 2020 (Geng et al., 2013). In Japan, the transition to circularity began in 1991 with the enactment of the law for the efficient utilisation of recyclables. Preston and Lehne (2017) found that most CE initiatives take place in Europe, North America, and East Asia.

In contrast, in the Global South, many small-scale actors in the CE are driving the transition towards a CE with the goal of realising the potential for job creation and income generation in participating nations. With predicted population growth and the resulting increase in consumption, waste management has become a severe challenge in many nations. However, a significant portion of the waste generated in countries of the Global South is still sent to landfills. Also, in the lack of strategic legislation and policies in countries of the Global South, the transition to CE is influenced by several minor actors, multinational corporations, businesses, social enterprises, and informal waste pickers. In India, for instance, recycling and composting programmes cannot keep up with the growth of waste, even though small start-up companies and nongovernmental organisations (NGOs) are introducing new solutions ranging from high-tech waste processing to improved training and support for waste picker communities (Fiksel & Lal, 2018; Fiksel et al., 2021).

As with other countries in the Global South, in Africa the transition to CE is characterised by many small players, a lack of policies fuelling implementation at the national level, and clarity surrounding the concept of CE, which makes its implementation difficult. Although the practice

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of CE is still at a forming stage, micro-level actors, multinational businesses, and nonprofit groups in Nigeria are driving the shift to a full CE. In contrast, countries in the Global North have implemented CE through a top-down approach typified by rules that reduce the amount of garbage sent to landfills. The growing popularity of the CE idea is primarily attributable to its influence on the sustainable development concept in two major areas: economic prosperity and environmental quality (Kirchherr et al., 2017). A CE may introduce novel methods of recycling products and resources in the future (Karell & Niinimäki, 2019). The novel methods can aid in conserving the environment in the fight against climate change (Esposito et al., 2017; Greyson, 2007). A CE has the potential to provide a waste-to-wealth pathway for economic growth (Lacy & Rutqvist, 2015) and a sustainable approach to health (Nanda et al., 2021), safety (Lia et al., 2021), and the environment moving the conversation of CE from mere rhetoric to action – leading to the formation of business entities whose major activities tend to close the loop presently evident in Nigeria.

Long before CE became an official word in Nigeria, waste pickers, scavengers, and other informal actors practised the concept of CE as a means of subsistence. In recent years, however, CE has gained popularity as an innovative approach to alleviating poverty and accomplishing SDGs in the country. The majority of these approaches are designed to combat plastic proliferation and to manage biodegradable waste (Ghosh, 2020).

There is the need to understand the specific catalysts of CE transition in the Global South. In this chapter, we examine Nigeria's CE transition because Nigeria, as a context, poses a rather interesting picture of the transition to a CE. We state that countries such as Nigeria seem to be implementing CE taking a bottom-up approach, which is unique and distinct from the top-down approach of the advanced countries (Russell et al., 2020). This chapter examines the CE transition in Nigeria through the reported lived experiences of nine owners of CE-inclined enterprises.

Context comparisons and synthesis: Circular economy as the tool for inclusive growth in Nigeria

Developing countries have strived to diversify to improve their national economic trajectories (Hamed et al., 2014). Most developing countries have achieved this diversification drive mainly in industrialisation, from primary production to industrial exportation (Gelb, 2010). Today, many developing countries are diversifying based on the idea of sustainability (Lee, 2005). The Sustainable Development Goals (SDGs) and the Africa Agenda 2064 have encouraged the creation of businesses and social enterprises that seek to advance ecological, social, and human progress rather than just for profit in some developing countries. It is essential to unearth why resource-rich countries such as Nigeria, with many natural resources (petroleum, natural gas, tin, iron ore, coal, limestone, niobium, lead, zinc, and fertile land) would contemplate circularity and sustainability in their diversification and transformation agenda. With many natural resources, Nigeria generally would prefer to diversify focusing on the exploitation of other resources, however, CE implementation requires the diversification into renewable resources. Countries such as Nigeria are learning from the environmental problems created by highly industrialised countries (Halog & Anieke, 2021). Lately, there has been a depiction of the advantages associated with the establishment of circular enterprises within CE (de Kock et al., 2020). Another reason for this shift is the promises of wealthier countries and other entities to set aside some funds to support environmental causes in Africa (Desmond & Asamba, 2019). Empirical evidence suggests that over 90% of Nigeria's waste is indiscriminately dumped or burnt (Agunwamba, 1998). Thus, circularity emphasises the creation of feeder loops that transform all the wastes into new inputs to be used for further production within the value chain (Fakunle & Ajani, 2021).

The goal of a CE is to eliminate waste while simultaneously encouraging the reuse of resources, which may in turn provide economic value. For instance, the waste glass may be recycled into new glass, and wastepaper can be recycled into new paper. This recycling process ensures a sufficient supply of materials of reproduction for shelter, warmth, and other essentials in the future; the consequence is that CE is the most viable option to achieve a situation where the waste will be avoided by more effective manufacturing and recycling of items and resources (Purchase et al., 2021).

Waste in Africa and its management

Africa is the second-highest populated continent and its people are growing at the fastest rate (Adeyeye et al., 2023). Some African nations are still plagued by poverty and a lack of resources like clean drinking water, food supplies, and electricity (Murshed & Ozturk, 2023). Socioeconomic changes on the continent are supported by development in Africa, which includes electrical energy production, agriculture, urbanisation, education, and infrastructure (Omwoma et al., 2017). Changes such as these will necessitate a sizable workforce, extensive planning, and efficient waste management as a result.

The amount of waste produced by Sub-Saharan Africa (SSA) countries increased by 55 million tonnes between 2012 and 2019 (Ayeleru et al., 2020), with an estimated population of 1.31 billion in 2019 and 244 billion tonnes of waste estimated by 2025 and an estimated population of 1.5 billion (UNEP, 2022). According to a report by the Water and Sanitation Program (WSP, 2012), annual costs of improper waste disposal for Nigeria and Ghana are USD$3 billion and USD$290 million respectively, equivalent to 1.3% and 1.6% of these countries' respective gross domestic product (GDP). According to the same report, annual indiscriminate waste disposal costs Zambia, Liberia, Madagascar, and Kenya USD$195 million, USD$17.5 million, USD$103 million, and USD$324 million respectively, amounting to between 0.9% and 2% of each nation's GDP. These figures suggest that waste disposal has a direct financial impact on the nations in SSA.

The massive amount of uncontrolled waste and the ineffectiveness of the current waste management system in most developing nations have unprecedentedly impacted environmental quality and human health (Marshall & Farahbakhsh, 2013). The push for sustainable waste management in Africa has resulted in the adoption of several laws and policies intended to boost the effectiveness of solid waste management strategies, particularly in South Africa. Nevertheless, despite the advancements made in South Africa's waste management systems over time, some problems and shortfalls remain.

To achieve sustainable development through the switch from a linear to a circular economic model, Africa's waste management industry needs to be modernised. In developing nations, landfills are still a common method of waste disposal. However, landfills produce methane gas, a greenhouse gas 21 times more potent than carbon dioxide (Couth & Trois, 2012), which degrades groundwater quality and poses a risk to both people and the environment. The lack of waste collection and disposal has resulted in waste buildup in public areas, on the streets, and at other unauthorised dump sites.

Ethiopia, Botswana, Nigeria, and Algeria are a few nations that lack national regulations governing the proper disposal of such waste. Due to the quick reduction of waste – up to 90% – as well as the generation of heat for boilers or other energy production, incinerating waste is frequently the preferred method of disposal. If the proper technologies are not used, this kind of method could possibly produce risky by-products like harmful emissions and residuals.

Although waste is viewed as a valuable resource (Debrah et al., 2022) in the SSA region, some nations, including Ghana, Nigeria, South Africa, Ethiopia, Kenya, Rwanda, Namibia, and Ivory Coast, either partially or fully practise recycling (Mayer et al., 2019) and some form of CE. In contrast, other nations, including Somalia, Congo, Sudan, and Zimbabwe, primarily practise linear waste management, or take-make-dispose. The SSA countries cannot fully recover waste materials and give them useful purposes due to the linear material flow economy and the partial waste management recycling practise. As a result, these nations are unable to recover useful resources from their waste and reintegrate them into the regional economy. Therefore, encouraging the local economy's growth becomes difficult.

According to Taherzadeh et al. (2019), the CE concept, which promotes sustainable waste management by turning waste materials into new products, is more effective at helping reduce the effect of waste on the continent. This is the ideal substitute. There are currently some firms, programs, and initiatives in Nigeria that are geared towards the development of a viable CE. In this chapter, we refer to these firms, programmes, and initiatives as micro actors.

Miro actors in the CE transition in Nigeria (some contemporary developments)

There seems to be a concentration of CE activities in 2 states out of the 33 states of Nigeria, Lagos, and Ogun. There are emerging actors playing a very crucial role in the nation's CE transition. In this chapter, we describe these emerging actors (which include small firms and initiatives) as micro actors.

'Circular Lagos', a project backed by the circular exchange innovation platform and the government of Lagos State, is an example of micro actors. This programme, meant to encourage the growth of circular business and investment activities in Lagos State was introduced in November 2022. Within the Circular Lagos Project are two other micro actors, LOOP Lab innovators and Circular Lagos Business Platforms. The LOOP Lab is an incubator designed to support long-lasting commercial and technical partnerships between young ventures and more established industry participants. The Circular Lagos Business Platform represents business interests and facilitates business development and investment opportunities for local and international companies that offer circular products and services (Raphael, 2022).

Businesses serve as the foundation of the shift to CE, in the absence of comprehensive waste management framework mechanisms, by developing innovations that address the unique difficulties of the Nigerian economy. One of these issues is the general public's lack of knowledge about the value of CE and its lack of waste segregation culture. Initiatives run by social entrepreneurs like Wecyclers support the culture of waste segregation in households by influencing them with incentives. Wecyclers is a social venture that operates drop-off locations in residential areas of big cities like Lagos State where people may dispose of their plastic waste in exchange for financial incentives. While another organisation, the electronics importing company Slot Nigeria, collaborates with the E-waste Producer Responsibility Organisation of Nigeria to promote waste segregation culture and remove electronic waste from the environment, Wecyclers focuses on the collection of plastic waste for recycling (Recyclepoints, 2022).

Education plays a significant role in fostering a culture of waste segregation and assisting the transition to CE. Organisations such as the FABE International Foundation are crucial in raising awareness among communities about the significance of switching from a linear consumption model to a CE model. Fabe International Foundation works with communities to recycle waste materials into useful goods that can be sold to make money through their Tidy Nigeria programme. Another organisation, Susty Vibes, a youth-led community, promotes environmental protection and the need to switch from a linear to a circular economic model (Fabe, 2022).

Aside from coalitions backed by the international community and the government, multinational corporations are also key players in Nigeria's transition to the CE through programmes like the Coca-Cola Foundation's initiative to empower collectors. The initiative attempts to enhance Nigeria's informal plastic waste collecting and recycling system. The Coca-Cola Foundation wants to improve aggregators' capacity throughout six Nigeria states by empowering 3,000 female collectors and micro-aggregators with effective collection techniques. Two separate categories of efforts in supporting the transition to CE in Nigeria – plastic waste management and agricultural waste management, largely by small businesses – are shown in an overview of the majority of multicultural corporations' actions (Falaiye, 2022).

The growth of small firms with creative business models centred on CE has been fuelled by education, incentives, and the backing of international organisations. Most of these companies operate at the value chain's collector end. In the nation, only few businesses recycle waste on a significant scale into useful products. One of the few companies embracing CE is the multinational Lafarge Geocycle, which turns waste into affordable building materials and electricity on a large scale.

Methodology

Research design

The study focuses on developing a framework to explain Nigeria's CE transition. This study was conducted by applying the phenomenological case study research approach to capture the experiences of nine entrepreneurs in the Nigerian CE space. The constructivist paradigm posits that people socially construct and influence meanings to events (Allen, 1994). Compared to a linear economy, CE is a global phenomenon involving actors building society in a way that reduces waste and leads to ecological sustainability. The transition to CE that we are witnessing on a global scale is a novel way of modelling waste management. Transitions to CE are responses to the possible need for a more sustainable society influenced by constructionist ideas of people. As Guba and Lincoln (1994) explain, all such phenomena are human inventions.

The purpose of applying the phenomenological case study design lies in examining and discussing phenomena from the viewpoint of individuals who "live" them (Van Wyk & Taole, 2015). Hence, the interpretive approach was adopted to understand the depths of the emotions and thoughts of the actors. Participants in the study are primarily those who founded CE-based businesses and are heavily involved in their management. We aimed at achieving a better understanding of the transitioning process by researching the concept of CE from the point of view of Nigerian CE entrepreneurs, focusing on waste management and the reuse of waste as their business models.

The study focuses on the representation of lived experiences of the object of study, in this case, the entrepreneurs involved with CE, and how they construct meaning out of the world around them (Husserl, 1981). The phenomenological perspective assumes that phenomena are always phenomena for someone and can, therefore, never be studied independently of how they appear to a particular consciousness. Husserl (1981) argues that phenomenology studies different structures of experience, including perception, ideas, feelings, desire, memory, and thought. This also posits that meaning emerges from human experience.

Ontologically, the phenomenon studied must be understood as it appears through the human experience. Like hermeneutics, phenomenology's underlying truth theory is the coherence theory. The phenomenologist's approach to theory is inductive, that is, theories are formulated based on iteratively assessing and reassessing the empirical data in a cyclical manner rather than the testing of theories (Morse, 1994).

Data collection

This section presents real-world case studies from Nigerian firms that developed along the lines of sustainability and circularity. Morse (1994) proposes that the phenomenological researcher enters into dialogue with participants to provide good details of their experiences. Different textbooks recommend various sample sizes for phenomenological research, but a sample of six to twenty individuals is acceptable (Dare, Ellis and Roehrig, 2018). In many qualitative studies, the sample size is frequently constrained by practical factors such as financing, time, and access to participants. That notwithstanding, the nine cases were specifically selected for this study because of their relevance to the study. The case organisations are start-ups that are making great strides in CE in Nigeria. They are also representative of the geographic blocks of the country. This provides the study with the diversity required.

The sampling method employed is criterion sampling. According to Korstjens and Moser (2018), criterion sampling is used in phenomenological research during which participants must satisfy predetermined criteria set in the research design. The participant's familiarity with the phenomenon under study is the most important criterion. The researchers seek out participants who have had a similar experience but differ in terms of their personal histories and life experiences. Therefore, it was appropriate for the current study to contact the founders of the selected organisations, because they have lived through and experienced the phenomena of Nigeria's state of circularity and the nature of enterprise development in CE from both a personal as well as an organisational frame. The data was collected through interviews with the firms' founders. The authors transcribed the interview recordings. Other research associates verified the transcription for validity and reliability. The companies were: Environsafe Logistics, Pliris Waste Management Ventures, Afrique Eco Solutions, Garbage in Value Out (GIVO), Redivivus, Jumoke Waste Museum, Zimmacraft, Quadloop, and Scratop Nigerian Limited (Table 5.1 presents the details of the interviews conducted). The analytical approach took the hermeneutic phenomenological approach (Plager, 1994), which looked at the interpretation of the text (Laverty, 2003; Sloan &

Table 5.1 Schedule of interviews

Code	*Role*	*Organisation*	*Time and date of interview*
INT 1	Founder	Quadloop	5:00 p.m.–5:30 p.m.; September 5, 2022
INT 2	Founder	Scraptop Nigeria ltd	6:55 p.m.–7:55 p.m.; September 14, 2022
INT 3	Founder	GIVO	4:00 p.m.–4:30 p.m.; August 29, 2022
INT 4	Founder	Zimajcraft	3:00 p.m.–3:30 p.m.; September 5, 2022
INT 5	Founder	Waste Museum	3:30 p.m.–4:15 p.m.; September 2, 2022
INT 6	CEO/ Founder	Pliris Waste Management Ventures	7:00 a.m.–7:30 a.m.; September 5, 2022
INT 7	Founder	Redivius	12:00 p.m.–1:00 p.m.; August 29, 2022
INT 8	Founder	Ifrique Eco Solutions	12:00 p.m.–12:30 p.m.; March 17, 2022
INT 9	Founder	Environsafe Logistics	3:00 p.m.–3:30 p.m.; March 11, 2022

Note
INT means interviewee.

Bowe, 2014). A thematic analysis of the data was conducted to find the principal and common issues that touch on the transition process.

Results

This section presents the study's findings. First, we provide a background of the case firms. Then, as expected of interpretive studies, we present the findings along with discussion and analysis.

Envirosafe logistics

Afamefuna Asoegwu founded Envirosafe Logistics in 2014. The company began as a part-time job and was inspired by an encounter he had while working in a recycling company in the United Kingdom. Afamefuna acquired additional training from several of the institutions with which he worked. In 2014, through a collaboration with the environmental consulting firm RSK, one of Europe's largest privately held environmental firms, Envirosafe Logistics became a reality.

In Nigeria, Envirosafe began as a church group collecting objects for recycling under a different company name before transforming into a consulting firm. The business began with a small truck. During its first two years, the company collaborated with larger companies to provide waste management and evacuation services. The company's other source of income was the rental of its lone compactor, and its financial base was expanded through environmental consulting, health and safety training, and additional equipment supply.

Envirosafe's main operations have since evolved to include the recycling of chemical and hazardous waste. According to Afamefuna, "the organisation was founded as a way for me to do something kind that would also benefit the neighbourhood and environment. The majority of organisations involved in waste management dealt with regular waste, leaving hazardous material unattended. Envirosafe began in an effort to assist in the management of such wastes" (interview March 11, 2022).

Pliris waste management ventures

Pliris composts biodegradable waste for fertiliser and manure to be used for environmentally friendly farming. According to Oluwayomi, the CEO, Pliris is on a quest to reduce the quantity of biodegradable waste disposed of in landfills in Lagos through collaboration with households, marketplaces, and organisations.

The organisation promotes compost manufacturing with the Bokashi Composting technique, a simple do-it-yourself composting technique and kit introduced to families and businesses. Piliris accomplishes this by collecting garbage from private businesses and decomposing it in composting facilities. Composting as a service to farms and other organisations assists with on-site composting. Pliris details several obstacles, including waste segregation culture, logistics, and government support.

The primary objective of the production process is to reduce biodegradable waste. To aid in food production, the production process reduces waste and sells the products to farmers. The organisation also manages these farmers' biodegradable waste. Pliris collects biodegradable waste from food markets and food processing companies throughout Lagos. Sawmills are the source of the sawdust used in the production of compost. The production cycle relies solely on natural processes. Diesel fuel is only used for crushing hard materials, such as coconut husks, which are extremely durable. However, this equipment is utilised sparingly, which lowers their carbon emissions. The majority of the organisation's raw materials are biodegradable waste that is fully utilised in the production process; consequently, the organisation generates little to no waste. Raw materials are the only waste product of the production process. However, plastic caps are difficult to manipulate, and these recyclable wastes are outsourced to other businesses.

Ifrique Eco Solutions

Ifrique Eco Solutions is a start-up with a mission to solve the housing deficit in Nigeria with affordable building materials recycled from plastic wastes. The company upcycles plastic waste into interlocking tiles, eco-toilets tiles to curb open defecation in Nigeria. This organisation was born out of a passion to curb the problem of indiscriminate disposal of plastic waste in Nigeria. Plastic waste is not biodegradable and poses a serious health risk to Nigerians. The passion for curbing this waste in Nigeria led to the establishment of Ifrique Eco Solutions, which raises awareness of the dangers of disposing of plastic waste indiscriminately.

Since the rate of plastic use is continually growing and knowing that plastics can be sustained for thousands of years before decaying, Ifrique Eco Solutions found the need to not only educate people about the product but also to gather the plastic waste and make good out of them. Due to its efforts, the company believes that the collection of waste plastic in its catchment area is expanding at both a speedy and a very big scale; this indicates that the problem of waste plastic can be eliminated for an extended period of time. It appears to be a more workable and effective technique to find a solution to the problem of plastic waste.

Garbage in Value Out (GIVO)

The lack of data on the amount of plastic waste produced in Nigeria and the absence of a culture of waste segregation represent a common barrier to Nigeria's transition to CE. Victor, the founder of GIVO (Garbage in Value Out), saw the need to collect data on plastic pollution in Nigeria and founded a social enterprise to address the issue. Through plastic collection community hubs in and around Lagos, GIVO disseminates the philosophy that waste is useful to other families and communities. Through these plastic collection community hubs, the organisation collects data on the amount of plastic waste produced and provides community members with incentives to promote a culture of waste segregation. According to Victor, "In the absence of government entities dedicated to enforcing plastic pollution regulations, incentives and advocacy are crucial tools for influencing changes in household behaviour" (interview August 29, 2022). The information collected from the homes where the hubs operate is used to provide loans and insurance to the communities surrounding the hub. Statistics can also be used to persuade Nigerian policymakers of the need for effective legislation to combat plastic pollution. GIVO collects the necessary information via a mobile application.

In addition to data collection, GIVO uses plastic waste to create toys, furniture, and personal protective equipment (PPE). Utilising its manufacturing capabilities, the company overcame the lack of PPE equipment for frontline staff during the COVID-19 pandemic. The production process at GIVO is designed to generate minimal waste.

GIVO faces the same difficulty as other small businesses in Nigeria in securing sufficient capital for its plastic recycling plants and manufacturing centres. Numerous Nigerian businesses face this problem due to a lack of research and manufacturing capabilities in the country. Due to the naira's low value, machinery is expensive and admission fees are exorbitant. Victor has emphasised the need for more financial institutions to fund initiatives in the waste management sector. In addition, legislation must be developed in Nigeria to ensure that local businesses have access to carbon credits and to enhance the institutional capacity of waste management agencies.

Redivivus

Redivivus, a recycling company headquartered in the eastern state of Anambra, began as an expert consultancy in small business development in Anambra. Through interactions with small businesses, Emeka, the business owner, observed a gap in the waste management system of Anambra State and devised a business model in response to a gap he observed in the waste management system of Anambra State. To go about solving the challenges he observed, he established a facility for waste recycling. To further solve the waste management challenges in the state, the company has transitioned from a typical recycling business to a manufacturing company that produces affordable building materials from plastic waste and also provides a solution to the housing deficit challenge in Anambra State. Utilising new waste management solutions for low-density polymers and polyethylene, write-offs adhere to the CE's waste reduction process. The prevalence of water sachets in Nigeria as a result of the state's lack of potable water makes the need for innovative solutions for low-density plastics in Nigeria all the more important. The organisation acquires its supplies from aggregators in Anambra. To preserve the integrity and quality of the output, approximately 28% of it is also composed of virgin materials.

The CEO admits that his recycling factories are not entirely eco-friendly, as they must use diesel generators to power the plants. The unreliable electricity supply in Nigeria necessitates the use of diesel generators in the waste management industry. Redivius collaborated with the energy distribution agency in Anambra to address this issue of an unreliable power supply. The organisation employs a waste management strategy that generates minimal waste from the industrial process. The organisation faces the fundamental obstacle of a lack of statistics on Nigeria's waste production.

Jumoke Waste Museum

Passionate about CE, Jumoke founded the Waste Museum as a summer camp that teaches children how to transform waste into valuable materials. Jumoke, the organisation's founder, initially taught children to create art from waste. She began stockpiling art supplies from her summer classes and personal projects before establishing the waste museum. After a number of years, Jumoke opened the Waste Museum to the public and transitioned to using the museum as a vehicle for raising the awareness of CE.

The Waste Museum, one of the organisation's core services, educates individuals on the various uses of waste in an effort to change their behaviour from take-make and waste consumption to circular consumption. The Waste Museum demonstrates the viability of the CE to encourage its use in visitors' daily lives. "In the Waste Museum, humans, animals, and plants coexist without producing waste" (interview September 2, 2022). The museum contains over 150 plants and animal species. In addition, the museum teaches families how to use waste to cultivate their own gardens using the CE model. Before 2025, the museum intends to teach 10,000 families how to grow their own food. The primary products of the museum are household items created from repurposed materials. In the museum, materials are sorted at the source (houses and businesses), and contaminated waste is not utilised. The museum utilises a combination of solar and regionally generated electricity for its production. The organisation intends to utilise biogas to power its facility in the future thanks to a bio-digester developed in collaboration with the International Institute of Tropical Agriculture (IITA).

The Waste Museum employs a system that does not generate waste. Animal waste is used to nourish plants, and plants in turn nourish the animals. Waste is disposed of using the standard procedure for waste disposal. A great deal of focus is given to the transition to a CE. According to Jumoke, there is a need to alter the consumption patterns of influential industry leaders to realise funding for entrepreneurs in the sector.

Zimmacraft

Zimmacraft manufactures and sells an alternative to charcoal made from rice processing by-products in Nigeria. The founder of Zimmacraft desires to combat climate change and deforestation in Nigeria's savannah region using her products. This idea was inspired by a desire to provide widows with a sustainable source of income. Zimmacraft teaches widows how to produce this alternative charcoal so that they can provide for their families.

Zimmacraft obtains its raw materials from western Nigerian rice farms and mills. Using a machine that transforms rice husks into the final product, Zimmacraft manufactures smokeless charcoal. The production process reduces carbon emissions and methane emissions. However, due to a lack of electricity, Zimmacraft uses diesel-powered machines in the production process; this form of power production contributes to environmental pollution. Despite this, most of the raw materials used in the production process are eco-friendly, and the small amount of waste is returned to the soil to enrich it.

Quadloop

The Nigerian e-waste management company Quadloop manufactures solar lamps and lanterns from recycled electronic waste. The solar lamps produced by Quadloop provide a cost-effective source of energy to households and hospitals in underdeveloped nations. Quadloop extracts valuable materials from electronic waste collected from Lagos's major electronic markets. Quadloop also assists large corporations in repairing and reusing solar batteries. Through this service, Quadloop assists these businesses in reducing expenses.

Chidozie, the founder of Quadloop, describes his production process a waste-free process, and the company depends on the power supply from the national grid. However, one of the key challenges Quadloop faces is obtaining sufficient raw materials for production since Nigerians do not readily dispose of their electronic waste. Another difficulty Quadloop faces is obtaining sufficient funding for the e-waste stream, given that this waste stream consists of hardware and that Nigeria lacks the skills necessary for the local production of hardware. Therefore, it is difficult to convince investors of the business's viability.

In Nigeria, it is also hard to find people with the technical expertise to design electronics from scratch. Consequently, Quadloop faces the difficulty of recruiting enough personnel with an understanding of electronic waste for the workshop. To address this issue, Quadloop trains young graduates as interns in its workshop then employs them as employees in its workshop. Since the level of environmental sensibility is low among consumers in Nigeria, people are not willing to pay more for environmentally friendly products. To address this problem, Quadloop collaborated with hospitals, which helped spread the word about the company's products to Nigerian households.

Scraptop Nigeria Limited

Scraptop Nigeria Limited is a social enterprise that purchases biowaste, food waste, fruit waste, and post-harvest losses, then converts them into Organic NPK fertiliser for crop production. The concept was developed during a Hult Prize competition for audacious businesses for a better planet. The CEO realised that biodegradable waste posed a challenge in Nigeria after speaking with local farmers about the need for organic fertiliser.

Currently, there is a high demand for organic NPK fertiliser, but not enough quantity is produced to meet this demand. To source for raw materials, the founder of Scraptop Nigeria collaborates with cassava farmers and food vendors, poultry farms, rice mills, and waste shops in the state's major markets. Scraptop is an environmentally friendly company because it removes waste from the environment.

In the Scraptop production process, very minimal waste is generated during the manufacture of organic NPK fertiliser, and waste generated is used as fertiliser. As with the other entrepreneurs interviewed, energy supply poses a significant issue in the manufacturing process. Another major challenge is the lack of a waste sorting culture that makes the production process somewhat difficult. Other challenges Scraptop faces include multiple licenses, fertiliser regulations, and multiple taxation, which make it difficult for businesses to expand. Nigeria's lack of a waste sorting culture makes the production process somewhat difficult. Nigeria requires additional education to influence the culture of waste segregation.

Analysis: A framework for transitioning from rhetoric to enterprise development

The interviews with the organisations led to development of a framework for explaining the transition from rhetoric among government and other stakeholders such as waste management organisations and the general public to active enterprise development in Nigeria. In the created framework, we describe at the individual firm level how the discussions on CE could lead to the establishment of enterprises (Figure 5.1).

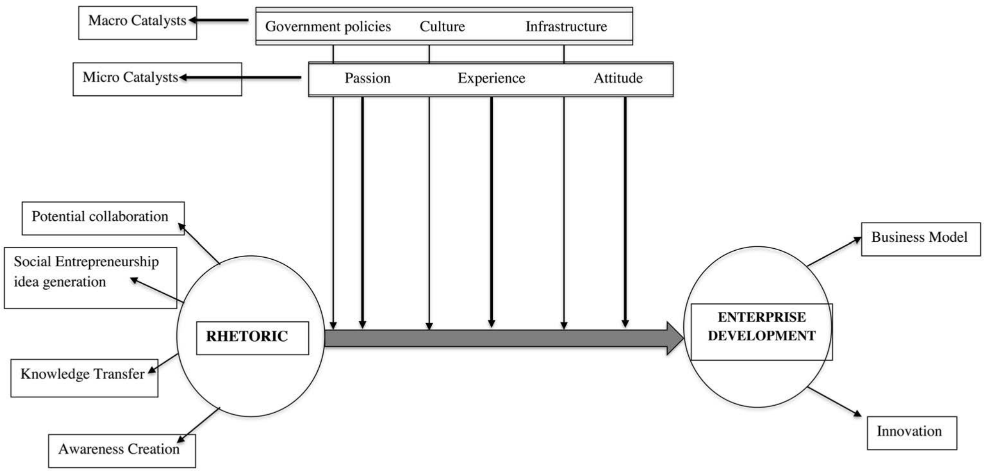

Figure 5.1 CE model.

Source: The authors.

First, the importance of the rhetoric about CE, meaning conversations about CE at the national and individual levels, cannot be underrated. This rhetoric results in awareness creation, knowledge transfer, social entrepreneurship ideas generation, and the potential for collaboration. Understandably, the rhetoric does not automatically lead to enterprise development. There is a need for some macro-level and micro-level catalysts, as identified from an analysis of the interviews. The micro-level catalysts identified after the thematic analysis were the respondents' passion, experience, and attitudinal change that led them to the establishment of their businesses. At the macro-level, it was found from the respondents that there is a need for government policies, national strategies, and enabling infrastructure on CEs that would enhance the activities of the CE players. The consequences of having enterprises developed along the lines of CE are estimated to be large, based on the interviewee responses. Business models, innovations, and CE collaborative enterprises are likely to be developed because of the catalysts' impact. These future developments were predicted to have national effects.

Key circularity catalysts in Nigeria

Macro-level catalysts

Macro-level catalysts refer to the national and institutional issues that enable CE development. An analysis of the interview data showed that the move from rhetoric to enterprise development requires macro-level catalysts, such as supportive government policies, culture, and infrastructure development. Although, thus far, most enterprises developed around the CE have been by private people, the government's role is felt to be imperative.

Government policies

According to the respondents, there are two things that must take place at the governmental level in terms of policy to promote a CE. First, the government policies put in place to handle the negative effects of production and consumption should be strategically developed. Pollution taxes should be set at a level higher than the detrimental effect of the same to deter polluters. While the respondents viewed the institution of taxes as a good thing, to ensure the progress of CE enterprise development, governments may compensate institutions that adhere to, for instance, segregation and proper gathering of waste, which will feed into CE enterprises as raw materials.

Second, the respondents require that the government would create an enabling environment for CE enterprises through the provision of funds. CE start-ups such as those interviewed for this research are growing at a slower rate as compared to larger businesses not focused on a CE. To allow for enough capacity to meet this escalating need, the government may support CE start-ups in the form of capital provision. According to one of the interviewee firms, "As a start-up, funds were limited for growing the business. Getting capital was a challenge as there are loans unavailable to support green manufacturing in Nigeria. Lack of capital has also hindered the expansion of the business" (see INT3). With government support, there would be the creation of many CE enterprises.

Since government agencies alone lack the capacity to handle the waste streams effectively, the participants viewed a comprehensive private-public partnership as being imperative. The government may provide an enabling environment for CE enterprises by partnering with them. Government partnership would then in turn help expand the base of the private CE enterprises.

Culture

The issue of culture was eminent in the responses received from the interview participants. One key among these catalysts is a change in the culture of waste disposal and its segregation. The respondents posit that there is a need for a change in the waste disposal and waste segregation culture of Nigerians. They further felt that most Nigerians are currently unaware or do not practice waste segregation or formalised waste disposal.

Additionally, the expansive and time-consuming nature of waste segregation makes it unattractive. Consequently, to promote a change in culture, respondents suggested that consumers would need to derive utility from the practice of waste segregation. Hence, a change in culture must first be promoted by focused education programmes to increase consumer awareness and interest in CE. These mass education intervention programmes could highlight the benefits of proper waste disposal and waste segregation at the grassroots level. This would require a broad planning and cooperation with multiple levels of social infrastructure. One of the interviewees lamented that "getting people to segregate their garbage voluntarily is quite difficult, as biodegradable waste stinks and pollutes the environment" (see INT4). Further suggesting that "more awareness is required to ensure waste segregation culture in Nigeria" (see INT4).

Infrastructure: Logistics and power

Infrastructure provision in the form of logistics is also critical to the development of CE enterprises. The respondents seem to have a convergent opinion on the need for logistical support, and this support would come from the government. Waste must be moved to various sites for recycling activities to be conducted, and to ensure this, there is heavy reliance on compartmentalised trucks, road sweeper machines, bulk refuse carriers, dumper placers, etc. These logistics are quite expensive for private CE entrepreneurs to acquire, so governmental support becomes necessary with logistical issues.

One of the interviewees proposed an alternative to the provision of logistics by suggesting a less expensive but viable alternative that would also reduce the pressure on dumpsites. He stated that "because biodegradable waste generates a foul odour, transporting it might be a chore depending on the situation. One possible answer to this problem is to build community composting sites to eliminate the need to transport waste from one location to another" (see INT1). Community compost sites could be a plausible alternative to logistical problems, yet again the development of a community compost site was seen to often be a part of the government's infrastructure development agenda. Admittedly, community compost sites may solve local logistic issues, but other aspects, such as environmental impact, should be considered.

Apart from logistics, electric power is pertinent in most CE businesses. The following statement was echoed in many respondents' interviews, "Access to energy is a major challenge to manufacturing firms in Nigeria. The unreliable power supply and the soaring cost of diesel needed for operating machines could lead to an increase in manufacturing costs and the price of the products" (see INT2). This unreliability in the power grid was seen to discourage the establishment of CE enterprises.

Micro-level catalysts

The micro-level catalysts refer to the individual-level dynamics that promote CE enterprise development. Individual passion, experiences, and attitudes were identified as the micro-level factors.

Passion

Data collected from the respondents shows that CE entrepreneurs usually have passion that is not only directed towards fellow humans, as in a close relationship, but also state they have a passion to the environment, which is inanimate. These entrepreneurs move with consistency, urgency, and a great desire to see their dream of waste management and circularity accomplished. This passion "represents the energy underlying such persistent involvement" (Vallerand et al., 2007, p. 506). Having a strong passion for something seems to motivate people to fully commit to it, which may enable them to persevere in the face of challenges and eventually achieve excellence.

According to Vallerand (2012, p. 1), "passion is defined as a strong inclination toward a self-defining activity that people like (or even love), find important, and in which they invest time and energy on a regular basis. Vallerand's (2012) model proposes the existence of two types of passion: harmonious and obsessive". All the CE entrepreneurs interviewed allude to the fact that they were driven by a passion "to see a change" (see INT 6), "to get the waste in Nigeria made useful" (see INT4, INT3, and INT1).

Experience

It is important to acknowledge the role of past experience of the CE entrepreneurs interviewed since most of them make reference to it. According to one respondent, "I worked with a company in the United States before coming back to Nigeria and that is where I learned about converting waste into something more useful" (note: Reference code restrained). The respondents talked about their exposure to CE firms they have worked with. This has become a motivating factor for them to establish their businesses. Apart from this kind of experience, the respondents revealed that they had experienced failures. They admitted that they have had to learn the hard way. Experience, therefore, can be characterised as an important catalyst for CE transition.

Attitudes

Attitude refers to the "a relatively enduring organisation of beliefs, feelings, and behavioural tendencies towards socially significant objects, groups, events, or symbols" (Vaugha & Hogg, 2005, p. 150). According to Zhang et al. (2021), the attitudes of people in relation to sustainability are usually formed based on economic (e.g., price, income), psychological (e.g., different hierarchies of needs), anthropological (e.g., religion, culture), and marketing (e.g., perceptions) factors. For instance, people will respond positively to the culture of waste segregation based on the cost associated with it, the need that they assign to it, their religious leanings, and perceptions about the act.

Data gathered in this study shows that positive attitude towards sustainability will lead to more CE enterprises developed than a negative one (as we found in the interviews, people with sustainability tendencies tend to promote the establishment of CE-focused businesses). The enterprises are developed as they reflect the innate attitudes of the founders towards sustainability. Amoah et al. (2022) posit that, like all Africans, Nigerians have natural sustainability tendencies.

Enterprise development

From the data, it is clear that the deployment of the right micro and macro catalysts identified in this study will lead to the development of business enterprises that promote a CE in Nigeria.

The shift to a value-creating CE will lead to new business models, value chains, and product-service delivery mechanisms. The shift influences the design, production, usage, and disposal processes, and the gathering of products and materials for reuse. A transition to a CE also introduces new methods to facilitate, maintain, share, repair, upgrade, and remanufacture items (Russell et al., 2020).

The literature presents five types of business models and enterprises in CE. These models are named as follows: "(a) circular supplies, (b) resource recovery, (c) product life extension, (d) sharing platforms, and (e) product as a service" (Chen, 2020). Businesses formed around the circular supplies model reuse, reprocess, and renew inputs for productive use. Businesses formed around the second model of resource recovery develop closed-loop recycling and cradle-to-cradle designs with discarded products into new products (Li & Su, 2012). The third model, "product-life extension", focuses on extending the life cycles of products' assets. The fourth model makes products and assets accessible to most people by promoting a platform for collaboration among product users, both individuals and organisations. The fifth business model promotes the product as a service as an alternative to the buy and owns model.

Of the five business models, the businesses we examined in the Nigerian context have business models around circular supplies, product life extension, and resource recovery models. Few businesses have harnessed the opportunities that abound in the sharing platforms and product as service models. A large percentage of the players in CE are the waste pickers in the informal sector and formal recyclers (Morais et al., 2022).

Infrastructural challenges – especially around logistics – power availability, and machinery continue to hinder the development of enterprises in the resource recovery model. As one of our interviewees who produces tiles from plastic waste noted "production costs at my factory are high due to the poor power supply in the country" (see INT 9). Respondents stated that if they were to incorporate the cost of power and logistics into the product price, this would result in high, noncompetitive pricing. The incorporation of power and logistics costs poses a major challenge for the case firms. The respondents lamented how difficult it was to start and sustain a business in Nigeria, as a majority of consumers are unaware of the importance of sustainability; therefore, the respondents felt that the customers would only purchase products that are affordable for them. This challenge highlights the urgent need to develop local machinery and technological solutions that promote circular businesses in Nigeria. Innovation is especially needed for machinery to incorporate the infrastructural challenges prevalent in the country into the design of products.

Conclusions

This study examined the perspectives of nine Nigerian entrepreneurs involved in CE. Through the analysis of interview data, it was determined that there is a need to transition from rhetoric to enterprise development in the context of CE, which respondents believe has the potential to boost Nigeria's national prosperity. The transition to a CE required a collaborative and concerted effort from all stakeholders, including entrepreneurs, government, social activists, researchers, policymakers, end users, and international actors.

The study highlights the significance of macro- and micro-level catalysts. It is evident that CE presents a promising opportunity for Nigeria to address environmental challenges while promoting economic growth, and the successful implementation of this transition will require a sustained and committed effort from all stakeholders.

Moreover, the study emphasises the importance of innovation and creativity in promoting CE practices in Nigeria. Entrepreneurs who successfully implemented circular business models demonstrated a high level of creativity and innovation in their approach. They were able to identify untapped resources, develop new products and services, and engage in collaborative partnerships to enhance their business models. These findings suggest that promoting innovation and creativity in the CE space could unlock significant economic and environmental benefits for Nigeria.

Additionally, findings from the study suggest the need for appropriate government policies that would encourage the establishment of CE businesses. Policymakers and stakeholders should prioritise creating an enabling environment for CE start-ups to thrive. This can be achieved through the provision of necessary support and infrastructure, such as tax incentives, grants, and favourable policies that encourage CE practices. The availability of waste management facilities, recycling plants, and renewable energy sources will also enable CE start-ups to operate effectively.

Founders of CE start-ups should prioritise developing passion, experience, and a positive attitude towards enterprise development. This can be achieved through acquiring relevant skills, seeking mentorship and guidance, and learning from successful entrepreneurs. A positive attitude towards enterprise development enables founders to overcome setbacks and challenges that come with enterprise development.

In conclusion, the transition from rhetoric to enterprise development in CE requires a collaborative effort from policymakers, stakeholders, and CE start-ups. By creating an enabling environment; prioritising education and awareness; fostering collaborations and partnerships; emphasising passion, experience, and attitude; and supporting research and development, CE start-ups can thrive and contribute to a more sustainable future.

Educational content

1 There is value in discussing the CE proactively as part of national discourse.
2 Can a CE occur without government support or intervention?

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Appendix
INTERVIEW GUIDE

Introduction

1 Self-introduction of the interviewer
2 Explain the purpose of the meeting
3 Explain the general purpose of the study

   a The study is basically to understand the reason for the move from rhetoric to the development of enterprises in CE.

4 Seek interviewee consent on recording
5 Assurance of confidentiality

Interview questions

1 How did your business start (please provide a historic background and what motivated you to start)?
2 What is your business into? (What role does your organisation play in the circular economy)?
3 How challenging has it been for you?
4 What challenges do you perceive as your business progresses?
5 How would you describe your ultimate goal as a business owner?
6 How do you think Nigeria can advance in its quest to enterprise development in CE (any workable recommendations)?

6

CATALYSTS FOR TRANSITION TO CIRCULAR ECONOMY SOLUTIONS IN THE BIOWASTE MANAGEMENT SECTOR IN INDIA

Bhavesh Sarna, Rahul Singh, and Pankaj Singh Rawat

Introduction

India is the fifth largest economy in the world and is growing fast to be in the top three global economies. India's economic growth is unprecedented, with about a 10% gross domestic product (GDP) growth rate (Asian Development Outlook [ADO], 2021). While industrialisation is growing at an accelerated rate, India faces three distinct challenges: (1) to provide a continuous energy supply to industries, (2) to reduce greenhouse gas (GHG) emissions to tackle climate change, and (3) to manage waste generated with the industrial and population growth. In response to these challenges and the diminishing and limited resources of traditional fuels such as natural gas, petroleum, and coal, there has been a need to develop an economy around biofuels.

Post–Paris Agreement in 2015, biofuels have gained significant attention around the globe since they are considered one of the most sustainable and environment-friendly forms of energy (Joshi et al., 2017). Countries have created national policies to motivate biofuel production and its usage in their countries. India also has its own National Policy on Biofuel (NPB), which was last updated in 2018. The NBP of India states, "biofuels are fuels produced from renewable resources and used in place of or in blend with diesel, petrol or other fossil fuels for transport, stationary, portable and other applications" (NPB, 2018, p. 15). The policy categorises biofuels into three generational categories:

1 First generation (1G): "Basic Biofuels" made of ethanol from molasses from non-edible oilseeds;
2 Second generation (2G): "Advanced Biofuels" – ethanol manufactured from municipal solid waste (MSW) to drop-in fuels; and
3 Third generation (3G): Bio-CNG, which is defined as a "purified form of bio-gas whose composition and potential energy is similar to that of fossil-based natural gas and is produced from agricultural residues, animal dung, food waste, MSW, and sewage water" (NBP, 2018, p. 15).

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In this chapter, we limit our focus to Bio-CNG production aspects in India, as it is a recent development and requires more in-depth analysis. The total Bio-CNG production in India, even though it has been an agrarian economy for a long time, is only 2.07 billion m^3/year, despite the massive potential of 29 to 48 billion m^3/year (Mittal et al., 2018). There is a vast, untapped Bio-CNG market in India, which needs proper utilisation of resources to generate higher levels of Bio-CNG production in India. To address this issue, a Bio-CNG plant has been built in the city of Indore in central India. As of 2022, this plant will be Asia's largest Bio-CNG manufacturing unit, producing 17,000 kg of Bio-CNG and 100 tonnes of organic compost from 550 tonnes of organic solid municipal waste per day (Press Information Bureau, 2022b). Further, the Indian government promises that 75 municipalities across India will receive similar Bio-CNG plants within the next two years (Press Information Bureau, 2022b). This large-scale transition uses a circular economy (CE) model to focus on using abundantly available waste, which is defined as solid waste, sludge waste, agricultural waste, and biodegradable waste. Also, this CE transition is creating a huge paradigm shift in multiple stakeholders that contribute to this circular economy.

Recent studies indicate that the use of biomass through using sustainable CE of waste for energy production can reduce GHG emissions (Kapoor et al., 2020). CE has emerged as a business model that integrates economic activity with environmental well-being for sustainable development (Murray et al., 2017). This emphasises redesigning processes and recycling waste materials to promote more environmentally friendly business models (Pearce & Turner, 1990), shifting away from the traditional waste management system in a linear economy. The traditional philosophy of efficient industries and economies worldwide has revolved around produce-use-dispose since the industrial revolution over the last century (McDonough & Braungart, 2010). Today, the 'cradle-to-grave' model (McDonough & Braungart, 2010) is still followed, creating a massive issue regarding waste management. For a country like India, a CE provides an in-depth industrial and economic development solution by managing waste and producing Bio-CNG.

As far as CE action areas are concerned, bioenergy and Bio-CNG are two fields that lack comprehensive analysis (Winans et al., 2017). Furthermore, in the Indian context, many articles and scientific journals have been written on several production and environmental opportunities and technical issues associated with biofuel generation (Dwivedi & Sharma, 2014; Joshi et al., 2016; Luthra et al., 2015; Mittal et al., 2018), but a few have focused on the business model and especially catalysts for such business models that support an economic transition to the use of biofuels through waste management for renewable energy generation (e.g., Goyal et al., 2018; Jonker et al., 2017; Rogge & Reichardt, 2016). To have a successful business model transition, India needs to understand which catalyst promotes CE to both manage large waste and manufacture Bio-CNG.

The primary aim of this study is to identify the catalysts of the transition to a CE for waste management by utilising waste for Bio-CNG production in the Indian context**.** To achieve this aim, we conducted 27 semi-structured interviews with the identified stakeholder group members to understand why they want to contribute to CE for Bio-CNG production. Specifically, we analysed how different factors serve as catalysts in the creation of an ecosystem that supports a CE for waste management and Bio-CNG production in the Indian context. The results show that there are six major catalysts that contribute to the development of CE in India that support efficient waste management for Bio-CNG production.

The contributions of this chapter are threefold. First, it introduces all the catalysts that are active in CE initiatives so India can create a business model that revolves around waste management for Bio-CNG production in the Indian context. Second, this chapter investigates the need for different stakeholders to participate and impact on circularity within the Indian Bio-CNG production process through waste management, offering yet another perspective on the literature with an emphasis on synergies based on different stakeholders' needs. Third, the study's focus on India and its waste management and Bio-CNG manufacturing industry contributes to the growing body of research on this topic coming from emerging economies.

The study presented in this chapter is organised into five sections. The current section presents the motivation and need for this study. The next section reviews relevant literature to understand the Indian context of waste management and the need for CE. After this, we describe the proposed methodology for this research with a description of data analysis. The results are presented in the following section and the last section presents a discussion of this study's findings and concludes the chapter.

The Indian context for waste management

Globally, the emission from the waste sector ranks low, which can be further managed with effective means (Koop & van Leeuwen, 2017). But in India, due to the population size and the waste management sector, waste emissions contribute to about 4% of India's total GHG emissions (Kolsepatil et al., 2019). These emissions come from municipal solid waste, agriculture, domestic, and industrial waste. As a result, waste generated has enormous potential as a large-scale alternative energy source through biofuel production, such as Bio-CNG. The waste management sector is divided into urban and rural segments. The urban sector is well organised and integrated with the local municipal bodies. The biowaste generated in the urban sector comes from places such as household, retail, and industrial wastes, which are collected by municipalities. The rural sector is not yet organised and generates multiple forms of agricultural waste.

The national-level composition of India's waste management profile is a concern both from a CHG emissions perspective and an opportunity to contribute to green energy production in the country (Table 6.1). A report by the Ministry of Environment, Forests and Climate Change

Table 6.1 Energy potential mapping from waste in India

SN	*Sectors*	*Energy potential – MW*
1	Urban solid waste	1,247
2	Urban liquid waste	375
3	Paper (liquid waste)	254
4	Processing and preserving of meat (liquid waste)	182
5	Processing and preserving of meat (solid waste)	13
6	Processing of fish, crustaceans (liquid waste)	17
7	Vegetable raw and processed (solid waste)	592
8	Fruit processing (solid waste)	21
9	Fruit raw (solid waste)	203
10	Milk processing/dairy products (liquid waste)	24
11	Maise starch (liquid waste)	47
12	Tapioca starch (solid and liquid waste)	53
13	Sugar (liquid waste)	49
14	Sugar press mud (solid waste)	200
15	Distillery (liquid waste)	781
16	Slaughterhouse (solid and liquid waste)	315
17	Cattle farm (solid waste)	862
18	Poultry (solid waste)	462
Total potential of energy (MW)		5,697

in 2021)states that India generates about 65 million tonnes of waste annually, including organic waste and recyclables such as paper and plastics (Ministry of Housing and Urban Affair, 2021). As per the Standing Committee on Urban Development Report (SCUDR) among this waste, 45–50% is biodegradable, 20–25% is recyclable, and 30–35% are classified as inert or debris (Ministry of Housing and Urban Affair, 2021). Out of this entirety, approximately 75% gets collected, and about 30% of this collection gets processed. Thus, increasing waste adds an environmental burden if it is not adequately treated, increasing the risk for major future climate concerns as waste production increases by multifold in the near future.

These waste management challenges have placed pressure on the Indian government, but they have also created a potential opportunity to drive energy production forward. It is expected that the use of waste in energy production, such as Bio-CNG, will reduce the import of fossil fuels to India and resulting from this, a reduction of carbon emissions into the atmosphere is expected, thereby potentially reducing global warming. It is also expected to create new jobs (Raza et al., 2011). India is committed to a "reduction in energy emissions intensity by 33%-35% by 2030 and the share of non-fossil fuel-based capacity in the electricity mix is aimed at above 40% by 2030" (NPB, 2018; p. 14). However, India already achieved this target in November 2021 and announced this accomplishment at the COP 26 meeting in December 2021. Consequently, India revised its targets to a 50% share of non-fuel-based capacity by 2030. In October 2021, to achieve this new target, the government of India (GOI) launched the second phase of the Swachh Bharat Mission-Urban 2.0 (SBM-U 2.0). This new initiative kicks off the implementation of the SBM-U 2.0 plan to make all cities in India garbage-free, which directly supports the integration of the waste management system with the cities' energy needs through Bio-CNG production (Departmentally Related Standing Committees, 2019). Along with this, GOI has initiated the second phase of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0) for capacity building to reduce, reuse, and recycle in urban spaces. These types of initiatives open possibilities for transitioning from linear to circular economies. These proposed initiatives are directly linked to the municipal waste collection system and cater directly to the waste management needs of the urban sector in India. While waste management in urban India is being addressed to a large extent, waste management issues in the rural sector are under-addressed.

Challenges in waste management for the rural sector

Rural areas remain neglected in waste management. In the past, GOI had heavily endorsed small-scale biogas plants, promoting their use for biogas. Most of these projects were off-grid applications, and most gasifiers were limited to individual households. In the 1990s and early 2000s, four million family-sized biogas installations were installed in India (Raza et al., 2011). The Ministry of New and Renewable Energy (MNRE, 2022) estimated that the annual capacity to produce biogas could reach 17,340 million m^3, which is sufficient to install approximately 12 million family-sized biogas plants (Raza et al., 2011). Since these initiatives were primarily off-grid, such biogas production did not contribute much to the large economy or national energy production or reduce the dependence on fossil fuels (Gotmare & Nair, 2019). However, this initiative was not financially viable, and the output was insufficient for local consumption (Mittal et al., 2018).

Another issue with small-scale biogas plants was the need for a constant supply of raw material for the biogas generation. Such family-owned biogas production units were heavily dependent on agricultural waste. Agriculturally based raw materials are seasonal related to agricultural harvest cycles (Kimothi et al., 2020). Harvest cycles are not a continuous process; hence, they are not heavily dependable for the continuous production of biogas. Thus, this model is commercially unviable in a regional or local model that does not support an economy of scale or the larger national economy (Gotmare & Nair, 2019). The Indian government implemented many small-scale projects to supply renewable energy to rural areas (TERI, 2010). However, such undertakings were made with seemingly little effort to understand the needs of rural India. The rural population's perceptions and attitudes toward these bioenergy resources had not been thoroughly investigated in the agricultural sector, thus the so-called 'felt needs' were never assessed, but the so-called 'real needs' were assigned (Raza et al., 2011).

Waste management in urban cities – Example from Indore

The rapid increase in population has made municipal solid waste management an increasingly significant activity in the urban areas of India. Among the numerous responsibilities of municipal corporations and local urban bodies are the reduction and efficient handling of solid waste. To achieve a CE in urban cities in India, waste source separation plays a crucial role in sustainable and integrated municipal solid waste management (MSWM). Even so, uncontrolled and open waste dumping continues to be an unofficial practice in many cities, where mixed waste is received without any preparation for disposal (Dickella Gamaralalage et al., 2022). However, this practice is changing in many cities such as Indore, Pune, Surat, Bangalore, and other cities across the country. Next, we briefly describe the change in Indore.

The city of Indore achieved 100% source separation and a door-to-door waste collection system within a short, two-year time period (2015–2017) (Kanojia & Visvanathan, 2021). Under the government's Swachh Bharat Mission's (SBM) Swachh Survekshan Competition, the city received the national award for India's Cleanest City in the over one million population category for six consecutive years (2017–2022). The previous MSWM provision in Indore Municipal Corporation (IMC) was inadequate, which resulted in the city being one of the dirtiest in the region until 2015 (Indore Municipal Corporation [IMC], 2019). Residents discarded domestic waste at will, community bins overflowed due to a lack of waste collection, and stray animals roamed the streets freely; citizens had continued to demand improved waste collection services. Ultimately, these individual citizens' concerns led to the implementation of source separation; in response, the IMC adopted the Solid Waste Management Bylaw 2018 (Ghosh, 2017, 2020). The source separation of waste created an ecosystem for investors to invest in a large-scale Bio-CNG production unit in Indore. Since February 2022, this Bio-CNG plant operates on 100% wet waste. This plant is built on PPP mode, from which IMC will receive yearly revenue of one crore rupees (approximately USD$121,066). Additionally, the city will purchase 50% of the Bio-CNG produced daily; this will support 400 buses that Indore can run on the gas generated from the Bio-CNG plant.

Potential of the circular economy as a solution

The modern Bio-CNG technology-led production are large-scale business units, which are driven by innovation and profitability. Continuous production of Bio-CNG involves many actors and entities in the value chain. If the rural sector is integrated in the value chain of the Bio-CNG production, then the waste management in India goes one step further using a CE for efficient energy production throughout waste management. The introduction of CE as a business model for energy production through waste management represents a significant paradigm shift in the business model for all stakeholders. Businesses and entrepreneurs realise a market that both needs to be addressed and has economic potential. This realisation is at the heart of the current understanding and valuation of Bio-CNG and resources that can be acquired for production through waste management. The potential benefits of Bio-CNG include efficient management of waste, which serves as raw material, and the reduction of greenhouse gases, which replaces fossil fuels. This business model has secondary benefits, such as the restoration of soil productivity and reclaimed land by using manure generated after Bio-CNG production. Biomass from biowaste is an abundant and underutilised resource, which still needs to be utilised more effectively as a commercial and social resource. Thus, the paradigm shift calls for regime transition (Loorbach et al., 2017) toward CE for Bio-CNG production scalability, which calls for decoding the catalysts characterised by social forces, technological changes, and power relationships among stakeholders.

To achieve the aim of finding the catalysts, we use the concept of the catalyst with an interpretation of an agent to sustainability transformation for the long-term development of society with enhanced human well-being built on environmental accountability and protection (Smith et al, 2010). For this study, we observed catalysts as a form of 'initiator' or agent that increases the speed and rate of change or transformation. However, the catalyst creates a reaction in the development system that leads to economic activities reaching a self-sustaining threshold. Thus, this chapter assumes a catalyst as an 'enabler' to execute the development in a disciplined manner. The capacity of catalysts to influence the system depends on their ability to work as a 'visible hand' and an 'invisible hand' (Köhler et al., 2019). For example, government tax benefits have been a known catalyst for economic activity development in the state, which acts as a visible hand in the initial years but becomes an invisible hand or absent over time (Erlinghagen & Markard, 2012).

Methodology

This study used qualitative methodology to analyse the empirical data (Silverman, 2005) to identify the catalysts. The qualitative approach allowed an understanding of the catalysts that is mapped through the responses of different stakeholders (Creswell et al., 2007). Semistructured interviews were performed to collect data. This data was collected to understand the participants' unique perspective rather than a generalised understanding of the phenomenon (McGrath et al., 2019). The responses to the interviews allowed us to understand the factors that function as catalysts aligning with the CE approach. We were especially interested in providing our interviewees with the opportunity to describe their motivations and perspectives (Eisenhardt, 1989; Patton, 2002) as active participants in CE and in identifying the catalysts for the transformation of the industry.

Braun and Clarke (2006) suggest the use of thematic analysis (TA) for interpretive thematic outcomes, a widely used method for interpreting and analysing patterns of meaning or "themes" in qualitative data. By drawing on interviewees' insights, we can identify broader themes and connections among the actors involved in the transition, as outlined by Yin (2009). Although some argue that TA should not be considered a research methodology as it focuses solely on analysing existing data, it is still a valuable tool to draw on a range of qualitative analysis techniques, including qualitative content analysis, grounded theory, and narrative analysis (Wæraas, 2022).

By leveraging the power of TA, we could identify and interpret patterns of meaning or 'themes' in qualitative data in a robust and effective manner. Wæraas (2022) highlights the value of TA as an inductive-based analysis approach that is grounded in transparency and the data, rather than being theory-driven or deductive. To avoid this criticism by Wæraas (2022) and with the intention to identify themes or catalysts and not construct a theory, we used a three-stage data analysis model (Gioia et al., 2013) for TA to maintain data integrity and generate first-order terms directly from the data, before moving on to identify second-order themes. Throughout this process, we assemble terms, themes, and dimensions into a clear data structure that facilitates systematic coding and conceptualisation of emerging themes as catalysts for CE, with complete transparency.

Data collection

Industry experts nominated the interviewees or the segment of stakeholders. We contacted and interviewed two industry experts, an academic researcher who studies the technical side of Bio-CNG production, and the production head at one of the newly constructed Bio-CNG plants. Once we connected with these two experts, we mapped the stakeholders who directly and indirectly contributed to the Bio-CNG production through waste management. We carried out purposeful sampling (Patton, 2002; Suri, 2011) to identify the interviewees representing various stakeholder actors of the ecosystem. This process ensured that respondents are sufficiently aware about the Bio-CNG production and the Bio-CNG market (Robinson, 2014), and they are also available (Creswell et al., 2007) in the study.

We started the interview process with the first two mentioned experts to map the entire value chain of Bio-CNG production and to understand their perspectives on the catalysts that promote a CE in India. We started using the snowballing technique to identify our next interviewee in the data collection procedure (Parker, 2019). We interviewed 27 individuals engaged as policy-makers, entrepreneurs, operators, householders, farmers, and industry experts. The details of all interviewees are shown in Table 6.2. The interviews ranged from 21 to 55 minutes in length. The

Table 6.2 Details of the interviewees

S. No.	*Title (Gender)*	*Interview type*	*Interview length*
1	Entrepreneur 1 (Male)	Video Call	40 min
2	Entrepreneur 2 (Male)	In Person	25 min
3	Entrepreneur 3 (Male)	Video Call	47 min
4	Researcher 1 (Male)	In Person	45 Min
5	Researcher 2 (Male)	Video Call	42 Min
6	Operator 1 (Male)	Video Call	34 min
7	Operator 2 (Male)	Video Call	39 min
8	Operator 3 (Male)	Video Call	29 min
9	Operator 4 (Male)	Video Call	30 min
10	Farmer 1 (Male)	In Person	38 min
11	Farmer 2 (Male)	Video Call	55 min
12	Farmer 3 (Male)	Video Call	44 min
13	Farmer 4 (Male)	Video Call	49 min
14	Farmer 5 (Male)	Video Call	23 min
15	Retail Juice Shop Owner 1 (Male)	In Person	26 min
16	Retail Juice Shop Owner 2 (Male)	In Person	25 min
17	Small Restaurant Owner 1 (Male)	In Person	21 min
18	Householder 1 (Female)	In Person	28 min
19	Householder 2 (Female)	In Person	24 min
20	Householder 3 (Female)	In Person	26 min
21	Householder 4 (male)	In Person	28 min
22	Householder 5 (male)	In Person	25 min
23	Municipal Officer	In Person	25 min
24	Policy Expert	In Person	22 min
25	Business Manager 1	In Person	37 min
26	Business Manager 2	Video Call	41 min
27	Industry Expert	Video Call	35 min

interviews were conducted both in languages in English and Hindi to capture the technical and contextual understanding. Out of 27 interviews, 11 interviews were conducted in Hindi capturing stakeholders such as farmers, retail juice shop owners, a small restaurant owner, and a few householders. All interviews were auto transcribed through artificial intelligence (AI) and manually verified. For the transcriptions in Hindi, interview content was translated in English through an electronic translator and then manually verified by a language expert. The complete transcription of 27 interviews was 254 pages in length. We continued the data collection until it was observed that there are repetitive responses in the interview indicating that we had been close to theoretical saturation (Locke, 2001), although any specific number of interviews is not a decisive factor for a theoretical interpretation of complete data saturation (Eisenhardt, 2021).

Data analysis

We used Atlas.ti (version 9) as the data analysis tool. We started the data analysis by reading the interview transcripts and labelling the data with initial thoughts and concepts. Then, after the initial analysis, we performed the final three-stage analysis as described next. Although the description is linear and chronological, the analysis was iterative.

Based on Gioia et al. (2013), the first stage of analysis involves creating a deeper foundation for developing detailed descriptions. First, we identified parts of the interviews related to the interviewees' understanding of their position in the value chain for creating a CE for Bio-CNG production. We analysed the data with an awareness of the perceptions of various stakeholders in the value chain. We compared and compiled different data segments for developing the first-order concepts, and identified differences in stakeholder perceptions as shown in Figure 6.1.

In the second stage, we compared the first-order concepts and started to group them based on common themes. During this stage, we identified practical issues that support the creation of a CE in India related to waste management through Bio-CNG production. We observed how different stakeholders from their position in the value chain have different perceptions and topics that help them to be part of the CE or push them further away from the CE value chain.

In the third stage, we integrated the categories for the previous two stages to identify the catalysts for developing a CE in Bio-CNG production. During this analytical process, we identified six catalysts that support and initiate the development of a CE for Bio-CNG transition in India through waste management. Figure 6.1 shows the complete data structure of the data analysis.

Identified catalyst in the Indian context

Six main catalysts emerged that influence the formation of CE for developing and producing Bio-CNG production for waste management in India. The identified catalysts are: societal transformation, policy change, business demands, technology and innovation, profitable production, climate change, and sustainable farming. We present the findings in a linear sequence. These catalysts can be interrelated, and their synergy makes it possible to create an ecosystem based on a CE for biowaste management.

Transforming society

Stakeholders such as residents, professionals, academics, and policy experts have experienced social sensitivity and a systems thinking approach towards waste management transformation in society. For example, the city of Indore in central India is located in an industrial belt and is a

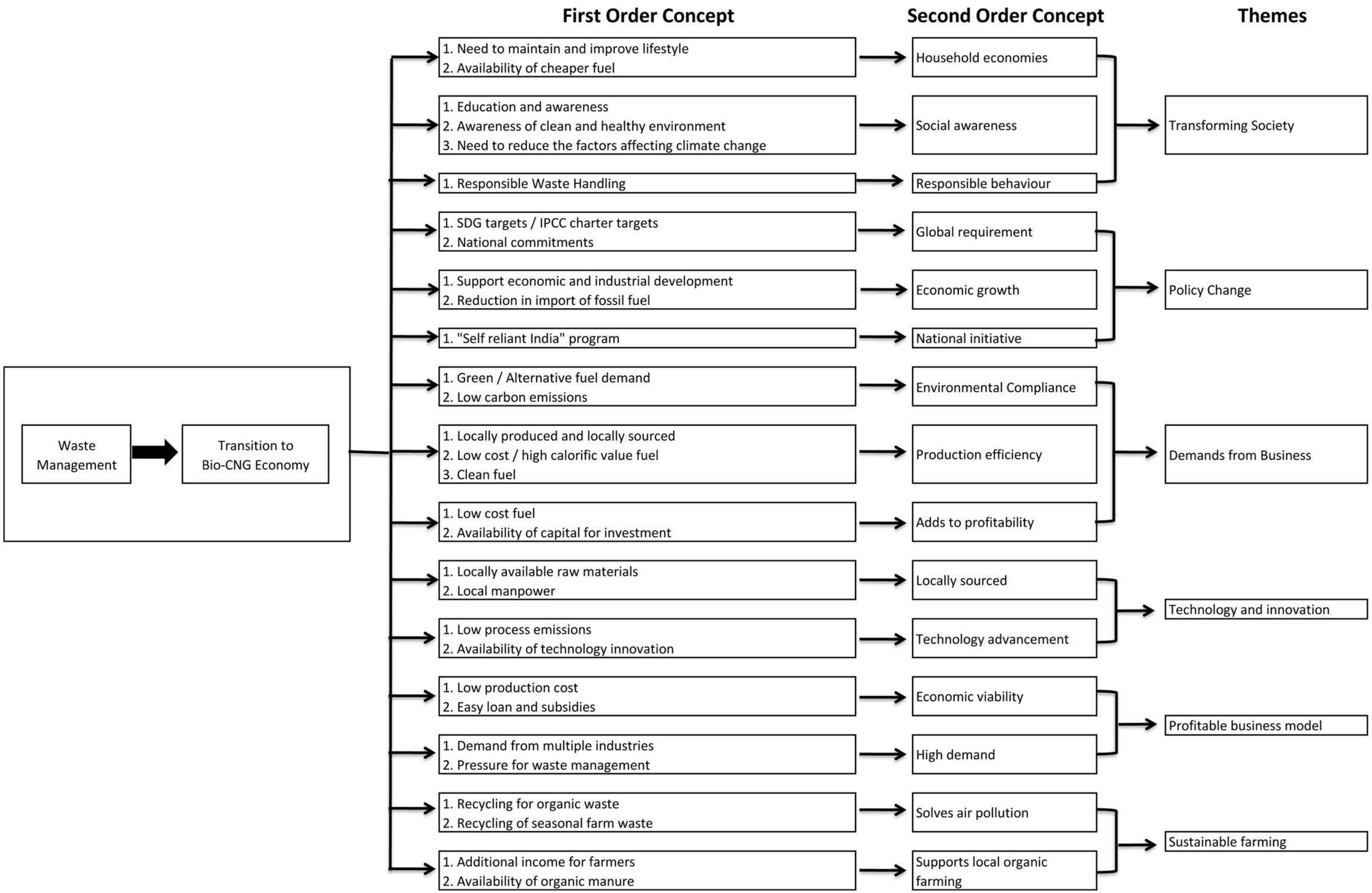

Figure 6.1 Identified catalyst framework in biowaste management in India.

densely populated city; its waste management systems were implemented with significant efforts in design, planning, and execution. A municipal officer had observed the need to empower the field workers and protect them from undue pressure of households with higher social status. The policy modification helped municipality workers to not accept the unsegregated waste from any household, irrespective of social status. Over time, the community started accepting the change.

> We now have stricter guidelines for waste managers, and our employees are trained to segregate the waste. We have also seen good response from the households […]. This was a challenge initially but the new policy on protecting municipality workforce helped us […], not every householder supports us, but many of them segregate their waste, and this is a good start. This is only an example of transition of society, but this is possible everywhere in India with sincere efforts by officials.
>
> (Municipal Officer, respondent 23)

While society stakeholders are well informed about the environmental impact, perceived benefits, lifestyle changes, and other direct or indirect benefits and need to change to a better waste management system was felt, but the path to the transition of society was unidentified. The waste management offered the opportunity to create economic value and Bio-CNG became a clean and locally produced commodity and the city Indore was branded as a clean city.

> It is a matter of pride for Indore to win the Cleanest City of India for consecutively six years due to the behavioural change of society. Citizens are aware now. They are educated or not, it does not matter but they appreciate the change and concerned to follow rules.
>
> (Retail Juice Shop Owner 1, respondent 15)

In another city in north India, Kanpur, which is an industrial city and one of most dense cities in terms of population, one of the respondents (Household 2) indicated his concerns about increasing dirt in the city, as well as the health and hygiene issues due to piles of waste.

> I would be happy if municipality could reuse the pile of waste being dumped in the peripheries of the city. It is not hygienic, and it is not good for health. […]. I am aware how things are developing in Indore. We should learn from them and create social pressure to influence the administration for change.
>
> (Household 2, respondent 19)

The social awareness and sensitivity that we define as 'transformed society' is observed as a catalyst because it creates peer pressure and force of change in social groups towards sustainability, in response converting the unsustainable into a CE model.

Policy change

Policy and regulations can push transformative institutional change (Kivimaa & Rogge, 2022) towards a sustainable transition. India has transitioned from protesting global environmental policies to actively shaping these policies at political leadership levels. Such an approach has led to a sustainable business model and transitioned into a stable CE model that had not been validated clearly in past research in India. However, one respondent reflected on how recent policy updates have made a contribution towards the market transition.

> We have not seen much policy and regulatory change with institutional mechanism to deliver in past. But now it's different. To honor its international commitments at the Paris Agreement, the government of India had to make several policy adjustments, institutional structuring, and supportive environment for business. The government created specific programs such as Swachh Bharat (Clean India) and Atma Nirbhar Bharat (Self Reliant India) which includes waste management and set specific targets to achieve.
>
> (Policy expert, Ministry of Petroleum and Natural Gas, respondent 24)

A respondent in the helm of policy cycle in the ministry of petroleum and natural gas observed how a national program is designed and delivered in a strategic way. The ministry develops national programs, which are rolled out as plans, while the responsible institutions take the responsibility of both the delivery and the continued performance of the program. This approach is well defined in terms of responsibility of each institution involved for effective policy-driven changes.

> Major focus has been on generating energy from waste like municipal solid waste (MSW), municipal liquid waste (MLW), farming waste, and farm produce targeted to produce biofuel under Swachh Bharat Mission.
>
> (Industry Expert, Chamber of Commerce, respondent 27)

> In the year 2015 at COP 21 meeting, India committed to reduction in energy emissions intensity to 35% by 2030 and increase the share of non-fossil fuel-based capacity above 40% by 2030. Political will and policy change makes a transformative change.
>
> (Policy expert, Ministry of Petroleum and Natural Gas, respondent 24)

In response to these international commitments, the government revisited national missions, revised its internal energy policy, and analysed alternative renewable sources. Modifications in the biofuel policy in 2018 focused on generating biofuel not only from the waste but also from the farming produce or any other source, helping to create a CE model. Thus, policy change is considered a key driver for CE business of Bio-CNG production not only contributing to the production of alternative energy but also achieving the national green India mission.

Demand from business

With the national agenda of the government and a change in national policy on biofuels (2018), fossil fuel suppliers have to mix biofuel with fossil fuel, and there are increasing targets of the mixture percentage (Press Information Bureau, 2022a). These changes are creating pressure on the market actors in the petroleum industry to produce more biofuel to achieve decarbonisation, this in turn is increasing demands for Bio-CNG production not only in the transportation industry but also in the industrial units.

> The environment impact is forcing drivers to change which is modifying the business demand, business models and entry of new players in the market to produce higher capacity. This is also driven by the availability of the waste raw material in both rural and urban settings […] We look forward to more Bio-CNG availability in the future.
>
> (Business Manager 1, Automobile firm, respondent 25)

The sustainability rating pressure on direct and indirect players in ecosystems such as industrial units, transport manufacturers, farming sectors, and others and combined with the development of relevant infrastructure and the introduction of policy has positively affected the demand of the clean fuel, including Bio-CNG. Additionally, carbon trading has changed the industry landscape from only production to trading of sustainability scores. Companies are not only collecting carbon credits from their clean and sustainable practices initiatives, but are also trading the carbon credits to earn money.

> The carbon trading has been strong push to companies and there is a trend of green investments. If we can reduce our carbon emissions, then we can definitely attract more investors towards our business.
>
> (Business Manager 1, Automobile firm, respondent 26)

> There are possibilities to construct Bio-CNG plants next to heavy industries that are energy intensive units. This way, we can save a lot on transportation. […] Also, Bio-CNG is a clean fuel compared to fossil fuels and has a high calorific value, which in turn improves the performance. […] This reduces environmental emissions and also provides access to low-cost fuel, which adds to profits.
>
> (Industry Expert, Chamber of Commerce, respondent 27)

The business side of sustainability, thus, is increasing demand in the industry, creating new business models, and increasing Bio-CNG production units to deal with the demand. Therefore, business demand is becoming an influential catalyst in dealing with waste management and developing CE business models.

Technology and innovation

A senior fellow (respondent 4) of the Council of Scientific and Industrial Research (CSIR) who has been dealing with the waste management research and development in the country, recognises the tectonic shift in the approach to deal with waste and create economic benefit. In the past, he dealt with many state governments that aimed at fulfilling the compliance of the GOI on environment compromising the quality of waste management units. The approach is different now, and same state governments have modified their working approach and model. Now, governments are promoting PPP models in collaboration with technology and innovation-led private companies to bring in state-of-the-art technology and a sustainable business model.

> The government is not only inviting the technologically advanced global companies to establish in India but also offering many partnership benefits under public private partnership model (PPP) including raw material supply, buy back of output, and operational support to keep the unit operational. This is new from the bureaucratic approach of government.
>
> (Entrepreneur 2, industrial unit, respondent 2)

Because of innovation and technological development, technology is available that is capable of handling large quantities of waste and producing large amounts of biofuel. The technological advancement and PPP approach has transformed the only compliance-based industry into a responsible solution-oriented business model industry, and entrepreneurs are attracted to the market to invest. This environment has motivated innovators developing locally aligned technology, which is also financially affordable in the Indian context.

> In the past, we had many small-scale biogas plants […] Such plants needed a certain mix of waste to produce biogas. Not all kinds of bio-waste could have been used in the past. Also, such bio gas plants were operated on a small scale and could not support the ambition to replace fossil fuels even in miniscule way, […]. We needed better technological capabilities and designs, and now we have them.
>
> (Operator 1, respondent 6)

> We sort and provide a mix of all kinds of biowaste to the CNG plant […] now we do not struggle to dispose of large quantities of bio-waste and we can also deal with huge legacy waste with present technology and big size units.
>
> (Municipal Officer, respondent 23)

The new technology has automated and eased the operations increasing efficiency, improving on the environmental factors, and creating smooth technology that requires less training from technology providers. Thus, technology and innovation are observed as catalysts that are not only changing the landscape of production but also addressing the environment challenges.

Profitable business model

The increase in profitable business models is playing out as a catalyst for the growth of CE in India. In the past, the waste management sector had practiced minimal compliance models to meet the government's environmental checklists. The approach did not deliver desired results such as managing environment issues or waste and hazards, or in engaging entrepreneurs to continue sustained efforts in the domain. This came from the international framework of millennium development goals (MDGs), which demanded the compliance reporting. Presently, the commitments are sustainable development in SDGs, which requires sustained business models and engagement of private sector market actors such as entrepreneurs (Rendtorff, 2019). These professionals develop stability in economic activity by their continuous effort and further contribute to achieve efficiency and better margins (Kothari et al., 2020). Innovation and technology development, financial support by government, and the initial demand creation by both state and central government invited professionals to establish business in Bio-CNG production, and it became a profitable business.

> There is sufficient financial support by government in form of debt and subsidiaries, there is good offer to the big players to invest in Bio-CNG production, and there is continuous growing demand both from the industry and individuals making it a lucrative business. Actually, return on investment (ROI) of this sector is now better than many manufacturing sectors after easing of the domain.
>
> (Entrepreneur 3, industrial unit, respondent 3)

Respondents resonate about the business models developed in partnership with municipality or agencies like fruit market, vegetable market, and farmers' communities are profitable, which was not so before policy modifications were instituted. Businesses invest money based on a business model and the continuity of the business for profit. The size of the profit is not the biggest concern, as long as it is financially stable to continue in a commoditised market.

> I do see high profit because of growing demand as the true catalyst for rapid growth in the industry. Now, we have the right balance between imported technology and equipment and locally produced equipment that makes the production a large-scale Bio-CNG production. I invested in two units as of now but plan to increase my business.
>
> (Entrepreneur 2, industrial unit, respondent 2)

> With the current level of production, our production unit will cross the break-even point in about four to five years […] We have started our production three months back. We have plans to scale up the production soon, which means we can be profitable before four years.
>
> (Entrepreneur 2, industrial unit, respondent 2)

Sustainable farming

Sustainable farming, acts as a good catalyst contributing in waste management and increasing biofuel production. Farming is an important source of raw material to the natural gas production, which is less costly due to its organic nature. In the past, India did not develop the system of farming produce or farming waste collection process that can be used for Bio-CNG production. With newer technology and business models, farming is becoming a significant source of continuous raw material supply. One respondent, who claims that this problem is echoed by many farmers, said that farmers were facing seasonal farming cycle issues, which becomes the reason of burning waste. If they did not burn waste by a time limit, then they did not get a water and fertiliser subsidy. Earlier there were no alternatives, but now farmers have other ways to manage the farm waste and to mitigate their financial burden:

> We usually reuse most of the waste generated in farming as manure or to feed the animals on the farm. […] but we do have seasonal waste from certain crops, such as paddy, cotton, and soy. This waste cannot be reused. We often burn this waste […] From the last few years, there has been a big problem, as the government has banned burning such waste. We do not have alternatives.
>
> (Farmer 1, respondent 10)

> If a Bio-CNG production plant is interested in buying our crop waste, we are happy to supply them with the waste in exchange for the right value for our efforts to transport the waste to the production site.
>
> (Farmer 3, respondent, 12)

Farm waste suddenly has a price that otherwise used to be dumped with a cost. This change has unified farmers into cooperatives and unions to negotiate the bulk deals with the businessmen and government for a long-term stable business partnership. Some seasonal waste such as straw after paddy cultivation, waste of sugarcane, and so forth cannot be used on the farms, so farmers were burning such waste post-harvest. Bio-CNG production is a solution to manage such waste. In addition, business started looking towards farming to supply continuous raw material that is not waste but organised farming for biofuel production that makes a good business model for both businesses and farmers.

The demand for farming produce and the waste as raw material for Bio-CNG production is a positive change and contributes to another national goal by, for instance, potentially doubling the farmers' income by 2025. Stakeholders of the farming and waste management or alternative fuel industry are exploring ways to increase production. Farming has become sustainable, with continued demand and in the process is profitable for farmers. The waste generated from Bio-CNG production is an excellent manure, and this supports farmers towards organic and sustainable farming.

Discussion and conclusions

This study aimed at identifying the catalysts that can facilitate the transition towards a CE for waste management in India, by utilising waste for Bio-CNG production. Qualitative thematic analysis was conducted based on data from 27 semistructured interviews. The study identified six catalysts that support the development of a CE ecosystem for waste management through Bio-CNG production. These identified catalysts are: transforming society, policy change, business demand, technology and innovation, profitable business models, and sustainable farming. This study provides valuable insights into the development of sustainable waste management practices through Bio-CNG production in India, highlighting the importance of a holistic approach to achieving a CE.

According to the findings, society is undergoing a transformation. The study highlights the importance of social sensitivity and a system-thinking approach to waste management transformation in society. The example of Indore demonstrates the significance of design, planning, and execution efforts in waste management systems, as well as the need to empower field workers. Over time, community acceptance of the changes resulted in a transition towards a CE model for waste management. The findings also bring forward how policy and regulations can lead to institutional change towards a sustainable transition to implementing CE, showcasing India's shift from protesting global environmental policies to actively shaping them.

Further, the pressure of achieving sustainability goals and carbon reduction is positively affecting the demand for clean fuels, including Bio-CNG. This change has resulted in an increase in demand for Bio-CNG in various industrial sectors. This is leading to the development of more innovative business models and the increase in more Bio-CNG production units to meet demand, thus making business demand an influential catalyst in developing CE business models. Additionally, CE in India is growing due to the increase in profitable business models, which are facilitated by government initiatives and support for entrepreneurs. The shift from minimal compliance with MDGs to SDGs has led to sustained business models and engagement of private sector market actors. Business models developed in partnership with municipalities or agencies like fruit markets and farmers' communities are now profitable. The development of efficient business operating models for medium- and large-scale waste units for Bio-CNG production is one catalyst for the growth of the CE in India.

Farming waste can be used for Bio-CNG production, which can help in waste management and increase biofuel production. Using newer technology and business models, farming waste has become a significant source of raw material supply. The waste generated from Bio-CNG production is also an excellent manure that supports farmers towards organic and sustainable farming. As a result, a two-way supply stream is creating a CE in India that meets the needs of both Bio-CNG production units and farmers. Entrepreneurs have attracted investors to the industry due to improved access to the latest and most efficient technology. In addition to automating and simplifying operations, new technology has also increased efficiency and improved the environment. This in turn enables large quantities of waste to be handled and for biofuels to be produced from that waste. Also, the findings suggests that the shift in government policies from compliance-based to solution-oriented promotes PPP models in collaboration with technology and innovation-led private players.

Past research in the CE domain notes that CE remains a concept and principle that is theoretically and practically evolving (Centobelli et al., 2020), with discussions about catalysts for CE in the recent literature. In their recent literature review, Sarja et al. (2021) identified different types of catalysts for an organisation to transit into a CE. These catalysts are very business-centric and keeps organisational-level transition to the CE in the focus. But we still do not know how these catalysts evolve under various context and which catalysts govern or motivate different stakeholders to get involved in the CE of a product or a production unit. Hence, the CE can be ambiguous in many contexts and stages of its implementation (Geissdoerfer et al., 2017; Kalmykova et al., 2018). Also, except for a few studies, it is difficult to find any literature that discusses the basic 'need' of the context as a catalyst for adoption of CE (e.g., Korhonen et al., 2018; Niinimäki, 2017). Based on the findings, we argue that stakeholders' fundamental needs serve as catalysts and their alignment to engage for implementing a CE.

In our study, the government's needs for economic growth, self-reliance, and achieving global targets for the mitigation of climate change can be achieved through policy change that promotes CE. For example, the government could incentivise businesses to adopt circular practices, such as reducing waste and reusing resources, which could lead to increased economic growth and self-reliance while also reducing greenhouse gas emissions, thus promoting CE. The municipality's need for efficient and clean waste management can also be met through a CE approach. By implementing a closed-loop system where waste is used as a resource for producing Bio-CNG, the municipality can reduce the amount of waste that goes to landfills and use it instead to produce a renewable energy source. This implementation could also create opportunities for municipalities to become important suppliers for Bio-CNG production, thus creating additional economic benefits for both the production unit for Bio-CNG and the municipality authority.

Similarly, the business sector's needs for cleaner and cheaper fuel and reduction in emissions can also be addressed through a CE approach. By buying Bio-CNG as a fuel, businesses can reduce their carbon footprint while also benefitting from a more affordable and sustainable energy source. Further, individual members in the society needs for a clean environment, affordable fuel, and maintaining and enhancing life choices can be met through their participation in a CE. By becoming responsible partners for waste management by partnering with municipalities, individuals can contribute to reducing waste and minimising the impact of their activities on the environment. In addition, Bio-CNG is a cheaper and cleaner fuel and could help to enhance the individuals in a society's life choices. Finally, the farmers' requirements of better seasonal waste management, extra income, and organic manure can also be met through participation in the CE. It is the combined needs of the stakeholders that is catalysing the creation of a healthy ecosystem for Bio-CNG production through waste management. Table 6.3 summarises the identified stakeholders' needs.

In India, the government and its policies continuously support the ecosystem of the stakeholders to adopt the CE practices; this is seen as a central enabler to CE. Other stakeholders will participate in the ecosystem to produce Bio-CNG through waste management, thus fulfilling and supporting a CE. The findings of our research show that the primary catalyst for any ecosystem to transition to a CE is the basic need for stakeholder transformation; when the needs of different stakeholders are synchronised, the CE transition is possible. If the essential requirements of the stakeholders are not aligned, then the actions of each stakeholder are also not aligned and even

Table 6.3 The need analysis of the key stakeholders

Stakeholders	*Needs*	*Actions*
Government	1 Economic growth 2 Self-reliance 3 Achieving global targets for the mitigation of climate change	Policy change
Municipality	1 Efficient and clean management of large-scale waste	Willingness to become an important supplier for Bio-CNG production
Business	1 Cleaner and cheaper fuel 2 Reduction in emissions	Willingness to buy Bio-CNG as a fuel
Individuals	1 Clean environment 2 Cheap fuel 3 Maintain and enhance life choices	Willingness be a responsible partner for waste management with the municipalities
Farmers	1 Better management of seasonal waste 2 Extra income 3 Organic manure	Willingness to become an essential supplier for Bio-CNG production

in the case of identified incremental improvements, finding an easy path to CE transition through continuous development may not be easy. Overall, the needs listed in Table 6.3 highlight the importance of reducing waste, increasing resource efficiency, and creating sustainable economic opportunities, all of which are key elements of a CE. By addressing these needs and promoting circular practices, stakeholders can contribute to creating a more sustainable and resilient future for all.

Future research and limitations

The purpose of this study was to identify the catalysts of transition of the biowaste industry to a CE in India. Since the segment is in a nascent stage, we employed qualitative methods and applied thematic content analysis to research the current field. There are limitations in the process such as it is based on open-ended inquiry about a phenomenon of interest, the CE.

In the context of India, there are several potential areas for future research to encourage the transition to a CE. First, research could focus on the role of policy updates in promoting circular practices among businesses, individuals, and other stakeholders. This could involve exploring the potential for new policies and regulatory frameworks that could facilitate the transition to a CE especially in the supply chain context. Second, there is a need to explore the social, technical, and economic feasibility of regime transition waste-to-energy technologies on a larger scale, especially in different regions of India, which are diverse both geographically and culturally. Finally, future studies could focus on the potential development of supply chains for the easy mobility of waste to production units and the easy mobility of Bio-CNG to potential users. This could involve examining the logistics of transporting waste and Bio-CNG across different regions of India, as well as identifying potential solutions to overcome barriers in the supply chain. By addressing these research gaps, policymakers and practitioners can gain a better understanding of the potential benefits and challenges of CE in India and identify strategies for promoting a more sustainable and resilient future.

The formation of CE in the biowaste context is in the nascent stage (Chhimwal et al., 2022). As the domain evolves, dynamics of the drivers and catalysts will change, which will be of interest to researchers, as this subject and research outcomes will modify many fundamental questions of interplay of groups and systems (Ghisellini et al., 2016). The interaction of the stakeholders plays a key role in guiding firms to adopt CE practices (Lahane & Kant, 2022). Through the passage of the industry life cycle, stakeholders' needs and catalysts will introduce new business models and cluster effects to enhance the effectiveness of CE in the long run (Wielopolski & Bulthuis, 2022). The development of the ecosystem and the scalability of market will depend on stakeholder acceptance (Esa et al., 2017). In literature, it has been found that a variety of stakeholder groups influence the adoption of CE practices in the development of ecosystems (Jakhar et al., 2018), however researchers still need to identify the strategic fit of the selected stakeholders in development of the CE's ecosystem. The shift towards manufacturing of Bio-CNG through waste management is a substantial paradigm shift in India, and involves many stakeholders that directly or indirectly contribute to the formation of CE. With the maturity of this industry in the future, we will have to understand how stakeholder needs evolve based on this and how catalysts change with the evolution.

Educational content

- The chapter introduces how India is leading the conversation about sustainability through providing a glimpse of achievements in waste management initiatives. Further, it introduces the Indian conversation about sustainability to a global audience. This chapter addresses catalysts in developing CE ecosystems and how Indore, a city in central India, has managed to shift to a CE model and win an award for the cleanest city.
- This chapter promotes understanding the performance of the government in dealing with complex sustainability issues in the given context of population, societal setting, institutional support, entrepreneurial spirit, and growth.

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7

PLASTIC WASTE AND A CIRCULAR ECONOMY IN CHINA

Current situation and future possibilities

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Introduction

As an important synthetic organic polymer material, plastic has played an important role in industrial production and people's lives since its invention in the 19th century (Bhatnagar, 2020). Approximately 8% of the world's crude oil is used to make plastic (Xue et al., 2022). In 2015, the world production of plastic and plastic waste was estimated at 407 Mt and 302 Mt, respectively. 14% of the plastic waste was collected for recycling, 40% was directed to landfills, 32% leaked into the environment, and 14% was directed for combustion (Coates & Getzler, 2020). Because most containers and packages made of plastic are chemically stable, lightweight, easy to shape, and convenient for transportation and storage, the annual output of plastic products is in a state of continuous growth. At the current growth rate, global annual plastic production could increase to 33 billion tonnes by 2050 (Xue et al., 2022). The use of plastic products has brought great convenience to our lives. However, the recycling and recovery of plastic that is currently performed is not enough. Almost 40% of plastics are discarded as plastic waste shortly after use, particularly in the form of plastic food packages and bags (Xue & Wang, 2022).

The degradability of plastic waste is very poor. If the post-use collection and treatment systems of plastic waste are not in place, it will not only cause a loss of energy and material, but it will also intensify ecological and environmental pollution. Pollution risk related to plastic waste has attracted wide concern in the international community. As a result, many countries have issued policies to limit the consumption of disposable plastics and are actively promoting the recycling of plastic waste; China has created these types of policies as well. The development of the circular economy (CE) has become a major strategy for economic and social development. Some large plastic consumer enterprises have also carried out green design and green procurement plans, which will further promote the green and sustainable development of the plastic industry (Chen & Chen, 2021).

In China, the rapid economic growth in recent decades has led to a significant increase in waste amounts (Havukainen et al., 2017). Formerly, China was the place where several countries exported their plastic waste; this practice changed in 2018 when China's National Sword and Green Fence programs limited the import of low-quality plastic waste, which also resulted in the steep decline of imports (Vedantam et al., 2022). This led to the diverting of waste plastic flows to

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other countries and to its stockpiling to await treatment. The policies in China have been developing to deal with the ever-increasing domestic waste, and more emphasis is given to the reduction of plastics production and to the efficient recycling and treatment of plastic waste.

The aim of this chapter is to review the transition of plastic waste management towards plastic recycling in the context of China from technological, regulatory, and environmental perspectives. The applied methodology for technology screening was based on a literature review focused on the main proven technologies and their future development. Regulatory information about plastic production and related polices about plastic reduction and treatment were collected from published journal articles, government reports, and news articles. The information can be directly found or indirectly calculated from the sources, for example, scientific articles, China National Knowledge Infrastructure database (CNKI), and government web pages (including the Ministry of Ecology and Environment of the People's Republic of China, National Development and Reform). The data about environmental perspectives was gathered from journal articles, European Environment Agency (EEA) reports, and European Recycling Industries Confederation (EuRIC) factsheets. These sources were specifically targeted to provide an insight into the environmental perspectives and challenges related to plastic waste and recycling.

This chapter presents plastic production and plastic waste challenges in China starting with a section on the current knowledge of the environmental performance of plastic management practices, which can provide insights to requirements for future sustainability related to plastics and their recycling. The following section summarises the technical possibilities in tackling challenges posed by plastic waste and provides ways to increase waste recycling. The section after that presents plastic production and plastic waste challenges in China including generation, treatment, and established policies. We conclude and synthesise the work in the last section.

Environmental perspectives

Recycling is considered more environmentally beneficial, while landfilling the least beneficial, although waste prevention will be most preferable (Fogh Mortensen et al., 2021). In the production stage of plastics, environmental challenges include impacts on resource consumption due to extraction of oil and gas. And if not well managed, in 2050, the plastics industry will account for an estimated 20% global oil use, which is 13% more than at the time of this printing (Bruyninckx, 2021). During the process of plastic production, multiple pollutants (nitrous oxides, particulate matter, sulphur oxides, heavy metals, volatile organic compounds, toxic organic chemicals, etc.) are emitted into the air. Oil and chemical spills and the potential leakage of wastewater containing hazardous substances and chemicals are part of the negative environmental impacts of plastic production. In the use stage of plastics, humans are exposed to toxic substances through migration of additives, impurities, particles, and degraded chemicals. At the end-of-life stage of plastics, the emission of pollutants from incineration, landfills, and leakages to the environment occur (Fogh Mortensen et al., 2021). Plastic waste is littered to the environment after use, and this affects nature and the environment, and especially the marine environment. All these pollution modes from plastic not only have detrimental effects on human health, but also on the health of wildlife and marine biota.

China only recently started paying attention to environmental issues, and we can see this when comparing the amount of plastic waste generated (Figure 7.1) and recycled (Figure 7.2) in China. Also, due to insufficient mechanical recycling technologies for plastics as mentioned in the 'Treatment' section of plastic and plastic waste in China, China's plastic recycling requires more effort and growth. From the European perspective, insufficient recycling capacities in the

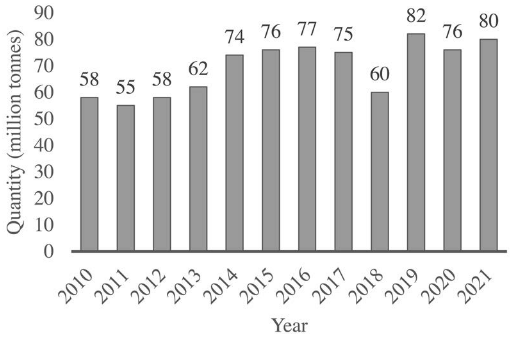

Figure 7.1 Annual production of plastic in China.

Source: Adapted from the China Business Intelligence Network, 2022.

European Union (EU) led to exportation of plastic waste to Asia. However, the restrictions China made on importation of waste as well as including certain plastic waste types to the United Nations Basel Convention, has led to increasing difficulty in the exportation of plastic waste from the EU (European Environment Agency, 2019). This has led to a reduction in plastic waste exportation from EU countries and if need be, exporting to destinations other than China and Hong Kong (European Environment Agency, 2019). Furthermore, insufficient capacity of recycling and reusing options for plastic waste in the EU and China has led to more incineration and landfilling of plastic waste (European Environment Agency, 2019).

Regarding plastic recycling, although chemical recycling has been gaining traction in recent years, there is still insufficient knowledge on the total life-cycle impact of chemical recycling, but indications show that the energy, water, and chemical resources consumed during chemical recycling contribute to water, air, and land pollution (Fogh Mortensen et al., 2021). However, plastic recycling reduces extraction of raw materials during virgin plastic production, and it is estimated that recycling of plastic waste can reduce CO_2eq emissions by 1.1–3.0 tonnes per each tonne of recycled plastics, when compared to producing plastic from fossil fuels (EuRIC AISBL, 2020; Fogh Mortensen et al., 2021).

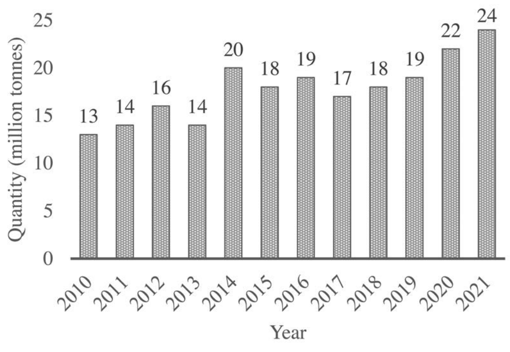

Figure 7.2 Plastic recycling in China from 2010 to 2021.

Source: Modified from Jin, 2021.

Some studies have been carried out to determine the more environmentally recycling option. Davidson et al. (2021) critically analysed the environmental impacts of chemical recycling of plastic waste using the life-cycle assessment (LCA). In their review, nine pieces of LCA literature were examined that contained one or more chemical recycling processes such as pyrolysis, gasification, depolymerisation, and hydrocracking, with pyrolysis being the most popular chemical recycling method assessed. The plastic waste in the literature was polylactic acid (PLA), pure polyethylene terephthalate (PET), and mixed plastic waste. All the reviewed LCA studies followed the ISO 14040 principle, which specifies requirements and provides guidelines for LCA (Davidson et al., 2021; EN ISO 14040, 2006). The LCA results from the reviewed studies cannot be directly compared due to the differences in the plastic waste combinations. However, the papers were examined for some commonality. When chemical recycling was compared to mechanical recycling, the latter was shown to have better environmental performance compared to the former. But then, when compared to incineration, mechanical and chemical recycling have better environmental performance, making chemical recycling a good complementary support for mechanical recycling for plastic waste, which cannot be mechanically recycled in addition to the fact that chemical recycling produces higher quality products and has a wider application range (Davidson et al., 2021).

In a consequential LCA study by Cornago et al. (2021), a PET chemical recycling technology was examined. This was done to assess the potential of this recycling technology at a European scale and evaluate the variation of marginal LCA impacts. In the study, comparison was done between a chemical recycling pathway, mechanical recycling pathway, and virgin PET pathway to produce bottle-grade PET. In the chemical recycling pathway, sorted waste PET was transformed to PET monomers and then to bottle-grade PET. In the mechanical recycling pathway, 30% of mechanically recycled bottle-grade PET was integrated with 70% fossil PET to produce a high-quality bottle-grade PET. Last, the virgin PET pathway is the conventional production of bottle-grade PET. In all the pathways, avoidance of the production of virgin PET was excluded from the study. The study further explored competition between European and extra-European manufacturers in the integration of fossil PET during mechanical recycling. The results showed that the chemical recycling technology presented higher environmental impacts than mechanical recycling in ozone layer depletion, ionisation radiation, and land use categories, and this is because of higher electricity consumption. However, the impacts can be reduced when biomass, nuclear, and natural gas sources of electricity are integrated more extensively in the European marginal mix. An advantage to the chemical recycling pathway over the mechanical recycling pathway in this study is that the former can also result in substitution of the current PET waste treatment processes (landfill and incineration) due to its multifunctionality. Additionally, the chemical recycling pathway does not need 70% fossil PET as in the mechanical recycling pathway to produce a high-quality bottle-grade PET, leading to a reduction in the use of virgin PET. Last, when comparing the virgin PET pathway to the mechanical recycling pathway, the former has a higher unitary impact in all the assessed impact categories (Cornago et al., 2021). To further this claim, another study considered chemical recycling a better recycling pathway in a circular economy approach. This is because chemical recycling produces lower greenhouse gas (GHG) emissions and retains the value of plastic residue for a prolonged period of time (Khan et al., 2021).

In another LCA study by Civancik-Uslu et al. (2021), mechanical recycling and thermochemical recycling pathways in a Belgian context were assessed for PP, PS, mixed polyolefins, and PE films and compared to energy recovery from incineration. The results show that mechanical recycling and thermochemical recycling had better environmental performance than incineration in resource consumption, global warming, and terrestrial acidification environmental impacts. When mechanical recycling is compared to thermochemical recycling where the products can substitute virgin materials on a 1:1 ratio, mechanical recycling had better environmental performance in the analysed environmental impacts. This is because of the mechanical recycling pathway having a higher avoided burden due to a shorter loop in the production of flakes and granulates, while the thermochemical recycling loop had a larger loop due to cracking process and associated burdens. Electricity consumption was a major contributing factor to the assessed environmental impacts for both mechanical and thermochemical recycling (Civancik-Uslu et al., 2021).

Technical possibilities for plastic waste utilisation

Promoting plastic recycling is an important aspect in enhancing the sustainability of plastic use besides the promotion on waste prevention and development of alternative materials. The initial step in the recycling chain is the efficient collection of waste. Separate collection of plastic waste fraction enables getting plastic-rich feedstock with a low share of impurities for the subsequent recycling processes. Comingled collection of plastic with other recyclables and centralised mechanical separation is also one option, such as the yellow bin in Germany (Schmidt & Laner, 2021) or recyclables (paper, plastics, glass, metal) collection in China. Plastic waste and other recyclables can even be separated from source-separated mixed municipal solid waste (MSW), which ideally would not contain too much biowaste. The success of different and separate collection schemes depends on the aspirations of the population to participate in waste separation.

Plastic waste utilisation options can be divided into four types: primary recycling, secondary recycling, tertiary recycling, and energy recovery (Hahladakis & Iacovidou, 2019). In this respect, disposal of plastic waste into landfills is not considered as utilisation because the value of plastic waste is lost. Primary recycling means that the plastic waste is derived directly from the plastic industry and can be recycled directly in similar processes (for example, by regranulation) while secondary recycling (mechanical recycling) and tertiary recycling (chemical recycling) concern end-of-life plastic packages and products, and usually require at least separation of impurities and can include detection and separation of plastic types (Jin et al., 2021). In addition to recycling, energy recovery is an option for plastic waste. Typically, in waste to energy plants at least electricity is generated if there is no need for the heat, which is produced from energy recovery.

Mechanical recycling

For secondary and tertiary recycling, the source-separated plastic waste requires initial treatment before the plastic waste can be further utilised. The removal of impurities consisting of other waste fractions and grit is an important step including particle size reduction (shredding, cutting), removal of fines (screening, washing), and sorting, which can include removal of metals (magnetic separation and eddy current separation) and separation of heavy fraction out of the stream (Gu et al., 2017; Havukainen et al., 2021). After this step, the low contaminant-level plastic waste stream can be directed for further processing.

After the initial treatment phase, the mixed plastic waste can be directed to recycling processes where recycled materials are produced or some of the plastic waste types can be separated from the mixed waste stream. Mechanical recycling of mixed plastic waste can be conducted without the separation of plastic types for example by producing composite material with the addition of fibres such as waste wood fibres to produce wood polymer composite (WPC) (Liikanen et al., 2019). The produced WPC can then be used to produce different products for use in fields such as construction or logistics, in construction panels, or pallets (Khan et al., 2021). The benefit of composite production is that a large share of the plastic waste can be utilised to the final products (Martinez Lopez et al., 2020). The drawback is that the quality of the products is less comparable to original plastic types and utilisation to different applications is more restricted (Khan, Deviatkin, et al., 2021).

Mono-plastic recycling of mixed plastic waste requires the detection and sorting of different plastic types from each other. Due to the development of analysis instruments, infrared spectroscopy, and other identification technologies, they are characterised by high sensitivity, a strong degree of automation, and high specificity. The sorting units include technology that probes the incoming material properties. This probing is often conducted by using sensors to detect the response of the tested material to electromagnetic radiation, which depends on the composition of material. The obtained response is then analysed and utilised for sorting the material. The most used identification technology utilising sensors is near infrared spectroscopy (NIR), while other technologies such as ultraviolet (UV) and visible spectroscopy red-blue-green (RBG) cameras also exist (Sormunen & Järvinen, 2021). The actual sorting process takes place in four steps: presentation, detection of the material, processing of the retrieved data, and separation by actuation (Yuan et al., 2015). The sorting unit can be, for example, a belt-type unit where a sensor is placed on top of the conveyer belt and the actuation is conducted by air nozzles blasting the identified material to a separate conveyer belt than the residual material. Several sorting units are needed to separate the desired plastic types and to increase the purity of the separated plastics.

The separated plastic types can then be converted into plastic granulates by melting and by a plastic extrusion process where pigments and required additives such as UV stabilisers are added (Gu et al., 2017; Ragaert et al., 2017). The plastic industry can then use these granulates in making new plastic products. Even if the separation of different plastic types is carried out, their properties are generally affected, which means that they are not comparable to virgin plastic granulates. The appearance of recycled materials is generally grey to black, which affects the use of the recycled granulates. Beside the separated plastic types, which can include, for example, LDPE, HDPE, and PP (Sormunen & Järvinen, 2021), there is a residual mixed plastic waste fraction coming out from the sorting that can be directed for making plastic or wood-plastic composite profiles. Low-quality residues of separation are commonly used for energy recovery purposes (Sormunen & Järvinen, 2021).

Chemical recycling

Besides the mechanical recycling of plastic, there is also an option to chemically recycle plastic waste by utilising various techniques such as pyrolysis, fluid catalytic cracking, hydrogen techniques, or gasification to degrade the polymer into monomers or polymers (Ragaert et al., 2017). The difference between chemical recycling and mechanical recycling is that the end products can be comparable to the virgin materials, and they can be used for recycling multilayer plastic waste treatment (Soares et al., 2022); this is difficult via mechanical recycling. The pyrolysis process breaks down the polymer into smaller molecules in the absence of oxygen and at moderate or high temperatures (above 450°C). The end products include gas, liquid, and solid residues. The produced pyrolysis gas can be used for production of required heat for the pyrolysis process, while the liquid fraction can be directed to further treatment by distillation to purify the monomers and produced liquids. The solid fraction can be also used in the production of heat, while other possibilities exist such as replacing lignite (Jeswani et al., 2021).

The difference between pyrolysis and catalytic cracking is that with the help of a catalyst, the temperature for the process can be lower, reducing the energy cost. The contact with the catalyst can be done either in a liquid or vapour phase. The advantage compared to pyrolysis is that more liquid products are obtained while major challenges are related to the bulky nature of polymers and finding suitable reactor technology. Hydrocracking differs from catalytic cracking by the addition of hydrogen into the process, which improves the end-product quality but requires the availability of hydrogen, which can be expensive (Ragaert et al., 2017). Gasification, on the other hand, produces a syngas from the plastic waste with the help of an oxidation agent (air or mixture of steam and oxygen), and the main product is syngas (Shah et al., 2023). The produced syngas can then be, for example, catalytically converted to methanol and used as methanol or further valorised to olefins by methanol-to-olefins (MTO) (Wang et al., 2020) or gasoline by methanol-to-gasoline (MTG) route (Liu et al., 2023).

The benefits of chemical recycling are the possibility to utilise mixed plastics and the quality of the end products, which is comparable to virgin plastics. The main challenge, on the other hand, is the rather limited yield of the plastic products ranging often between 10% and 20% of the input plastics.

Plastic and plastic waste in China

The annual output of plastic products in China is shown in Figure 7.1 and presents an upward trend, except for a slight decline in 2018 correlated to the plastic reduction policy of 2018. Even then, the production of plastic products reached a maximum of 82 million tonnes in 2019, which in turn correlates with both the very large demand for plastics in 2019 and the large-scale development of China in 2019.

The generation of plastics

Plastic waste in China can be divided into four categories: industrial, agricultural, medical, and household (Wang, 2021). Industrial plastic waste mainly refers to the plastic waste materials generated during production. Most of these are from specific sources, with good-quality raw materials and a high-potential recycling value. Agricultural plastic waste mainly includes discarded agricultural mulch film, shed film, agricultural pipe, pesticide packaging, etc., of which the waste agricultural film composes the largest volume and is the most difficult to collect and dispose. This type of plastic waste is not easily degradable, it contaminates farmland and harms the ecological environment. Medical plastic waste mainly comes from disposable plastic products used in medical treatment and epidemic prevention, such as protective clothing, surgical masks, protective goggles, etc., which are directly or indirectly infectious, toxic, or hazardous. Medical waste is defined as hazardous waste, so most of medical plastic waste is treated in a treatment centre where it is incinerated or placed in special landfills. The treatment of medical waste is gaining attention, as more disposal facilities were built in China during the COVID-19 pandemic (Hantoko et al., 2021). Household plastic waste is primarily composed of discarded plastic products during diverse daily life activities, such as plastic bottles, plastic bags, paper-plastic composite materials. Most household plastic waste is mixed in with municipal solid waste, except for the collected drinking bottles.

According to the analysis of municipal solid waste composition, plastic waste accounted for more than 24% of the total waste count. Plastic waste is primarily composed of 66% polyethylene (PE): 27% low-density polyethylene (LDPE), 21% high-density polyethylene (HDPE), polypropylene (PP, 18%), followed by 16% polystyrene (PS), 7% polyvinyl chloride (PVC) and 11% are categorised as others. Most household plastic waste is PE and PP, which are present as waste in higher volumes than PS and PVC. Approximately 44% of plastic waste is a mixture of different types of polymers, and roughly 10% are black in colour. These black polymers are required to be sorted before recycling (Jin, 2021).

In 2003, the production of plastic products from formal companies reached 16.51 million tonnes in China, while the real amount was estimated to be more than 25 million tonnes, if calculating the products made by small enterprises and family workshops (Tang et al., 2013). Until 2005, the domestic recycling of plastic was planned to be 5 to 6 million tonnes (Song et al., 2011).

China is short of plastic raw materials, so a large amount is imported (Huang et al., 2020). Plastic waste recycling and treatment could be helpful to solve the shortage of raw materials and environmental pollution in China (Yi et al., 2013). In 2008, China's total plastic consumption reached 52 million tonnes, ranking second in the world (Tang et al., 2013). In the same year, the domestic plastic waste recycling amount was approximately 9 million tonnes (Tang et al., 2013). This means that the recovery ratio of plastic waste was about 22%. In addition, 7.07 million tonnes of plastic waste were imported in 2008, meaning that over 16 million tonnes of plastic waste were recycled in China (Tang et al., 2013). To protect the local environment, China banned the import of plastic waste since 2018. The policy required that the import of harmful environmental solid wastes would be completely banned by the end of 2017; the import of solid wastes that can be replaced by domestic resources would gradually be stopped by the end of 2019, and a complete ban on the import of solid waste would be imposed starting 1 January 2021.

According to the 2011 statistics of the Chinese Ministry of Environmental Protection, production of China's disposable plastic lunch boxes and all kinds of foam packaging was as high as 95 million tonnes, scrap home appliances and car plastic waste was up to 65 million tonnes. The total plastic waste was nearly 200 million tonnes of which total recycling accounted for only 15 million tonnes; the recovery ratio is thus less than 10% (Tang et al., 2013). Comparing these figures to those in Figure 7.1, we note discrepancies.

Treatment

The easiest way to dispose of large quantities of plastic waste is to place it into a landfill. About 10% of plastic waste is handled in this manner (Mrowiec, 2018), which poses a risk to the environment. The disadvantages of landfills are obvious; the release of landfill gas and additives to the plastics pollutes the air, soil, and water resources. Plastic waste is difficult to degrade, and this will hinder the landfill area use (Canopoli et al., 2018). Recently, landfill mining has attracted the attention of government and scientific communities, but the research related to landfill mining shows very limited economic possibilities for implementation (Laner et al., 2019).

Plastic usually has high heating value, up to 50 MJ/kg, basically comparable to fuel oil (Cudjoe & Wang, 2022). Plastic waste can be converted into oil by pyrolysis, heat, or electricity by a combustion process (Xayachak et al., 2022). Besides recycling, incineration is widely used for energy recovery from plastic waste in municipal solid waste incinerator-installed steam turbines and generators (Xiao et al., 2022). Of course, pollutant emission from incinerators is a public concern, especially dioxin emissions and exposure risks (Wei et al., 2022).

Recently, plastic waste recycling has attracted more attention in China, but more research in plastic recycling and recovery technology is necessary (Tang et al., 2013). The recycling and reuse of plastic waste is a way to establish a CE and sustainable development. Figure 7.2 shows the development of recycling of plastic in China. The Chinese government has spent much effort to establish the waste sorting system, which has significantly influenced the municipal solid waste generation and treatment (Wu et al., 2021).

With sorting regulations, more plastic waste recycling sites are set to be built in China. However, there is a smaller amount of recycling sites for plastic waste than for paper and metal recycling. The number of enterprises and personnel engaged in the recycling, utilisation, and processing of recycled plastic is large and growing steadily (Liu, 2006), including mainly self-employed persons and farmers and a small number of investors. The plastic waste processing capacity varies between the different regions in China and the largest share of the capacity is in the Yangtze River Delta with 40% of the processing capacity being located in this area (Plastic Recycling Association of CRRA, 2020).

Policies and future trends

The production and use of plastic in China is huge; this in turn directly contributes to large amounts of plastic waste. One example is plastic fast-food boxes, which have been used since 1986 during train travel to store food. Many plastic fast-food boxes were subsequently discarded along the railway, which caused serious ecological risk (Deng et al., 2018). Since May 1995, China banned the use of nonbiodegradable fast-food boxes in train services, but plastic fast-food boxes continue to be used in daily life (Hu et al., 2001). The wide use of plastic bags began in the 1990s, as plastic bags were cheap and convenient to use for shopping and packaging. Most of the plastic bags are discarded in the environment without any treatment (Zhou & Wang, 1999). Yet another important source of plastic waste is agricultural plastic film. In the early 1950s, plastic film was used in agriculture around the world. In 1978, plastic film technology was introduced in China from Japan, making an important contribution to improving China's agricultural output (Zhang et al., 2019). However, most plastic film is discarded in farmland areas, and the productivity of the land is gradually affected (Zhou, 2016); this eventually led to the government realising the problems of plastic film usage in agriculture (Zhang et al., 2019).

Before the 2010s, problems and challenges of plastic waste control in China included ineffective plastic waste regulation, incomplete plastic waste recycling systems, and inadequate management systems for biodegradable plastic (Deng et al., 2018). China has issued relevant regulations on the management of plastic waste. There remains, however, a big gap between the actual implementation efficiency and expectations due to the vast number of plastic production enterprises and the scattered use of plastic in all aspects of daily life (Deng et al., 2018).

Regarding an incomplete plastic waste recycling system (Deng et al., 2018), China currently has a large and fragmented number of plastic manufacturers who have largely failed to take responsibility for recycling plastic waste. Due to the large number of enterprises engaged in plastic production, it is difficult to effectively supervise the implementation of their plastic waste recycling task in actual operations. At present, there are three main challenges in China's plastic waste recycling (Deng et al., 2018): first, the cost of plastic recycling is high and the income from it is very low. It is impossible for the recycling companies to make a profit in addition to the insufficient relevant policy incentives. Second, even if a large amount of plastic waste is collected, it will be mostly disposed through landfills or incineration because of the low value of the recycled material (Ma et al., 2023). Third, after the release of the ban on plastic bags, the income from charging for plastic bags provides income to supermarkets. This is not converted into the cost of recycling and treatment of plastic bags and does not reflect the purpose of polluter pays.

Discussion on the challenges and catalysis possibilities for plastics recycling in China

From the review of the current situation in plastic waste treatment and development of recycling and regulations, we can conclude that the main challenges in China are the following: 1) the separate collection system of plastics and other recyclables does not work properly, 2) the regulations have not been implemented sufficiently in practice, and 3) there is not enough capacity in the whole country to treat and recycle the plastic waste materials. In China, a large share of collection and recycling is executed by private companies or entrepreneurs. Private recycling is competing with the public attempts to get material flows in control. The regulations are developing; plastics separation is not yet economically feasible. Plastic waste collection is the most expensive part of recycling light and very distributed materials such as plastic waste. When there is no guarantee that proposed treatment plants will get sufficient mass flow of plastics with a feasible cost, it is not attractive to make investments.

It is possible to catalyse and thus speed up the development towards plastics circularity using previous experiences both from China and other parts of the world. The extended producer responsibility (EPR) regulation and system has been used in many European countries for improving the collection and recycling efficiency of several waste fractions, and packaging waste is one of them (European Commission, 2008). EPR is based on the responsibility of the product manufacturers and importers to arrange the collection and treatment of their products after their use. An example from Finland for implementing the EPR system is that the manufacturers and importers of certain products (e.g., metal packages or waste electronic and electric equipment [WEEE]) establish a common enterprise to organise and implement the collection and treatment of the products they have sold to the product's end of life. The EPR company's shareholders then pay fees for the company according to their share of the product market. This way the waste management and recycling costs will be included in the prices of the original products. EPR can be used to fund the collection and pretreatment of plastic waste from diverse sources, which will help to make plastics recycling a profitable business. A challenge for implementing an EPR system in China for such products as plastic packages as the largest source of plastic waste, is the fact that there is a huge number of plastic package producers in the country, and it is difficult to get all of them involved and contributing to the costs of the system. Similar problems exist even in smaller countries (Finland's Environmental Administration, 2023), and for China it could be a very big administrative task to get all the relevant stakeholders involved.

Previously, China has good experiences catalysing investments in waste management. For example, landfilling of MSW has decreased between 2003 and 2019 from about 85% to about 45%, mainly by building incineration capacities for mixed MSW. This has meant construction of a more than 115 Mt incineration capacity in 16 years. The same kind of tested methods could be used for building up plastics separation and recycling capacity in different parts of China, but the precondition for the capacity building is that there will be a guarantee to get the material flows into the treatment plants.

Improvement of recycling has been done successfully in such countries where the source separation system of recyclables works well, like in Germany and Austria (Statista, 2023). Source separation needs the active involvement of citizens. The economic incentives for citizens in waste management are rarely very effective, which means that the people need to be motivated in other ways. Awareness campaigns of the environmental and societal impacts of waste and possibilities to improve the sustainability and welfare of the future generations are needed also in China to activate people in source separation at the same time when investments in the separate collection systems are implemented. Another possibility to direct the recyclables to the effective treatment plants is getting the private and self-employed waste collectors involved in the public or other official collection systems.

Conclusions

The reduction, treatment, and management of plastic waste has recently attracted more attention in China. With the promotion of waste sorting and circular economy establishment, more policy, regulation, and efforts related to plastic waste are being implemented, especially since 2020. The current treatment of plastic waste is relying heavily on incineration and landfill disposal, and mixed methods are used with municipal solid waste. Plastic waste recycling is developing, but more work is needed to realise the set targets. Much plastic waste is generated from agricultural plastic (farmland film), shopping plastic bags, express and logistic plastic packages, and industrial waste.

The technical possibilities to recycle plastic waste include mechanical recycling and chemical recycling out of which mechanical recycling is the more commonly used technology. Both technologies require pretreatment of collected plastic waste, and the quality of the input waste depends on the waste collection practices, which would ideally include source separation, while mechanical separation can be utilised to separate plastic from other waste fractions and even different polymers from each other. Compared to mechanical recycling, chemical recycling has the advantage that the quality of decomposed chemical raw materials can be comparable with that of virgin materials, while mechanical recycled polymers have lower quality. However, mechanical recycling and chemical recycling can complement each other. For example, multilayer plastic packaging is challenging for current mechanical recycling processes, and there, chemical recycling can be more suitable. In addition, interesting waste materials for chemical recycling via pyrolysis include multilayer plastic packaging materials, also fibre-reinforced composites and polyurethane derived from construction and demolition waste.

Municipal solid waste management has developed quickly in China during the last 15 years from almost total landfilling to less than 50% of landfilling. Recycling has, however, increased very slowly, due to the balancing between profits and cost on plastic waste treatment. Recycling is leaning too much on very small private operators and market prices of the materials like recycled plastics. Thus, recycling systems need an active push from regulative steering mechanisms. Recycling can be supported with such regulations like EPR or taxes for optional, less sustainable treatment methods (such as landfills and incineration). Furthermore, the public infrastructure for a recycling system is important to support recycling development; this includes separation, collection, utilisation, and disposal facilities. To have a successful implementation of this kind of steering mechanisms can confirm the control of the material flows of the recyclables for the separation and recycling plants, and in such a way catalyse the investments in the recycling sector. High yields of recycling can be additionally increased with long-term awareness campaigns among citizens.

So far, the challenges of plastic waste management have brought to light the unsustainable practices in our production and consumption systems. To reduce the environmental impact of plastic waste and accomplish a circular and sustainable plastic system, increased circularity, smarter use of plastic, and use of renewable materials will be the pathways needed in the future. Integrating circularity in plastic will reduce the need for virgin materials and natural resources consumed in plastic production. This will ultimately minimise the environmental pressures associated with resource extraction, production, consumption, and waste generation. Furthermore, promoting and facilitating plastic reuse, repair, remanufacture, recycling, design improvement, and adopting higher quality plastic will aid in longer-lasting plastic products and waste reduction within the economy.

Educational content

Consider and discuss the following:

- What type of measures could you take to increase the environmental sustainability of production, consumption, and end-of-life of plastics?
- What regulations and policies do you know, or can find, from your country that deal with plastic waste?
- What can you as a consumer do to increase recycling?

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8

THE ROLE OF INSTITUTIONAL ENVIRONMENT IN CATALYSING CIRCULAR ENTREPRENEURSHIP

A cross-country comparison of Finland and Italy

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Introduction

Circular economy (CE) entrepreneurs seek to address sustainability challenges by reducing the use of materials extracted from nature, keeping the materials in use as long as possible, and minimising the amount of waste so that resources can be kept in the economy as long as possible. Circular start-ups are newly established ventures that have been founded to follow circularity principles (Henry et al., 2020). CE start-ups have a central role in accelerating CE, and to do so they need an enabling institutional framework that supports the transition in the market and society (Ranta et al., 2018; Uusikartano et al., 2020; Zucchella & Urban, 2019). The institutional environment plays a key role in catalysing the development of circular start-ups by providing a support system that advances and shapes entrepreneurial activities (Korhonen, 2001; Zeng et al., 2017; Zucchella & Urban, 2019), and thus sustainability changes in society. In this chapter, we present a cross-regional comparison of institutional environments of circular start-ups in both Finland and Italy.

The comparison of two European Union (EU) countries allows for exploring differences in the institutional environment of CE start-ups. To do this, we first identify the key actors and their functions in the Finnish and Italian institutional environments. We compare and contrast the national innovation systems in Finland and Italy in relation to CE initiatives. Second, to increase our understanding about catalysing mechanisms in the institutional environment, we present an analysis of six case ventures, three from each country. The selected cases were chosen to represent the three areas of the CE model: reuse, reduce, and recycle. We interviewed the entrepreneurs and public actors that had collaborated with the venture to understand both the business and institutional environment views on the CE and its implementation. By rooting our work in institutional theory (DiMaggio, 1997; North, 1990; Scott, 1987, 2008), we examine the three pillars of institutional environment, namely the regulative, normative, and cultural-cognitive frames, and elaborate on the similarities and differences in both countries. Institutional theory offers important insights to circular entrepreneurship research in understanding how rules, norms, activities, beliefs, and attitudes support and constrain entrepreneurship. The results of our study show

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that a holistic integration of all institutional pillars is needed for catalysing CE start-up activity. One challenge for circular start-ups is that the solutions they provide are not necessarily aligned with prevalent social, economic, or political institutional structures. For example, regarding the regulative pillar, the timing of laws and regulations either support or constrain the CE start-up innovations. The normative pillar directs attention to the terms and availability of public and private funding for CE start-ups. With the cultural-cognitive pillar, the awareness of citizens to act sustainably becomes highlighted. In both countries, the CE start-ups are active in taking a role in building the sustainable culture, for example by educating their citizens and fostering behavioural change towards sustainability.

This chapter is structured as follows. The first part is devoted to introducing institutional theory and describing institutional environments in Finland and Italy. The second part is dedicated to illustrating the six case studies and analysing them according to the three institutional pillars: regulative, normative, and cultural-cognitive. The third and final part of this chapter will present a discussion and the practical implications of our findings.

Theoretical background: institutional theory

Institutional theory concerns the way groups and organisations conform to the rules and norms of the institutional environment (Scott, 2007). It analyses those long-established and resilient social structures that guarantee societal stability (Scott, 1987). This theory deals with all the regulatory, social, and cultural influences that allow organisations to survive and find legitimation (Roy, 1997). Institutional theory has long been employed in entrepreneurship research to study environmental influences on entrepreneurship (Bruton et al., 2010; Eijdenberg et al., 2019; Sine & David, 2010; Tolbert et al., 2011). Bruton et al. (2010) identified three streams of research related to institutional theory as applied to entrepreneurship: institutional setting, legitimacy, and institutional entrepreneurs. The institutional setting regards entrepreneurs as both constrained and supported by the institutional environment they are embedded in at macro, meso, and micro levels. The institutional setting plays a key role in enabling or restricting entrepreneurial opportunities (Aldrich & Waldinger, 1990), and affecting, for example, the rate of new venture creation (Hwang & Powell, 2005). Legitimacy addresses the way entrepreneurs seek legitimacy for their new ventures by gaining the right to perform in a particular way through conforming to the environment, selecting between environments, or seeking to manipulate the environment (Ahlstrom & Bruton, 2001; Suchman, 1995). The institutional environment affects entrepreneurial organisations in their processes of gaining legitimacy and overcoming the liability of newness (Stinchcombe, 1965). Institutional entrepreneurship concerns entrepreneurs as they enter an under-organised domain (Trist, 1983) and examines the ways in which they improve the business environment and grow their business operations while gradually assuming the role of institutional entrepreneur.

In this study, we embrace the first stream of research, the institutional setting, and follow Scott's (1995, 2008) conceptualisation of an institutional environment as composed of regulative, normative, and cognitive pillars; these pillars can be distinguished individually, but interdependently contribute to the resilience of the social structure (Ranta et al., 2018). These pillars are summarised in Table 8.1.

The regulative pillar posits that institutions guide behaviour through the rules of gaming, monitoring, and enforcement that stem from governmental legislation, industrial agreements, and standards. This means that institutions provide guidelines to entrepreneurial organisations, mandating them to comply with laws and regulations and react if these are not met. The normative

Table 8.1 The three pillars of institutions

	Regulative	*Normative*	*Cultural-cognitive*
Basis of compliance	Expedience	Social obligation	Taken-for-grantedness Shared understanding
Basis of order	Regulative rules	Binding expectations	Constitutive schema
Mechanisms	Coercive	Normative	Mimetic
Logic	Instrumentality	Appropriateness	Orthodoxy
Indicators	Rules Laws	Certification Accreditation	Common beliefs Shared logics of action Isomorphism
Affect	Sanctions Fear, guilt/innocence	Shame/honour	Certainty/confusion
Basis of legitimacy	Legally sanctioned	Morally governed	Comprehensible Recognisable Culturally supported

Source: Scott (2008, p. 51) and Ranta et al. (2018).

pillar refers to institutions that guide behaviour by stating what is deemed as appropriate in diverse social and commercial contexts, and they include social obligations to comply with (March & Olsen, 1998). Finally, the cognitive pillar refers to models of individual behaviour, which tend to be based on a set of learned rules that operate at individual levels and are embedded in culture language (Carroll, 1964) and other taken-for-grantedness features that people barely think about (Meyer & Rowan, 1991). The cognitive pillar is important to entrepreneurship research, as it addresses the ways societies see entrepreneurs and may create a cultural mindset whereby entrepreneurship is encouraged and fostered (Li, 2013).

Since CE facilitates the harmonisation of economic development (efficiency) and environmental protection (legitimacy) (Ghisellini et al., 2016; Murray et al., 2017), the extended institutional theory is well suited as a theoretical lens in studying how the institutional environment catalyses circular start-ups. Recent studies (Do et al., 2022; Ranta et al., 2018) highlight the lack of empirical investigations on extended institutional theory within CE literature. Ranta et al. (2018) underline the importance of understanding the institutional pillars and apply them within the CE discourse as interdependently and mutually setting the legitimacy of the CE in the institutional environment (Ranta et al., 2018, p. 72). Despite this, the theory has been rarely applied to study and investigate circular start-ups. Our study offers a contribution in this direction by comparing two EU countries' institutional pillars as catalysers of circular start-ups.

Institutional environment of the circular economy

Institutional environment for circular ventures in Europe

The overall impact of EU innovation policy is to strengthen the EU's economy, competitiveness, and to boost the sustainable and digital transition of the whole continent (European Commission, 2020). Moreover, innovation policy targets to transform the EU as the leading global area in science and technology; the EU targets to increase R&D expenditures to 3% of EU GDP (European Parliament, 2021). The most important funding instrument has been the Horizon 2020 fund, which offered nearly 80 billion EUR of funding in 2014–2020. To continue with the success of the first round of Horizon 2020 funding, the EU designed a new Horizon Europe funding, which will offer 95.5 billion EUR to five areas it determined were the most important to study: climate change; cancer; healthy oceans, seas, and waters; climate-neutral and smart cities; and healthy soil and food (European Commission, 2021).

Institutional environments for circular ventures in Finland and Italy

Finland and Italy are both members of the EU and, hence, part of the EU's innovation policies and strategies (European Commission, 2020). EU has promoted CE since 2014 with some early regulations dating back to the 1970s. Some key examples of EU-level CE actions are the European Green Deal, which aims to accelerate the sustainability transition and Next Generation EU, a recovery plan for 2021–2027 of over 800 billion EUR to foster climate and digital transitions, fighting climate change and biodiversity loss, and financing research and development (R&D) (European Commission, 2021).

Finland

For decades, the innovation policy of Finland has been based on new knowledge, innovativeness, and R&D investments (TEM, 2019). The main two purposes of the national innovation policy are the following. First, it is a critical instrument to increase employment and productivity of the whole economy leading to a better competitive position for international markets and reacting to societal challenges like an aging population. Second, to increase knowledge and know-how, to increase R&D quality and impact and thus have a potential to produce competitive ventures and support growth (TEM, 2019).

Overall, in Finland, R&D expenditures increased by 3.2% to 6.9 billion EUR in 2020, private sector expenditures were 4.644 billion EUR (67% of all expenditures), universities expenditures were 1.7 billion EUR (25% of all expenditures), and government expenditures (all governmental agencies, municipalities, social security funds and departments, and all other government-based nonprofit activity) were 585 million EUR (8% of all expenditures) (Statistics Finland, 2021). These expenditures are 2.94% of Finland's GDP and this is above the OECD and EU average (OECD, 2019). The overall R&D funding is channelled through many public actors and agencies. Here we present the most important ones, which are responsible for EU funding for ventures, universities, universities of applied sciences, vocational schools, and additional actors for R&D and for other projects. Next, we describe the institutional actors and innovation policy systems in Finland and Italy. We will depict the political decision-making that supports sustainability and growth related to the CE, describe the long-term regional and national innovation policies related to CE, and review funding and advice opportunities available for CE ventures in both countries.

a Political decision-making supporting sustainability and growth related to CE

Finland aims to become carbon neutral by the year 2035. This objective includes energy strategy, land use programmes, fossil-free transportation and mobility, low-carbon buildings and construction, and carbon-free food strategy, among other aspects. According to this goal, all the ministries in Finland implement a CE strategy. The agreement is an important guide for policy and funding actors who work with ventures and organisations (YM, 2021). In parallel, Finland aims to increase national R&D expenditures from 2,7% to 4% of GDP in 2030. The R&D roadmap strategy aims at radically increasing investments in both public and private sectors. For the national growth portfolio, the most promising business opportunities to support employment and innovativeness include digitalisation, new technologies, transportation and logistics, resource efficiency, new industry, health and well-being, new consumerism, and diverse communities (TEM, 2019). Moreover, the plan is to increase government R&D expenditures and target them in an optimal manner and aim at ventures with the highest innovation capability (Einiö et al., 2022).

b Long-term regional and national innovation policies related to CE

There are 19 regions in Finland (18 regions in Mainland Finland and the Province of Åland). The regional council's main tasks are regional planning and the implementation of the regional strategy. The development plans are mainly crafted for 20 to 30 years, and they include plans for land use from the perspective of commercial development, transportation projections, and investment plans. Councils are responsible for applying regional project funding through the European Regional Development Fund and the Regional Development Funds. The funds are channelled to universities, research institutes, and ventures for project development on, for instance, sustainable business opportunities or CE business development (TEM, 2022b).

c Funding and advice for ventures related to CE

Business Finland is a public organisation under the Finnish Ministry of Employment and the Economy; Business Finland aims to promote the growth of Finnish businesses through innovation and internationalisation. It also supports collaboration between ventures and research institutions. They provide services for start-ups, small- and medium-sized enterprises (SMEs), large ventures, R&D organisations, and the public sector (Business Finland, 2022). For CE firms, they provide a variety of services and funding. Circular start-ups can have their business ideas evaluated and supported for developing products and services for international markets and scaling up their existing business (Business Finland, 2022). One example of the programmes Business Finland is financing is the Sustainable Growth Program for Finland. It channels 530 million EUR for Finnish ventures to accelerate competitiveness, investment, expertise, and research, development, and innovation (RDI). This entails structural renewal in business and industry with a purpose of supporting the creation of a competitive edge based on Finnish ventures' sustainable solutions (Business Finland, 2022).

There are 15 regional Centres for Economic Development, Transport and the Environment in Finland that provide business and venture funding, guidance and development services, employment funding, and infrastructure development. They provide support to increase transportation safety, advance learning and focused educational activities, implement environmental tasks, and execute the EU's structural fund projects in universities, ventures, and other organisations. The Centres report to the Ministry of Economic Affairs and Employment of Finland (TEM, 2022a). For CE ventures, the Centres provide funding for investments targeted for growth, technology, internationalisation, productivity, and building business competence (ELY, 2022).

The Finnish Innovation Fund (SITRA) is an independent public fund, which, under the supervision of the Finnish Parliament, promotes the transition towards a sustainable future in Finnish society. It published the first CE roadmap for Finland for 2016–2025 to envision concrete actions that would be needed for implementing CE (SITRA, 2016). The roadmap 2.0 promoting SDGs through Finnish investment was published in 2019 with strategic targets for all sectors in society. The main objectives were built on a notion that the future competitiveness will focus on circular solutions and a sustainability transition to low-carbon energy. The goal was that every actor in the public sector, cities and municipalities, ventures, and citizens would be involved, thus gaining a maximum effect of the transition towards CE. In addition, to advance sustainable well-being and business, SITRA funds projects that involve sustainable solutions, digitalisation, capability renewal, and experimentations. In 2019, SITRA published a list of 41 of the most interesting and pioneering ventures in CE in Finland. Ventures were categorised based on their circular business models into product-as-a-service, renewability, sharing platforms, product-life extension and resource efficiency, and recycling (SITRA, 2019).

Italy

Italy's National Strategy for Sustainable Development (SNSvS/NSDS) was approved by a governmental decision in December 2017. The NSDS was intended to be the framework for implementing the 2030 Agenda in Italy and abroad. The development of the CE paradigm was a part of the provisions of the new Action Plan for the CE (COM/2020/98), as one of the pillars of the European Green Deal, approved on 11 March 2020. This Action Plan presented a strategic framework and measures to ensure the design of sustainable products, the accountability of producers and consumers towards more sustainable choices, and the increase of circularity in production processes and referenced sectors that use more resources such as electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction, and food. In September 2020, Italy implemented the directives of the Circular Economy Package, with the recycling targets and reduction of urban waste by at least 55% by 2025, at least 60% by 2030, at least 65% by 2035, and a restriction on their disposal in landfills of no more than 10% by 2035. In line with this reference framework, Italy's project proposals about CE aim to fill the structural gaps that hinder the development of the sector. Moreover, the Italian government earmarked 250 million EUR for a fund to support start-ups and active venture capital in the ecological transition.

a Political decision-making supporting sustainability and growth related to CE

In Italy, regional authorities play a relevant role in implementing policies to support CE. According to Compagnoni (2020), there are three policy instruments to implement circularity: Research and Innovation Strategies for Smart Specialisation (RIS3 or S3), single Regional Laws (RL), and Regional Waste Management Plans. To benefit from the EU Cohesion Policy, regions are required to elaborate research and innovation strategies for a 'smart specialisation'. The S3 identifies regional innovation and industrial transformation trajectories starting from a medium-long run development vision. The visions and implementations vary according to each region's specific competitive advantages, socioeconomic structures, and resources. The region that has completely integrated the CE concept in the S3 is the Emilia-Romagna region. In addition, several regions have introduced circular principles through specific laws providing eco-innovation incentives, and targets and policies for waste management. These regions are Friuli-Venezia Giulia, Umbria, Marche, Basilicata, and Emilia-Romagna.

The CE is a priority also for Italian municipalities. In 2021, the National Association of Italian Municipalities (ANCI), and the National Packaging Consortium (CONAI) engaged in a process of regeneration and further implementation of the waste industry throughout the country. The previously mentioned NRRP dedicated resources to further implement the CE within municipalities.

b Long-term regional and national innovation policies related to CE

In 2021, the intervention of the Fund for Sustainable Growth (FCS) defined by the Minister of Economic Development in agreement with the Minister of Economy and Finance granted financial concessions to support research, development, and innovation for the ecological and circular transition to support the goals of the Italian Green New Deal. The Ministry of Ecological Transition (MISE) launched the National Recovery and Resilience Plan (NRRP), which envisaged investments and a consistent reform package. The Green Revolution and Ecological Transition allocated a total of 68.6 billion EUR (31.05% of the total value of the NRRP) to improving the sustainability and resilience of the economic system and ensuring a fair and inclusive environmental transition.

c Funding and advice for circular start-ups related to the CE

Public start-up incubators devoted to financing innovative start-ups have been established in Italy. They are managed by public institutions having goals of both economic growth and promotion of entrepreneurial activities and the decrease of the failure rate at the venture level. The first two incubators in Italy were university incubators: Polihub of Milan Politecnico and I3P of Turin Politecnico. The latter has been recognised as the best public university incubator in the world (UBI Global World Rankings of Business Incubators and Accelerators 2019–2020). In addition to these, in 2018, the public research institute ENEA launched the Italian platform for the CE actors (ICEPS – Istituto per la Cooperazione Economica con i Paesi in via di Sviluppo) to promote collaboration and networking to transition towards the CE both in supply chains and within towns.

Comparison of institutional environments in Finland and Italy

To summarise, Table 8.2 presents the key actors and their functions in both countries. As illustrated in the table, the institutional environments are somewhat similar in both countries (e.g., ministries and regional policies). The key difference we found is that incubators, regional, and occasionally municipal-level initiatives seem to play a much higher role to support circular entrepreneurial ideas in Italy than in Finland; while Finnish regional councils have a much more prominent role in funding entrepreneurship, business growth, and internationalisation when compared to Italy.

Methods

We performed a qualitative, exploratory study (Stake, 1995) with six case studies. Each case study included an interview with a circular entrepreneur – or alternatively a knowledgeable informant within the venture – and a public servant who had worked in collaboration with the venture. We conducted a total of 12 interviews, two for each venture. To identify the ventures, we used two databases: the Italian Atlante Storie di Economia Circolare, an official Italian database of circular ventures that reports 249 cases of Italian circular ventures, and SITRA, a Finnish database reporting 50 ventures with 100% circular business. We selected these two countries because Italy is the EU country showing the best performance index in terms of CE (Circular Economy Network & ENEA, 2020), while Finland is a forerunner in CE, expected to add about 3 billion EUR to Finland's national economy by 2030 (SITRA, 2022).

In refining the selection of ventures, we proceeded with the purposeful selection (Patton, 2015) of the ventures with the following criteria: they had to: 1) be founded in recent years (typically from four to six years ago) by pursuing a circular business model from inception, the so called circular start-ups, 2) adhere to one of the three practices of the 3R framework of waste management (reuse, reduce, and recycle) (Neves & Marques, 2022), and 3) have the either founders or the most knowledgeable informants within the organisation (Eisenhardt & Graebner, 2007) available for repeated, in-depth, semistructured interviews during the research time. The interviews rotated around two main topics:1) key steps of the entrepreneurial process, and 2) the public institutions that played a role in each venture's development.

Table 8.2 Institutional actors and their functions in the Italian and Finnish innovation systems catalysing CE

a Political decision-making supporting sustainability and growth	
Institutional actor	*Function*
Regional Councils, Finland	Regional planning, the implementation of the regional strategy and funding through the European Regional Development Fund and through the Regional Development Funds.
Regions, Italy	Implementing policies to support CE. Main three policies: Research and Innovation Strategies for Smart Specialisation (RIS3 or S3), single regional laws (RL), Regional Waste Management Plans.
Municipalities, Italy	Implementing the CE within municipalities through concrete actions (e.g., related to packaging waste). Circular City Index (tool developed by Enel energy company) to calculate the circularity of Italian municipalities.
b Long-term local and national innovation policy	
Ministries of Finland, Finland	Ministry of Economic Affairs and Employment of Finland is mainly in charge of innovation in CE including budgeting and policymaking. The Ministry of Education and Culture is responsible for science and CE-related innovation policy.
Ministry for Ecological Transition (MISE), Italy	Supports the ecological and circular transition and the goals of the Italian Green New Deal. In June 2022 the Minister of MISE signed the decree adopting the National Strategy for the Circular Economy
EU, Finland & Italy	The EU supports and accelerates CE with, for example, Green Deal and Next Generation Europe Recovery plans including budgeting policymaking and financial concessions to ventures, universities, research institutes, etc.
c Funding and advice for CE ventures	
Business Finland, Finland	Services and funding for CE ventures.
Finnish Innovation Fund (SITRA), Finland	Enables funding for research projects and technology transfer; recent focus includes CE, SMEs, and ventures.
Centre for Economic Development, Transport and the Environment, Finland	Funding, guidance, and development services for CE ventures.
Italian government	Support for start-ups and active venture capital in the ecological transition (250 million EUR).
Start-up incubators, Italy	Incubator services for CE ventures.
Public research institute ENEA, Italy	Platform promoting collaboration and networking in CE transition.

Source: The authors.

Table 8.3 summarises the six cases included in this study. We selected two ventures, one in each country, that were involved in CE innovation related to reuse, two that were involved in reduce, and two in reuse. We then interviewed the public servants as named by the entrepreneurs as the most important public actor in connection with the development of their venture. Table 8.3 shows the business markets the venture operated in, either business-to-business (B2B) or business-to-consumer (B2C) markets. Also, Table 8.3 includes the CE issue focus and the type of innovation the venture has made. The interviews were conducted between October 2019 and

Table 8.3 Description of the cases

Case	*Finland/Italy*	*B2B/B2C*	*CE issue focus*	*Interview details*
	CE innovation related to reuse			
1	Finland	B2C	Waste	Venture: 4/2020 (91 min) Public actor: 1/2022 (83 min)
2	Italy	B2B, B2C	Textile	Venture: 1/2022 (52 min) Public actor: 1/2022 (49 min)
	CE innovation related to reduce			
3	Finland	B2B	Waste	Venture: 4/2020 (43 min) Public actor: 5/2021 (20 min)
4	Italy	B2B, B2C	Changing habits, behaviour	Venture: 12/2020 (28 min) Public actor: 12/2020 (29 min)
	CE innovation related to recycle			
5	Finland	B2B	Decreasing use production process	Venture: 10/2019 (54 min) Public actor: 6/2021 (52 min)
6	Italy	B2B	Waste	Venture: 1/2022 (49 & 40 mins) Public actor: 1/2022 (47 min)

Source: The authors.

January 2022. The interviews lasted between 20 to 91 minutes. All interviews were conducted in either Finnish or Italian and transcribed in English by the researchers.

First, we performed a single-case analysis focused on the venture's operations. We analysed the type and purpose of support provided to the circular venture by a public actor and created a description of the collaborative activities between the venture and the public actor. Thereafter, we used secondary data composed of our reviews on the CE initiatives in both countries and other secondary data, such as academic articles, ventures' websites, news articles, and reports from established sources to identify the institutional pillars in each case. Through investigator triangulation, we shared and discussed the outcome of the data analysis within the research team to increase the reliability of the findings.

Findings

Circular economy innovation related to reuse

Case 1: Finland

The venture in Case 1 provided services for customers to effortlessly sell used good-quality clothes. The venture provided branded boxes for customers to send their used clothes for resale (they could mail the clothes directly to the venture or drop them off in shopping malls throughout several cities in Finland). The venture set the price of clothes, photographed the items, and sold them through an online store. The services provided by the venture relied on a cost-effective and easy process of selling used clothes. The entrepreneur had experienced that people are increasingly more receptive towards environmental issues and proudly adopt circular practices; as expressed in the excerpt: "I found this awesome cardigan for just a few EUR" (Venture representative, Case 1).

Public actors involved

The representative from the venture considered that the public organisations that give funding and advice to them as the most important public actors for their venture. Additionally, political decision-makers who supported sustainability and growth, especially on behalf of the EU, were mentioned as important enabling stakeholders.

Public sector support

The venture had received funding from the Ministry of Economic Affairs and Employment of Finland. Additionally, it had applied for funding from Business Finland. The representative of the venture described that getting funding did not go without challenges:

> The funding we received from the Ministry of Economic Affairs and Employment of Finland is now a bit of a baggage for us, because in granting new funding they looked two years back and even if you have rationale for new funding, you may not receive it in full, because of the de minimis rule.… And I have found out that the de minimis rule is based on EU regulations. At least there could be some exceptions to this in crisis situations such as corona.
>
> (Venture representative, Case 1)

De minimis rule applies to all ventures, but the interviewee expressed frustration when facing that funding was out of reach to the CE ventures:

> … when you offer loan to ventures, but there are certain economic conditions, economic key ratios, and it is a larger problem that you have to fill certain economic conditions you actually cannot fill at that point of time. Nice that they offer funds, but if you have no chance of getting the fund to start with, then it is just nothing but words to the entrepreneurs.
>
> (Venture representative, Case 1)

Public organisations provide advice to start-ups. The following excerpts elaborate on the variety of support that was provided, including sparring sessions, matchmaking, webinars, and pitching opportunities.

> There has been sparring sessions on certain markets and business opportunities and also matchmaking sessions. Also, there were webinars where one could do pitching for a large crowd. Also, private matchmaking sessions have been organized.
>
> (Venture representative, Case 1)

> You get to talk directly to the large ventures' representatives and tell about their offering and how it could fit to the brand of the larger venture.
>
> (Public actor, Case 1)

Institutional pillars

The public sector in Finland had increasingly implemented initiatives and support mechanisms for CE to make it a mainstream economic system. However, also private investors were needed to support CE ventures. In summary, from the regulative perspective, a key catalyst in promoting a CE is represented by recovery and resilience funding from the EU, while a key constraint is de minimis of 200,000 EUR per EU regulations. Regarding the normative pillar in Finland, key catalysts are angel investors who have made circularity a priority in their impact investing agenda, and people who are generally receptive towards environmental issues and the transition towards a circular paradigm. Conversely, a key restraint is that CE is still a new and unproven concept, and consequently, public funding organisations and banks find it too risky. Finally, with respect to the cultural-cognitive pillar, the catalysts are represented by the progressive cultural change, for instance something secondhand was in the past considered as something for the poor (identity), while nowadays it is progressively seen as 'cool' and environmentally friendly.

Case 2: Italy

The venture recycled and reused textiles. It was founded in 2019 based on an idea by the founder, an entrepreneur who had the desire to find concrete solutions to the disposal of fabric waste. Through a recycling process, the circular venture transformed industrial textile waste and used clothes into new products, such as hangers for clothing and wine boxes that can be reused as trays or suspension lamp holders.

Public actors involved

A key role in the development of the business idea was played by two public actors (Veneto Region Green Cluster and Trentino Sviluppo) and a private actor (Vicenza Elevator Innovation Hub). The private actor had been a key mentor in supporting the venture in its initial stages and in establishing the stakeholders' network. Regarding public actors, Veneto Region Green Cluster played an important role in the venture's development. Veneto Region Green Cluster is a Regional Innovative Network that brings together the best excellences in the field of waste enhancement, involving industrial sectors oriented to the supply of environmental goods and services (green business) and ventures committed to reducing the environmental impact of their production processes and of its products (green production). The Veneto Green Cluster Regional Innovative Network had been recognised by the Veneto Region with DGR n. 54 of 27/01/2017 and it was represented by Green Tech Italy – business network. It helped the venture to find the most interesting calls to apply for funding according to the topic of interest, and to find partners willing to collaborate on that topic. Trentino Sviluppo had been a central actor in promoting a call for entrepreneurial projects at the initial stage of development (Startup Trentino).

Public sector support

In 2019, the venture got the second position in the competition of Startup Trentino, winning a grant of 10,000 EUR and 12 months of settlement at the Progetto Manifattura spaces in Rovereto. As stated by the venture's founder: "This was the most important award, the one that allowed us to open the laboratory". In 2021, the venture was selected for the Global Startup Program, an international acceleration programme organised by the Italian Agenzia per la promozione all'estero e l'internazionalizzazione delle imprese italiane (ICE) on the recommendation of the Ministry of Foreign Affairs and International Cooperation.

Institutional pillars

A key regulative catalyst in supporting the venture's development was the end of waste law (Article 177, Decree Law 152/2006), which mandates the cessation of waste status at the end of a recovery process; the law became effective on 29 April 2006. Moreover, the implementation of circular business was favoured by Veneto Green cluster, a Regional Innovative Network that brings together organisations aimed to give value to waste. This is enacted by involving industrial sectors oriented towards the supply of goods and services (green business) and ventures committed to reducing the environmental impact of their production processes and of their products (green production). This cluster also represented a catalyst from the cultural-cognitive perspective as it contributed to connect those actors engaged in CE, and to stimulate an entrepreneurial mindset prone to embrace sustainable innovations. The inhibitory factors were mainly related to a lack of regulations concerning different aspects despite the advancement in the 'end of waste' law. As stated by our interviewee:

> "We have tested our innovative product (packaging) made out of waste garments, but we could not get the certification of biodegradability since it has never been regulated as a product category. Moreover, since we could not get the waste management authorisation, we had to make research to find possible solutions, for instance we found a cooperative that manages garments' waste and transform them into a secondary raw material".
>
> (Ventures representative, Case 2)

Two other key constraints were mentioned by the venture's founder. The first constraint concerns the phase of funding and grant applications, with the assumption that ventures applying for funding and grants were already well-structured, thus making starting from scratch a challenge. The second constraint regards the complexity in creating a network of diverse and committed actors sharing know-how, apart from the previously mentioned Veneto Green Cluster. The municipality did not contribute to the venture's development.

In summary, from the regulative perspective, a key catalyst in promoting a CE is represented by a step forward to the end of waste, while a key constraint is the lack of regulation regarding new circular product categories. Regarding the normative pillar, a key catalyst is represented by the Veneto Green cluster of circular innovation, and related new-born industrial symbiosis, while a key constraint is the assumption that ventures applying for public grants are already well-structured internally. With respect to the cultural-cognitive pillar, key catalysts are represented by local clusters of proactive ventures that are prone to adopt circularity principles and are gradually fostering the establishment of a consortium. There are still barriers represented by the complexity in network creation of actors who are committed to developing circular practices (e.g., municipalities).

Circular economy innovation related to reduction

Case 3: Finland

The venture manufactured food packaging that uses up to 85% less plastic than similar, standard plastic packaging. The venture's packaging consisted of a container made of cardboard or corrugated cardboard made from virgin raw materials and a plastic film that keeps the packaging gas tight. The packaging is easy to recycle, as the container and plastic film can be easily separated and recycled as waste.

Public actors involved

Key public actors in this case were decision-makers whose role was to support sustainability and growth, such as the Parliament, ministries, and the EU (see Table 8.2).

Public sector support

EU directives influence ventures operations. The following excerpt elaborates on the challenges a CE venture faces due to differences in regulation in different countries.

> EU will set new directives, for instance establishing 25–30 recycling goals for variety of materials. For us it is very important how the hybrid solutions are dealt with, especially from the producer responsibility perspective. And, how the circulation systems develop. And we are also eager to know how the monomaterial solutions are approached and if they are wanted. And can we steer customer behaviour with payments. At the EU-level there are no monomaterial definitions especially from the circulation perspective. For example, in Thailand you can have 5% plastics in your cardboard solutions and in some countries, you can have up to 49% plastics. The scale varies a lot, and it would help a lot if there were some EU-level categorizations. Because the selling arguments vary from country to country, that is, in which country you can say that you can recycle this with cardboard and in which country you cannot. It would help our product development a lot, that is, do we need to go below a certain percentage of plastics [in our solution].
>
> (Venture representative, Case 3)

Institutional pillars

In summary, from the regulative perspective, a key catalyst in promoting a CE is represented by EU directives on the CE concerning material-related recycling goals. However, the regulation itself emerged as the most important constraint, for instance in the lack of clear descriptions regarding what monomaterials are, especially from the recycling point of view. Uncertainty about the development of the circular systems, as well as payments related to producer reliability are also constraints. The issue is a system-level one.

Regarding the normative pillar, there are more ambitious norms concerning the circularity of materials, while constraints are evident as different norms concerning circularity and its impact on product development in the long run. With respect to the cultural-cognitive pillar, key catalysts are represented by the fact that customers and consumers lean towards sustainable consumption.

Case 4: Italy

The venture had a CE innovation related to a digital platform providing benefits and rewards to citizens adopting sustainable lifestyles, such as commuting by bike instead of using a car. The rewards are spendable in local shops so that the venture supports also local businesses.

Public actors involved

One key public actor contributing to the circular venture's development was the municipality of Parma. In May 2021, this municipality launched a project that addressed the local citizens to act sustainably by offering them rewards, such as discounts to be spent in local shops. As stated by our interviewee from the municipality of Parma:

> With the venture we have signed a contract so that we can address all citizens that behave sustainably, for instance commuting by bike instead of by car. We have made agreements

> with local businesses to offer discounts to those citizens tracking their actions on the app, to reward them for their virtuous behaviours.
>
> (Public actor, Case 4)

Public sector support

The venture and the Municipality of Parma had the common goal of making the city more sustainable. The municipality of Parma contributed to promoting the app in town to citizens as well as to local ventures, such as Barilla, the Italian brand of pasta, and to establishing partnerships with local businesses to provide rewards to the most involved citizens. Parma represents an exception in the Italian mid-sized towns, since it is a symbol of the car-free environments in Italy (Tozzi et al., 2014), therefore the citizens' mindset is particularly prone to adopt sustainable alternatives to safeguard the environment and fight against urban pollution. Moreover, Parma is in the Emilia-Romagna region, the most advanced Italian region in terms of the development of sustainable practices (Tozzi et al., 2014). As an example, it is the region that shows a regional cycling system with a percentage of trips that double the national one (10% against the 5% of the Italian scenario) (Tozzi et al., 2014).

Institutional pillars

In summary, from the regulative perspective, a key catalyst in promoting a CE is represented by the Emilia-Romagna region laws to promote sustainable mobility, especially in terms of urban and suburban cycling. This, in turn, reinforced the pride of local municipalities in promoting sustainable practices and local citizens' proactiveness to sustainably move around the city. No specific constraints have been identified with respect to the regulative pillar. Regarding the normative pillar, key catalysts can be the willingness of the local municipality, ventures, and citizens to promote sustainable practices. However, some constraints may relate to finding appealing incentives and rewards to promote sustainable behaviours.

Regarding the cultural-cognitive pillar, key catalysts may be the local citizens' mindsets and shops' proactiveness in adhering to the developed sustainable initiatives, yet constraints can be indicated by the fact that changing employees' mobility patterns takes a lot of time and effort.

Circular economy innovation related to recycle

Case 5: Finland

The venture recycled nutrients. The hybrid biofilter consists of biochar and wood chips. The mechanism is simple: the biofilter is placed in a waterway, such as a ditch, where it collects excess nutrients and other contaminants dissolved in the water that passes through the biofilter. Using a biofilter is an inexpensive and easy solution for reducing the environmental impact of agriculture, for example. The nutrients filtered by the biofilter can be recycled back into the soil, thus reducing the need for chemical fertilisers.

Public actors involved

The key public actors were those providing funding and advice for CE ventures, including the Ministry of Economic Affairs and Employment of Finland; the Centre for Economic Development, Transport and the Environment; and Business Finland.

Public sector support

The interviewee explained that there were many good concrete actions that can be implemented towards sustainability. The excerpts that follow show appreciation for public sector support, but also show that some actions on the political level appear as distant from the entrepreneur's reality.

> Good that government has invested in experimentations of nutrient-related projects and money for water quality projects. Also, previous government did good job in encouraging entrepreneurship, startups, and experimentation culture.
>
> (Venture representative, Case 5)

> But political documents such as roadmaps are sometimes too far away from practice. If you can create business out of something, there will be someone who will do it.
>
> (Venture representative, Case 5)

New laws and reforms in the agricultural subsidy system change the institutional environment. The excerpt that follows elaborates on the attitude of the entrepreneur regarding these changes. The interviewee highlights the importance of a positive outlook on the changes, while indicating that not all CE entrepreneurs have such a positive mindset towards changes in law and regulation:

> Politics changes and now we have agricultural subsidy system coming up as well as new law reform concerning fertilizers. But I think these reforms create new possibilities. I like to look at the positive side of things.
>
> (Venture representative, Case 5)

The excerpt that follows emphasises the importance of networks and engagement in projects with public actors in product development. The collaborators include both research institutions and public sector actors.

> We have had two Business Finland projects and one project financed by the Ministry of Economic Affairs and Employment of Finland and one other experimental project on nutrients. We have intentionally built networks and conducted research. Our idea has been all the time that our solutions, products, that we produce are scientifically valid. We have searched for scientific competence from variety of scientific institutions [research institutes, universities, universities of applied sciences]. Centre for Economic Development, Transport and the Environment provided information and helped to network.
>
> (Venture representative, Case 5)

Institutional pillars

In summary, from the regulative perspective, a key catalyst in promoting a CE is represented by opportunities related to new agricultural reforms and new reforms concerning fertilisers, while a key constraint is also represented by new agricultural reform. Regarding the normative pillar, key catalysers may be represented by funding for experimental projects on nutrients and water quality. Interviewees report that the Finnish society should be encouraged to be bolder risk-takers.

The esteem for entrepreneurship and a fear of failure run deep in Finnish society, and this may hold back circular innovation. This trait may be seen in the non-optimal rates of circular innovation commercialisation. Regarding the cultural-cognitive pillar, key catalysts may be an awareness building on issues related to food production such as fertilisers and the quality of water, while no specific cultural-cognitive inhibitors have been identified by the venture.

Case 6: Italy

The venture upcycled cigarette stubs. The entrepreneur was inspired by an ashtray full of cigarettes and thought: "Why don't we do something with this waste?". Starting from his initial query and intuition, he spent three years studying a system to recycle cigarette stubs. In 2019, he patented a system to transform the cigarettes stubs into plastic materials that are now widely used in the eyewear industry and in the production of small objects.

Public actors involved

Before setting up the venture, the entrepreneur participated in competitions for ventures. In particular, he reached the third position in the 120 secondi – Business Idea Competition organised in Trento by Trentino Sviluppo, the Agency of the Autonomous Province of Trento dedicated to promoting the sustainable development of the region Trentino Alto Adige. This geographic area is particularly concerned about sustainability issues, and Trento has been named by EY as the most sustainable and virtuous town in Italy (Smart City Index, 2020). The start-up faced regulative barriers because the municipalities considered the cigarette stubs as urban waste, which is the property of municipalities and is typically collected by local waste management ventures. The founder had to deal with the municipality and the waste management venture in implementing the business idea. As stated by our interviewee:

> To implement our business in the municipal area, you need several permissions, and you need to establish a dialogue with two parties, such as the municipality and the municipal waste management venture. I can state that the institutional environment does not favour the development of circular ideas like ours.
>
> (Venture representative, Case 6)

Public sector support

The green incubator Progetto Manifattura from Trentino Sviluppo has supported the initial phase of the venture project through its incubation process, which has played an important role in terms of training. As highlighted by our interviewee from Trentino Sviluppo:

> Trentino Sviluppo has developed an initiative called 120 secondi – Business Idea Competition, which was a competition for entrepreneurs, providing final prises. [The entrepreneur and the team] from [the venture] reached the final, and he has been supported by the incubator for around a year (initial phase). As they became more mature, they began to find other production spaces outside the incubator.
>
> (Public actor, Case 6)

The firm currently works with more than 50 municipalities spread throughout Italy.

Institutional pillars

One key regulative catalyst in favouring this venture's circular idea is represented by the Ministerial Decree of 15 February 2017, which in part regulates the destination of use of the administrative pecuniary sanctions stemming from the abandonment of cigarette waste and it foresees that the revenues derived from the sanctions that will be employed; ashtrays must be purchased to make it easier for the venture to collect cigarette stubs. Regarding the constraint from the regulative perspective, there is a law (Article 184, Legislative Decree 152/2006) requiring that the cigarette stubs are considered as urban waste and, therefore, the municipality needs to manage them. From the normative perspective, the area of Trento is particularly interesting because it makes investments towards sustainability, but the normative constraints means that it is difficult to convince municipalities to adopt the service also for economic reasons. With respect to the cultural-cognitive pillar, there are virtuous cases of an external environment fostering networking and entrepreneurial mindset, yet there are still issues in the management of municipal waste, as making a system between public actors and innovative start-ups may still be complex.

Comparison between Finland and Italy

In Table 8.4, we present a comparison of the differences between regulative, normative, and cultural-cognitive pillars. Our analysis shows that in Italy, from the **regulative** perspective, some laws are still inhibiting the widespread creation of circular businesses since several current circular practices lack proper regulation. Consequently, advances in the legislation are necessary to catalyse circular business ventures (for instance, by redefining the concept of waste and clarifying its possible business applications). In Finland, the need to have CE legislation is also highlighted, because CE choices are not necessarily made if it is not mandatory. However, legislation does not always seem to be able to keep up with the change, and this causes uncertainties in areas such as product development or waste disposal.

From the **normative** point of view in Italy, the development of local clusters and networks of actors with a clear orientation towards sustainability are key emerging concepts. In Italy, the main public actors catalysing circular businesses are start-up incubators and regional authorities issuing the funds that start-ups can apply for. In the Finnish context, the local perspective is not so apparent, but CE is seen more as a national-level issue. In Finland, the circular entrepreneurs say that public funding is managed to mostly support a linear economy. For example, investors need to see the financial outcomes right away. This mode of operating needs to change to achieve climate change or carbon neutral thinking. Currently, this situation means that private investors play a major role in funding circular venture activities. Public organisations and banks need to abandon the risk aversion and support investments in sustainability. In both countries, the requirements for funding are seen as being quite high; Italy requires start-ups to be well organised internally and Finland requires start-ups to have international growth aspirations.

Regarding the **cultural-cognitive** pillar, findings in Italy highlight the importance of the networking places and the entrepreneurial environment in fostering ideas and innovation as the relevance of citizens' mindsets in being prone to adopt circular practices, although concrete actions in terms of sustainable habits are still at their infancy. More effort is needed from the start-ups' perspective to involve and cocreate with customers that are prone to adopt environmentally friendly and conscious behaviours in Finland. Changing mindsets requires time but start-ups seem to have a great responsibility in making efforts in this direction. In Finland, the

Table 8.4 Institutional pillars in circular venture operations

Regulative	*Normative*	*Cultural-cognitive*
Reuse		
Case 1: Finland		
Support: Recovery and resilience funding (EU).	Support: Angel investors who have made circularity a priority in their impact investing agenda. People are generally receptive towards environmental issues, including the CE.	Support: Buying secondhand goods has become considered trendy and as integral in fashionable environment- friendly consumption.
Constraints: De minimis of 200,000 EUR (EU regulations).	Constraints: The CE is new and unproven. Public funding organisations and banks find it too risky.	Constraint: Negative attitudes towards secondhand items, (e.g., "It is for those who cannot afford new").
Case 2: Italy		
Support: Step forward of the 'end of waste' law (Article 177, Legislative Decree 152/2006).	Support: Veneto cluster of textile firms, industrial symbiosis.	Support: Local cluster of proactive firms prone to adopt circularity principles, gradual establishment of a consortium.
Constraint: Lack of regulation regarding new circular product categories.	Constraint: Assumption that firms applying for public grants are already internally well-structured.	Constraint: Complexity in creating a network of committed actors.
Reduce		
Case 3: Finland		
Support: EU directives on CE, material-related recycling goals.	Support: The trend towards more ambitious norms concerning circularity of materials.	Support: Customers and consumers have a novel urge to get rid of plastics for example in packaging.
Constraints: No clear descriptions of what monomaterials are, especially from the recycling point of view. Uncertainty about the development of the circular systems as well as payments related to producer reliability.	Constraint: Different norms concerning circularity and its impact on product development in the long run.	Constraint: Established practices of consumerism.

(*Continued*)

Table 8.4 (Continued)

Regulative	*Normative*	*Cultural-cognitive*
Case 4: Italy		
Support: Regional law "Interventions for the promotion and development of the regional cycling system" (5 June 2017, n. 10).	Support: Pride of local municipality, firms, and citizens in promoting sustainable practices.	Support: Local citizens' mindsets and shops' proactiveness.
Constraints: None specific.	Constraints: Finding appealing incentives and rewards.	Constraint: Changing employees' mobility patterns takes a lot of time and effort.
Recycle		
Case 5: Finland		
Support: Opportunities related to new agricultural reform and new reform concerning fertilisers.	Support: Creating an experimentation culture in entrepreneurship. Encouraging risk taking. Funding for experimental projects on nutrients and water quality.	Support: Awareness building on issues related to food production for example fertilisers and water quality.
Constraints: New agricultural reform. New reform concerning fertilisers.	Constraints: No specific normative inhibitors identified.	Constraints: No specific cultural-cognitive inhibitors identified.
Case 6: Italy		
Support: Ministerial Decree 15 February 2017.	Support: Orientation towards sustainability of the Trento area.	Support: Networking places and entrepreneurial environment.
Constraint: Cigarette stubs are considered urban waste (Article 184, Legislative Decree 152/2006.	Constraint: Public administrations do not have funds to pay for the service offered.	Constraints: Issues in the management of municipal waste, barriers in 'making a system' with other actors.

Source: The authors.

commercialisation of circular products and services may also be inhibited by the non-willingness to take risks (culture of risk aversion), which may be typical of Finnish culture. However, Italy is not immune to the risk-avoidance culture, either. This cultural aspects undoubtedly represent obstacles in the acceptance and commercialisation of CE innovations.

Discussion

Our analysis of institutional environment in Finland and Italy sheds light on catalysing mechanisms in the three institutional pillars. Regarding the normative pillar, we found that directives, laws, and legal reforms catalyse the circular economy through a complementing of each other and creating grounds for certain circular economy innovations while constraining others. The catalysing mechanisms in the normative pillar include private funding for CE start-ups, industrial clusters and symbiosis, regional clusters and local pride, and public funding that is typically risk-avoidant and rules based. In the cultural-cognitive pillar the catalysing mechanisms revolve around awareness about environmental sustainability by buyers and consumers, changing the taken-for-granted practices of consumption, seeking collaboration with other actors, and positive attitudes towards sustainability change.

Previous research has shown that regulation is not enough to catalyse the change in norms, values, worldviews, visions, concepts (see Korhonen et al., 2018; Ranta et al., 2018). In their study on institutional pillars on CE in China, the United States, and the EU, Ranta et al. (2018) found that the regulatory pillar is the most important pillar in accelerating CE, but not sufficient when alone. Their study shows that regulation is particularly effective in fostering recycling, but normative and cultural-cognitive pillars are important for advancing the reduce and reuse in both industry and society.

Our study contributes empirically to the existing literature on institutional pillars and the CE by elaborating on the intertwinement of institutional pillars in CE start-up venturing. In line with the studies of Korhonen et al. (2018) and Ranta et al. (2018), our study shows that while the regulative pillar sets the stage for CE venturing, the normative and cultural-cognitive pillars are particularly relevant in the local contexts as catalysing mechanisms for the success of CE start-up venturing. The results of our analysis show that despite many similarities across the analysed countries, there are local differences in attitudes, beliefs, norms, and the taken-for-granted behaviours between regions and nations. Detailed attention to these factors increases our understanding about the uncertainties CE start-up venturing deal with, and direct attention to the changes that are needed in the institutional environment. CE start-ups not only introduce new innovations and solutions to the market but as institutional entrepreneurs, but they also improve the institutional environment. It is found that catalysing mechanisms for sustainability transition in the institutional environment are integral in sustainable innovation in CE start-up venturing. The catalysing mechanisms of institutional pillars are at play in risk evaluation by the entrepreneurs, funding agencies, and customers. When assessing the uncertainties in CE venturing, a comprehensive understanding about what should or even can be changed in the institutional environment, with what cost, and within what timeframe is essential in the decision-making process.

Conclusions and future research avenues

The purpose of this chapter was to investigate the role of the institutional environment in catalysing circular entrepreneurship. We identified both similarities and differences in institutional environment between two EU countries, Italy and Finland. Both countries have several ministries with sustainability activities and funding opportunities for circular ventures through which EU-related strategic funds such as the Green Deal are channelled. Ministries and the EU plan and implement long-term local and national innovation policies. Political decision-making that supports circular ventures' growth in both countries rely on regional public actors, but in Finland regional councils have a much more prominent role in funding entrepreneurship, business growth, and internationalisation. Finland has more public actors providing services and funding compared to Italy. In Italy, start-up incubators that manage public funds and regional authorities that manage calls for funding for circular business projects play an important role in supporting circular entrepreneurial ideas. Furthermore, we identified different levels of awareness regarding circular practices in the two countries and even across different regions in the country. For instance, there were clear differences in proactivity across Italian municipalities, as some of them were engaged in supporting circular ventures and giving incentives to citizens to adopt circular practices, while others were more conservative with no identified effort in these directions.

We propose future research to address some of the limitations of our study. First, our study is limited to six case ventures. As expected by the chosen qualitative methodology (Stake, 1995), this means that our findings allow for analytical generalisation, but not for statistical generalisation. Second, the case ventures are limited with respect to size, industries, and geographical areas. We propose that future studies should consider other institutional environments, especially non-European ones, to further deepen our understanding about catalysing mechanisms in different institutional environment for circular start-up venturing. We suggest that future research should focus on how circular entrepreneurs and managers and public sector actors understand and interpret the normative and cognitive environment, in particular, as part of their entrepreneurial process and support to the advancement of CE.

Regarding practical implications, we suggest practitioners further invest in developing value cocreation processes between public actors and circular start-ups (Re & Magnani, 2022) to increase understanding about reciprocal needs and to overcome the constraints that limit the development of circular practices, especially from the normative and cultural-cognitive perspectives. The CE is a systemic change with public sector, private sector, and CE start-up as change agents. Effective regulation and legislation are needed to encourage and require the development of new circular business, but to foster the sustainable CE replacing the linear economy, a closer attention to norms and culture is needed. Working to change the culture and the taken-for-granted practices (Meyer & Rowan, 1991) is a task with which circular start-ups and public sector actors need to work synergistically (Lehtimäki et al., 2022).

Educational content

CE is about a systemic change in which start-ups are among the key change agents. Regulation is a necessary starting point in creating the markets for CE start-ups driving sustainability change. However, particular attention to norms and cultural and cognitive aspects of the institutional environment is needed to accelerate and sustain the sustainability transition through CE start-up venturing.

What catalysing mechanisms in the intersections of the institutional pillars should we identify to enable a faster and more profound change from linear to sustainable CE?

CE start-ups not only create sustainable innovations in the market and society, but they also change the institutional environment that shape the market and society through challenging the norms, culture, taken-for-granted behaviour, and attitudes.

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PART II

Types of catalysts

9

REGULATORY CATALYSTS FOR THE CIRCULAR ECONOMY

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Introduction

The endeavour for a circular economy (CE) has evolved in recent decades. CE entails a total change in the current production and consumption models; it will not be achieved automatically. There is a need to redefine the rights and responsibilities of private and public stakeholders and their relationships, to promote value-creation mechanisms that are decoupled from the consumption of finite resources. This can be achieved using regulations. Thus, regulations have an important role as catalyst for the shift to a CE. Towards this end, many regulatory instruments have been introduced in different jurisdictions globally. This chapter examines the regulatory approaches towards CE and highlights their key ideas. In addition, it also examines specific instruments for CE that are enacted globally.

This chapter identifies different approaches to regulate CE and presents examples of regulatory instruments that have been used to address the problems standing in the way of achieving CE. CE requires addressing the whole product's life cycle including design, manufacturing, consumption, and end-of-life. Hence, this chapter divides the approaches based on the different life cycle stages: product design, manufacturing, consumption and use, as well as end-of-life and recovery. It assesses where and how regulation can function as a catalyst for CE throughout the product's life cycle. Through a selection of versatile regulatory instruments, this chapter illustrates the underlying circularity objectives, the mechanisms used to achieve them and the regulatory and environmental considerations that arise with the instruments. To give a comprehensive description of the relevant CE regulation, the review contains both traditional and innovative new regulatory instruments.

This chapter also looks at persistent challenges when regulating towards CE based on the diverse regulatory examples discussed. In most countries, CE regulation does not fall under a single substantive regulatory framework but extends over different sectoral legislation, for example, waste, chemicals, or public procurement. At the same time, different sectors face different types of challenges and barriers when transitioning to CE, which stem from various structures, industrial practices, and attitudes. This also necessitates the use of an array of obligations, incentives, disincentives, informational guidance, and administrative and industrial practices (Turunen et al., 2021) to address the different challenges. The diversity of regulatory instruments needed

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highlights the need to ensure that they are working together towards the same overarching objective. Furthermore, the complexity of different environmental impacts within CE requires a careful trade-off between the tensioned objectives (Kautto et al., 2021). This chapter concludes that mainstreaming circular thinking inevitably requires a new overarching regulatory framework to ensure coherence, synergise, and prioritise the different CE mechanisms towards environmental sustainability.

Regulating product design and manufacturing

Product design

In the product design stage of the product's life cycle, the designers try to imagine and create a product that addresses a given market's specific need. The key point is to design a product that is compatible with the relevant legislation and fulfils the consumer's needs.

A significant amount of the environmental impacts of a product's life cycle are decided in the product design. Therefore, instruments affecting product design are crucial for CE (Backes, 2017, p. 43, 64). It makes sense to regulate certain features of products that have significant environmental impacts: In CE, it is important to regulate, for example, a product's durability, repairability, recyclability, recycled-material content, and upgradability (Moreno et al., 2016).

Regulation on product design can lay down minimum performance standards for products. If the standard is not fulfilled, the product cannot be put on the market. This kind of policy should be drafted to encourage continuous improvements in the performance of a product. The performance standards are prone to be technical and product-group specific; every product group is different and requires a different CE approach to optimise environmental impacts (Bocken et al., 2016; Mestre & Cooper, 2017). It is important that these differences are considered while regulating product design. It is unlikely that common rules and performance standards can be drafted for separate product groups. Product groups that are regulated should have significant potential to promote CE.

For obvious reasons, regulating product design cannot affect the performance of products that have already been manufactured. Therefore, there is a natural delay in the impacts of this type of regulation. The longer the product's life cycle, the longer it will take for products complying with the new performance standards to replace the products currently in use.

To monitor and enforce the policies, it is important that the performance of the products can be verified. This requires laying down calculable requirements and a suitable methodology for their verification. Verifying the compliance of products can be costly, involve extra work, and can be a time-consuming effort. Multiplicity of performance standards relevant for CE can make it even more complicated (Egenhofer et al., 2018). Nevertheless, the many CE-related features "can be easily verified, often at low cost and with minimal training, while ensuring objectivity, consistency and repeatability" (ECOS, 2018, p. 7).

Table 9.1 presents examples of instruments that promote CE through regulating the product design. The instruments lay down minimum standards for new products to promote their circularity later in the life cycle.

Manufacturing

The manufacturing stage covers everything that happens in the production facility from receiving the raw materials until when the final product is ready (gate-to-gate approach). Although

Table 9.1 Examples of regulatory instruments regarding circular product design

- Regulation (EU) 2019/2023 lays down ecodesign requirements for household washing machines and household washer-dryers including provisions concerning their repairability as well as availability of spare parts and repair instruction. Products that do not fulfil the requirements cannot be placed on the EU market.
- The EU Directive on single-use plastic products (2019/904/EU) lays down a target of incorporating 25% of recycled plastic in PET beverage bottles from 2025, and 30% in all plastic beverage bottles from 2030.
- Ontario (Canada) has created regulations concerning designing for the environment for electrical and electronic equipment. The regulation 522/20 (made under the Canadian Resource Recovery and Circular Economy Act, 2016) sets out requirements concerning: a) post-consumer recycled glass or plastic content, b) extended warranties, and c) right-to-repair including both no-cost information on repair (in some medium) and no-cost or cost-recovery only charges for tools and parts to repair the product (Section 18 (2)).

regulating the manufacturing process has certain limitations, it can be used as a tool for minor CE modifications (Ricardo Energy & Environment, 2019).

One way to promote CE in manufacturing is the use of Best Available Techniques (BATs) (Dahlbo et al., 2021; Ricardo Energy & Environment, 2019). BAT is a process in which regulators define a standard for an industrial process to promote pollution abatement. The concept of BAT has been adopted in many countries and economic areas around the world (e.g., European Union and United States). Legislators or regulators can approve BATs for the manufacture of specific products to promote material efficiency and pollution abatement. It is possible to promote CE through prescriptive requirements, for example, related to the quantity and quality of wastes generated at the manufacturing plant affecting the amount and recoverability of the waste generated at the plant in BATs (Dahlbo et al., 2021).

Besides BAT, other instruments are also being used to equip manufacturers with tools to implement resource efficiency concepts and techniques into their processes. These include developing and providing toolkits and successful case studies, such as lean manufacturing (see United States Environmental Protection Agency, n.d.), as well as supporting the development of standards on the methodological principles and strategies for the assessment of resource efficiency measures among firms (see German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety [BMUB], 2016, 2020).

Additionally, CE in manufacturing processes can be promoted with the help of industrial symbiosis. The objective of industrial symbiosis is to minimise inefficient material and energy use by utilising local waste and by-products and energy flows as inputs, thereby cutting down the need for new resources. The symbiosis is based on a collaborative supply chain management aiming to make industry more sustainable and achieve collective benefits between economically independent industrial actors (Herczeg et al., 2018). This cooperation should enhance the profitability of both actors. In addition, it provides environmental benefits by cutting down the need for new resources, even though symbioses are not automatically sustainable (Lehtoranta et al., 2011; World Bank Group, 2019). Industrial symbioses can develop spontaneously, but it is also possible to promote their expansion through policy instruments (Lehtoranta et al., 2011). Industrial symbioses can be promoted through various methods such as setting out different financial incentives or indirectly encouraging actors via land use regulation and planning (Lehtoranta et al., 2011).

Table 9.2 Examples of regulatory instruments regarding circular manufacturing processes

- The Portuguese Decree Law 178/2006, as amended, provides for the establishment of a voluntary organised waste market (Mercado Organizado de Residuo) with the intention of centralising transactions involving different waste streams (including by-products and recycled materials) to facilitate their reintroduction into the economy and reduce the demand for primary materials. The online platform provides access to potential users interested in buying and selling waste. The platform is complemented by financial and administrative incentives to, among others, the producers themselves/ holders of waste and waste recovery entities to facilitate the use of the platform. For example, wastes traded in the organised market are exempt from licensing requirements for waste recovery operations (Hirschnitz-Garbers et al., 2015).
- China has enacted a regulatory framework that covers multiple aspects of industrial park management, including requirements on their economic and environmental performance (World Bank Group, 2019). Moreover, China mainstreams the development of industrial symbiosis by encouraging its integration in land use and regional planning (i.e., Article 29 of China's CE Promotion Law). Industrial park authorities can apply for a designation as a CE pilot or demonstration before the National Development and Reform Commission. Designated entities are assessed against key performance targets (utilisation of industrial solid waste and used resources, etc.) and receive funding as such. Lessons from designated experimental zones (i.e., eco-industrial zones) in theory inform future policies (McDowall et al., 2017).
- Finnish Waste Act (646/2011) requires that the holder of the waste seeks market-based waste management services via a national database for waste and by-products (Materiaalitori, translated as 'Material market'). Supplementary municipal waste management services can only be received if no adequate offers are received from the private actors. The instrument aims to promote the use of waste-based materials by pairing the waste holders with potential users.
- Germany supported the development of VDI (German Association of Engineers) Standards on efficient use of resources in enterprises (VDI 4801, VDI 4803). These standards provide enterprises with a step-by-step approach in determining where resource efficiency measures can be implemented in their operations. This is part of Germany's broader initiative to incorporate resource efficiency into standards and specifications.

Table 9.2 provides examples of instruments that promote CE through regulating the manufacturing processes. The instruments aim at the enactment of CE by fostering resource efficiency in the manufacturing processes and industrial symbiosis between different companies.

Regulating consumption and use

Product-Service systems

Regulating consumption and use of products is complicated. Regulations that directly restrict consumers' freedom of choice are usually not popular. Therefore, promoting CE in consumption and use typically entails promoting consumption models that offer ways to fulfil consumer needs that decouple value creation from consumption of primary resources, such as offering services instead of products and sharing the use of underutilised assets instead of individual ownership.

Offering services instead of products gives consumers a possibility to reduce the resource use of their consumption habits. So-called product-service systems (PSSs) are business models that combine 'tangible products and intangible services' to fulfil consumer needs (Tukker, 2015). They include providing access to certain products or functionality to consumers rather than selling physical products (Tukker, 2015). Prominent examples include product-rental, leasing, pay-per-service, and product-as-a-service business models.

A PSS can create value while increasing profitability by leveraging on prolonging the lifetime of physical assets, increasing asset utility, optimising operational efficiency, and substituting with less material-intensive alternatives (see also Kjaer et al., 2019). Despite this, PSSs do not automatically lead to resource efficiency (Kjaer et al., 2019; Tukker & Tischner, 2006) nor to overall environmental sustainability (Kautto et al., 2021; Martin et al., 2021). Thus, regulations have a role in incentivising PSS providers to implement resource efficiency strategies in their products and operations when also sustainable, as well as creating competitive conditions for the resource-efficient providers to emerge and prevail in cases where commercial incentives are inadequate (Mont & Lindhqvist, 2003; Plepys et al., 2015).

The context-specificity of the factors that impact the resource efficiency and sustainability of PSSs makes it challenging to tailor CE policies that directly target PSSs to produce the desired outcome. Thus, it is crucial that the regulation of specific PSSs and the choice of the regulatory instruments are informed by life cycle assessments, which consider possible environmental trade-offs and net impacts (Kautto et al., 2021).

Towards this end, regulatory instruments can target the product, the overall system, or the behaviour of PSS users. Command-and-control instruments, such as product standards, are relevant in promoting the material efficiency of the tangible products used in a PSS. Meanwhile, market-based instruments that internalise the environmental costs of production and consumption or which increase the costs of resource use can also indirectly stimulate PSSs (see also Ceschin & Vezzolli, 2010; Hannon et al., 2015). These instruments disincentivise resource use and stimulate system-level innovations towards resource-efficient solutions, including, but not necessarily, PSSs (Mont & Lindhqvist, 2003). Examples of these policies are product or material taxes such as a pesticide tax (Hojnik, 2018) or use charges (e.g., charging based on volume of water consumed) (van der Veen et al., 2017). To be effective in reducing resource use, the previously mentioned instruments often need to be complemented with policies that mainstream PSS (see also Ekvall et al., 2016).

Regulations are often needed to mainstream sustainable and resource-efficient PSSs (Plepys et al., 2015). This is especially important when considering that certain PSSs require a high market penetration rate to produce significant environmental impacts (see also Sigüenza et al., 2021). From the demand side, information instruments help create awareness and identify which PSSs have demonstrated environmental benefits (Ekvall et al., 2016; Kautto et al., 2021). On the supply side, information instruments are also important to build technical, organisational, and legal know-how to enable PSS providers to undertake economically viable and resource-efficient PSSs (Plepys et al., 2015). Economic instruments are also relevant to level the playing field vis-a-vis less resource-efficient and sustainable options, for instance by removing fiscal advantages in favour of ownership-based consumption (see also Akyelken et al., 2018).

Table 9.3 presents examples of instruments that promote CE through regulating on PSSs. The instruments lay down incentives to move from consuming products to consuming services instead.

Sharing economy

A sharing economy is defined as a circular business model involving "consumers granting each other temporary access to under-utilised physical assets, possibly for money" (Frenken & Schor, 2019; OECD, 2019a). Based on this definition, the sharing economy qualifies as a type of use-oriented PSS, which is focused on peer-to-peer exchanges, such as peer-to-peer lodging or community tool libraries. The sharing economy aims to reduce overall consumption by enabling

Table 9.3 Examples of regulatory instruments regarding product service systems

- Denmark's Act No. 277 of 2013 introduced a differentiated VAT rate on pesticides. The tax is imposed per weight or volume, using differentiated tax rates depending on a pesticide's risks on the environment and human health. This meant that more hazardous pesticides are taxed higher. The tax scheme was introduced with the aim of reducing the total pesticide use in Denmark. Preliminary evidence demonstrates that this objective has been fulfilled (Slunge & Alpizar, 2019). The scheme, complemented with regulatory measures supporting alternative pest control mechanisms, has contributed to the emergence of service business models (e.g., service providers specialising in integrated pest management) (Plepys et al., 2015).
- Germany plans to support chemical leasing, a results-based PSS, by providing advisory programmes that help firms on questions relating to contract formulation, third-party investment, and liabilities management. Germany is also exploring linking financial incentives (subsidies, tax rebates, etc.) to certification schemes that cover efficient management of resource use (BMUB, 2020).
- The City of Zurich, Switzerland, decided to procure services instead of procuring or leasing multifunctional devices for its printing and related needs. Instead of paying for the equipment, the city pays a per-page-printed basis. Since the bidders are responsible for the entire service, it was possible for the bid's technical specifications to include provisions to improve the system's material efficiency. The specifications included minimising the number of printers to be installed, reuse of newer printing equipment, provision of high-quality maintenance to ensure the optimal functional duration of the devices, management of the toners to ensure their proper recycling, etc. Shifting from products to services has resulted in a reduction on the number of printer units from 5,500 to 3,600, and the number of pages printed by the city per year has decreased (European Commission, 2015).

increased utilisation of underutilised assets that are already in use. This allows for the fulfilment of consumer needs with less assets, potentially reducing material stocks over time (Mi & Coffman, 2019).

Regulations promoting a sharing economy require an understanding under which conditions the model can produce positive environmental and resource efficiency benefits based on a life-cycle assessment (OECD, 2019a). These conditions are sector or product specific (Rademaekers et al., 2018). Regulation should aim to incentivise shared use, which would include regulations outside of the conventional environmental command-and-control instruments, such as establishing high-occupancy vehicle lanes to promote carpooling (International Resource Panel [IRP], 2020). Regulation should also impose conditions on exchanges to ensure that only underutilised assets are used (Rademaekers et al., 2018). Otherwise, there is a risk that sharing does not give rise to resource efficiency benefits (IRP, 2020). However, non-business model specific instruments that incentivise resource efficiency remain important to promote sharing models with the greatest scalability and environmental potential (Mont & Lindhqvist, 2003; OECD, 2019a).

Meanwhile, mainstreaming the sharing economy requires identifying which examples have demonstrated resource efficiency benefits and promoting their uptake. Economic instruments, such as subsidies to sustainable pilot projects, can help establish their presence (Ekvall et al., 2016). Command-and-control regulations that remove legal barriers to sharing practices also enable the business model to emerge (see also Demailly & Novel, 2014).

Governments, in particular at the local level, are also experimenting to integrate the sharing economy through information instruments, such as strategic or planning documents, Command-and-control regulations such as zoning and land use planning or economic instruments such as using underutilised public assets for sharing (World Economic Forum, 2017). However, there is still limited data on the actual environmental impacts of these initiatives on resource efficiency

Table 9.4 Examples of regulatory instruments regarding the sharing economy

- Seoul's Metropolitan Government Ordinance on the Promotion of Sharing (as amended) enabled the city to promote sharing via financial incentives, information instruments, and public-private collaborations as well as to amend laws to promote sharing. The city implemented many sharing initiatives, including installing tool libraries and shared bookshelves in communities throughout the city, and connecting senior citizens with extra rooms to students needing a room. The city also provided subsidies to sharing organisations to improve their services (Seoul Metropolitan Government, n.d.).
- The City of Minneapolis's 2040 plan introduced reforms to remove single-family zoning requirements. The plan allows multifamily housing to be built on public transit routes, as well as up to three dwelling units on an individual lot in areas previously restricted to single-family homes. Oregon House Bill 2001 also sets out similar reforms by requiring certain cities to allow duplexes in areas previously restricted to single-family homes. These developments will enable multiple families to share residential buildings and plots of land. The policy is expected to increase housing density, decrease home size, and contribute to a reduction of material use (IRP 2020).
- The City of Helsinki adopted a Roadmap for the Sharing and Circular Economy. This roadmap aimed to incorporate the sharing economy in land use and facility planning by requiring neighbourhood-specific plans for shared premises and requiring facility reservations for sharing economy services in land use planning (City of Helsinki, 2020).
- The Sharing Economy Trust Mark is a private-led certification system in Japan. The Sharing Economy Association, Japan implements the certification system with the aim of promoting the safety, reliability, and recognition of primarily consumer-to-consumer sharing services. Compared to the United States and the UK, the sharing economy has less patronage in Japan partly because consumers have safety and security concerns when using shared services. In addition to vetting services for reliability and safety, those which are certified under the system enjoy benefits in the discounts on their insurance fees. However, the certification system does not currently verify resource efficiency impacts or other environmental standards. (Sharing Economy Association, Japan, n.d.).

at such levels. These efforts are nevertheless important in understanding and targeting drivers and structural patterns of consumption at a more systemic level. Information instruments are also relevant in identifying environmentally beneficial shared solutions (see also Demailly & Novel, 2014).

The sharing economy is not automatically environmental beneficial. For example, it was found that peer-to-peer lodging can save water resources compared to hotels, but it has made travelling much cheaper and accessible, leading to more consumption (Laukkanen & Tura, 2020). Regulations are also important in guarding against this kind of rebound effects. Information instruments that nudge consumers to prefer non-ownership-based consumption and to develop well-being practices that are not linked to consumption (Ekvall et al., 2016; Wilts & O'Brien, 2019) have a role in mitigating such rebound effects.

Table 9.4 lists examples of instruments that promote CE through regulating the sharing economy. The instruments lay down incentives and enabling framework for different kinds of sharing models.

Regulating end-of-life and recovery

Allocating end-of-life duties

In CE, the general objective of end-of-life management is to facilitate recovery of embedded value of materials so that they can be recirculated back to the economy. Waste that cannot be recovered should be disposed in an adequate manner. Due to existing recovery techniques, usually it is easier to recover waste streams that are separately collected, such as metals, glass, paper, or plastic. Therefore, regulation on the separate collection of waste streams significantly promotes CE. Moreover, it is crucial to allocate responsibility for carrying out the collection of waste and waste management.

The universal principle for allocating waste management costs is the polluter pays principle. However, sometimes it is not clear who the polluter is. Essentially, there are two ways of considering this dilemma; the polluter could be defined as the manufacturer of the product from which the waste originates, or as the consumer who bought the product and now holds the waste (Wiesmeth, 2021). Many countries have allocated the responsibility for adequate waste management to 1) the holder of the waste or 2) the original producer of the product that becomes waste. It is common that the waste holder delivers waste to a company that takes care of the waste treatment. Often the responsibility for waste management and collection is placed in the hands of the one that generates the waste.

In practice, the polluter pays principle is applied in a way that the ultimate cost is borne by the consumers because the costs of the waste management are internalised in the price of the product. The producer of the product only pays initially (OECD, 2008). This approach is taken in extended producer responsibility (EPR), which has been widely used with certain waste streams worldwide. EPR systems refer to the idea of shifting the responsibility (administrative, financial, and operational) on waste management of certain product groups from the public sector to private producers. EPR schemes have been used, for example, in packaging, batteries, electrical and electronic equipment, waste oil, and construction and demolition waste. The idea behind the EPR is that shifting the economic burden of managing products' end-of-life to producers incentivises them to reduce waste or facilitate end-of-life management in product design. EPR should go further than just focusing on arranging waste management and take-back systems for their products. Usually, EPR's organisational and financial duties are carried out through producer responsibility organisations (PROs).

Despite the goal of enhancing the whole life cycle management of the products under EPR, it has been hard to verify whether this has actualised (Mayers et al., 2011; Mayers et al., 2013; Van Rossem, 2008). It is argued that EPR schemes mainly serve the purpose of allocating financial responsibilities for waste management (Micheauxa & Aggeri, 2021). Ecomodulation has been proposed as one way of enhancing the impact of EPR schemes in promoting the CE. Ecomodulation refers to differentiating the fees producers pay, based on their product designs according to certain CE or environmental criteria, including recyclability, durability, and reparability (Kautto et al., 2021). The need for introducing stronger obligations with concrete implementation and verification methods concerning ecomodulation criteria has been identified (Turunen et al., 2022).

Sometimes so-called 'waste holders' can encompass private individuals through various schemes such as pay-as-you-throw policies where individuals are charged a rate based on the amount of waste they produce for waste collection. It is also common for the public sector to be given the responsibility of oversight for municipal waste management at the city or municipality level.

Moreover, the recovery of waste is promoted by making waste disposal more difficult or more expensive. Countries have implemented economic instruments such as landfill taxes and charges as well as strict bans for landfilling recoverable waste materials. It has been acknowledged that countries with higher landfill taxes tend to have lower landfill rates (OECD, 2019b). However, in some countries the diminishing landfill rate has not significantly impacted the recovery of secondary materials but mostly boosted the waste-to-energy sector (see, e.g., Official Statistics of Finland, 2020).

Table 9.5 Examples of regulatory instruments concerning circular waste management

• The French EPR scheme on e-waste lays down bonuses and penalties based on ecomodulation criteria. The payments that the producer must make to the PRO depends on the criteria, for example, a producer of a telephone that does not have a universal charger would have to pay more whereas producers of lamps using only LED lights would have to pay less (Micheauxa & Aggeri, 2021).
• In Germany, the national packaging legislation obliges EPR schemes to promote the use of recycled content and to use renewable raw materials through their individual fee structure (German packaging law [VerpackG] para §21(1)2).
• In 2016, Finland enacted a landfill ban for organic wastes that aims to steer biodegradable waste or other waste containing organic material away from landfills to be used as material or energy and to reduce the adverse impacts of waste management to the environment (Government Decree on Landfills [331/2013]).
• South Korea and parts of the Netherlands have endorsed volume-based, pay-as-you-throw pricing models for municipal solid waste services to promote sorting and reduce waste, as seen in volume-based pricing for municipal waste management services (OECD, 2019b).

Table 9.5 provides examples of instruments that promote CE through regulating of waste management. The instruments impact the allocation of waste management duties in different manners and promote CE in that way.

Recycling

Waste-based materials as substitutes for virgin raw materials

The starting point of waste policies is to protect the environment and human health from waste's negative impacts. In the linear economy, the generation of waste is inevitable, and the regulation of waste and products are separated. However, in CE, the objective of waste policies includes turning waste into commodities. Usually this happens through recycling or other forms of recovery.

Waste management plays an integral part in facilitating the recovery and the commodification of waste; if waste is not properly collected, it cannot be recovered as a material. Without policies enabling the commodification of waste, there really cannot be any material circulation beyond the end-of-life stage. For example, the EU has enacted the concepts of 'by-products' and 'ceasing to be waste' to differentiate between waste and materials that would normally be waste but, under certain conditions, are considered commodified (Articles 5 and 6 of the EU Waste Directive [2008/98/EC]).

Essentially, there are two alternatives in waste management: recovery (including recycling as well as energy recovery) or disposal of the waste. In CE, the recovery of the materials is, naturally, preferable; for instance, EPR schemes are created to promote the recovery of the products, and recovery targets are laid down to create tangible duties for recovering waste. Recycling is often divided into downcycling and upcycling. Downcycling refers to recycling "something in such a way that the resulting product is of lower value than the original item" (Ortego et al., 2018, p. 25), whereas upcycling refers to the conversion of waste materials into a more valuable product (Cambell-Johnston et al., 2020). In the context of CE, upcycling is preferred because it leads to more efficient substitution of virgin raw materials.

First, waste-based materials substituting virgin raw materials must be fit for purpose (Steinmann et al., 2019). The quality of recycled materials should be high to ensure their mainstreamed use as substitutes for virgin raw materials. Virgin raw materials should not be substituted with waste-based materials that cannot fulfil the same purpose. Upcycling of waste-based materials requires that its main properties are similar to the virgin raw materials. Materials of inferior quality are more likely to be used for downcycling. It is important to identify when waste materials do not require a significant treatment to be safe and fit for purpose. If, due to heavy treatment, the overall environmental impacts would be negative, materials should be downcycled. In some cases, recycled materials cost more than virgin materials, hindering their use. Policies, such as taxes on virgin raw materials, can help level the playing field. Moreover, the adoption of recyclability standards that ensure the high quality of secondary materials can also improve material utilisation.

Second, products made of waste-based materials should be compliant with regulations applicable to similar products through relevant product legislation, standards, and other technical requirements. Of course, it is possible to have different requirements for waste-based materials to promote their use over virgin raw materials. However, setting too lenient safety or quality requirements for waste-based materials produces reasonable doubt related to their safety and quality as substitutes for virgin raw materials.

Table 9.6 identifies examples of instruments that promote CE through regulating the use of recycled materials. The instruments clarify when waste-based materials can be used in different purposes of use and create legal certainty for their users.

Substances of concern in the circular economy

Recovered materials may contain chemical substances that pose a risk to human health or the environment, known as substances of concern. Consequently, the regulation on chemical safety plays an essential role in the development of sustainable CE. While the regulation of chemicals has radically improved over the last decades, many hazardous chemicals are still used for legitimate purposes around the world. On the other hand, a comprehensive chemical regulation is still missing from many jurisdictions, and the sectoral separation of waste and chemical regulations may cause a lack of traceability of hazardous substances also in those jurisdictions where the most stringent chemical regulation is followed (Alaranta & Turunen, 2021).

Table 9.6 Examples of regulatory instruments promoting recycling and the use of recycled materials

- EU fertiliser regulation (EU) 2019/1009 states that material that constitutes waste can cease to be waste if it is contained in a compliant EU fertilising product (Article 19).
- The United Kingdom has enacted quality protocols that determine when a certain waste stream has ceased to be waste. Quality protocols have been drafted regarding biodiesel and aggregates from inert waste, for example. The quality protocol aims to promote high-quality waste-based materials and products and to protect human health and the environment. Quality protocols can be applied in facilities with an environmental permit. Although quality protocols are not official binding regulation, they are treated as such in practice.
- The Finnish MARA Decree (843/2017) regulates the recovery of certain wastes in earth construction. According to the Decree, using certain waste in earth construction does not require an environmental permit; this contrasts the normal procedure for using waste. Instead, when the criteria described in the Decree is complied with, waste recovery only requires a notification to the state supervisory authority. The Decree is applied to planned earth construction and temporal storage of waste linked to it. Under the Decree, the waste is still considered waste and its recovery is limited to certain applications, and the Decree is not applied to groundwater areas.

Both the presence of substances of concern, and the lack of information on that presence pose challenges to the CE. If a secondary material is known to contain substances of concern, they must be either: 1) used in such a way to exclude the exposure of human beings and the environment to those substances, or 2) disposed, if exposure throughout the second life cycle cannot be excluded.

It is also obvious that the use of all the substances of concern cannot be completely phased out at least in the foreseeable future, and therefore tracking them appears to be the only feasible option for achieving the safe material cycles. The current lack of traceability of substances of concern is problematic for the functioning of the CE market. In addition to potential adverse environmental and human health impacts, the mere lack of sufficient information on the exact composition of a potential secondary material often leads to disposing it or directing it to a less preferred recovery, like combustion, instead of reuse or recycling.

Conducting chemical analysis of each batch of a potential secondary material is usually not a financially feasible option. Therefore, doubts on whether a secondary material contains hazardous substances can limit its use or lead to its disposal. The safety of the end product cannot be guaranteed if a suspicion of a chemical risk remains. On the other hand, a recycling operator may also face practical challenges in complying with the requirements of chemicals and product legislations if the exact composition of the materials is not known (de Römph & Van Calster, 2018). Hence, some waste streams are not feasible for recovery as materials because they pose risks that cannot be eliminated in a financially and technically feasible way.

Moreover, while new chemicals are continuously placed on the market, chemicals will be restricted or prohibited if they are found to pose significant risks to the environment or human health. Therefore, the previously mentioned targets of detecting and tracking are and remain moving to a certain extent.

Novel, innovative approaches for addressing the traceability problem of the CE have been proposed. One solution to enhance the traceability of the hazardous substances is through the digital product passport that would contain information on the origin and chemical composition of the product and on the options for reuse of the product or recovery or proper disposal of the materials that the product contains (Adisorn et al., 2021; de Römph & Van Calster, 2018). In addition, blockchain technologies could be applied to enable the allocation of the waste management responsibilities to the original producers of the product (Steenmans et al., 2021), and also to enable the information flow on the chemical composition of circulated materials.

A specific challenge is posed by legacy substances, which are prohibited or severely restricted under the chemicals regulation today but may still be present in the waste material (Bodar et al., 2018). Such a legacy substance may be found as, for example, a plasticiser that was phased out from the use in packaging materials, a heavy metal that was phased out from the use in electronic appliances, or a flame retardant that was phased out from use in construction materials.

From a regulatory perspective, the above-mentioned problems can more generally be perceived as a tension between the different objectives of product, chemical, and waste legislation. The waste legislation often promotes the reuse and recovery of residual materials. Meanwhile, the environment and human health protection objectives of waste legislation on the one hand, and the objectives of chemicals legislation on the other, regulate the risks posed by these materials, for instance, by means of discarding materials that include substances of concern (Alaranta & Turunen, 2017).

Whatever policies and measures are applied, the transition to a CE calls for a reconciliation of waste, product, and chemical regulation, as they are intrinsically entangled. The tensioned objectives of the chemical and waste regulation are not mutually exclusive in achieving safe, secondary

Table 9.7 Examples of regulatory instruments regarding the management of substances of concern in CE

- Since January 2021, all companies that place articles and products on the EU market are required to notify the European Chemicals Agency (ECHA) if those articles and products contain substances that have been identified as substances of very high concern under the REACH Regulation (Article 9(1)(i) of the Waste Directive). ECHA collects that data in a database that is publicly available. The aim is to increase the knowledge on the presence of the hazardous substances in articles and products and thereby contribute to reducing the hazardous substances in waste, encourage substitution of those substances with safer alternatives, and enhance CE. By January 2022, ECHA had received 15 million notifications to the SCIP database concerning seven million articles and products (European Chemicals Agency, 2022). Therefore, compared to the past, much more information as regards the presence of the hazardous substances in the products and material cycles is now available. However, some scholars have pointed out that the SCIP database does not provide sufficient information for the recyclers (Friege et al., 2021).
- In 2016, the government of Sweden introduced a tax aiming at reducing the presence of hazardous chemicals in electronic and electrical devices (Act 2016: 1067 concerning a tax levied on chemicals in certain electronic items). The act sets out a weight-based tax for all home appliances, but the appliances that do not contain certain bromine, chlorine, and phosphorus-based flame retardants are subject to deductions of the tax (Slunge & Alpizar, 2019). In their 2020 analysis, the Swedish Tax Agency and the Swedish Chemicals Agency found out that the tax had been passed on to the consumer prices as evidenced by higher prices for electronic products. However, it could not be evaluated whether the tax had led to the substitution of hazardous flame retardants in electronic appliances, as the respective substances were also subject to restrictions set out in other legislation (Skatteverket and Kemikalieinspektionen, 2020).

material flows while achieving the maximum environmental benefits of CE. Promoting material recovery should not entail trade-offs on the environmental and safety objectives of the product and chemical regulation. Conversely, the requirements for acquiring information on the composition of the secondary materials should not be so stringent that they form unnecessary obstacles for material circulation. Notably, in most cases, it is not appropriate to require chemical analyses to obtain exact information on the composition of each batch of a material that is intended for secondary use. Such a requirement would lead to unnecessary disposal of potential secondary materials and, therefore, hamper the objectives of CE. Most importantly, the different objectives of waste, product, and chemical legislation should ensure a high degree of environmental and human health protection.

Table 9.7 presents examples of instruments regulating chemical management in the CE. The instruments promote the safety of waste-based materials.

Overarching regulatory framework is required

The different stages of a product's life cycle are intrinsically connected to each other, and regulatory instruments create a management continuum that formulates the regulatory framework for CE. Nevertheless, the life cycle stage-specific measures are not enough for achieving sustainability (see Milios, 2018). CE requires instruments that address the whole life cycle of materials and products. Such overarching policies include, for example, the following:

- Public procurement.
- Resource taxation.
- National CE strategies in which the CE is approached as a whole.

Among other things, these overarching instruments can incentivise more efficient resource use at a systemic level. One approach is to encourage an innovative public procurement system that prefers solutions that are resource efficient and environmentally sustainable. First, the high volume of public procurement would substantially increase the intake of CE products and services. Second, the public sector should clarify its policy direction by making circular procurements (Rijkswaterstaat, 2017). Public procurement can also be used to establish niche markets and support innovative sufficiency practices and solutions that contribute to CE (Alhola et al., 2019).

Often it is argued that the virgin raw materials have a price advantage over waste-based materials because of administrative burden and costs of using waste-based materials (Turunen et al., 2021). This could be addressed with different economic incentives such as raw material taxes and charges to make the consumption of resources in general more expensive and stimulate resource reduction in different stages of a product's life cycle to promote low-resource solutions (Stahel, 2013).

In addition, CE strategies and programmes can have significant environmental impacts. These strategies can stimulate CE transition through action such as setting out guiding principles, identifying focus areas, and creating indicators to measure progress towards achieving CE objectives. These all have the potential to extend the impact of the legislative provisions and to provide a future vision to catalyse CE further. Moreover, other informational materials and guidance documents can also have huge catalysing impacts towards CE.

Table 9.8 presents examples of instruments overarching between different life cycle stages that promote CE. These instruments do not address a specific stage of the product's life cycle, but incentives and enabling framework towards CE in all its stages.

Table 9.8 Examples of overarching regulatory instruments

- Japan has set out legal acts for green contracts (2007) and on promoting green purchasing (2001) to create a comprehensive legal framework for green public procurements. The former lays down requirements for green contracting for government agencies and public institutions in the purchasing contracts for electric power, automobiles, energy service company projects, and building designs. It is mainly focused on greenhouse gas emissions; it complements the Act on Green Purchasing. The Japanese Ministry of the Environment lays down the basic policy of the Act on Green Purchasing, including evaluation criteria for every designated procurement item. In February 2016, the basic policy indicated evaluation criteria for 270 items in 21 categories. The evaluation criteria include requirements that promote circularity, such as the recycled content in products. Government agencies and public institutions define their own procurement policies and targets in reference to the basic policy and to report its achievement to the Ministry of Environment once every year. The basic policy is reviewed annually (Ministry of Environment, Japan, 2016).
- Different virgin raw materials taxes have been enacted in many countries (Sweden, Italy, Spain, United Kingdom, etc.). Sweden has had a tax for natural gravel, sand, cobble, and boulders since 1996. The tax was introduced with concerns about resource scarcity, water quality, and preserving the landscape and to promote material substitution of natural gravel. The tax percent has been raised after the initial tax came into force. Despite the clear objective, it can be argued that there is only very weak evidence to show that the gravel tax has had the intended effect (European Environment Agency, 2008).
- Many countries have adopted national CE strategies and roadmaps yet have different timelines and ambition levels. These countries include, but are not limited to, Austria, Denmark, Estonia, Germany, Finland, Israel, Spain, and Ukraine (UNECE, 2021).

Conclusions

CE will not be achieved without regulatory interventions. Regulation can be used to redefine the rights and responsibilities of actors and their relationships. Regulation can prohibit or hinder undesired activities, as well as enable and create incentives for desired actions. This way, regulation can promote the value-creation mechanisms that are decoupled from the consumption of finite resources, and thus function as a catalyst for CE. In this chapter, we examined different regulatory approaches to promote CE throughout a product's life cycle. The regulatory approaches can either directly regulate resource use or make CE solutions more attractive by creating demand as well as create disincentives and restrictions for non-circular solutions.

Currently the regulatory approaches to CE are often limited to a single stage of the product's life cycle. Reaching CE requires the introduction of regulatory instruments that address the entire product's life cycle, including policies that change the incentives for economy-wide material use. Moreover, there is a need to address the different challenges in mainstreaming CE. The foregoing entails harnessing a wide toolkit of regulatory instruments including command-and-control, economic, and information-based instruments. Given the wide scope of measures that can be deployed to promote CE, there is a need for overarching regulatory frameworks that ensure coherence and synergies in the implementation of the different instruments.

While the CE aims to reduce material use and environmental impacts, the pathways to achieving this do not only depend on conventional product policies and instruments. There is an increasing recognition of the need to mainstream CE goals in other policy areas, such as urban planning, and to invite a reconsideration of how society is organised in a manner that facilitates less material consumption at a systemic level and breaks away from siloed thinking.

The different approaches to CE will require balancing between the different CE sub-objectives. For example, pursuing climate change prevention and other environmental objectives of the CE should not lead to compromises in the protection of human health and the environment from chemical risks. A coherent regulatory framework that streamlines CE objectives and provides corrective mechanisms to consider and reconcile trade-offs should be reached. It is important that regulatory catalysts for CE address multiple objectives; they should enable resource efficiency drivers, support their uptake, and avoid rebound effects and other environmental trade-offs.

Educational content

1 Regulatory interventions are crucial for a CE. The regulation can either directly regulate resource use or make circular solutions more attractive by creating demand as well as create disincentives and restrictions for non-circular solutions.
2 Achieving a CE entails addressing the impacts from products' entire life cycle; current regulatory approaches are often limited to a single stage of the product's life cycle and, thus, are inadequate to meet the challenge.
3 Achieving a CE requires harnessing a wide toolkit of regulatory instruments including command-and-control, economic, and information-based instruments: prohibiting or hindering undesired activities as well as enabling and creating incentives for desired actions.
4 A coherent regulatory framework that streamlines CE objectives and provides corrective mechanisms to consider and reconcile different policy trade-offs is needed.

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* All opinions and mistakes are the authors' own and cannot be attributed to the institutions they represent.

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10

MISSION-ORIENTED POLICY AS A CATALYST FOR TRANSITION TO A CIRCULAR ECONOMY

Lina Dagiliene, Jurgita Bruneckiene, Viktorija Varaniute, and Justina Banioniene

Introduction

A transition to a circular economy "must be understood as a fundamental systemic change instead of a bit of twisting of the status quo to ensure its impact" (Kirchherr et al., 2017, p. 229). This is a complex process that requires systemic transformations (Senge et al., 2007), which simultaneously involve deep, system-wide and rapid change in a complex multi-actor setting (Aarikka-Stenroos et al., 2021). Transformational change affects the entire system (Korhonen et al., 2018) and is not limited to certain products, single companies, or individual regions (Termeer & Metze, 2019). Therefore, the multi-level approach (Geels & Schot, 2007), which emphasises interactions among multiple actors and the need to facilitate profound change and make it irreversible, is widely applied in discussing key catalysts in circular economy (CE) transitions.

The problem is that various sustainability transitions are characterised as being too slow. For example, in the context of global climate change, Roberts et al. (2018) describe the struggle to achieve the 2.0-degree limit set by the Paris Agreement, let alone its 1.5-degree desired goal. Another example is given by van den Bergh (2020), who compares recycling rates and the speed of ecosystems and economic systems. Van den Bergh (2020) notes that unlike the economy, ecosystems are distinguished by high recycling rates, and some recycling time scales are very long; meanwhile, the current recycling level is far too slow to achieve a closed loop (Ghisellini et al., 2016). The dynamics of circular innovation also indicate that the slow process of technological and economic transformation should be considered more of a reform than a revolution (Cainelli et al., 2020).

Considering the above-mentioned challenges regarding modest CE transitions, we provide an overview and conceptualisation of how mission-oriented policy can act as a catalysing factor in the transition to a CE. The transition to a CE occurs at multiple levels (Aarikka-Stenroos et al., 2021) and requires a new approach to the formation of CE policy (Murray et al., 2017). Our key assumption is that the public sector should be a key partner in solving sustainability issues, rather than just a facilitator of growth (Hekkert et al., 2020; Mazzucato, 2013) to guarantee social, economic, and environmental sustainability. In the transformation to a CE, the role of the public sector should be much more active and larger than just creating the right infrastructure for waste management and setting the rules. Many contemporary grand challenges cannot be

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solved through purely scientific and technological solutions (Hekkert et al., 2020). Instead, these challenges require a long-term commitment from public, private, and non-profit sector representatives (Mazzucato, 2018). In many cases, addressing these challenges will require changes in regulations and tax policy as well as strengthening civic engagement in changing consumption patterns (Hobson & Lynch, 2016).

This chapter starts by focusing on the public sector as a catalyst at the broader EU level. It presents a theoretical argument for how the public sector can act as a catalyst in CE by involving existing public policies that support the transition to the CE, collaboration with stakeholders, and a mission-oriented policy. It is unlikely that any single European country, no matter how advanced from an environmental point of view, can fully achieve a CE. However, at the EU level, real progress can be achieved through concrete missions for societal challenges, the experience of a multi-level governance system, and the scale and diversity of talent and ideas (Mazzucato, 2018).

To foster new industrial transitions, the European Commission initiated the Pilot Action on Regions (European Commission, 2019) to test new policies and to facilitate the development of novel co-creation approaches and regional collaboration towards growth and higher productivity. Ten regions and two small member states were included in the pilot action. Among the selected pilot countries, Lithuania's pilot objective was to develop a CE roadmap throughout its national industries. The case of this country is well-suited for analysis, as it actively applied innovative policies during the analysed period to promote the industrial transition to a CE. The study considered Lithuania in the broader context of the Baltic Sea region to understand the level of CE implementation that has been achieved in these countries and why a gap between the countries has appeared. In addition, the research sought to identify the role of public policy in circular transformations, comparing the distribution of responsibility for environmental protection in the countries by evaluating the efforts of different stakeholders in terms of economic value through spending on environmental protection.

Many governments in the EU have subscribed to mission-oriented innovation policies aiming to address grand societal challenges (Wittmann et al., 2021). The transformation towards the CE is itself a grand challenge, which is exactly what a well-designed mission can achieve (Mazzucato, 2018). Wittmann et al. (2021) emphasise the role of the public sector in mission-oriented policy, drawing attention to the implementation process and governance requirements as key features of mission implementation. Identification of the country's CE policy readiness for a mission-oriented approach (the coherence and integrity analysis) provides the state of the art needed for the CE policy design process and the creation of dedicated instruments. Such an analysis narrows the gap between the conceptual debate and policy implementation in practice.

Using a mission-oriented policy approach for analysing public policies as catalysts for CE transitions, this chapter also presents the case of the co-creation of the roadmap for Lithuania's industrial transition to CE. The case description reveals that Lithuania's industry is only 3.3% circular; however, it has tangible potential for circularity. To reach this potential, active participation in the co-creation process and systematic dialogue with different stakeholders should be ensured to prepare the public strategic documents based on co-creation principles.

Finally, this chapter reveals the key multi-level challenges for a transition to CE through the lens of the public sector. In line with Wittmann et al. (2021) and Mazzucato (2018), we argue that these challenges could be solved by focusing on the preparation of public strategic documents based on co-creation principles and by ensuring a co-creation process involving different stakeholders, which enable benefits to be gained from synergy and the creation of a higher value for the whole circular ecosystem.

Public sector as a catalyst for the circular economy transition

Circularity strategies range from extending and/or intensifying the use of the product and product services (Tukker, 2015) to recycling or recovering useful materials at the end of product life. Therefore, institutional conditions play an important role in transforming these strategies into action. The determination of who bears the costs of externalities (Moreau et al., 2017) – that is, environmental impacts (e.g., waste management or resource scarcity) – relates directly to institutions and particularly to the public sector.

This study reviews the role of the public sector as a catalyst for the CE transition from three perspectives: 1) the direction of public policies and the need for the public sector to play a more active role, 2) collaboration with stakeholders, and 3) a mission-oriented policy.

Direction of public policies in the circular economy

Policies that support the transition to a CE can be developed in a centralised or decentralised manner (Bauwens et al., 2020; Lieder & Rashid, 2016). For example, centralised waste management can involve a single centralised waste treatment technology, with little regard for the low predictability of the waste sector (Corvellec et al., 2021). Waste collection, sorting, and recycling can be carried out in centralised facilities, entirely under the responsibility of large producers and with minimal consumer-driven interventions (Bauwens et al., 2020). Without political reforms and appropriate institutional conditions, the level of recycling in the economy will remain low at the regional and global levels (Haas et al., 2015; Moreau et al., 2017). Therefore, centralised waste management policies including measurable targets have direct impacts on the rates of recycling (Dagilienė et al., 2021).

Among the most prevalent top-down policies and strategies are taxation reforms that incentivise the expansion of markets for secondary raw materials and repair activities (Lazarevic & Valve, 2017), changes in the tax base from resources to labour (Stahel, 2010), the empowerment of public procurement (Witjes & Lozano, 2016), and product policy, such as extended producer responsibility, mandatory warranty service requirements, or the mandatory disclosure of expected lifetime information to consumers (Lazarevic & Valve, 2017). Proponents of bottom-up policies usually support a decentralisation agenda (Lazarevic & Valve, 2017) and a market-driven approach with a focus on market competition and minimal state intervention, supply chains, collaborative business models, and product design. For example, responsible waste management activities can be organised by involving consumers and community organisations more closely in various waste recycling and reduction programmes (Bauwens et al., 2020).

These two opposite approaches should be joined to achieve a meaningful transition to the CE. Innovative policies, meaning more than a top-down approach, are needed to encourage citizen engagement beyond green consumerism (Johansson & Henriksson, 2020).

For the public sector to become an active catalyst for the CE's transition, it is important to actively engage in the governance of transformation (Termeer & Metze, 2019). Governments can contribute to circular transformational change by accumulating a series of small wins, including the continual transformation of the linearly organised governance system. Türkeli et al. (2018) emphasise the lack of in-depth knowledge on the governance of a transition to the CE through appropriate supporting mechanisms and tools. Mazzucato (2013) emphasises the active role of the public sector through the creation of proactive, innovation-led strategies and policies, and by financing the most uncertain phases of innovation research and development, which are too risky for the private sector.

Collaboration with stakeholders as a catalyst for the transition to the circular economy

The transition to a CE is a continuous process within which production systems, consumption patterns, society, and the broader context continue to evolve (Murray et al., 2017; Velenturf & Purnell, 2021). When investigating changes in environmental policies in the context of a CE, Johansson and Henriksson (2020) emphasise the prevalence of marketisation in driving the discourse around public policies. The process of marketisation is justified by the fact that the state is too big to be effective (Mazzucato, 2013), so it should transfer services and encourage the private sector through eco-innovation (Cainelli et al., 2020), tax reductions, and similar incentives. However, Dagilienė et al. (2021) argue that the local government actions typically used to foster the transition to a CE relate mostly to appropriate waste collection and infrastructure, whereas activities encouraging the development of secondary markets or co-creating local recycling and reuse conditions with regional stakeholders are almost absent. Therefore, the development of local recycling conditions (van den Bergh, 2020) might foster regional closed loop systems. Johansson and Henriksson (2020) point out that the current political discourse shifts the responsibility for circularity from the state to industrial companies and entrepreneurs, which can actually lead to weak circularity. By contrast, a strong concept of circularity requires changing the culture of collaboration across a network of producers and consumers (Korhonen et al., 2018), and the public sector need to be responsible for creating a circular value ecosystem based on responsible resources management.

The previous literature implies that the acceleration of sustainability (circular) transitions is most politically effective when environmental benefits are combined with issues of concern to citizens, such as personal health or security (Roberts et al., 2018). Examples of successful circular actions and transitions support this finding. Sweden's biogas sector has one of the highest shares of renewable resources in the EU (Eurostat, 2018). Such achievements are the result of large investments in the production of renewable energy, active cooperation between public and private companies, and an advanced value chain from the pre-treatment of raw materials to the production of biogas for different usage purposes (Kanda et al., 2021). Lithuania achieved high rates of recycled plastic packaging waste after the state promoted successful cooperation among Lithuanian beverage producers, importers, and sellers, who manage the activities of the country's system according to the principle of extended producer responsibility, as well as consumers, retailers, and municipalities. Around 3,000 collection points, namely manual collection points and reverse vending machines, exist throughout Lithuania, mainly located near supermarkets in each municipality. This successful public–private collaboration collects nine out of ten beverage cans, or 92% of one-way glass and plastic bottles marked with the deposit system mark, which are placed on the market each year. This example confirms that to accelerate the transition to the CE, policy incentives should focus on support for reuse schemes and take-back programs that enable reuse and recycling (Ranta et al., 2018), and diffusion of responsibility (Murray et al., 2017).

Mission-oriented policy as a catalyst for the transition to the circular economy

The emerging concept of mission-oriented policies targeting complex and multidimensional societal problems, including CE, is particularly insightful. Mission-oriented policies require innovation by diverse public and private actors and different sectors (Mazzucato, 2018). Such policies should emphasise a reorientation from a narrow focus on short-term economic progress to a wider focus on long-term multidimensional prosperity (Velenturf & Purnell, 2021). In addition to aiming for success, mission-oriented policies must enable bottom-up experimentation and learning to ensure dynamic feedback in the innovation process (Mazzucato, 2018). Mission-oriented policies tend to involve a greater diversity of stakeholders influencing and influenced by strategic policy agendas, in addition to established innovation systems built around industrial companies, consumers and local communities (Bauwens et al., 2020). A successful transition to a sustainable CE requires matching business models, policies, and technologies to local contexts rather than assuming that one size fits all (Velenturf & Purnell, 2021).

Missions should not aim to achieve results through a single solution or technology but remain open to different types of solutions (Mazzucato, 2018). The key underlying assumption is that transformational processes are based on uncertainties and changing individual perceptions and practices (Schulz et al., 2019). Thus, to achieve CE transitions beyond their technical aspects, it is important to understand how companies and citizens become – or fail to become – part of new collective practices. Missions typically require the integration of a range of technological and social innovations (Hekkert et al., 2020). For example, the Mission Zero initiative in Sweden to reduce traffic accidents led to a combination of new safety technologies in cars, suitable infrastructure, and institutional change. To demonstrate the transformative potential of the mission and the challenges in the implementation process, Wittmann et al. (2021) provide the illustrative case of the diverse missions of Germany's Hightech Strategy 2025. The mission of creating sustainable and circular economies can be considered a transformer, although the focus is on the activities of producers and consumers, with the transformation receiving only limited attention.

Therefore, mission-oriented policies might contribute to a system-wide circular transformation. In the next section, we present the case of Lithuania, 1 of 12 pilot regions that initiated a circular industrial transition through the mission-oriented European Commission (EC) pilot action industrial transition programme.

Lithuania in the Baltic Sea region

The goal of this section is to introduce Lithuania in the broader context of the Baltic Sea region. We compare countries using selected CE indicators from the EU monitoring framework on CE progress (European Commission, 2018). We carry out an analysis of countries in the Baltic Sea region by comparing each country's indicator value with the EU value and expressing the difference as a percent.

The level of economic development is measured by GDP per capita, expressing the economic gap and economic power among the Baltic Sea countries. As presented in Table 10.1, Denmark, Germany, Sweden, and Finland have more than twice the GDP per capita of Poland, Latvia, Lithuania, and Estonia. Therefore, the eco-innovation index corresponds to the GDP per capita, suggesting that economically stronger countries have more resources to create and implement eco-innovations.

Based on Eurostat data, Germany and Estonia's circular material use rates exceed the average EU value and are constantly growing. By contrast, Latvia and Lithuania have the lowest rates of circular material use. Denmark, Poland, Finland, and Sweden remain modest economies compared to the average level of circular material use in the EU. Analysis of domestic material consumption per capita shows that Finland and Estonia consume more than the other Baltic Sea countries, and their consumption levels are more than twice the EU level. Furthermore, in addition to being the largest consumer of domestic materials, Finland has recently experienced a trend of growing consumption. Furthermore, Sweden, Lithuania, and Latvia show increasing levels of domestic consumption, but only Latvia has a domestic material consumption level close to the EU average.

Germany and Denmark have the highest recycling rates, at 67.0% and 53.9%, respectively. In other countries, the recycling rate varies between 38% and 45%, excluding Estonia, which has a 28.9% recycling rate. Furthermore, Estonia and Poland have low eco-innovation indexes; however, these indexes have positive tendencies.

Table 10.1 CE indicators in the Baltic Sea region

Country	*GDP per capita*		*Circular material use rate*		*Domestic material consumption per capita*		*Recycling rate of municipal waste*		*Eco-innovation index*		*Positive indicator*	*Negative indicator*
	Euro		%		T/capita		%		Index		0–20%	0–20%
	2020		2020		2020		2020		2019		21–40%	21–40%
	Positive		Positive		Negative		Positive		Positive		41–60%	41–60%
Denmark	53,600	↑	7,7	↓	23,913	↓	53.9	↑	146	↑	61–80%	61–80%
Germany	40,490	↑	13.4	↑	13,291	↓	67.0	↓	123	↓	81–100%	81–100%
Estonia	20,190	↑	17.3	↑	28,356	↓	28.9	↑	73	↑	101–120%	101–120%
Latvia	15,500	↑	4.2	↓	14,896	↑	39.6	↑	86	↑	121–140%	121–140%
Lithuania	17,710	↑	4.4	↑	20,043	↑	45.1	↓	82	↑	141–160%	141–160%
Poland	13,650	↑	9.9	↓	17,014	↓	38.7	↑	59	↑	161–180%	161–180%
Finland	43,030	↑	6.2	↑	33,075	↑	41.6	↓	145	↑	181–200%	181–200%
Sweden	45,940	↓	7.1	↑	24,647	↑	38.3	↓	143	↑	>200%	>200%

Source: Eurostat (2022).

Notes

↑/↓ – indicator is increasing/decreasing. The trend is estimated by comparing the indicator value for the presented year with the average value during the last five years.

Colour scales express the differences between countries, where the most intensive grey shows the lowest benefit to society and vice versa. Also, the positive indicators show growing benefits for society when the indicator's value increases, while the negative indicators show decreasing benefits to society when the indicator's value increases.

When comparing deviations in national expenditures, Estonia had the highest level of GDP spent on environmental protection (2.4%) in 2018, followed by Sweden (2.1%) and Germany (2.2%). Lithuania, Finland, and Latvia spent the lowest part of their GDP on environmental protection. Furthermore, the structure of environmental protection expenditures varies greatly between the selected countries (see Figure 10.1). For example, in Poland, households incur more than half of the country's expenditure on environmental services, followed by Denmark at 36%. By contrast, household expenditure on environmental protection varies between 19% and 23% in Germany, Latvia, Lithuania, Finland, and Sweden. Estonia and Sweden spend the highest portion of general government expenditure on environmental protection. The portion of expenditure on environmental protection borne by corporations varies between 60 and 67% in Germany, Finland, Estonia, Lithuania, and Latvia. In Poland, however, spending by corporations makes up only 26% of the country's total expenditure on environmental protection.

Environmental protection expenditures allow us to measure a country's efforts to prevent, reduce, and eliminate pollution or to reverse the degradation of the environment (Eurostat, 2022). Although these efforts only represent those circular activities that can be expressed in the form of economic value, environmental protection expenditures illustrate the distribution of environmental responsibility in a country. In addition, the allocation of responsibility is a key public policy concern, because a fair distribution of responsibility leads to positive changes in the transition

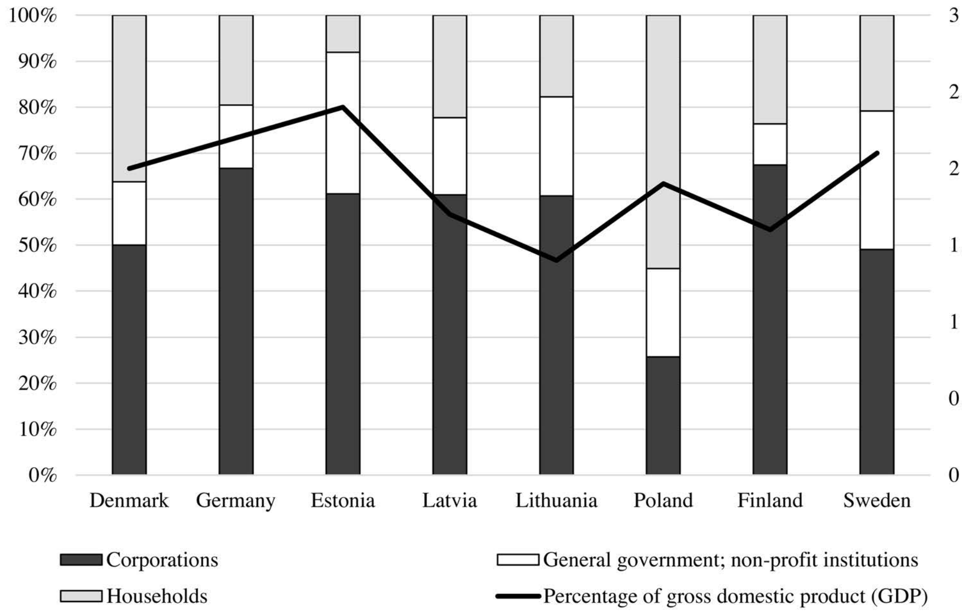

Figure 10.1 National expenditures on environmental protection: Structure by institutional sector and percentage of GDP.

Source: Eurostat (2022).

to a CE. Considering that the implementation of a CE requires the involvement of companies and changes in consumer behaviour, shifting costs from the government to companies and consumers can indicate and lead to positive changes towards circularity.

In summary, as an economically strong country, Germany has a modest domestic material consumption rate and a high performance in the usage of circular materials and recycling. The country's high level of national expenditure on environmental protection and the high level of corporation expenditure could be the reason for its successful circular transitions compared to other countries in the Baltic Sea region. By contrast, Poland has the lowest GDP per capita, as well as the lowest eco-innovation index together with the lowest portion of corporate expenditure on environmental protection. This could explain why Poland's recycling rate is only 38.7%, as households, instead of corporations, incur the largest part of the country's environmental expenditure.

Historically, Lithuania has had a strong focus on energy, material efficiency, and waste management. The growing consumption of domestic material aligned with the volume of waste generation indicates an increase in consumption in society, although consumerism in Lithuania is weaker than in economically stronger economies. Lithuania still lags behind in areas such as circular design, prioritisation of alternative business models, incorporation of digital technology, and innovation. As a positive sign, companies pay more attention to sustainability and issues related to CE.

Readiness of circular economy policy for a mission-oriented approach

Mission-oriented policy refers to policies designed to solve grand challenges and support transformative system change. However, the readiness for a mission-oriented approach to public policy at the legislative level is a serious prerequisite for success. Policy readiness is understood as

Research approach:	Mission-oriented policy	
Research focus:	Coherence analysis	Integrity analysis
Data analysis method:	Descriptive analysis of formal documents: name, geographical coverage, period of validity, date of approval, components, reference areas.	Qualitative content (text content / thematic) analysis: meaning of sentences related to mission-oriented policy approach criteria and logical interconnections among different documents

Figure 10.2 The framework for the analysis.

the willingness, capability, and ability of governments and policymakers, declared in the public documents, to incorporate further changes and implement particular practices, which support the transition towards a CE and sustainable development. The interoperability between strategic documents is crucial, both from a vertical (coherence) and a horizontal (integrity) perspective.

Research methodology

The research methodology used to determine the readiness of CE policy for a mission-oriented approach by analysing public policies as catalysts for the CE transition is presented in Figure 10.2.

Research on CE policy readiness is based on Mazzucato's (2018) mission-oriented policy approach, which is characterised by the criteria shown in Table 10.2.

The research focuses on coherence and integrity analysis. Coherence is understood as a clear relationship between documents over time and at different hierarchical levels. Integrity is understood as how the document flows logically, that is, how the goals set for the CE, their decentralisation across key actors, and tangible indicators to measure progress are included in the analysed documents.

The coherence analysis identifies the characteristics of the formal documents: name, geographical coverage, period of validity, date of approval, components, and reference areas. The aim of this analysis is to identify whether and what kind of technical overlap exists between documents.

The integrity analysis covers qualitative content analysis, which includes text content/thematic analysis, that is, the meaning of sentences related to mission-oriented policy characteristics and logical document interconnections. The goal of this analysis is to identify readiness for public policy transformation toward a mission-oriented approach.

The starting point for the analysis is 1 October 2021. This date was chosen because it is 1.5 years after the adoption of the New Circular Economy Action Plan (COM/2020/98) in 2020. This date is also considered transitional or preparatory as it is characterised by the transition from the 2014–2020 programming period to the 2021–2027 period.

Documents were selected for the research based on the criteria that they are directly related to strategic development and the CE. Keywords directly related to strategic development include 'strategic development', 'progress', and 'economic resilience'. Keywords directly related to the CE include 'circular economy', 'waste production', and 'waste recycling'. Keywords indirectly related to the CE (cognate words) include 'sustainable development', 'environmental protection', 'environmental education', 'waste', 'green', 'climate change', 'reduction', 'sorting', and 'recycling'.

Table 10.2 Mission-oriented policy approach criteria for strategic documents

Criteria	*Description*
The mission (namely transformation towards CE) should be well defined.	Missions must be clearly framed in context. Mission objectives should be set in an ambitious manner. Mission objectives should provide legitimacy, such as relevance to the sustainable development goals (SDGs), EU priorities, and/or member state priorities. Missions should engage as much as possible with member state strategies, including industrial ones.
A mission comprises a portfolio of various projects.	Missions should not be achievable by a single development path or a single technology. Missions must define a concrete target and objectives. Appropriate indicators and monitoring frameworks must be established to measure progress.
Missions should result in investments in different sectors and involve different types of actors.	Missions should be framed in such a way as to spark activity across and among multiple scientific disciplines (including the social sciences and humanities) and across different industrial sectors and different types of actors (public, private, third sector, and civil society organisations).
Missions require concerted policy making, in which priorities are translated into concrete policy instruments and actions to be carried out at all levels of the public institutions involved.	Missions must be clearly framed in terms of time and responsibilities (i.e., a clear timeframe within which actions should take place). Although missions should involve a variety of public institutions, a strategic division of labour among them, with well-defined responsibilities for coordination and monitoring, is crucial.

Source: Based on Mazzucato (2018).

The analysis was based on 86 documents at different hierarchical levels (see Table 10.3): the EU level (four units), national level (eight units), regional level (ten units) and municipal level (66 units), namely municipal strategic development plans (60 units) and municipal waste management plans (six units).

Of the 60 strategic development plans of the Lithuanian municipalities, only 29 (48.3% of all plans) were newly prepared or updated during the 2021–2027 programming period.

Coherence analysis

Achieving coherence among EU, national, regional, and municipal documents, necessary for the country to stimulate more active CE transitions, takes time; this can lead to delays in the compatibility of lower-level documents with higher-level documents. Documents from the different hierarchical levels according to their approval date are presented in Figure 10.3.

The fastest achievement of coherence, meaning the shortest time between document approval dates, is seen between the EU-level documents and the national-level documents, which are oriented towards the progress of the entire Lithuanian economy (by National Progress Plan for 2021–2030) and waste management (by National Waste Prevention and Management Plan for 2021–2027 [draft]). By contrast, the focus on industrial transformation at the strategic level is delayed, as the Roadmap for Lithuania's Industrial Transition to a Circular Economy was approved in March 2022.

Table 10.3 Research objects

EU level	*National level*	*Regional level*	*Municipal level*
The European Green Deal (COM/2019/640) The New Circular Economy Action Plan (COM/2020/98) A New Industrial Strategy for Europe (COM/2020/102) EU Directive 2008/98/EC on Waste (latest updated 2018/851).	Lithuania's Progress Strategy 'Lithuania 2030' National Progress Plan for 2021–2030 The National Climate Change Management Agenda Economic Recovery and Resilience Building plan 'New Generation Lithuania' Roadmap for Lithuania's Industrial Transition to a Circular Economy Roadmap for the Integration of the Lithuanian Industry into European Value Chains The Roadmap for Lithuanian Industry Digitization 2020–2030 National Waste Prevention and Management Plan for 2021–2027 (Draft).	Regional strategic development plans. Regional waste management plans.	Municipal strategic development plans. Municipal waste management plans.

In a CE, it is critical to seek ambitious goals, namely those set at the EU and/or national levels and at the local levels (i.e., at the regional and municipal levels). The regional development plans have been updated with minimal emphasis on the circular transformation of the entire socioeconomic system (including industries and society). For Lithuanian municipalities, circular transformation guidelines typically arise from EU- and national-level documents, which actually override regional-level documents, while the term 'circular economy' is not even directly included or reflected in the CE family of terms such as 'sustainable', 'green', or 'clean'.

The waste management system is based on the regional principle; that is, ten regional waste management centres cover all Lithuanian municipalities. According to local governance laws, municipalities are responsible for the implementation of municipal waste management systems

Figure 10.3 Documents of different hierarchical levels according to their approval date.

and the organisation of the collection and recycling of secondary raw materials. Municipalities prepare municipal waste management plans, which are to be integrated into regional waste management plans and ultimately aligned with the National Waste Prevention and Management Plan for 2021–2027. The lack of coherence in time is also seen in municipal waste management documents. During the analysis period, municipal waste management plans in Lithuania for the 2021–2030 period were either not publicly available or were already enforced, but their preparation took place earlier than the active and significant integration of the concept of CE into strategic documents.

Integrity analysis

The integrity analysis of the strategic documents based on the identified criteria of Mazzucato (2018) indicates a readiness for a public policy transformation towards a mission-oriented approach.

Missions should be well-defined

The Lithuanian Progress Strategy 'Lithuania 2030' (prepared in 2012) and the Lithuanian National Progress Plan for 2021–2030 (prepared in 2020) can be considered a strategic basis for the circular transformation of the entire ecosystem. The objectives set at the EU level are directly reflected and aligned with four national documents through four objectives:

- Reorientation of the industry towards climate neutral practices.
- The use of renewable energy and increased efficiency.
- The use of alternative fuels in the transport sector and sustainable mobility.
- Waste reduction and efficient management.

As expected, the clearest targets at the EU and national level are related to waste management and show clear directions: waste prevention, primary sorting, and the development of waste management capacity. Therefore, the focus is on answering the question of how much (e.g., the share of municipal waste prepared for reuse and recycling should reach 60% by 2030). Municipalities include CE-related objectives and at least the minimum measurement indicators in their strategic plans.

Even though the industrial sector plays a critical role in the CE, it is not clear how the industry will become circular. The New Circular Economy Action Plan (COM/2020/98) and the New European Industrial Strategy (COM/2020/102) and its latest update in 2021 only indicate guidelines or possible directions on a broad scale. The same situation is seen in Lithuania; Lithuania's National Progress Plan 2021–2030 indicates possible directions with a focus on the use of secondary raw materials, eco-innovation, energy efficiency (savings), and reduction of greenhouse gases and sets targets for the industrial sector (answering the question of how much); however, it provides no detailed guidelines on how to achieve these goals. More detailed information is provided in the Roadmap for Lithuania's Industrial Transition to a Circular Economy.

In a noticeable trend, municipalities, especially those of the largest Lithuanian cities, create their visions in alignment with sustainable development goals (e.g., green municipalities, sustainable development and growth, socially responsible businesses and communities, smart and green economies, green infrastructure); however, they include no clear focus on becoming circular. The term 'circular economy' is not directly reflected in the priorities or goals of any municipality. The

Table 10.4 Integration of CE-related documents at the national, regional, and municipal levels in Lithuania

Focus	*National level*	*Regional level*	*Municipal level*
Whole ecosystem (public sector, industry and business, society)	• Lithuania's Progress Strategy 'Lithuania 2030'[a]. • National Progress Plan for 2021–2030[a]. • The National Climate Change Management Agenda. • Economic Recovery and Resilience Building Plan 'New Generation Lithuania'.	Regional strategic development plans[a]	Municipal strategic development plans[a]
Industry and business	• Roadmap for Lithuania's Industrial Transition to a Circular Economy[a]. • Roadmap for the Integration of the Lithuanian. Industry into European Value Chains. • Roadmap for Lithuanian Industry Digitization 2020–2030.	-	-
Waste	• National Waste Prevention and Management Plan for 2021–2027 (Draft)[a].	Regional waste management plans[a]	Municipal waste management plans[a]

Note
[a] Analysed documents related to CE in this research.

term 'circular economy' appears only in the Lithuanian National Progress Plan for 2021–2030, and this may be one reason that this term was not found in municipal strategic plans that were approved through the end of 2020 (all except for one municipality). Only 10 of 29 (35%) strategic plans approved through 1 October 2021 directly used the term 'circular economy'. Municipalities rarely name waste as a raw material or emphasise the extension of life cycle objects.

A mission comprises a portfolio of various projects

The CE concept is directly correlated with several major Lithuanian strategies and roadmaps, covering various focuses (see Table 10.4).

Missions should result in investments in different sectors and involve different types of actors

In strategic documents, CE is mainly identified as an opportunity, whereas climate change and pollution are identified as threats. This shows that coherence among the economy, the social environment, and the natural environment is the dominant aspect in the project's implementation.

Despite the fact that strategic documents aligned with the CE (see Table 10.4) cover the whole ecosystem (public institutions, industry, business, and society), industry and business in Lithuania receive the latest attention at the national level, while they receive attention in a fragmented way (through strategic plans) or not at all at the municipal and regional levels.

Missions require joined-up policymaking

The principle of hierarchical integration dominates in municipal strategic documents. For example, the municipal strategic development plan was prepared considering national-level documents important for CE transformation, although EU-level documents are rarely mentioned. The principle of horizontal integration is fragmented and is usually limited to a specific function, for example, tourism or mobility. Municipal strategic development plans rarely mention the regional centres or main cities of the region where the municipality is located. Neighbouring municipalities consider cooperation only in the fields of public transport and tourism and in the development of a common water supply and wastewater infrastructure, while in the CE context, they fail to emphasise cooperation between different sectors from different municipalities (e.g., for industrial symbiosis). Furthermore, most municipalities compared the current situation in their territory with similar municipalities and the averages for Lithuania and their region. However, in the context of CE, comparisons with indicators from neighbouring municipalities, especially regional centres (cities), are also important.

As a mission-oriented policy could be used to solve wicked problems, the next section introduces an example of this type of policy by analysing the Lithuanian Industrial Circular Economy Transition Roadmap in detail according to key capabilities (such as a well-defined mission, a portfolio of various projects that comprised the mission, joined policymaking, and the involvement of different types of stakeholders).

Example of mission-oriented policy: Roadmap for Lithuania's Industrial Transition to a Circular Economy

The project Roadmap for Lithuania's Industrial Transition to a Circular Economy was the first co-creation project in Lithuania and can be considered an example of a mission-oriented policy to catalyse the CE transition in Lithuania. This project aimed to envisage specific actions that could help maintain the competitiveness of the country's industry while considering the principles of the CE.

Since 2018, the Ministry of Economy and Innovation has participated in the pilot project Industrial Transformation in the Regions initiated by the EC. Through this project, it was determined that the biggest shortcoming of Lithuanian industry is its lack of a unified vision and action plan for the transition to a climate-neutral CE. Therefore, in October 2020, the project Preparation of the Lithuanian Industrial Transition to the Circular Economy Roadmap was launched.

During the co-creation process, a comprehensive map of the circular ecosystem was compiled, identifying key stakeholders, organisations and associations in this field who wished to assume responsibility for the long-term viability and sustainability of the Roadmap for Lithuania. In this process, a systematic dialogue was used that allowed representatives of different stakeholders to share information, collaborate and discuss common goals, thus encouraging participants to change their beliefs, strengthen their relationships, and take responsibility to help them find a strong common ground for the future. As the project implementation period was from 2020 October to 2021 December (15 months), the systematic dialogue process for the development of the Lithuanian Industrial Circular Economy Roadmap was comprised of four stages (Science, Innovation and Technology Agency, 2022a):

- **Preparation**: activities such as mapping the CE ecosystem; conducting an industry questionnaire; policy and legislative analysis; formation of a coordination group for the Lithuanian Industrial Circular Economy Roadmap; selection and validation of the methodology; kick-off meeting for presentation of the project; invitation to a wider list of stakeholders.
- **Identifying the vision of a CE**: activities such as the vision/scenario session, that is, the context and CE's influencing factors, and an additional educational session.
- **Strategic directions**: activities such as periodic meetings of the coordination group; identification of strategic directions within the strategic policy groups and industry sectors' representatives.

- **Preparation and development of the roadmap draft**: activities such as periodic meetings of the coordination group; presentation of the draft of the Lithuanian Industrial Circular Economy Roadmap project; presentation of the roadmap to various stakeholders; approval of the roadmap.

Mission-oriented policies generally involve a large diversity of stakeholders who can influence not only policy agendas and well-established innovation systems but also society as a whole, including incumbent firms, consumers, and local communities. The co-creation of this roadmap was based on the stakeholder map, a voluntary coordination group of 50 representatives and experts from government, industrial, business, non-governmental, municipal, waste management, consumer, science, and educational institutions. The role of the coordination group was to ensure the equal representation of different interest groups, to support their motivation and to express the relevant needs of various stakeholders. Representatives of various industries (such as food and agriculture, construction, textile, furniture and wood products, plastics and packaging) were actively involved.

During the process of developing the Roadmap for Lithuania's Industrial Transition to a Circular Economy, a series of events was organised (see Figure 10.4). These events allowed us to get acquainted with the different stakeholders' attitudes towards the CE and to understand how the transition of the Lithuanian industry from the linear economy to the CE could be better implemented by combining different experiences.

As a result of this project, the following documents were prepared (Science, Innovation and Technology Agency, 2022c):

- An analysis of the circularity of Lithuanian industry.
- The vision of Lithuanian industry based on the principles of co-creation and partnership.
- 'Roadmap for Lithuania's Industrial Transition to a Circular Economy'.

The authors of the 'Roadmap for Lithuania's Industrial Transition to a Circular Economy' noted that the analysis of Lithuania's circularity revealed a wicked problem, namely "that only 3.3% of Lithuania's industry is circular, which means that the circularity gap exceeds 96%" (Science, Innovation and Technology Agency, 2022d). According to the Science, Innovation and Technology Agency (2022d), the Circularity of the Lithuanian Industry Analysis also presented Lithuania's portfolio, which presented Lithuania's current policy readiness for a circular industrial transition; a SWOT analysis, infrastructure analysis, opportunities analysis based on industrial sectors such as food and agriculture, construction, textiles, plastics and packaging, and furniture; and recommendations for Lithuania's industry transition to more of a CE by paying attention to regulatory framework, market, technological, governance, and cultural aspects. The analysis of Lithuania's circularity also revealed that "the Lithuanian economy has tangible potential for circularity" (Science, Innovation and Technology Agency, 2022d).

The vision and mission of the 'Roadmap for Lithuania's Industrial Transition to a Circular Economy' were expressed through both long-term (2050) and short-term (2030) goals. The three long-term goals were closely correlated with the EU's industrial transformation goals: full circularity, ensuring competitiveness, and climate neutrality. The short-term goals that were refined during the co-creation process include increasing competitiveness, creation of innovation, creation of a market for secondary raw materials, ensuring cooperation, establishment of a mechanism for the functioning of the CE, availability of raw materials, creation of a CE infrastructure, creating an environment for new business models, education and science, promoting sustainable consumption, and changing socioeconomic patterns (Science, Innovation and Technology

Event	**Introductory event: Establishment of the Lithuanian Industry Transition to the Circular Economy (coordination group)**	**Introductory event: Establishment of the Lithuanian Industry Transition to the Circular Economy**	**Lithuanian Industrial Circular Economy Roadmap: Process and Benefits**	**Lithuanian Industrial Circular Economy Roadmap: Session of the Circular Economy context**
Aim	To inform interested stakeholders of government, business, associations, non-governmental organizations, science and education, consumers, waste sectors, experts about the Lithuanian Industrial Circular Economy Roadmap and its development process.	To inform interested stakeholders of government, business, associations, non-governmental organizations, science and education, consumers, waste sectors, experts about the Lithuanian Industrial Circular Economy Roadmap and its development process.	To introduce the process and benefits of Lithuanian Industrial Circular Economy Roadmap.	Gain basic knowledge of the Circular Economy; To gain a general understanding of the level of perception in Lithuania; To get acquainted with the tendencies; Raise expectations, fears, success factors for successful further cooperation
Date	**2021-02-25**	**2021-03-10**	**2021-03-18**	**2021-03-25**

Event	**Lithuanian Industrial Circular Economy Roadmap: Good practices**	**Lithuanian Industrial Circular Economy Roadmap: Scenarios and vision**	**Lithuanian Industrial Circular Economy Roadmap: Discussion of strategic directions**	**Circular Economy Conference 'How Can Industry Lead the Transformation to a Green and Circular Economy?'**
Aim	By bringing together key stakeholders to learn about best practices in the Circular Economy in different levels.	By mobilizing key stakeholders, using the methods of co-creation, systematic dialogue and scenario development, to refine the transition of Lithuanian industry from linear to the Circular Economy: possible scenarios and vision, common points of contact and understanding.	By mobilizing key stakeholders , using the methods of co-creation, systematic dialogue and scenario development, to refine the transition of Lithuanian industry from linear to the Circular Economy strategic directions and identify concrete proposals from various stakeholders.	To present the roadmap of the Lithuanian industrial Circular Economy.
Date	**2021-04-22**	**2021-07-08**	**2021-08-13**	**2021-12-17**

Figure 10.4 Events to develop the roadmap for Lithuania's Industrial Transition to a Circular Economy.
Source: Based on Science, Innovation and Technology Agency, 2022b.

Agency, 2022e). The mission of the roadmap includes multiple aspects, such as 1) setting conditions, including creating or improving the regulatory environment, development of technological renewal and innovation, dissemination of knowledge-intensive innovations, the creation of a sustainable funding model, and 2) the definition of the CE monitoring indicators and evaluation system (Science, Innovation and Technology Agency, 2022e). The co-creation and systematic dialogue process for the development of the roadmap involved and ensured the equal representation of different stakeholders with different biases in terms of knowledge, competencies, interests, and responsibilities. In such processes, the collaboration and cooperation between different stakeholders is the key aspect (Bauwens et al., 2020; Velenturf & Purnell, 2021). Participation in this co-creation process through fruitful discussions led to new knowledge sharing and a common understanding of the CE's complex and multifaceted issues.

Challenges to implementing circular economic policies

The various stakeholders in the value chain have different goals and attitudes, leading to contradictions and tensions when working to achieve and reconcile different goals. For example, if more secondary materials, such as regenerated-recycled cotton, are used in production, this can be seen as an example of a circular action. However, the quality of such products may be lower and have a shorter useful life. This is contrary to the idea of circularity, which aims to keep products on the market as long as possible. Obviously, the needs and complexity of the plurality of stakeholders raise challenges in promoting transitions to the CE from a public sector point of view.

The coherence and integrity among EU, national, regional, and municipal documents take time; for this reason, the Lithuanian CE policy remains at an early stage. Not all documents, especially at the municipal level, are prepared as guidelines for how ecosystem actors should be involved in the transition to CE. The coherence and integrity analysis of CE policy in Lithuania, as well as the overview of the roadmap, identified several challenges that must be overcome (see Figure 10.5).

One way to reduce ambivalence is to set clear goals and strategies. The European Commission has established common EU goals for the recycling of municipal waste by 2030 (65%) and packaging waste (75%). Such measurable targets in areas related to waste management reduce ambiguity and can facilitate transitions to the CE. The analysis of Lithuania's policies shows that although the visions or priorities set out in many municipalities' strategic plans emphasise the environmental dimension, no concrete environmental indicators (circular) are included in the monitoring system. Only a few municipalities have quantified environmental indicators in the vision or impact indicators group. To meet this challenge of a lack of measurement, a common list of monitoring indicators

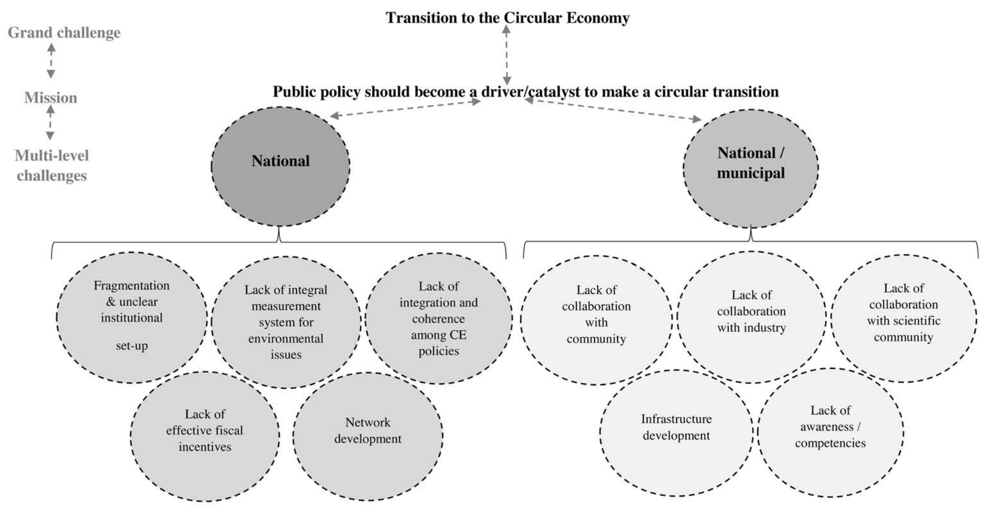

Figure 10.5 Key multi-level scale challenges for the transition to the CE from a public sector perspective.

should be introduced, specifying the indicators and the methodology for calculating them, as the existing indicators in the monitoring systems are different, making it impossible to measure and compare progress between different municipalities. However, other important areas of the CE, such as eco-design, reuse, and remanufacture, do not have clear measurement objectives, so the challenge of ambivalence remains.

To be more circular, achieve more efficient waste management, and to avoid fragmentation, regional and municipal waste management plans and other documents must be prepared in parallel. In addition, to meet this challenge (i.e., the lack of integration and coherence between documents and the fragmentation of institutional set-up), more ambitious CE-related targets should be set within CE policies. Currently, the concept of the CE is mostly reflected in the lowest product or target-level indicators.

At the municipal level, cooperation with businesses and research institutions is fragmented, even though municipalities are aware of the importance of cooperation among all ecosystem actors. Following local governance legislation, the municipality's only function is to create suitable conditions for the development of business activities. However, the municipality is not intended to collaborate with business or build joint business networks. Thus, this function remains national, although it is needed at the municipal level, where the businesses operate. Therefore, an important challenge for the public sector is to create conditions for the development of a circular business model and to promote various CE initiatives, beyond what is written in the local governance laws – that is, to develop a network within local ecosystems. Despite the fact that all municipalities plan to develop a waste management infrastructure, the main challenges involve societal awareness regarding municipal waste sorting as well as local businesses' lack of environmental responsibility. These challenges lead to the need for infrastructure development. From the perspective of the public sector, this could be achieved through actions such as promoting the separation, recycling, and reuse of waste; developing a sustainable waste management system; implementation of CE principles of sharing and reuse in households; and developing and implementing a unified textile waste collection and management system.

One way to increase the awareness of the CE and environmental responsibility is to actively raise the level of knowledge and competences of society, businesses, and the public sector. It is obvious that Lithuanian municipalities increasingly aim to disseminate environmental information through educational and cultural programs. Another method is to organise various events that promote environmental protection initiatives. In addition, a lack of competence and knowledge exists among public sector specialists, especially in the regions. Most of them only equate the CE with a higher level of recycling. Staff training and competency building could be a way for public organisations to accelerate the transition to the CE.

Hence, we can state that the key multi-level scale challenges for the transition to the CE identified in this research are in line with the challenges of public policies related to the CE mentioned by Wittmann et al. (2021), Johansson and Henriksson (2020), Lazarevic and Valve (2017), and Stahel (2010). Therefore, institutional conditions, political reforms, and the active participation of the whole society play an important role in encouraging the public sector to become a catalyst for the transition to a CE.

Conclusions

The transition to a CE presents difficult governance challenges for policymakers. Therefore, the focus on mission-oriented policies targeting complex and multidimensional grand challenges is particularly relevant.

Currently, the public sector deals with CE issues mainly through waste management and recycling. Notably, the public sector has not played the role of an active catalyst in encouraging society and businesses to transition to a CE. Implementing the principles of a CE should be based on a mission-oriented policy, which could lead to a win-win situation for all stakeholders by reducing the circularity gaps in Lithuania. The ambivalence and lack of specificity and clarity related to CE in policy documents (setting targets and indicators) require a stronger interpretation of the concept and more resources (personal knowledge, initiative and leadership, networking) and time to achieve these goals.

Co-creation involves collaboration within the whole ecosystem among interested actors and the integration of various resources and unique capacities for overcoming challenges. Strategic documents created on the basis of co-creation gain advantages via synergy and are capable of creating higher value than they could otherwise. Such documents are aligned with mission-oriented policy and may enable the transition to a CE.

The co-creation process of the 'Roadmap for Lithuania's Industrial Transition to a Circular Economy' revealed that, based on voluntary participation during open conversation, the different stakeholders not only reconciled different interests and competencies, but also developed a common motivation for the practical implementation of a circular transformation by setting long-term and short-term goals for Lithuania's industrial transition to a CE. Analysis of the integrity of the roadmap revealed that all key capabilities (such as a well-defined mission, a portfolio of various projects' comprised mission, joined policymaking and the involvement of different types of stakeholders) met the requirements for a mission-oriented policy, which could be used to solve circularity challenges in Lithuanian industry.

Educational content

- The public sector must be a key partner in solving sustainability issues, rather than just a facilitator of growth, to ensure social, economic, and environmental sustainability.
- The active engagement of the public sector might foster the transition to a CE via a) integration of top-down and bottom-up public policies, b) collaboration with stakeholders, and c) implementation of a mission-oriented policy.
- The readiness of public policy for a mission-oriented approach at the legislative level is a serious prerequisite for success. The interoperability between strategic documents is crucial, both from a vertical (coherence) and a horizontal (integrity) perspective.
- Public policy that is created on the basis of co-creation principles gains advantages via synergy and is capable of creating higher value. The co-creation process develops common competences and motivates different stakeholders for the practical implementation of public policies.

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11

INFORMATION AS A CATALYST FOR THE CIRCULAR ECONOMY

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Introduction

Interest in the circular economy (CE) is growing because of unresolved global challenges, such as climate change and resource scarcity, and it is seen as an important driver to achieve green growth and sustainability transition (European commission, COM/2020/98). In general, the CE is understood as an economic system that creates value from waste by capturing and then reusing finite materials and energy (Geissdoerfer et al., 2017; Korhonen et al., 2018; Kraaijenhagen et al., 2016) by slowing down, closing, and narrowing material and energy flows (Bocken et al., 2016). The CE is expected to contribute towards increased resource efficiency, reduced extraction and reduced processing of natural resources; in addition, earlier research has also linked CE to increased business opportunities (McCarthy et al., 2018). Despite these potential benefits and the vast amount of research directed towards CE, the process of transitioning towards CE has been relatively slow. One potential explanation for this might be that the CE literature traditionally recognises two distinct cycles – biological and technical (Braungart & McDonough, 2002; Ellen MacArthur Foundation, 2013) – and even though the previous studies concentrating on these cycles have advanced the discussion on CE, they lack the crucial perspective of information circulation.

In general, paying attention to the management of information circulation has the potential to enhance the efficiency of business processes, reduce surpluses, lengthen the life span of goods and diminish transaction costs (Baines & Lightfoot, 2013; Jäger-Roschko & Petersen, 2022). With information, we generally refer to different levels of a hierarchy consisting of data, information, knowledge, and wisdom (Ackoff, 1989). To understand different CE strategies, consideration should be given to how these different levels are to be managed and how information circulates across various systems and stakeholders, in addition to technological and biological resource cycles. A lack of information may reduce collaboration (Patricio et al., 2018), and incomplete information can hinder remanufacturing process improvements (Despeisse et al., 2017; Kurilova-Palisaitiene et al., 2018). As Tura et al. (2019) concluded, it is essential to understand the importance of information management when designing a circular business concept and that a lack of methods and platforms to share information can hinder this development.

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Even though the importance of information has been shown in previous studies, the current discussion on widely used CE models, such as the one from the Ellen MacArthur Foundation (2013), neglects an information circulation perspective. Many of the previous studies consider only technological or biological cycles and are conceptual in nature. The focus in previous CE studies has largely been on identifying and understanding various material flows in economic systems, and has paid significant attention to the recycling of materials (Husgafvel et al., 2016; Milios et al., 2019), CE business models (Lüdeke-Freund et al., 2019; Ranta et al., 2018; Vermunt et al., 2019), and the enablers of and barriers to a CE (Kirchherr et al., 2018; Patricio et al., 2018; Tura et al., 2019), for example. Furthermore, it has been acknowledged that successfully transitioning towards a CE requires collaboration between multiple interdependent actors within the system (Ghisellini et al., 2016; Kraaijenhagen et al., 2016; Marra et al., 2018). Recent research has increasingly focused on the human-centric, social, and institutional changes that are required for transitioning towards a CE (Bocken et al., 2017; Clube & Tennant, 2020; Moreau et al., 2017; Wiener et al., 2018), as well as the implications of a CE for business decision-making (e.g., Mendoza et al., 2017).

Based on the literature and an empirical study of four case companies from the energy, forest, waste management, and information technology sectors, we found that information such as conceptual, procedural, policy, stimulatory, empirical, and directive information types crucially affects the planning of companies' CE initiatives. Therefore, following a design-oriented perspective, this chapter examines the role of *information* as an enabler of the technical and biological resource cycles and poses the following research question: How does information catalyse the transition towards the CE? The results highlight the crucial role of information in facilitating this transition by explaining how – by systematically collecting, processing, and sharing information related to the material flows, resources, capabilities, and goals – new circular business can be enabled. Consequently, information works as a catalyst (i.e., a mechanism of the sustainability change) of the CE. We derive a model that sheds light on the different stages of the information circulation, namely data, information, knowledge, and wisdom (Ackoff, 1989), and their relation to circular business decision-making. Our model emphasises the different levels of information circulation at the intra-firm, network, and societal levels.

Conceptual background

The two-dimensional model of the CE

The CE is expected to gradually replace the traditional and linear so-called end-of-life (EOL) logic, which has been criticised for unsustainable resource consumption (Ghisellini et al., 2016; Lieder & Rashid, 2016). The CE is strongly linked to sustainable development (Murray et al., 2017) because it gives rise to additional opportunities for environmental, social, and economic value creation (Geissdoerfer et al., 2017; Tura et al., 2019).

Traditionally, and as illustrated in Figure 11.1, the CE literature distinguishes between two types of cycles: biological and technical (Braungart & McDonough, 2002). Biological cycles consist of renewable biomaterials, such as timber and cotton. Biomaterials circulate in the system because they can typically be renewed by specific processes, for example, by composting and replanting. Technical cycles include the flows of various product assemblies and the flows of nonrenewable resources. These flows re-enter the economic system through processes that differ from their biological counterparts, through repair, recycling, and remanufacturing (Ellen MacArthur Foundation, 2013).

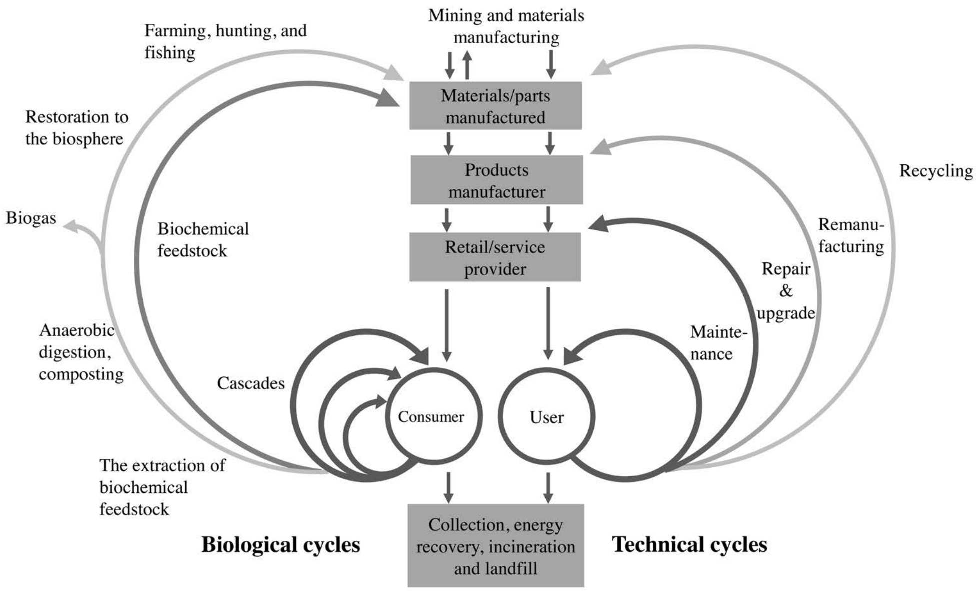

Figure 11.1 The model of the CE.

Source: Adapted from the Ellen MacArthur Foundation (2013).

The CE's underlying driver is the motivation to constantly seek out opportunities for applying the principles of "reduce, reuse, and recycle" (Ghisellini et al., 2016; Jawahir & Bradley, 2016) in both production and consumption. Although these three principles also cover intangible resources, such as human resources and knowledge, the literature has mainly focused on material flows while neglecting information flows (Hanski & Valkokari, 2018). However, business model innovation (Kraaijenhagen et al., 2016), sustainable value creation (Ghisellini et al., 2016), information, and knowledge sharing and collaboration (Centobelli et al., 2020; Marra et al., 2018; Wiener et al., 2018) are acknowledged as being crucial aspects of CE development. In addition, if a system's suboptimisation and so-called rebound effects of CE (see: Kjaer et al., 2019; Korhonen et al., 2018; Millar et al., 2019; Zink & Geyer, 2017) are to be avoided, this requires efficient information gathering and processing throughout the whole system. For example, this information may reveal if reducing energy consumption in one area takes place at the expense of another area. In the following, we proceed to discuss how information may enable additional circular business.

The role of information in circular business

Information and communication technologies (ICT) are seen to have positive environmental, social and economic impacts, being an important contributor towards sustainability transition (El Bilali & Allahyari, 2018), meaning a long-term, multidimensional and fundamental shift of established socio-technical systems to more sustainable modes of production and consumption (Markard et al., 2012). For example, the use of ICT may provide new ways of visualising and measuring impacts, communicating changes, connecting actors, and reducing logistics costs and inefficiencies within value chains (El Bilali & Allahyari, 2018; Elliot, 2011; Watson et al., 2010). Furthermore, the CE is seen to provide multiple opportunities for action to achieve sustainability transition (European

Commission, COM/2020/98) and the use of data and information technologies has the potential to drive the transition towards the CE, renewing the logics of value creation and increasing resource efficiency (Despeisse et al., 2017; Ellen MacArthur Foundation, 2016; Jabbour et al., 2019). Many current CE solutions are supported by – or their existence is even enabled by – data and digital platforms, such as mobile marketplaces for selling leftover food (e.g., ResQ), vehicle sharing (e.g., DriveNow), and IT equipment as a life cycle service (e.g., 3 Step IT) (Sitra, 2019). Information can significantly support firms' attempts to increase the lifetime value of their assets through various actions such as refurbishment and remanufacturing activities (Bocken et al., 2016; Campos et al., 2017; Jäger-Roschko & Petersen, 2022; Kurilova-Palisaitiene et al., 2018).

Many manufacturers have started to look for new circular concepts (Bocken et al., 2016) and are providing their products to customers as a service (Tukker & Tischner, 2006). In these service strategies, the business is typically based on gathering data, for example, on the usage and performance of the product (Rymazewska et al., 2017) and managing the flow of information (Centobelli et al., 2020; Vezzoli et al., 2015). Furthermore, firms experienced in leveraging side streams within their production operations have been collecting data, which, as shared across company boundaries, hold considerable potential for the development of novel circular business solutions (Aminoff & Kettunen, 2016; Husgafvel et al., 2016). Circular business is also closely linked to enhanced information management practices and supporting digital solutions applied to monitoring performance, redefining maintenance requirements, and extending use cycles (Ellen MacArthur Foundation, 2016; Hanski & Valkokari, 2018; Ren et al., 2019). Furthermore, circular business is supported by sharing platforms that provide opportunities for increasing asset productivity by connecting asset owners with asset users (Ghisellini et al., 2016).

With the importance of information being acknowledged in CE business solutions, scholars have presented several CE business frameworks. For instance, Lieder and Rashid's (2016) CE implementation strategy model acknowledges the different levels, from micro to macro, of the CE business landscape and mentions information technology's role as an enabler for product life cycle thinking. Jabbour et al. (2019) integrate the use of large-scale data and the integration of different stakeholders in pursuing CE objectives. Ren et al. (2019) connect big data analytics in sustainable smart manufacturing and discuss the role of accurate information for decision-making. Lüdeke-Freund et al. (2019) propose six major CE business model patterns that have the potential to support the closing of resource flows but fail to look at information flows, such as where to get relevant information on developing a CE business model. Finally, Mendoza et al. (2017) present a framework for how to implement eco-design perspectives into CE business models and discuss information needs in the decision-making process.

The previously mentioned studies address information management aspects in specific contexts and hence do not aim to take a comprehensive view in examining current CE models, especially from an information flow management perspective. Finally, information is often discussed at a rather general level, instead of considering what specific type of information is needed, how it could be gathered, and how and with whom it should be shared.

Information circulation

Building on the literature, Figure 11.2 illustrates the process of information circulation. This process incorporates the creation of wisdom in business decision-making, with emphasis on the aspects related to data, information, knowledge, and wisdom (DIKW) (see Figure 11.2).

Data covers the values and observations from selected variables (Ackoff, 1989; Zack, 1999), such as a temperature or humidity value measured by a sensor in a manufacturing process.

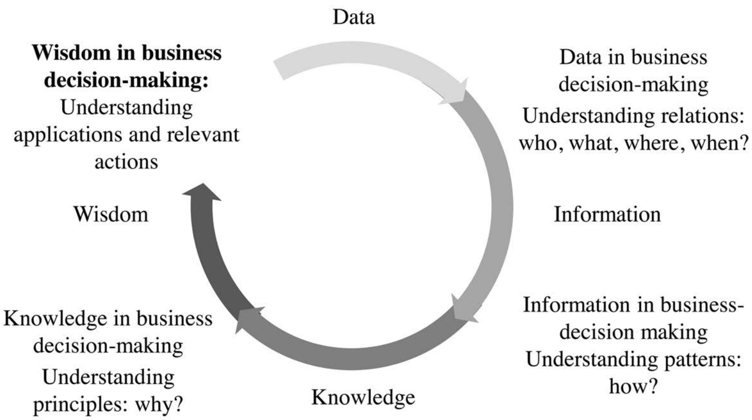

Figure 11.2 Developing wisdom in business decision-making.

Source: Adapted from Ackoff (1989).

Information is inferred from the data, meaning the data is transformed into a meaningful and useful form (Ackoff, 1989; Rowley, 2007), such as a manufacturing process efficiency trend or product failure rate. *Knowledge* is related to know-how and is the ability to interpret trends and put information into productive use (Ackoff, 1989; Kakabadse et al., 2003). For example, this can be the professional skill of understanding information that has developed over time. Last, *wisdom* is the ability to understand relevant alternative actions within the context and time, to compare them, consider the effects on stakeholders, and to make an optimal business decision by utilising the appropriate decision support tools (Kakabadse et al., 2003; Kunttu et al., 2016; Rowley, 2006).

To create wisdom and for a firm to remain competitive, it must effectively and efficiently generate, capture, analyse, and share information and knowledge (Hicks et al., 2002; Kakabadse et al., 2003). Knowledge creation refers to converting data to information and connecting pieces of information together. This information needs to be stored in a specific format, such as in databases or platforms, and leveraged to support business decision-making. For example, analysing resource usage data enables the identification of opportunities for increasing process efficiency or sharing materials with other firms. To remain competitive in complex, interdependent, and dynamic business environments, there is also a need for information and knowledge sharing at micro-, meso-, and macro-levels; making the knowledge available and distributing it internally (such as in maintenance activities) or externally between several organisations (e.g., recycling activities) (e.g., Hicks et al., 2002).

Methodology

The current study follows a design-oriented research approach (van Aken & Romme, 2009) aiming to develop a solution to an identified problem – here being the slow rate at which society has been transitioning towards a CE. Specifically, our objective is the development of a conceptual model that clarifies the relationship between information circulation and CE. Our assumption is that such a model could support organisations in their efforts to develop products, services, and production processes in a manner that is aligned with the well-known CE principles. In addition to earlier quantitative and qualitative studies, we argue that adopting a design-oriented approach would have considerable potential for further enriching scientific knowledge about the

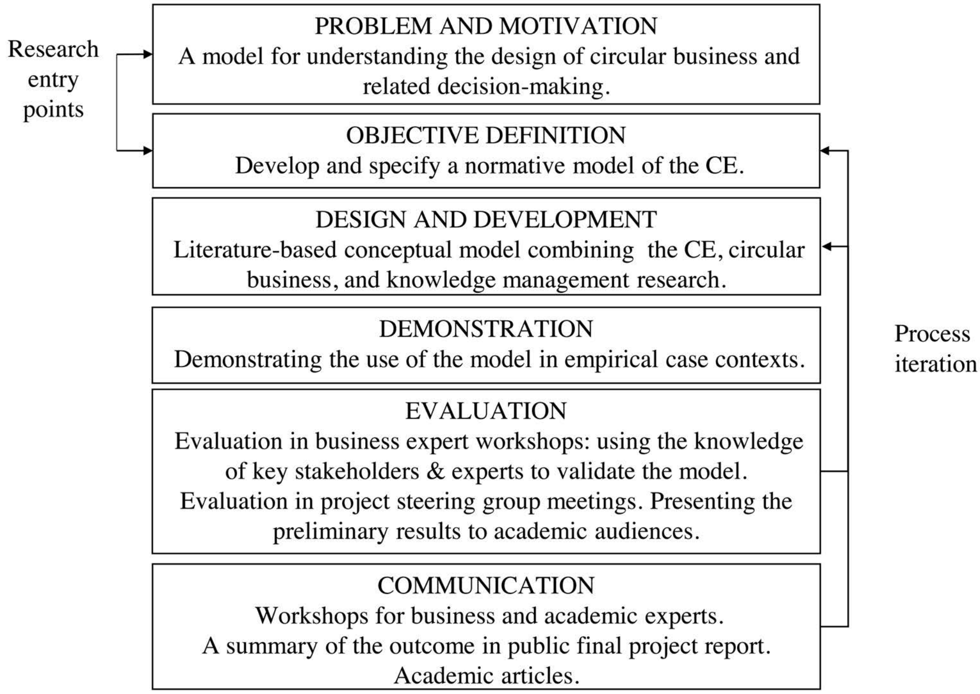

Figure 11.3 The flow of design-oriented research.

Source: Adapted from Peffers et al. (2007).

CE, while bringing the CE a step closer to practical application in organisations (Sein et al., 2011; Tanskanen et al., 2017). This approach is supported by the findings of Peffers et al. (2007), who reviewed multiple cases in which a design-oriented research approach was found to produce findings of high practical relevance and impact.

In this study, insights from earlier literature were combined with empirical research conducted over a 2.5-year research project focusing on the identification and description of the factors enabling the CE. Figure 11.3 describes the research process for design-oriented research (Peffers et al., 2007). The research began with familiarisation of the research context, then proceeded to bridge the conceptual environment and design science activities. This was followed by the design cycle, which included building and evaluating the research process and design artefacts. The research was finalised by a detailed consideration of the research limitations and connecting the findings with existing scientific knowledge and the experiences of practitioners (Hevner, 2007).

In the process of developing the artefact, the model, we drew upon existing literature on the CE, circular business design, and information and knowledge management. In the iterative development efforts that took place, we noted a lack of focus on information in the literature base. Therefore, emphasis was placed on identifying and achieving an in-depth understanding of the specific business contexts and challenges of the four firms involved in our research. We then sought access to case companies that would represent different industries, both process and project-based firms that serve both business and consumer customers, and hold established, stable positions in their market areas.

The four participating firms are as follows: BMH Technology, a provider of customised environmental technology solutions to industrial clients; Fortum HorsePower, a business unit of the energy company Fortum, which leverages synergies between horse stables, power plants, and logistics firms; Solita, an information solutions provider that serves its customers in creating value by sharing information; and UPM, a process industry firm specialised in producing high-quality products from renewable materials. Additionally, we selected a recent CE case from each firm for a detailed analysis. Next, we present the case descriptions

Case descriptions

BMH Technology is a globally operating, medium-sized firm providing its customers with complex fuel production and waste management systems, and services that include spare parts, life cycle maintenance, and modernisation. BMH's systems produce solid recovered fuel (SRF) from collected waste. SRF mainly consists of plastics after separation of other valuable materials, such as biowaste and metals. These technical and biological materials are reused and circulated back to the consumption system. This process results in SRF that is transported to power plants and converted to heat and electricity. As a service concept, SRF is based on the idea of providing an SRF production plant for waste management companies and collecting a monthly fee for delivering a certain capacity and amount of SRF to customers. When BMH operates the production plant, the use of SRF production assets is optimised, resulting in a longer life cycle for the assets.

Fortum is a large energy company offering its customers clean energy solutions, including electricity, heating, and cooling to improve resource efficiency. The HorsePower business concept is based on the idea of linking material flows across forest, farming, and energy industries. Sawdust, a by-product of the forest industry, is delivered to horse stables for use as a bedding material, where it gradually becomes covered by and combined with horse manure. The resulting material is then retrieved as part of Fortum's waste management service and delivered to power and heating plants; it is then utilised as bio-based fuel material in energy and heat production. Combustion ash, a side stream of energy production, is further utilised as forest fertilizer and in civil engineering.

Solita is a medium-sized digital business consultancy firm. The company provides a variety of services, including enterprise architecture, service design, e-commerce, analytics, business intelligence, and cloud services. One of Solita's customers is Amer Sports, a provider of consumer market sporting goods. The Amer Sports information platform, developed in collaboration with Solita and Amer Sports, connects the production, sales, retailers, and users of sport watches, providing real-time sales forecasts for production, sales, and retailers. Through a platform, the increased transparency and predictability of the sales of certain types of watches in certain locations translates into an optimised number of specific products to be manufactured. This optimisation, in turn, results in decreased material costs and waste, reduced storage costs, avoidance of sales loss, and avoidance of costs related to preparing sales forecasts. This solution is an example of using sharing platforms to enhance the sustainability and resource efficiency of consumer markets.

UPM is a large, globally operating company in the bio and forest industries. UPM produces a variety of products, including biofuels, biocomposites, biochemicals, paper, and pulp. The concept of refurbishing and reusing equipment and components is linked to UPM's strong focus on life cycle thinking and the urge to seek operating efficiency through effective maintenance and asset management. The concept is based on the idea that the circulation of technical materials exploits the economic value committed to the equipment and components in EOL pulp and paper plants. The technical cycle includes actors such as UPM's reuse function as well as internal and external clients. CE principles are addressed through the lifetime extension of components and equipment, although the materials for unwanted devices are recycled. The desired components and equipment are collected from the EOL plants and refurbished when necessary. After this, they are sold to internal and external customers.

Data collection and model development

In the four firms, 36 semistructured interviews were carried out with senior members of the organisation involved in the development of CE initiatives. The interviewees represented different functions (e.g., sales, technology, services, R&D) and levels (e.g., workers, managers, directors) of the studied organisations. The role of the ensuing workshops was to jointly develop and evaluate specific CE concepts, plan their implementation, and discuss the experiences from piloting concepts with clients. An early version of the model was tested and further developed during project steering group meetings and workshops held between 2016 and 2019 in close collaboration with representatives of the case companies, project members, and research organisations. Table 11.1 describes the role of different data sources in the research process.

The analysis was cyclical and inductive in nature (Locke, 2007) and followed the principles of data triangulation (Jick, 1979). The authors facilitated the workshops and steering group meetings, and two researchers took detailed notes of the discussions. In addition, memorandums describing initial interpretations were produced after workshop debriefings. The summaries of the produced reports and other results were provided for participant validation, and the preliminary findings were reviewed and discussed among the research team. Furthermore, the principles of the model were presented to academics in research conferences for review and to attract ideas for further development.

Information – A catalyst for CE

Drawing on CE, circular business, and knowledge management perspectives, Figure 11.4 is a model describing how the circulation of information supports technical and biological cycles, working as a catalyst for CE. This model emphasises the data, information, knowledge and wisdom hierarchy, and the hierarchy's relations that enable circular business. The following discussion explains this figure in more detail.

As illustrated in Figure 11.4, much as in biological and technical cycles, information circulation can take place within a small circle of actors, such as within an organisation's business unit, or can include multiple actors across society. When moving from micro to the meso- and macro-levels, an increasing amount of effort is required to transform data into wisdom. At a minimum, data and information are generated, captured, analysed, and shared inside an organisation to create knowledge that is utilised in business decision-making; for example, the acquired knowledge is used to seize business opportunities or to utilise production process waste. This type of micro-level, intra-firm information circulation such as information about the condition of the production assets, can take place across the whole organisation or between smaller groups or business units.

The second level in our model places attention on information circulation among multiple network actors. For example, a mine operator collects information on the production process efficiency and technical condition of equipment, such as pumps and reactor vessels. If this information is shared with another firm that provides maintenance services, the service provider may be able to detect problems with the customer's equipment before a serious malfunction occurs, thus being able to offer pre-emptive maintenance services that help the customer lengthen the

Table 11.1 Information about the workshops and meetings

Data source	*Purpose*	*Information*
36 semistructured interviews in autumn 2016 and spring 2017	1 Identification of circular business challenges 2 Motivation for the research	45 informants from 4 case companies
9 project steering group meetings • 2 in 2016 • 2 in 2017 • 4 in 2018 • 1 in 2019	Results (preliminary): review and feedback	10–14 participants in each meeting: • 4 company representatives • 6–9 academic representatives • 1 facilitator
3 expert workshops 2016–2018 15 company workshops 2016–2018 2 expert workshops with a co-research project	1 Review of circular business challenges 2 Model assessment Results: review and feedback	10–14 participants in each workshop: • 4 company representatives • 6–9 academic representatives • 1 facilitator 3–10 case company members 20–23 participants in both workshops • 7–9 company representatives • 9–12 academic representatives • 2 facilitators
8 academic conferences • 2016, Luleå, Sweden • 2017: Tampere, Finland; Lappeenranta, Finland; Melbourne, Australia; Oregon, USA • 2018: Stavanger, Norway; Fukuoka, Japan; Bangkok, Thailand	Preliminary research validation and communication	International academic and managerial audiences
1 public research seminar (January 2019)	Communication and validation of results	National academic and managerial audience

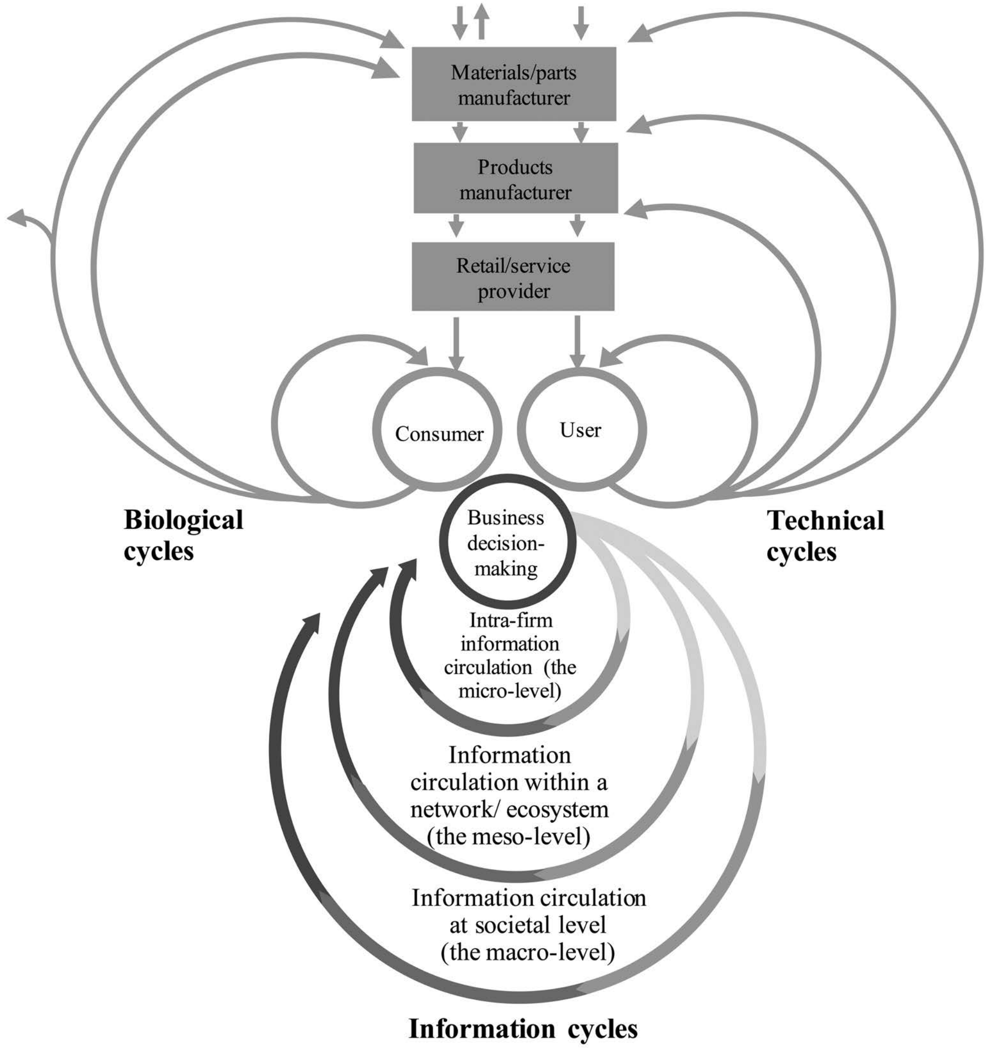

Figure 11.4 Circulation of information enabling CE.

life span of costly equipment and avoid production stoppages. At this level, managing the practices for information sharing and distribution are especially crucial, as problems related to data ownership, security, governance, and distribution channels often exist and require remediation.

The third level of our model addresses the societal level. This is the largest level in which the DIKW process involves multiple actors, including from business, academic, and governmental levels. For instance, producing energy from waste requires enabling legislation on both a national and global level, for example EU regulations, hence the need for actors at different levels to share and process information effectively is increased. By adding the institutional and social dimension to CE models, companies face increased pressure to obtain relevant information at the societal level. In addition, to feed valuable materials back into circulation, the public may require education on how and why to recycle the materials correctly.

Empirical illustrations of information as a catalyst for CE

The designed model was tested and further developed in close collaboration with the four firms. In this chapter, the information dimension is illustrated by the case companies. Table 11.2 provides a summary of information circulation at different levels within the cases.

BMH technology: Solid recovered fuel as a service

BMH acts as a central information node that captures information concerning end users, waste management companies, power plants, and their various requirements and expectations. Internally, data and information about the composition and amount of waste is crucial for the optimisation of production systems and for the quality of service delivery to waste management companies. Externally, detailed information is required about the materials separated from the waste to be shared with external recyclers that reuse and deliver them back in different forms. Furthermore, waste management companies hold information about multiple phases of logistics (e.g., delivery and collection times, locations, and available vehicles) that is vital in delivering the

Table 11.2 A summary of the information circulation identified in the case studies

	Information circulation within firms	*Information circulation within a network of firms*	*Information circulation at the societal level*
BMH Technology: Solid recovered fuel as a service	Intraorganisational information exchange to optimise the production process and promote the new business concept	Interorganisational information exchange to promote the service concept to customers and orchestrate the network	• Sharing the best practices across nations with different cultural and political contexts • Convincing traditional industries of the possibilities to utilise waste as a resource
Fortum HorsePower	Intraorganisational information exchange about the requirements for equipment and the composition of horse manure to be used in the development of biofuel	Interorganisational information exchange to enable the utilisation of material flows across industries	• Advancing political decision-making by an information exchange among organisations, academia, and authorities • Supporting wider structural and system-level shifts towards the CE
Solita: Amer Sports information platform	Intraorganisational information exchange to improve process optimisation and increase material efficiency	Utilising end-user data to provide demand forecasts and orchestrate the network	Highlighting the potential of both digitalisation and platforms as enablers of circular business development
UPM: The refurbishment and reuse of equipment and components	Intraorganisational information collection and exchange of equipment-related data to recognise opportunities for reuse	Interorganisational information exchange to evaluate the reuse possibilities of different equipment and components	• Recognising the possibilities for the reuse of equipment and components across industrial and national borders • Sharing best practices

waste and SRF to the right places at the right times. In the end, to orchestrate the network and apply this type of service concept in a traditional industry requires wisdom on the part of BMH. This CE concept requires the understanding of different actors and their needs and the capabilities to process different types of data and information flows and transform them into knowledge used in decision making. The whole business model of SRF as a service can be considered as new, especially for the waste management businesses; therefore, the model would transform the entire business logic among the companies involved. Finally, international collaboration and information sharing are needed to convince different societies and traditional industries of the possibilities of utilising waste as a resource. Depending on the country and the market, waste is not always considered a valuable energy source and is not always even permitted to be used in the generation of energy. In these societies, active information sharing between actors and policymakers about the possibilities of utilising SRF as an energy source would be required.

Fortum HorsePower

At HorsePower, information is circulated between different actors (e.g., authorities, customers, service partners, suppliers). Fortum analyses and summarises this information to understand the patterns and relationships. As such, HorsePower works as an information platform that integrates multiple data sources from multiple actors and then transforms this into knowledge that can be used in business decision-making. For example, forest industry companies have information about properties of available material. This information is combined with additional data on the volume and type of requested material and the pick-up times. Stables possess information about the amount of horse manure, the required needs for bedding material, and operational performance; they require information about the availability of bedding material and reliability of the material delivery and pick-up, as well as the price of the waste management service. Based on calculations related to the information about the amount and exact physical characteristics of the composition of the delivered manure (e.g., the moisture percentage), plant operators can optimise their processes in a manner that ensures an efficient burn process that fulfils environmental regulations and site-specific permits. Logistics service partners have information about the available vehicles and estimates for delivery times but require logistics-related data, such as the weight, size, characteristics of delivery, collection/delivery time, and destination. Fortum combines all the data from the actors with regulatory and energy price information. All the data needs to be analysed to create an understanding of the relationships and information needs among different actors and to transfer this information into wisdom to be used in business decision-making; one goal is to optimise the complex logistics puzzle and thus keep costs under control.

Circulating information among organisations, academia, and authorities is needed to advance political decision-making to support the wider structural and system-level shift towards CE. This allows for so-called ‘matchmaking activities’, where one person’s waste is another person’s treasure. Furthermore, allowing the utilisation of waste materials such as horse manure as an energy source not only provides possible solutions to waste management challenges, but it also creates new opportunities for innovations within various industries.

Solita: The Amer Sports information platform

At Solita, the aim of information circulation is to manage data and information from various sources, including consumers, production, sales, and retailers. The information platform serves as a tool for managing the network of suppliers, connecting data on activated products by users, transforming this data into on-demand information for specific products in specific markets, and further transforming this data into knowledge on how to plan production and optimally respond to the demand. In addition, the availability of information on specific products is important from the deliveries and sales perspectives. The solution produces more accurate demand forecasts throughout the value chain, which can be further transformed into the wisdom to understand applications and relevant actions, such as the wisdom to orchestrate the network and utilise the possibilities for reverse logistics by combining the different information sources. The success of the solution depends on the quality of data, the accuracy of analytics solutions in forecasting the demand, and combining and sharing the forecasting-related information in a suitable format with production, sales, and retailers. Across different industries and contexts, the business concept highlights the potential of digitalisation and platforms as the enablers of a circular business. Connecting real-time information with the key actors in the business network as presented in this case is highly transferable to other business-to-consumer sectors (e.g., textiles and consumer electronics) to provide similar benefits at a societal level. Therefore, the information platform has the potential to considerably increase the sustainability of consumer-to-business sectors by decreasing their material, energy, and waste footprints.

UPM: The refurbishment and reuse of equipment and components

Information circulation focuses on basic equipment and components-related information from the EOL plants and the equipment demand and criticality information. UPM acts as a central node regarding the availability of information related to reusable components and equipment. This data is combined with the criticality analyses of different equipment and customer demands, enabling the creation of knowledge and wisdom with which to make decisions regarding the reuse of installed equipment. This is important for customers, especially when planning larger renovations or replacement investments. When the component is in reuse, operational data is collected and transferred into knowledge and wisdom to support the decision-making related to continuous improvements and to take advantage of potential further reuse possibilities. This results in more sustainable use of the used components and equipment. The solution depends on connecting the pieces of data from various sources, translating this data into information and knowledge, and sharing this internally with different network actors. Furthermore, translating this knowledge into wisdom means the creation of expertise in evaluating the reuse possibilities of the different components used by different customers and operating environments. Creating a transparent market of EOL equipment and components would be a major step forward for enhancing the sustainability of asset-intensive sectors such as the pulp and paper industry. The concept is also transferable to other asset-intensive sectors such as heavy machinery, mining, water, sewage, and electricity networks to provide more extensive societal-level sustainability impact. Extending the life cycle of these assets reduces their carbon and material footprint and is also a viable business for firms.

Discussion

The current study contributes to the CE literature by discussing the information as a catalyst for CE. Previous research on CE has mainly examined business concepts through biological and technical material cycles (Braungart & McDonough, 2002; Ellen MacArthur Foundation, 2013), but recently, the role of information has also been increasingly noticed as a crucial factor contributing to the success of these concepts (e.g., Despeisse et al., 2017; Jäger-Roschko & Petersen, 2022; Marra et al., 2018; Wiener et al., 2018; Winans et al., 2017). For instance, the use of data, information technologies, and emerging platforms has the potential to renew value creation logics, enable increases in resource efficiency, and discover new types of cross-sectoral business models by facilitating multidisciplinary information sharing and promoting collaboration (e.g., Aminoff & Kettunen, 2016; Ellen MacArthur Foundation, 2016; Ghisellini et al., 2015; Husgafvel et al., 2016; Tura et al., 2019).

The developed model sheds additional light on the different stages of information circulation, moving from understanding the data and information to transforming these into the knowledge and wisdom required to understand applications and the relevant actions required for making decisions regarding circular business solutions. The current study stresses the importance of the DIKW cycle (Ackoff, 1989) and knowledge management practices (Kakabadse et al., 2003) in circulating information from various sources and within different levels of actors in circular business development. To understand what kind of knowledge and wisdom can be created and what is needed often requires an understanding of what data and information flows exist and what their relationships to each other are (Rowley, 2007). As the case studies showed, data inputs assume different forms (e.g., information about processes, products, resources, needs and requirements) depending on the business concept. Some concepts require detailed information about a firm's internal processes and production equipment, as in UPM's case, while others expand outside the focal company's boundaries and consider the various needs of the network actors, as in Fortum's HorsePower and BMH's SRF as a service. In addition, different types of information pose different challenges for the required technologies and managing actions. The solutions can be centred on data, information concerning production processes, or information describing the status or condition of the production equipment. In other cases, orchestrating the whole network of actors requires deeper knowledge and the creation of wisdom regarding the needs of different actors, or how to apply new CE concepts to traditional ways of working.

In addition, the model for information use that is presented in this chapter emphasises the different levels of information circulation: the intra-firm level, which enables operational optimisation; network-level circulation, which facilitates multidisciplinary business development; and societal-level circulation, which supports wider system-level change towards the CE. As observed in the four case studies, although information circulation happens at the micro- or meso-levels, many CE solutions also have the potential to support the wider system-level shift towards CE, which has previously been acknowledged to be important in the achievement of sustainable development goals (cf. Korhonen et al., 2018; Schroeder et al., 2019). Thus, information works as an important catalyst in the on-going sustainability transition. However, further development calls for more concrete actions for information circulation to be made by different actors within a society, including local, national, and international authorities, academics, and business actors across industry boundaries. As previous studies show, unclear information management practices and a lack of methods and platforms can hinder the development of a CE business (e.g., Tura et al., 2019). Geng et al. (2019) argue that globalising CE requires the conservation of resources and energy, requiring the establishment of a global database to capture the trends and links between resource uses, and the development of a platform to share knowledge and experiences to both learn about CE and to coordinate industrial policies and trade.

It can be concluded that to circulate scarce materials, information needs to circulate as well; circulation may be a prerequisite for biological and technical material circulation. By generating, capturing, analysing, and sharing the DIKW, CE solutions can focus either on improving the efficiency of existing cycles or discovering entirely new cycles. Applying the developed model for empirical cases not only helped in specifying the most crucial information sources and related actions, but also highlighted the potential links with which to utilise the created knowledge and wisdom to enhance wider CE development.

As is the case with all research, our research has its limitations. As a methodological approach, design-oriented research is usually relatively context-specific. To enhance the generalisability, the developed model was tested in close collaboration with various actors from business and academia. However, developing and testing the model in other contexts is suggested. It has not yet been empirically explored how the type of business (e.g., a manufacturing or project-based business) affects the need to process information across different levels and what type of information is needed in various CE concepts. This chapter has predominantly focused on the role of information as an enabler of CE solutions. However, information-based solutions have their own extensive carbon, energy, and material footprints (e.g., Eerola et al., 2021).

Managing and refining information flows requires infrastructure and specialised competencies that can be expensive and difficult to obtain. Therefore, when designing CE solutions, firms should always consider the necessity and extent of collecting and analysing information to produce and maintain the solution. In addition, public and private organisations have somewhat different motivations and needs when it comes to implementing CE practices, and the availability and transparency of the information differs across these contexts.

Although the DIKW hierarchy has been widely used, it has been criticised for its oversimplification of the process of transforming data and information into knowledge and wisdom (Frické, 2019). Criticism has been directed at knowledge and wisdom being 'filtered' from information and data instead of resulting from a far more complex social, goal-driven, contextual, and culturally bound process (Weinberger, 2010). The criticism of the DIKW model was considered when developing this chapter's model, which accentuates the importance of collecting and refining data according to specific business needs to enable a CE business.

Although information was acknowledged to be based also on human resources, many of the studied concepts were based on considering information circulation regarding technical processes, products, and equipment. Thus, following Clube and Tennant (2020), future studies could focus more closely on examining the circulation of knowledge and its impacts on circular business development. Also, because many CE solutions are currently established at the intra-firm or network level, further studies could examine the requirements of information circulation at the societal level. The creation of circular solutions on a wider societal level necessitates the creation of mutually beneficial business relationships within heterogeneous networks of business actors, as well as relationships with nonbusiness actors.

Conclusion

The present study illustrated that information plays a crucial role as a catalyst in the development of a new circular business. To increase the rate at which societies are gradually transitioning towards CE, the role of information as an enabler for CE was discussed, complementing the previously emphasised biological and technical dimensions. CE solutions leveraging information may focus either on improving the efficiency of existing material flows or discovering entirely new opportunities for value creation. Information flows in CE solutions may relate, for example, to the condition of assets, the composition of material flows, relevant partners, and stakeholders. Including the role of information more closely in the research and design of CE models shows the potential for the development of more impactful circular business solutions at the firm, network, and societal levels. Thus, it promotes not only firm-level efficiency improvements, but also the development of multidisciplinary circular business, and provides support for wider structural and system-level shifts of economies towards CE.

Educational content

Information plays a crucial role as a catalyst in the development of a new circular business. How should the current CE model be revised?

Including the information more closely in the research and design of CE models is crucial in increasing the impact of circular business solutions at the firm, network, and societal levels. How can information support the research and design activities within these levels?

How can information circulation promote efficiency improvements, the development of multidisciplinary circular business, and support wider structural and system-level shifts of economies towards CE?

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12

DESIGN AS A CATALYST FOR THE CIRCULAR ECONOMY

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Introduction

Design *is* a powerful tool for change in the material world. We can design better products so that no materials go to waste, as in the natural economy, but this requires that the rationality, purpose, and direction to catalyse the circularity of economies is developed – not just in politics, but also in our educational programmes. This chapter's intention is to contribute insight into how design can be a catalyst for full circularity of products and materials. It presents both a review and critique of contemporary design's inability to address the complex problems of both today and the future that engage in closing the materials loop and going circular.

The chapter introduces a case about the design of typical solar cell panels and points out issues in relation to design for full circularity. The case is a real issue, a pedagogic case, which indicates the necessity to provide argumentation for change and show that by applying different sustainable design principles, new approaches can contribute to our thinking about design as a catalyst. This can be accomplished by specifically tying design strategies to how they might be used to effectively overcome the challenges of the current state of the take-make-dispose business models. One could argue that these design and production methods have grown out of a capitalistic economy that sees nature as a waste resource reservoir (Pearce & Turner, 1989). In a circular economy (CE), the focus is shifted from a treatment-of-waste strategy only to also include prevention-of-waste strategies. This is accomplished by applying certain principles, such as designing for disassembly to enable repairability, reuse, or recycling.

This chapter delves into available literature and draws upon the authors' experience in research-based teaching to identify and discuss directions for design as a catalyst for CEs. We look at the wicked problem posed by solar cell panels as an example of a product that generates renewable energy using green technology, that is not designed for end-of-life circularity. But we also discuss how they could be. Through design interventions, next-generation (photovoltaic) solar cell panels could be more sustainable at the materials, product, and service system levels. The case example is a typical design-challenging product that has provided the motivation (among many other cases) behind the development of a new design course, which aims to support a mindset for full circularity of products – one that will support an inner transition in educating and preparing designers for a sociotechnical transition towards a CE.

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The chapter discusses the implications, when teaching eco-design principles, of introducing new methodologies early in product development or when redesigning existing products. The design process is a complex cognitive process with several shared challenges. These emerge in the conflicts of routine versus disruption, old methodologies versus potential innovative ideas, and deductive problem-solving versus inductive idea generation.

The meaning of design and its potential as a catalyst for change

The word 'design' relates to the Latin word *designare*, which means 'to mark out' and has been used since early history to define how humans create, maintain, and transform the artificial, man-made environment (Cross, 2001; Moles & Jacobus, 1988). From the creation of simple artefacts and structures to intricate products, machines, and socio-technical systems, the history of design reflects on the co-evolution of knowledge, culture, social development, and the conditions of the environment with which we interact. So, it is not surprising that the meaning and use of the word 'design' is also in constant, context-dependent, re-definition, and diversification (Buchanan, 1992). Through the 18th and 19th centuries, industrialization deeply transformed both the artificial and the natural world and marked the beginning of design as a discipline, partly art and partly science, focusing on the acceleration of industrial, technological, and economic development (Buchanan, 1992). Several philosophical and theoretical movements followed this development, arguing either in favour or against the further alignment of design and the scientific method (Cross, 2001). In the early 1960s, the rise of increasingly complex problems, engendered by the cumulative effects of mass production and consumption, marked the further formalization of design as a *problem-solving* methodology widely applied in engineering and social sciences.

Design principles are more than creativity

Since the 1960s, there has been both a diversification of design activities in engineering, businesses, government, and other social services (Ceschin & Gaziulusoy, 2016; Manceau & Morand, 2014), and the reemergence of debates about the design-science relationship. As an example, Cross (2001, p. 5) claims that whereas scientific methods need to be repeatable, a method of design practice need not be. In most cases, it would be preferable that it cannot be copied. Considering this contrast to the epistemology of science, Cross (2001) argues that the theory of design has little to learn from science, and that it is better positioned to undertake the task of developing the *logic* of creativity. An argument against this perspective emerges when we perceive design as a means to achieve sustainability. Importantly, a design is made of more than creativity, and more than sustainability; it is about how to integrate the two, while ensuring functionality (i.e., mechanical engineering, quality, product standards), value properties, and aesthetics. We claim that no other discipline than design holds so much potential to excel in working with constraints.

This argument brings up another perspective on methodologies; Buchanan (1992) emphasises flexibility as one of the most important attributes of the design methodology when approaching problem-solving tasks. He says that in design, flexibility emerges from eluding reductionism (intrinsic to the scientific enquiry) and from the availability of various methodologies and principles that support the practice. Another concurrent debate pertains to the role of creativity in the design process. Dorst and Cross (2001) argue that, although it is very difficult to verify the occurrence of the creative event during the design process to assess the novelty of its outcomes, creativity is present in any design project, either as an explicit event (e.g., breakthrough) or as the implicit value that unique solutions might acquire over time. Runco and Jaeger (2012) suggest that the problem with, or perhaps confusion about, creativity in design derives from the lack of a standard definition linking originality and effectiveness. They conclude that originality, the basic attribute of a creative act, is not enough to ensure that a novel product or solution is in fact useful or valuable, therefore, creativity in design must also either have or be guided by appropriateness. Such distinctions have acquired notoriety in recent decades, as more design principles and methods are radically influencing the outcomes of the processes of innovation in circular economies and strategic decision-making in both private and public organizations, (Ceschin & Gaziulusoy, 2016; Liedtka, 2015).

During the last decade, much attention has been given to an emerging problem-solving approach known as Design Thinking (DT). Liedtka (2015) has indicated that although DT was originally used to improve the quality of the product development process and its outcomes, it is currently applied in the development of services, strategies, policies, education, and other social services. In practice, DT is a transposition of the creative way designers solve problems into a hypothesis-driven process of "how-might-we" questions that focus on the dual nature of human thinking, dynamically assessing the problem, multiple alternative solutions, and the tensions between constraints and possibilities through abduction and experimentation (Liedtka, 2015).

DT is particularly useful when decisions are made under conditions of high uncertainty or ambiguity, and when active iteration through learning and/or experimentation is required. However, we argue that the traditional design approach, serving foremost as a process for creativity, is not enough to guide system transformation; it needs methodologies and valued principles, not just at a product level, but from a product-service and system perspective. There have been several initiatives at the macro-level to push for more sustainability in our consumption and in our production systems. The United Nation's Sustainable Development Goal (SDG) no. 12, entitled "Responsible consumption and production", focuses on changing unsustainable patterns of consumption and production to achieve global sustainable development, and all major groups should play an active role. (United Nations, 2021). This goal emphasises the need for national and regional initiatives to accelerate a shift to promote social, environmental, and economic development.

Our recommendations on how design can be a catalyst for a sustainable CE are approached from various perspectives, for example, through the evolutionary path of eco-design practice and theory, and critique of previous and present design-thinking approaches when the primary focus is on the logic of creativity alone and not on integration with the logic of sustainability.

The logic of sustainability is approached from the perspective of design for CE and an example is illustrated by solar cell panels (photovoltaics). A solar cell panel represents a critical and illustrative example of not only the need to understand innovation opportunity at the product level, but also of the need for alignment at the policy level, meaning how policy frameworks can push for innovation and products that are better prepared for a CE than those we currently have.

Designing for a circular economy

In recent decades, one significant example of the co-evolution of design and developmental history has been the emergence of dedicated design principles, techniques, and methodologies for addressing the contemporary challenge of sustainable development. This section provides a brief discussion on the evolution of two concepts that are particularly relevant to the contemporary role of design in the context of socio-technical transitions: *sustainability* and *circularity.*

Design for sustainability

The concept of design for sustainability, although vague and with more than a hundred different definitions (White, 2013), has been roughly operationalised by integrating environmental requirements early in the design process of products, along with common social and economic needs. Initially, sustainability in design focused on reducing potential environmental impacts and the environmental footprint – the intensity of consumption of natural resources and services of a product over all stages of its life cycle, from important decisions taken in the design phase, during its production, and in its use to the end of life. This life cycle approach gives the designer an important responsibility when considering, visualizing, and selecting materials and manufacturing methods to design for a specified lifetime.

Sustainability in design has been all about minimizing the negative impact on the environment through eco-efficiency However, the critique is that eco-efficiency takes the linear approach to make the cradle-to-grave models more efficient by seeking methods to minimise the energy, volume, velocity, and toxicity of the material flow system (Braungart et al., 2007). Yes, materials can be recycled, but often as an end-of-pipe solution, because the materials were not selected nor the mix of materials designed for recycling, and therefore it most often ends as a downcycling, such as a degrading of the material quality by crushing or incinerating. Every year, we overshoot planet Earth's regenerated biological resources earlier than the year before. In this paradigm, the slopes will not be so steep on the Earth's minerals and metals, but the sources of the problems will not be affected. The benefit of the introduction of eco-efficiency is that it will make a clear difference in the short run, but in the long run, it will not change much.

Eco-design principles

The EU Commission introduced the Ecodesign Directive in 2009 to reduce the consumption of virgin materials and natural resources by decreasing energy consumption and increasing the recyclability of products. The Ecodesign Directive focused primarily on energy consumption, use of toxic substances, and the end-of-life (EOL) perspective on energy-related products (ERPs). Since 2015, materials are an integrated part of CE ideas that favour requirements for material efficiency, thus overcoming the previous critique of design for sustainability alone being an insufficient approach. In the M/543 Mandate of the EU Commission, the delay in the inclusion of material efficiency is partly explained by the absence of adequate metrics. "These include absence of standards for assessing material efficiency aspects identified in previous product specific Ecodesign implementing measures" (EU Commission, 2015, p. 2). According to the mandate: "An increased focus on material and resource efficiency aspects in the application of Directive 2009/125/EC should make a sizeable contribution to the transition towards a more CE by making consumer goods more durable, resource-efficient and recyclable" (EU Commission, 2015, p. 3).

The standardization request on material efficiency in the Ecodesign Directive is linked to three aspects of value supply in designing for sustainability: extending product lifetime, the ability to reuse components or recycle materials from products at their EOL, and the use of reused components and/or recycled materials in products. The M/543 Mandate presents a driver in the Ecodesign Directive for designing with a material-efficient approach in product development. The extension of the Ecodesign Directive and the material efficiency mandate to more product categories provides a framework that will allow producers to consider the environmental impact in a product's life cycle from the initial design stage to mitigate the negative influence of the product on the environment. One example is the recent inclusion of electronics, such as smartphones and tablets, with energy-efficiency transparency on the battery and the consumer's right to repair and change the battery if the battery is only chargeable up to 500 cycles. Whereas, if the charging function is possible for 1,000 cycles, then the product's battery can be designed and specified for professional replacement.

Although the Ecodesign Directive is complementary in use and purpose, due to the absence of an overarching design philosophy in sustainability to unify the design task, organizations will tend to use these tools indistinctly, to adapt the design process to external changes in national or international policy and regulations (den Hollander et al., 2017), or to shift consumption preferences guided by cultural and social purchase motives. As a result, the design tends to focus on a reactive optimization of the environmental performance of a product rather than on proactive innovation.

Design for cradle-to-cradle

The cradle-to-cradle perspective is a current global product standard, where product owners can achieve a certificate on their products. It is a private certification, yet highly a recognised one. It is a standardised type of 'product due diligence' across five categories of sustainability performance: (1) the materials used are safe for people and the environment, (2) the design enables regenerative product and process design for circularity, (3) the product design is protecting clean air, promoting renewable energy, and reducing harmful emissions, (4) the product is designed, produced, and can be circulated while safeguarding clean water and healthy soils, and finally, (5) the product's life cycle upholds social fairness by respecting human rights.

In contrast to eco-efficiency in the sustainability framework, the concept of cradle-to-cradle introduces eco-effective designs that strive to create material flows that create a workable relationship between the ecological systems and economic growth. Instead of a cradle-to-grave flow of materials, eco-effective design creates flows in which materials are used repeatedly at a high level of quality, and thus forming a cradle-to-cradle perspective. Eco-effective design is an integrated part of CE thinking as an approach that will take time to establish, since it requires design changes at the system level. Cradle-to-cradle design includes the creation of new value chains, business models, and supply chains that will have to be established. In the long run, the aim is that such an economy will allow the recirculation and reuse of materials, thus changing the future impact to establish the full CE (Braungart et al., 2007).

Design for full circularity

The circularity of products and materials is framed within a large and complex challenge, shifting from a linear economy to a CE. This shift implies looking at circularity not as one more economic function, but as a new economic paradigm. This means that we need to solve the challenge of economic growth, so that it becomes decoupled from the fast consumption of natural resources, and the vast amount of waste that goes to landfills or incineration is eliminated or at least slowed down by maintaining products, components, and materials at their highest utilities and values (Dokter et al., 2021). For design practice, this implies the further diversification of the Design for X (DfX) toolbox of Design for Durability, Serviceability, and Disassembly, and the adoption of new guiding principles for technological upgradability and energy efficiency.

The foundations for CE have emerged from the synthesis of several schools of thought. Major contributors include Walter Stahel, who introduced the service, or performance, economy proposed in his *Inertia Principle*: "Do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle a product that can be remanufactured. Replace or treat only the smallest possible part to maintain the existing economic value" (Stahel, 2010, p. 195). Other giants who have played a central role in laying the foundation for schools of thought are William McDonough and Michael Braungart with their cradle-to-cradle design philosophy, Reid Lifset and Thomas Graedel with industrial ecology, and Amory and Hunter Lovins's natural capitalism. But it was Gunter Pauli (2011), with the blue economy, who noted that the world market for waste and recycling was worth USD$450,000 million in 2010, while Nam (2015) estimated that the market for "reusing those materials takes up 0.01% of the overall market" (Ahn & Lee, 2018, p. 3). However, circularity is not without challenges. Bocken et al. (2016) argue that establishing CE flows requires that recycled materials have properties equivalent to the original ones; they claim this can only be accomplished through de/re-polymerization or closed-loop recycling. This is a complicated task and can be considered as a utopian approach, because all materials will degrade over time.

To catalyse a product's material circularity calls for the consideration of not only one product purpose during the design phase but in designing the product for a second or even a third commercial afterlife. For den Hollander et al. (2017), the operationalization of this principle in design refers to maintaining a product's *integrity* – its original form and function at manufacturing – if possible, in circular use, which would reduce, or even eliminate, the environmental cost of any intervention needed to maintain or restore the product's added economic value. However, shifts in cultural or socio-technical conditions can render the use, appeal, or value of a durable product as obsolete, limiting value retention options to recycling and upcycling. In this case, upcycling – the use of discarded materials to create a new object of higher value (Sung, 2015) – is preferred over recycling. Nevertheless, as an economic activity, upcycling is not yet as well-established as recycling.

In general, complex durable products are often easy to repair or refurbish but much more difficult to recycle (den Hollander et al., 2017). Still, even if discarded products, components, or materials can be fully recycled, value retention might still be limited by cultural, economic, or technical barriers to the use of recycled materials, recyclates, in manufacturing new products. Although unused recyclates can be stored until further use becomes possible, in large quantities and over undetermined periods of time, this is no different than hoarding. If materials do not circulate, new material inputs will be required to supply demand. To survive as an economic service, the recycling activity needs to achieve and sustain a considerable and constant flow of materials and recyclates. However, this is in opposition to the goal of increasing product value retention through durability and integrity because recycling is basically a destructive activity (den Hollander et al., 2017). These important conceptual contradictions emerge from the approach of the current DfX toolbox, since each technique focuses on one aspect or activity in the CE independently, and not on circularity itself; this leaves many choices open for the designer.

The subsequent introduction and popularization of the concept of circularity in business organizations encourages focusing on the optimization of quality products and towards innovation of products and services. In its most basic form, circularity in businesses means keeping the flow of products and materials circulating, and if possible, to increase value retention by mimicking the efficiency of ecological cycles during which nothing is wasted. Value retention in products is commonly achieved through design that prolongs the product usage stage through reuse, repair, refurbishment, or remanufacturing, while value retention in materials commonly refers to recycling at the product's EOL (Ceschin & Gaziulusoy, 2016; den Hollander et al., 2017; Dokter et al., 2021). In this context, the role of design focuses not only on product development, but also on the development of new services, function, and processes. However, den Hollander et al. (2017) argue that in practice, circularity often focuses on material retention, recycling. This is a less costly and challenging type of innovation from the perspective of both design and management, but also a far less valuable option than product retention in terms of environmental and economic sustainability. In this context, one would argue that if circularity is based only on material retention, it is not sustainable. A product that cannot be recycled for reuse in some form at its EOL does not hold value.

When designing new products or redesigning exiting ones, we must remember that design principles and approaches are currently the only means to solve design problems, and the extent and value of design solutions are only as great as the scope of the problem they attempt to solve. Ceschin and Gaziulusoy (2016, p. 119) suggest that sustainability is currently understood as “a system property and not a property of individual elements of systems” that involve a process-based, multi-scale and systemic approach to planning, rather than the usual goal-based optimization. This distinction is relevant. For example, when we discuss a CE, we also focus on nature’s resources for a sustainable future; when we talk about green conversion, climate, and nature’s resources, we must make sustainable designs and avoid toxic materials, use fewer materials, and make sure we can separate the materials afterwards in clean fractions (i.e., design for disassembly), so that they can be recovered and recycled, thus avoiding landfills and incineration.

In the next section, we show how a design for circularity can be used to assess products and thereby innovation opportunities at the product level and the manufacturing level. We also show how policy frameworks, if they are aligned, can be a catalyst for change in design – provided, of course, that the consumer or industry is willing to pay a little more for the most sustainable solution for the future or at least during the transition period.

Example: Solar cell panels for circular design

Solar power is one of the champions in the green transitions that are shifting from coal, oil, and gas. But who really knows what happens to solar cell panels when they no longer work efficiently and need to be scrapped? The solar cell panel is a typical and challenging example of transitioning towards a CE.

The International Renewable Energy Agency estimates that by 2050, there will be 78 million tons of solar-panel waste in the world. Today, 85% of the material used in solar cells can be recycled (Heath et al., 2020); the remaining material is scrap. From a design-for-recycling perspective, the issue is that some of these products’ materials are glued or melted together making some part unrecyclable or even not allowed to be incinerated as the process would release unhealthy chemicals (SDU Press and News, 2021). Figure 12.1 show a 3D model of a typical solar cell panel illustrated using Autodesk Inventor (2022). In the following, we will refer to ‘the backside’ foil and ‘the stringed solar cell’, when discussing issues such as the material composition of the backside foil and lead in the soldering connecting cells.

Issues with the current design

Two design issues that block a circularity strategy can be mentioned, because even though we have the knowledge that certain chemical compounds are unhealthy, they are used anyway because they are legal, cheap, and very functional.

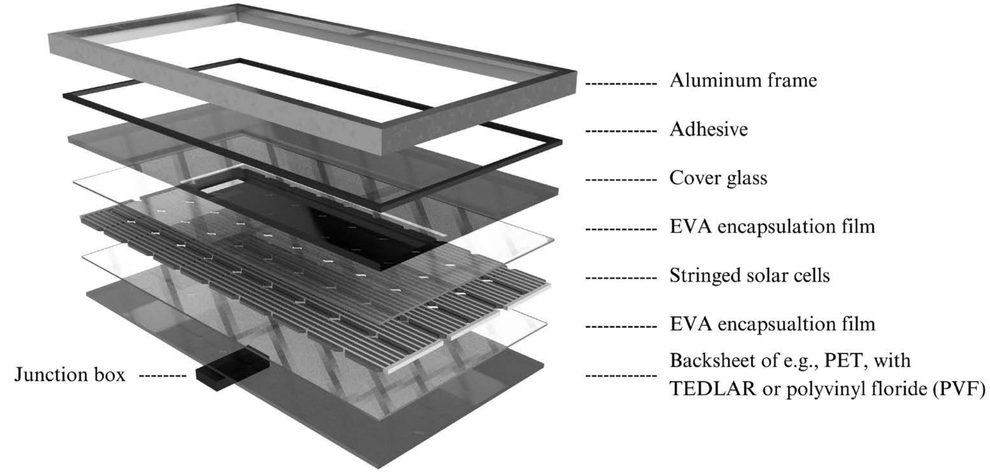

Figure 12.1 The sandwich layers of a solar cell panel, 3D model.

Issue one is the backside foil that is designed to last but not for recycling. Some of the first-generation solar cell panels consisted of glass panels on both the front and back sides of the unit, but to make them more lightweight, most manufacturers have substituted the backside glass panel with a foil – either a polyethylene terephthalate (PET) polymer (what water bottles are made of) or a polyvinyl fluoride (PVF) polymer. To compensate for the glass protective side for the electronics, most foils are made of PVF – a material with excellent protective functional properties for the outside. But the backside foil is glued together to the stringed solar cells by the tough EVA (ethylene-vinyl acetate) encapsulation film, which is making it hard to separate these parts as to prepare for recycling (Fiandra et. al, 2019). Materials like the backside foil cannot be easily recycled (often too costly) and incineration, is only an option if the incinerator is fitted to scrub out hydrogen fluoride. So, the backside foils are currently placed in landfill deposits as the "best" option for their disposal.

Issue two is the use of lead in the soldering. Lead is a toxic heavy metal that accumulates in nature and in humans; the EU has banned lead in nearly all electronic products. Most photovoltaic (PV) products or solar cell panels contain lead, as these products are still excused from the EU lead-free directive. According to *PV Magazine*, which is a leading international solar cell magazine, a typical 60-cell crystalline silicon solar module contains up to 12 grams of lead (Hutchins, 2019). As long as the lead is in the solar cell panels, it is not dangerous for the environment. However, factory workers are exposed to it during manufacturing, and if solar cells are not handled correctly in recycling, there is a risk that the heavy metal will be released as dust particles. It can be argued that the exemption in EU legislation is from the time when solar energy had to compete with fossil fuels in terms of price and efficiency, and lead was the solution to make solar cell panels cheap and energy effective. But today, the situation is different. It seems unnecessary to use lead in the solar panel soldering. The electronics and automobile industries have shown us that it is possible to manufacture complex products without lead. Retaining this exemption for solar cell panels does not exactly drive the innovation and development of new solutions. As Hutchins (2019) argues, there are several alternatives that could completely replace lead, but the problem is that PV manufacturers are not motivated to replace lead with more expensive solutions, such as tin, when it is still legal to use lead.

Policy support to design out unnecessary chemicals

It is obvious that EU policymakers should reconsider the necessity to continue to exempt solar cell panels from the general legislation applying to electronics, thus pushing the solar cell panel manufacturers to compliance.

The International Technology Roadmap for Photovoltaic (ITRPV, 2022) publishes a yearly report overseeing the market share for solar cell technologies. In this report there is among others an overseeing of also the market share of different cell-connecting technologies. As the diagram of the ITRPV 2022 forecast in Figure 12.2 shows, solders that contain lead are today the standard technology. Even though lead is being phased out by producers, lead is still expected to be present in over 55% of the solar cell contacts in 2030. In the ITRPV 2019 forecast it was expected to be 50% by 2030. It is good news that phasing out is underway, but this transition moves slowly in relation to how fast we want the green transition to move.

How design for circular economies can fix the problem

To be sustainable, products also need to be designed with eco-friendly design principles, such as designing out chemicals that may present a barrier at the EOL to either reuse or recycling. We could say that the problems design has created, are also problems that sustainable design can fix.

For example, using material from scrapped solar cell panels to make new ones is still problematic, so how can we make reuse easier in the future? For one thing, we could design solar cell panels that avoid using toxic materials such as lead. We can use fewer materials as to design for durability and not mortality, and we can make sure materials can be separated afterwards so they can be reused at a higher value than now (i.e., reuse of silicon in new panels) instead of being crushed and downcycled. Particularly, the EVA glue film (ethylene-vinyl acetate) that binds the solar cell together and keeps it robust in all kinds of weather makes is incredibly difficult to disassemble the panel in large elements.

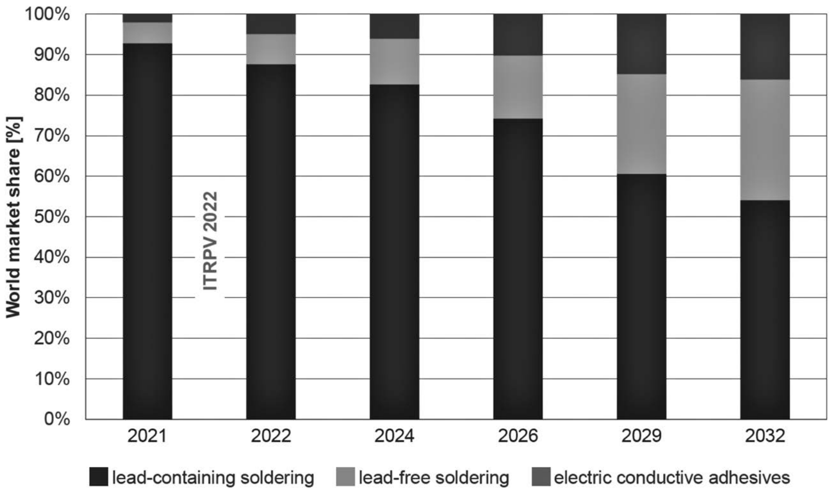

Figure 12.2 Expected market share for different cell-connecting technologies, ITRPV 2022 forecast.

Today, wires are removed, and aluminium from the frames recycled, while some of the remaining material is crushed and used in the steel industry or as road fill. Much of the glass is crushed into small fractions, leaving mixed residues consisting of common polymers, non-polymers, and residues of lead, silver, and copper, which have not been separated before crushing. These mixed fractions are not very valuable; they cannot be recycled for use in new solar cells, because it is cheaper for manufacturers to buy new materials. If a way could be found to dissolve the incredibly strong polymer lamination, the glue between glass and solar cells, it would then be possible to recycle more silicon and glass in whole and separate parts. This could create a market at a higher value for reusing more of the fully moulded materials. Recycling these materials would utilise the resources of the waste material, but also increase the product's carbon footprint. The argument, however, is that recycling is not likely to emit more carbon than the current process of both acquiring new raw materials and processing them. Repurposing the product is the alternative for retired material, but products are generally not designed for that either.

The solar cell panel is a very typical example and a strong motivator for the need to learn from the problems that we face from the linear design thinking approach, and then make a change in educating for the future when designing for circularity. It is no longer enough to point to the wider ecosystems and socioeconomic developments to assess and address their current problems. There is also an urgent need for capacity building. We have understood that the teaching of sustainability in universities needs more integral approaches, and this motivated us to develop a new intensive course for our design engineers named 'Sustainable Materials in Product Creation'. In the next section, we share the background motivation and the course's learning objectives.

Education: Designing the inner transformation

Universities play a vital role in capacity building because education is a tool for inner transformation. In the publication "*Engineer of 2020*" (US National Academy of Engineering, 2004), problems related to climate change and the environment were expected to become critical in 2020, and solutions to sustainability were expected to be a high priority focus for engineers' aptitude and ingenuity. Engineers were also anticipated to have a strong ability to learn new things and to apply their knowledge to entirely new problems and contexts, and at a faster pace than earlier generations. Although academic preparedness for attention to environmental developments was proclaimed a high priority a decade earlier, a study from Chalmers University in Sweden supported the prospect that companies would experience a lack of knowledge in sustainable development among newly graduated engineers (Hanning et al., 2012). Already then, scholars pointed to more engineering courses integrating sustainability as part of the solution. Guerra (2017) argued that a successful integration of sustainable development in engineering curriculums would require an approach in which students develop a holistic and systemic view of technical problem-solving that uses sustainability principles and applies a broad framework that covers both environmental, economic, and social contexts. However, each of the various types of engineers in an industrial organisation often works within its own specialised issues (Gericke et al., 2020). This leads to what is known as working in silos, which is described as one of the key challenges for improving the absorption of new methods. Design methods often aim directly at creativity, while the indirect link between systematic design methods and innovation is often disregarded. Junyent and Geli de Ciurana (2008) advocate a shift in the engineering educational paradigm by highlighting the importance of contextualization in teaching. With an ambition to break down silos and integrate CE with Design Thinking, we created a new design course for engineers.

The experience of creating a design course for engineers in a circular economy

During the spring semester of 2020, the course 'Sustainable Materials in Product Creation' (SMPC) was implemented for the first time as a part of the master's level engineering programme in product development and innovation (PDI) at the University of Southern Denmark. The ambition behind the new course was to educate engineers to think about sustainability from the outset.

The main idea behind starting the course is that designers and product developers play a key part in developing more sustainable products. As the EU Ecodesign Directive has recently pointed out, up to 80% of a product life cycle's sustainability impact is determined at the design stage. In the course, students work with thinking in circular value chains and with how to develop products with CE principles in mind. Thus, the students work with designing the entire product life cycle and not just the product itself. This means that the students need to have an extensive knowledge of the materials used in the products they develop.

The course integrates eco-design and green engineering principles in the didactics of problem-based learning. The learning objective of this approach was to provide students with insight into the different aspects of sustainable design and an understanding of limitations and opportunities shaped by materials when they considered sustainability and the possibility of circular material flows. The aim was also to engage the students with companies in several innovative processes, where they focused on re-creating or redesigning products and/or creating new products from upcycled materials. For the learning objectives, see Figure 12.3.

The intention in rethinking this master's course was to prepare the candidates for a future where they think beyond the traditional uses of materials. Instead, they should think in terms

This course will assist students to develop their understanding and knowledge of:

- Recycled and sustainable materials in the product creation process.
- The practical considerations of incorporating sustainable materials into the production process.
- Methods of reflective practice in the field of product design.

Students will have multiple opportunities to apply and reflect upon their ability to:

- Explore approaches to understanding material selection by gaining real life input from external companies.
- Plan creative product design concepts and prototypes as a strategic approach to understand the limitations and opportunities of sustainable materials.
- Effectively communicate an understanding of value added via sustainable materials.

In this course, students will work in teams to challenge themselves and so develop competencies in:

- Practical project management.
- Identifying and initiating action on opportunities that emerge from real world research and practical experimentation.
- Reflecting on the role of sustainable materials in the entire product lifecycle.
- The ability to feed test data into the product value creation process.

Figure 12.3 Learning objectives: Master of science course in sustainable materials in product creation.

of circular material flow and develop new methods to make the best possible use of materials. The course involves group work, participatory teaching, and curiosity-driven research. Through the company cases that the students work on, the aim is that they can apply the knowledge they acquire from the course to real-world sustainability challenges. Through their work with sustainable materials and design of the entire product life cycle, students become better equipped to handle the world of change they encounter when they enter the job market – precisely because so many companies, either right now or in the future, face challenges when it comes to restructuring to the use of more sustainable production methods.

In the course, students are split into groups, in which they participate in an array of workshops. Through these workshops, the students learn about the repurposing of materials, system thinking, and CE. When developing the course, we contacted companies with expertise in sustainable development and the reuse of materials. In their groups, the students work with concrete cases through cooperation with real businesses. To solve these cases, the students must come up with ways to repurpose materials from the businesses' products. Through the cases, students gain an extensive knowledge of materials, reflect on the challenges of recycling, and gain experience with building concepts and mock-ups for visualising their ideas.

By letting the students work in groups with company research teams, the aim of the course was to let the students experience what it is like to work in both a practical and academic way with material driven product development. Furthermore, it gave the students a way to critically reflect on how products can be designed in a more environmentally friendly way even today, and how the materials we choose in the design phase have an impact on whether materials can be reused or whether they just end up in a landfill.

Material design thinking for circularity

A Material Driven Design approach and system thinking are introduced as a guide to design based on waste materials or to investigate the CO_2 bill of materials for a given product and the materials' recyclability. This method contradicts their normal way of thinking, which is usually linked to the three phases of the DT method: 'inspiration', 'ideation', and 'action' (Coco et al., 2020).

As an experiment, the course introduced a new approach framed as a material driven design approach. Instead of teaching the students to select materials for a product idea, they were given one material related to a current and relevant societal waste problem, where the task was to understand and analyse a waste material through the lens of the CE. The students were challenged to explore the material's properties through research and lab tests, to take a design approach to materials in which the idea for a product's commercial afterlife would emerge from the opportunities and limitations of the material. This method clashes with the traditional material science approach, which selects materials on a business-as-usual basis, but the course presents students with the actual environmental problems existing in the backside of the take-make-dispose model. This approach introduces students to designing for a product's commercial afterlife. Thus, students are being challenged to design using circular value chain thinking and not only focus on the product.

Normally, and in classic DT approaches, the designers select materials based on matching product requirements with material properties. In the cases described previously, it was vice versa – after selecting the materials, the application idea was based on exploring the used or recycled materials' limitations and opportunities. The Material Driven Design Method (MDDM) starts with a selected material, then designing for a commercial afterlife, or working with an existing EOL product (e.g., wind turbine blades, upcycled textiles, or eelgrass). These were just some of the cases that we worked with.

One question to ask is: what is the product material afterlife? Sometimes, also for pedagogic reasons, to discover that the 'afterlife' options for a product are limited and often caused by some design decisions; this leaves us with the question: how could it be redesigned? As a reflection, Anastas and Zimmerman (2003) introduced, in 2003, the 12 principles of green engineering as a foundation for what is also grounded in the eco-design principles, where principle 11 is 'Designing for a commercial afterlife'. This principle focuses on designing products with the aim of recovering components that remain functional and valuable through up-front modular design, so allowing for repair, refurbishing, or sorting of materials in clean fractions for recycling. The aim of incorporating this principle in this new method is to create meaningful applications of materials with all aspects considered, especially both aspects of the material experience and aspects that ensure that the properties of the material are fully and optimally exploited throughout the product's life cycle and can be reused or recycled.

Even though both material and design industries are becoming increasingly involved in the challenge to realise the functionality and meaning of a material in a creative way, systematic approaches are currently limited when it comes to defining the experience of a material (Karana et al., 2015). Karana et al. (2015) distinguish between 'material thinking', where the technical material properties are explored as embodying a product (what it is) and material driven design, where the experience perspective is added as an extra layer to embrace the material for what it does, expresses to us, provokes in us, and makes us do.

The process of development with a MDDM is advised as an organised approach to explore and understand the material, in cases where the material is fully developed, partly developed, or entirely unknown, and thus having limited databases of the technical characteristics of the materials available. The initial experimental step of the method, engineering tinkering with the material, allows the designer to assess sensorial, interpretative, affective, and performative levels of the material through the construction of a mind-map to discover implicit motivations for using a material or composites in different applications (products). The construction of such mind-maps could also allow the designer to discover interrelationships between emotions, performances, sensorial potentials, and meanings of the material.

Material Driven Design as a method for product development is a four-staged process (see Figure 12.4). Material benchmarking is part of the experimental first step, where the material is positioned with a group of comparable materials and their corresponding applications. This is done to compare and expand the search for applicability areas. Benchmarking the material is expected not only to illuminate the potential application areas, but also lay the foundation for revealing strategies, values, or issues within the design domain, which is part of the second step. This step accentuates the current time dimension, for example, 'cradle-to-cradle' and 'design for sustainability'. After this initial step, designers have often established a probable intended use but deciding on the application of the material from this basis alone could lead to conventional solutions and utilizing only the value of the material, such as its mechanical or aesthetic properties.

How does the designer visualise the role of the material and its contribution to the performance of the potential product it embodies? Developing the material experience vision is the second step of the MDDM. This vision should address the material's purpose in relation to people, the planet, and society to recognise paths toward future applications. The mind-map, benchmarking, and vision now serve as the foundation on which to create a material experience pattern in the third step of identifying the interrelationships between the formal qualities and the experience vision of the material. Using the MDDM should be considered an iterative process that could potentially

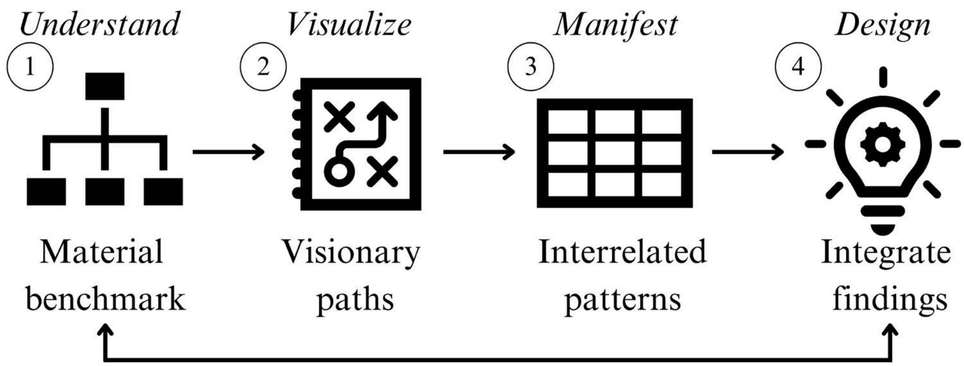

Figure 12.4 A simple illustration of the Material Driven Design Method.

require interrelated loops. In the course, we applied the use of an online materials library, a software license programme named Ansys Granta Edupack, where our students could look up each material or create a layered hybrid material and thus get information on the mechanical properties, the carbon footprint, cost, and the opportunities for reuse, recycling, downcycling, or if the created material would go to landfills or incineration. The use of this materials bank was an important step for the analysis before tinkering with the materials in practice or combining two materials.

How we did it: Teaching method

To summarise the pedagogic teaching model for combining design principles with material tinkering (the MDDM) and application in real cases, we:

- Taught the students about design principles for CE to envision diverse directions of sustainability (design lifetime, commercial afterlife, and/or recyclability) – already encountered in the decision stage.
- Invited industry case owners into the on-going process of expert knowledge sharing.
- Presented students with cases derived from real-life challenges in industry, either redesign of existing products to design for repair, technological upgradability, or new commercial afterlife of waste materials for material circularity.
- Encouraged material driven design thinking to offer a design approach grounded in material properties, and analysis of the environmental footprint and their cyclability (before initiating Design Thinking).
- Offered material test lab work and online library material, and software for obtaining knowledge about the materials, their properties, potential substitutions, and their recyclability.

Observations

A general challenge with the new teaching method was found to be the students' inherent tendency to start with creativity related to product ideas, meaning they formulated a problem using a confirmative approach: "Can the material be applied for this specific use in a commercial afterlife?" rather than the explorative approach of sustainability that asks: "For what use can this material optimally be applied in order to secure a commercial afterlife?" It was most certainly a struggle to stay with this new method of exploring the material and let ideas grow from its properties. In the end, it was a challenge that the students reported they were proud of and learned a lot from, as we see through the implementation of these concepts in the master thesis projects that they worked on afterwards.

One of the first case challenges in the course was the recycling of wind turbine blades to avoid end disposition in a landfill. This challenge included separating chemicals and reusing composite materials like coal and fiberglass in a new, circular process. Another case challenge was to explore solid boards made from upcycled textiles using air-laid technology, which used no water. The solid boards were introduced by the company as converting textile waste materials into either acoustic felt or solid boards. Here, the students had to understand the material, its mechanical properties and its aesthetic qualities of what it could become. As well, students had to consider the materials' weaknesses, meaning what the materials could not be used for, such as the material would absorb water. An example of a common challenge reflected upon in the students' reports is the challenge of finding or gaining access to information on the products and their materials. The following example is from a case investigating a commercial afterlife for used wind turbine blades that consist of both organic materials like balsa wood, but mostly composite materials made of glass fibre enforced epoxy (plastic) in sandwiched layers, and thus are difficult to recycle:

> Transparency issues contributed to the problem because blade manufacturers keep blade data close as part of the company's intellectual property. Information on the exact material composition and the adhesives used for assembly could clarify the problem and make it easier to find possible solutions. . .
>
> or
>
> Lack of knowledge around composite mechanics and calculations also proved to be restricting and time-consuming, and in combination with the uncertainty of the composites resulted in an unknown factor of the applicability of the materials. The material origin and damage potential create uncertainties of how to use these materials because planning of strength requirements is quite difficult without knowing the properties of the laminates, e.g., condition, orientation, matrix, and fibre type, etc.

This experience from teaching the course shows that design for contemporary product development reflects the systemic nature of CE with its diversity of available techniques and lack of conceptual integration to support system innovation. What is urgently required to facilitate the flow of materials at the systemic level is transparency in the supply chain and traceability in the material streams. One consideration is to introduce traceability in a circular supply chain by implementing unique identifiers in products, as also suggested by Franco (2017) or what is already done in medical device products, they have unique device identifiers (UDI) traceable to manufacturing and supply chain.

Key takeaways: The dynamics of the learning

Considering the key takeaways from theory and the reflective learning practice identified from the course's student reports, changes are required on a broad spectrum to improve the problem-based learning approach related to designing for a CE. Clear principles of sustainability are relevant tools for the students, and a material driven design perspective is necessary for an explorative approach to what decisions we as designers make. Such decisions will have consequences for the environment and for either hindering or creating possibilities for product or material recirculation. We need new approaches that can relate to the challenges of circularity from today's product design – and which include both EOL challenges, material flows, and solutions that integrate the environmental impact with the social and economic impact.

First, we experience that the students gained an understanding of the meaning of sustainable design and the design principles this involves. Second, and more importantly, the students also gained an understanding of how important their role as designers is for sustainable products. Third, through the business-driven cases used in the course, the students also were able to implement the knowledge they gained in the course to solve real sustainability challenges.

Every year, we take in new cases, as this provides not only flexibility but also enables us to develop the course and the methodology to moving from a problem-centred method to a flexible problem-solution process that recognises the explicit duality of human rationality and behaviour. Because as we see it, solutions must reflect the dynamics of the times we live in and challenge the assumptions.

Perspectives on design as a catalyst for socio-technical system transformation

Clearly, the role of design in the transition towards CE does not begin and end at the level of product or service innovation; rather, it restarts with the synthesis of the economic transition. As Banathy (2013, pp. 1–2) suggested already in 2013, "In an age when speed, intensity, and complexity of change increases constantly and exponentially, the ability to shape change, rather than being its victims or spectators, depends on our competence and willingness to guide the purposeful evolution of our systems, our communities, and our society." This notion leads us to bring design into a discussion of socio-technical systems.

The fundamental transformation of a socio-technical system is the result of multiple processes. It is a transition unfolding over several decades, leading to extensive changes across different technological, material, organizational, institutional, political, economic, and socio-cultural dimensions (Markard et al., 2012). During a socio-technical transition, new functions, processes, products, services, business models, and organizations emerge to complement or replace existing ones. At this level, design approaches focus on promoting radical changes on how societal needs are fulfilled through technological, social, organizational, and institutional innovations (Ceschin & Gaziulusoy, 2016). However, it is important to note that in practice a socio-technical transition, for example, the practice of moving towards sustainable development, is a wicked problem (Buchanan, 1992), and there is little experience designing transitions at such a level of complexity.

The process of sustainable design is an evolutionary one, but it can be stimulated by changes at the meso-level created when new problems arise, for example, public resistance to pollution or price increases for scarce resources. There can be changes in technology or changes in the landscape pushed by policy; we have argued that the EU Ecodesign Directive or the EU Lead-free Directive should apply for all product categories and not select exceptions. Transformations occur when developments at multiple levels strengthen each other in a new form (Geels & Kemp, 2006), resulting in dynamic transitions between industries, new policies or regulations, new networks, and value chains, or even because of industrial symbioses.

A particularly difficult, yet critical task when designing transitions is the need to anticipate and ideate the conditions of the system we want to achieve; an ideal system that does not yet exist. Transitioning from present to future states can be either the result of an unintended effect or a rational endeavour. If an intended effect, we need to design a roadmap for actions to achieve the desired future; a strategic set of plans defining roles, goals, and timelines needs to be generated. Although design inherently always looks into the future by producing something that does not yet exist, we argue that the abstraction required to define alternative futures is not an explicit function of the design process, but rather an implicit trait of design thinking. Gordon et al. (2019) suggest that, as a problem-solving approach, DT inherently looks into the future of potential solutions. We argue that education-informed design has ample application in system innovation, notably for the ideation and synthesis of alternative distant future socio-technical scenarios and potential roadmaps for transition to a CE; in this context, inclusive participation and collaboration of actors and stakeholders is in the process of co-creation of alternative futures. Wilkinson et al. (2014, p. 1) conclude that large-scale changes in socio-technical and political conditions can be induced through "open and collaborative innovation processes in which diverse interests collaborate to co-create the future."

Design processes can be both participatory and exploratory, and they can internalise the knowledge, interests, and expectations of multiple actors within the socio-technical system. By enabling the co-creation of alternative narratives to assess past and present conditions and to devise future outcomes, design can act as a democratic platform for social learning, a crucial requirement for effective system innovation (Wilkinson et al., 2014). In retrospect, we can conclude that the relationship between design and change has a dual nature: design changes the artificial and the natural, but also reflects such changes in the constant evolution of its meaning and use. The theory and practice of design, therefore, both internalises and externalises the changes in our collective evolution.

Design can change the fast consumer product trends, an almost neophiliac culture, when it shifts from designing products for short life cycles to longer life cycles. However, as a process to guide the required innovation of systems, the current design methodology is not sufficient. It must be supplemented with the theory and practice of other disciplines as we seek long-term sustainable solutions. We argue that a systemic innovation view of design is needed; it couples design thinking with future planning to support the vision of decoupling economic growth from the increasing resource use and boost sustainable growth. One way to achieve this is to introduce foresight methodology that focuses on participatory processes and techniques, such as exploring EOL scenarios and co-created roadmaps for developing solutions across the entire value chain, from design to manufacturing to full circularity. We see these steps as more open innovation approaches with interesting possibilities for both the theory and practice of system innovation. The how-to includes an emphasis on coupling the design process and the strategic policy process at both the macro- and micro-levels as well as strategic decision-making processes in business organizations. A catalyst from a design perspective for a CE, in this sense, is not just one thing. Multiple drivers and forces with an impact on product design choices can become a catalyst if they are aligned with a vision of a sustainable future based on dynamic learning processes.

Conclusions: The full circle

Product design is a highly adaptive process at the micro-level of system innovation, responding dynamically to new conditions at the meso- and macro-levels. But we also need to focus on the inner transition and reform our education by teaching design that integrates sustainability and circularity to show how we can get to a sustainable outcome. We will then be able to fully utilise design as a catalyst for CEs in a sustainable future.

We conclude that the role of design as a catalyst of change, as a rational and creative process, can guide the development of valuable products and services to design for circularity. We have argued that, in the context of a CE, the strategic value of design as a catalyst of change lies in creating and accelerating movement towards a sustainable future. This requires the co-creation of a future CE through collaborative and inclusive definition of distant scenarios for sustainable systems of production and consumption, which can elicit new narratives to discuss and define the new directions and timelines our current socio-technical systems could follow. We see a need to produce clear visions of what the future of a sustainable CE should be, including action plans for aligning policy and product standards with the application of eco-design principles.

As a catalyst of change, design overcomes inertia and creates movement, operating simultaneously at all levels of socio-technical systems as a quality, function, process, and product. Thus, design can modify behaviour, guide strategies and decisions, set and reflect patterns and trends, fulfil and create needs, visualise and materialise ideas, solve problems, innovate functions and processes, and transform the material and immaterial configuration of the human-made world.

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13

CIRCULAR ECONOMY AND FINANCE*

Either a straightforward relation or a virtuous loop?

Claudio Zara and Luca Bellardini

Introduction: The sustainable finance environment

A serious and effective transition toward a circular economy (CE) has become an urgent need to keep economic systems competitive, as well as to match the economic development with the needs of sustainability. This statement is matched by evidence in different geographies, such as in the EU (European Commission, 2018), North America (Enel North America, 2021), and China (Bleischwitz et al., 2022). Hence, policymakers are acting to set up and boost the rethinking of the current linear economic paradigm, like in Europe with the European Circular Economy Action Plan, issued by the European Commission (2020). This extensive change asks to mobilize significant amounts of financial capital to support the broad investments that the transition needs. As proof thereof, the EU's *Action Plan: Financing Sustainable Growth* (2018/097 final, 8.3.2018) includes – among its main actions – steering the flows of financial capital towards the investments needed for targeting the foreseen transformation, as well as necessary for reaching the political goals related to sustainability issues, such as climate change mitigation (Schröder & Raes, 2021).

In a widespread and commonly agreed view, finance is called to play a key role as a catalyst for supporting the circular transformation of the economy (Tellini et al., 2022). This is the position usually taken by policymakers: either regional, such as the EU with the previously cited *Action Plan: Financing Sustainable Growth*, or global, such as the *2030 Agenda* (United Nations, 2015), which pursues 17 Sustainable Development Goals (SDGs) needing huge capital flows to fund investments for them to be achieved (WBCSD, 2017). In accordance with this view, in the first decade of this century, the debate on the relationship between CE and finance was around the claim that the latter should promote and support the circular transition, asking why finance was not acting as expected (*inter alia*: European Investment Bank, 2015; European Commission, 2019; FinanCE Working Group, 2016; UN PRI, 2016). In the current decade, the focus has partially shifted from a 'must do' approach to discussing which are the obstacles that slow down the expected financial flows toward circular investments (e.g., NSW Circular, 2022; Sitra, 2016). Nevertheless, if we are willing to understand why finance has neither targeted nor scaled the CE as a major investment theme, it is of paramount importance to understand the conditions that may empower the relationship in the next years. Without a complete engagement of the financial

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services (FS) industry, the transition to a CE would be negatively affected by a lack of financial capital necessary to invest in it. Consequently, the transition would slow down its expected pace of development and adoption and, eventually, miss the goal of building a sustainable economic system that goes beyond the limits of the current linear economic paradigm and contributes to society's well-being.

In this chapter, we develop a theoretical framework aimed at understanding this relationship. We embrace the financial system's point of view, and observe that the existence of potential opportunities offered to financial players by a circular transition is a crucial trigger for steering the FS industry in supporting it, thereby acting as a powerful catalyst. Opportunities must be considered alongside the constraints introduced by policymakers and the compliance with the rules of sustainable finance, and enforced by financial authorities to implement policy orientations. We prove this relationship by focusing on a specific opportunity: that is, the de-risking of financial assets. There is a peculiar condition for finance to undergo a sustainable or circular transformation, yet relative to the role played by non-financial info disclosure. Evidence arises from the results spreading from an extensive programme of research on this topic, which we have been carrying out for the last five years.

The remainder of this chapter is structured as follows. In the second section, we focus on the main areas in the FS industry that are impacted by a transformation of finance in a sustainable way. In arguing it, we introduce a four-pillar theoretical framework that provides a comprehensive view of how finance is undergoing a transformation in a circular sense: that is, what we hereby label as 'circular finance'. Furthermore, we state that, among the four pillars, the one that refers to the opportunities flourishing from the adoption of a CE is the real driver of motivation that may attract the financial capital toward circular investments. We provide more details on such driver, developing the conceptual model of the 3Rs of opportunities – *Risk*, *Revenue* (or *Return*), and *Reputation*; these help in the understanding of why supporting the CE can be a good strategy for financial players. Among the three R's, there is a deeper digging on the first category, as risk is the readiest area of opportunities to catch for financial players such as banks. In the second part of this chapter, we provide some evidence in favour of the previous argumentation. More in detail, we follow on by describing the Circularity Score (CS) as an example of a measure of circularity at company level, matching the informative needs of investors to first acknowledge and then to assess the circular assets, aimed at supporting their investment decision process. In the next section, we justify the claim that a CE can be an effective de-risking strategy, considering either credit risk for the lender or equity risk for the investor in capital markets. A specific analysis, relative to the COVID-19 pandemic, is also presented as evidence in favour of circular assets' enhanced resilience in case of external shocks, reflected in a lower degree of risk. We then focus on the role that non-financial information disclosure plays as a vehicle for conveying information on the degree of circularity, as well as its contribution to establish a positive relationship between the CE itself, on the one hand, and financial performance, on the other. Finally, we review our arguments and draw our conclusions.

The interactions between finance and CE: A conceptual framework

The inclusion of sustainable and circular considerations in the framework of financial activity implies the need for the analysis to be focused on specific factors of consideration, highlighting the main areas of ongoing change. The first field refers to corporate information disclosure as a pre-requisite for having a clear view of the benefits that sustainable financial assets could generate. For example, Healy and Palepu (2001) argue in favour of a negative association between the level of disclosure on non-financial information and cost of capital; Cheng et al. (2014) connect a stronger corporate disclosure on sustainability with lower capital constraints. A clear assessment of the positive relationship between transforming the economy in a circular way and overall financial performance might be limited by the availability of data on the circular operations of non-financial companies (e.g., Bernardini et al., 2021), as well as on the quality of the corporate disclosure, particularly in respect of its degree of financial materiality (Chong, 2015; Murninghan and Grant, 2013).

The need for having a clear view on what a CE is, and what the right metrics for measuring the degree of circularity at company level could be, is strongly backed by the EU's *Action Plan* (European Commission, 2020). In fact, the *Action Plan* includes a key recommendation when it relates to the need for developing a classification system for economic activities, to ensure a common understanding of what is sustainable and what is not.

When we refer to the CE specifically, another key topic is how to measure the degree of circularity at company level. In fact, several metrics have been developed for such purpose; however, as a general understanding, they never consider the informative needs of those financial players who wish to rely on entity-level data, embedding economic and material measures (Pauliuk, 2018).

The idea that finance should become increasingly oriented toward the inclusion of sustainability issues and support the adoption of a circular paradigm in the real economy can find a remarkable driver if a set of opportunities and benefits generated by this orientation can be put on the table. Financial players are very pragmatic and can rapidly steer their operations in a given direction if they foresee clear and firm advantages. When we refer to sustainability in a broad sense, a huge strand of literature argues in favour of sustainable asset classes exhibiting a higher financial performance (e.g., Eccles & Serafeim, 2013; Friede et al., 2015), yet the financial literature has never targeted the specific field of sustainability pertaining to a CE.

The opportunities offered by the CE adoption are not always 'ready to print': in fact, within the FS industry, catching them often requires changing the features of operations to a certain extent. The inclusion of sustainability risks within the assessment of a counterparty offers an interesting example. It implies to acknowledge that the underlying methodologies evolve, as well as include new and different sources of information (e.g., Vezér et al., 2017). Since circular practices are gradually adopted in the real economy, also, the FS industry must change its specific features and operations accordingly.

Figure 13.1 introduces a framework connecting all these arguments. It identifies the four pillars underpinning the main fields of consideration when we address the relationship between CE and finance.

The first pillar – namely, non-financial information disclosure on CE (and, broadly speaking, on sustainability) – is not directly influenced by the FS industry, and it refers to data and information on circularity that should be provided by security issuers. This pillar involves mainly non-financial companies as outside capital raisers and regulators as standard-setters on information transparency. In financial markets, information plays a key role in supporting the transfer of funds from investors to fund raisers. When circular, companies engaged in fundraising must endow investors with a specific information flow on their degree of circularity for letting them carry out proper screening, valuation, and monitoring of investments. In this area, regulators can play a pivotal role in fixing the rules of the game, like in the European Economic Area (EEA) with the Non-Financial Reporting Directive (NFRD, No. 2014/95/EU) and the Corporate Sustainability Reporting Directive (CSRD, No. 2022/2464/EU), which is set to apply starting from 2024. Information disclosure on circularity becomes even more relevant with regard to the

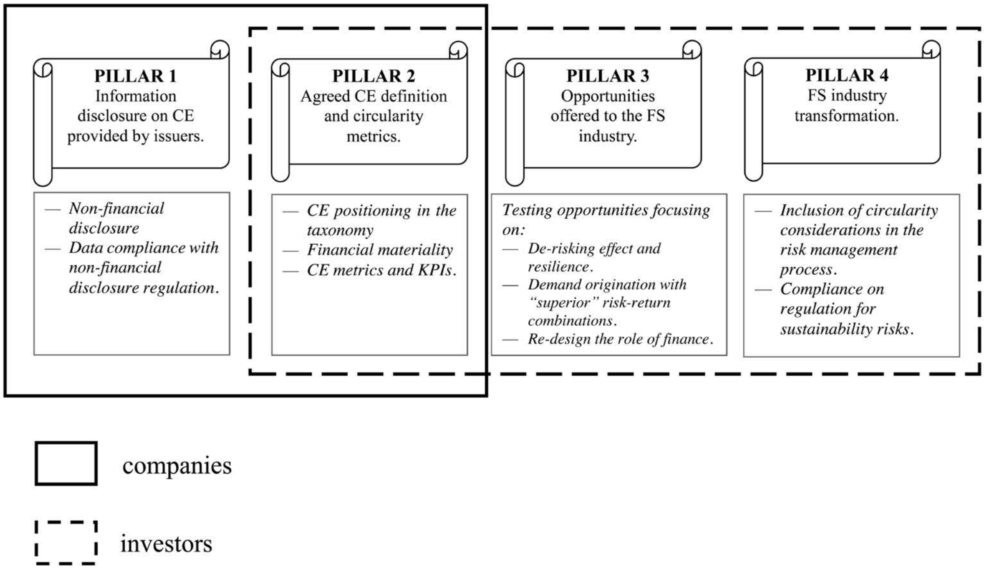


Figure 13.1 The four pillars of the circular finance chain.

content of innovation, both technological and managerial, which often characterizes the transition to a CE. For instance, in 2020, upon launching a 'call for evidence' on that topic, the Italian financial markets authority (CONSOB) highlighted the need for improving 'non-financial information' disclosure and reorient regulatory practices to include this topic into both the micro- and the macro-prudential discipline (Linciano, 2020).

Directly connected to the first one is the second pillar: namely, the agreed CE definition and circularity metrics, which could not be properly addressed without an effective non-financial info-disclosure. It implies a direct involvement of both issuers, according to the previous pillar, and financial players, which develop and adopt suitable metrics and measures. First, financial institutions need a clear and shared definition of CE in order to distinguish what is circular and what is not, as well as to recognize circularity from other sustainability-related frameworks, like CSR and ESG. The development of an EU Taxonomy on Sustainability (Regulation No. 2020/852) is the first key action among those identified by the European Commission (2020).

Second, in order to adequately screen and assess circular assets, financial players need a framework for measuring the companies' degree of circularity in a way that must be financially material, with the ultimate purpose of being able to recognize them among investment opportunities. In respect of non-financial information, 'materiality' carries a twofold connotation: *financial*, as companies are required to disclose information on those aspects that affect corporate financial performance and, thus, further strengthen the predictive capacity of metrics for financial value (Barman, 2018); or *environmental and social*, which requires companies to disclose information on the impact of their activities on the environment and society-at-large. Finally, a definition of suitable key performance indicators (KPIs) that allow to measure the results achieved by becoming circular is essential to link financial contracts, such as their covenants, with the targeted capital allocation and the needed monitoring.

Provided that the two previous pillars are properly addressed, the third pillar – namely, opportunities that the transition to a CE offers to the FS industry – points out how a transformation of the economy in a circular way can yield positive effects for financial market players. Advantages can be foreseen across three main dimensions of financial business, which pertain to the 3R Model (Zara, 2018, 2020, see par. 2) and refer to the following:

- *Risk*, due to a comprehensive de-risking effect for financial assets.
- *Revenues* (or *Return*), which consists in the origination of non-speculative business opportunities with, possibly, superior risk-return combinations.
- *Reputation,* which entails the redesign of the role of finance within society.

This array of opportunities is not always a ready-to-print option; in fact, the transformation of the current economic model into a circular way can imply a transformation of operations and techniques in the FS industry. This leads to formulating the fourth pillar, namely the transformation of specific features in the FS industry, which results from the need for setting new processes or redesigning already existing ones within the industry's value chain, as well as products offered to the market. Drivers of change can be either external to the industry – such as regulators, who are increasing compliance on sustainability for financial institutions as well as a growing demand for sustainable and circular financial products – or internal, such as the need to include new and different sources of linear risks affecting the redesign of the credit risk assessment process. Other examples can refer to adopting new and unexplored criteria to properly handle circularity in the investment selection process, as well as actively managing the existing portfolios of linear assets that are expected to become more and more stranded in the medium term.

Some notable examples have arisen over the last few years. In 2018, Intesa Sanpaolo (ISP) – i.e., the largest Italian banking group in terms of both market capitalization and total assets – launched a five-billion-euro 'CE plafond', subsequently increased to six billion, which aims to construct a portfolio of circular private loans. The access of credit proposals to the plafond rests on a 'circularity screening' process – based on six main criteria – to assess whether a customer's project is either eligible for getting the circular label, or not. In the new 2022–2025 business plan, ISP has re-financed the plafond with an additional eight billion euros. In September 2019, ING – a large Dutch banking group – presented its *Terra* methodology, which steers and monitors its strategy of loan portfolio decarbonization through an asset reallocation that aims to be consistent with relevant 2030 climate change goals. A similar initiative, though a broader one, is the Net-Zero Banking Alliance, launched in 2021 by more than 90 financial institutions that cumulatively hold about 40% of global banking assets at end-2022 (according to UNEP-FI).

When considered on a standalone basis, laws and regulations – which are external to the business realm – might have a limited effect on the behaviour of financial players. For instance, financial institutions could manage regulatory changes from the narrow spot of just being formally compliant with the rules, thereby ringfencing the effect on their business activities. A major role could be played by changes in demand, such as large institutional investors that are attracted by investment opportunities that properly include sustainability themes in their features, or consumers who ask for green-labelled products because they wish to positively contribute to environmental targets with their consumption choices. Even in this case, financial institutions could adopt opportunistic positions to catch the rising demand with a limited change in their operations.

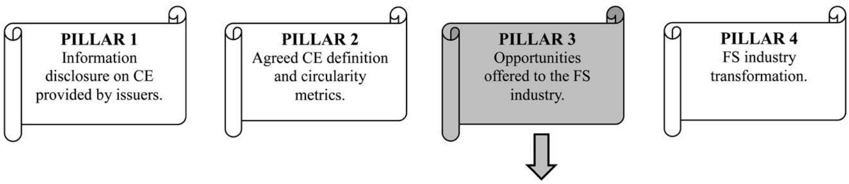
So, even if outside the industry there is a request, or a constrain, for finance to act as a catalyst, this condition does not imply that finance – that is, as a pool of economic players with their own goals, such as pursuing the financial interest of shareholders – will agree to take on this role and act accordingly. In a step-by-step process of transformation of finance in a circular and sustainable way, the third pillar (opportunities), plays the role of the major trigger of the process inside the industry. Only when financial players foresee real business opportunities in going circular and sustainable, thereby improving their own performance, they start to regard the CE and sustainability as strategic topics, rather than ringfenced to the compliance and risk management fields; hence, they become interested in adopting and scaling them. So, embracing the financial system's point of view entails shifting the standpoint from the usual 'what finance can do for CE' to the new 'what CE can do for finance', which implies a clear focus on the opportunities that can be generated when supporting the transformation of the economy in a circular way, what is their extent in terms of results, and what is the evidence in support. The 3R Model of business opportunities for the FS industry (Zara, 2018, 2020) answers these questions and focuses on the triggers for the CE adoption in financial markets. The ultimate interest is to explore the CE as a catalyst for the FS industry, not just the reverse.

The 3R Model of opportunities driven when supporting the transition

As previously highlighted, the third pillar of opportunities can be seen through the lens offered by the 3R Model, which considers three key dimensions: risk, revenue (or return), and reputation. The 3R Model is summarized in Figure 13.2.

Risk

Some of the features that characterize the circular transition act in support of an internal hedge against several new sources of risks related to the limits affecting the linear economic model. Moreover, the adoption of circular business models, and the subsequent diversification with respect to the linear business as usual, drives a growing reduction of systematic risk, which affects the current and linear economic system. Such de-risking effect can be linked to four circular key levers (Zara, 2018, 2020).



	Risk	Revenue	Reputation
Main claim	A comprehensive ***de-risking effect*** on the financial business.	Origination of non-speculative business opportunities with ***superior risk-return combinations***.	Redesign the ***role of finance*** in the society.
CE drivers	— **Decoupling** economic growth from finite resources. — Right **natural capital** management. — Economic **resilience**. — **Policy action**: internalization of negative externalities.	Demand for: — New investments in **innovation**. — Supporting **circular BMs** adoption. — **Impact trends** in end-user markets. — Sustainable investments in **policy plans for growth**.	— Back to basic: supporting **real economy development**. — **Social impact** and shared value strategies. — **Compliance** with regulation on sustainability and stability.

Figure 13.2 The 3R Model of opportunities: Main claims and drivers.

From a more overarching standpoint, the first positive effect on risk reduction to be associated with the CE paradigm is the decoupling of economic growth from the exploitation of finite resources (Lacy and Rutqvist, 2015). In a linear production system, the dependency of transformative economies on sources that supply finite virgin materials is a factor of intrinsic volatility, for these materials are becoming even more intensely consumed and, thus, scarce. Moreover, they are often subject to extremely competitive commercial conditions, and/or located in politically unstable areas. By fostering decoupling, the CE reduces the exposure of resource-intensive businesses to volatility in prices and procurement, as well as other possible sources such as operational and legal risks. The disconnection from finite virgin resources enables the reaping of benefits in terms of lower amount of the systematic component of risk, and potentially the idiosyncratic one. In a CE environment, finite resources and materials are replaced with renewable, regenerative or, at least, secondary ones; therefore, the stocks of finite resources are managed in a way that accounts for the limits associated with their exhaustion.

A second lever of risk reduction is constituted by the (effective) management of natural capital: that is, not only regenerating natural systems (*ex-post*) or replacing finite resources with regenerative ones (*ex-ante*) but, to a much larger extent, optimizing the use of products and materials to reduce the consumption of natural resources, such as water and land (e.g., Stahel, 2016). Jointly taken, these avenues enable the circular transition to exert a fundamental impact on the protection of natural capital and the environment at-large, something that the linear paradigm does neither consider nor ensure. Generally speaking, this is the way we can address the problem of preserving the natural habitats of our planet, withstanding the threats generated by demographic trends, increase in consumption, and growing pollution.

In the microeconomic realm, the two above-mentioned levers can contribute to strengthen the resilience of products over time, thus abiding by or, at least, contributing to uphold the most basic principle of the economic science itself: the pursuit of an efficient allocation of resources. The transition toward a CE is strongly connected to the redesign of products and their life cycles; this results in goods that are manufactured with better input requirements and used longer and more often, even after their first life; also, this highlights the intrinsically higher efficiency of the circular design. When products and services are redesigned in accordance with the circular principles, companies can develop and adopt different business and revenue models – vis-à-vis 'business as usual'– that diversify their operations and increase their efficiency inside the economy (Lacy and Rutqvist, 2015). Companies that diversify business operations through the adoption of circular practices will be less exposed to the volatility of the economic cycle, embedded in the global economy, which is still mostly linear. For example, in the automotive industry, original equipment manufacturers (OEMs), like BMW and Daimler-Benz, to enter the car-sharing business, add a new revenue model characterized by a continuous stream of revenues in comparison with the 'business as usual' car sale, which generates mainly upfront revenues from selling the ownership of cars. Knowing that demand for new cars might be highly affected by the economic cycle in one case, or by a supply chain disruption on the other, having a different revenue model – that is, the car-sharing business line – allows to de-correlate part of the revenues from the main model (that is, the car-sale business line). Moreover, the direct relationship between the car's life and the amount of revenues generated by driving prompts OEMs to design and manufacture cars that are more durable and efficient, in order to keep them longer in the loop and exploit better their economic value. (Circle Economy, 2022).

Companies that realize a revenue/business model diversification through the adoption of circular principles are usually less linked to the economic mainstream, more stable against the economic cycle, and become more resilient and persistent in their operations; these effects result in an expected risk mitigation.

However, companies are not islands; that is, they cannot act in full autonomy but have to abide by some constraints that regulatory authorities create and enforce. Therefore, another important lever is constituted by the ability to reduce negative externalities and system leakages to better match the effects of policy action. In this respect, going circular allows to become less impacted by the forthcoming policymakers' action. Regulators are orienting the costs generated by negative externalities from the whole society to originators, thus exposing the latter to emerging legal risks and related additional costs, such as new tax burdens for offsetting externalities and leakages (EMF, 2019). In light of this, the transition to a CE offers solutions to decrease companies' negative externalities, such as reducing pollution and minimizing or eliminating waste to landfills, which accelerate an internal hedging against the rising legal risks to curb their level of idiosyncratic risk.

Revenue (or return)

In the FS industry, 'revenue' refers to financial intermediation businesses, such as lending and other retail services (e.g., payments); conversely, 'return' pertains to investment activity in capital markets, such as asset management. Regardless of the adoption of this double level of turnover definition, the arguments reported in this paragraph can be extended to both revenue and return (Zara et al., 2022a).

A CE can generate new and additional streams of revenue spreading from four different areas of demand for outside capital, which refer to: investment and financing of innovation that involves both technology and managerial practice; supporting the adoption of new circular business models in companies; matching new trends in impact demand for financial products; sustainable investments that are compliant with policies related to economic growth and economic competitiveness. The first channel whereby profitable opportunities may arise stems from investments in innovation. A radical change in the economic paradigm opens up to a period of relevant investments to manage the transition and achieve the transformation from linear to circular. The adoption of circular business and revenue models, like the development of new activities in circular value chains, is prompted by managerial innovation. The magnitude of such trend is even higher if tied to the development of new technologies (for instance, digitalization, connectivity, biomaterials, etc.). Each of the former requires significant investments in innovation within companies. Therefore, demand for outside capital will increase to support the investment stage. A CE could represent a great driver of recovery in the corporate and investment banking area. Even if sustainable issuances are still a small amount of the market, they have been growing at a very fast pace; for example, in 2021, according to Bloomberg, sustainable debt market amounted to \$1.644 bn (that is, a similar size to the annual GDP of Canada), and with a 116% growth rate year-on-year. In particular, the demand side included not only already established companies undergoing transformation but, also, new innovative enterprises devoted to the transition.

Eliciting a relevant transformation of the invested capital of the companies, the adoption of circular business models and practices originates new sustainable/circular asset classes that are particularly attractive to institutional investors. This occurs thanks to three major features: the ability of generating stable returns in the medium-to-long run, a risk-return profile allowing the construction of more efficient and diversified portfolios, and the internal hedging against operating risks, which support the stability of performance. In asset management, the CE may become a powerful theme for putting in action an investment strategy crossing some relevant megatrends, such as demography, resource scarcity, and climate change, and allow the achievement of clear goals in the sustainability area, alongside financial returns.

Nevertheless, the CE is important not only for investors and not merely in terms of the classical ways to assess an investment's profitability. Another very promising area is impact demand, as the CE can play a significant role also in retail banking. Consumers show a growing preference for responsible purchases. The introduction of new products and services, also fostered by regulatory action, drives and targets the demand for consumption-specific financial instruments linked to sustainability-related topics. In this way, financial institutions might be able to exploit the case where clients could be willing to pay a premium on the price of products and services that generate a positive impact on society (Pavoni, 2019).

Finally, non-negligible opportunities lie in the activities deployed by the public sector; that is, the involvement of the CE in policy plans for growth. In areas like Europe, there is a common view on sustainability as a key element for keeping the competitiveness of the economic system in the global arena (European Commission, 2020). In their decisions, policymakers are increasingly relying on the CE as a key factor for a sustainable transition (Sitra, 2016). They link the access to public funds to projects that embody the principles pertaining to the circular paradigm; also, the access to public funds is a catalyst for financing projects, such as the case of sustainable infrastructures, and a requirement to boost the supply of private capital, too.

Reputation

Since the 2007–2009 Global Financial Crisis (GFC), there has been a wide debate on the role played by finance in society, given a growing feeling that it was somehow 'disconnected' from the real economy or even operating against it (e.g., Schoen, 2017). Although a CE is focused on the change of the economic paradigm and constitutes the economic engine of sustainability, going circular may also help the financial system regain a better positioning within society and contribute to the development of its well-being. Advantages in terms of reputational capital increase may be obtained in respect of three main areas of action, related to: 1) the support to the real economy and its growth, 2) investments in shared value projects, which combine impact and financial results, and 3) a contribution to fostering the stability of the financial system.

As for the reconnection with the economy, the transition to a CE offers the opportunity for a repositioning of the financial system's role in society, after the negative consequences in terms of reputation due to the GFC. Finance has the chance to reconnect with the real economy by supporting the transition and contributing to social well-being. Offering products and services aligned with sustainability allows financial institutions to enlarge their intangible capital of trust and reputation, which is critical for players like commercial banks. Becoming a 'circular bank' promises to be a winning position for a credit institution (Bocconi University et al., 2021).

A natural consequence of such commitment is the implementation of strategies aimed at creating shared value (Porter and Kramer, 2011), which implies the ability to generate business opportunities from tackling social issues such as reducing poverty, providing equal opportunities to minorities, closing the gender gap, etc.; the extant literature has already investigated its connections with the banking industry (Akpinar et al., 2022; Bockstette et al., 2015). Supporting the adoption of a circular paradigm allows creating the conditions for regaining an economic role in communities, such as cities, internal geographical areas, and social clusters. For instance, the ability to reduce and eliminate negative externalities, as well as either replacing virgin materials with secondary ones that are mined in urban areas, or swapping physical products for virtual ones, enables the cities to bring back some economic activities that had been outplaced over the last decades, due to their environmental and social costs. When cities regain an economic role, they can also offer income opportunities to their inhabitants, particularly young people, and let them avoid leaving their community due to unemployment. Financing projects and ventures that lie on the principles of the shared value theory, which has significant overlaps with the CE paradigm, allows banks and other financial actors to play a part in supporting the recovery of the economic role of communities, as well as to finance people for exploiting new business opportunities that also generate a positive social impact.

The system-wide outcome is an increased stability. If banks are more circular, they will also reduce their asset-side risk, becoming more stable and ultimately matching the banking stability goal pursued by regulators and authorities. Hence, this convergence highlights an alignment of goals between regulators and financial players. As pioneers in supporting the CE adoption, financial players could be also in a position to advice authorities and regulators on the benefits for the financial ecosystem entailed by the CE, in order to accelerate the acceptance of possible incentive factors that could support early adopters.

Digging deeper on risk

Among the three R's, risk is currently gaining a momentum as the area of opportunity that could be caught faster and with significant advantages, from a regulatory standpoint as well. Opportunities around risk are important for financial institutions, particularly banks, not only because they allow pursuing a generalized de-risking of their asset side, mainly relative to corporate lending and specialized lending: also, this area entails a strategy to manage the prospective divestiture from linear assets' portfolios. Moreover, the opportunity to increase the stability and persistence of asset-side performance is another strong argument in favour; additionally, it is particularly relevant to some categories of players, such as institutional and value investors. Figure 13.3 shows the relationship between CE de-risking drivers and financial players' interests, showing how they can transfer the effect on operations (distinguished between 'strategic' versus 'tactical').

When a financial institution, like a bank, targets a direct strategy of CE investment, its main rationale is to build a portfolio of fresh circular assets that can perform well and grow in value over the medium term. This could happen by exploiting the four CE drivers that should enable to hedge against the rising sustainability-related risks, as well as a lower connection with the risk implied

Risk	
CE drivers	— **Decoupling** economic growth from finite resources. — Right **natural capital** management. — Economic **resilience**. — **Policy action**: internalization of negative externalities.
Reasons for the FS industry to transition	— De-risking of financial assets through all the drivers — Active management of linear risks & stranded (linear) assets. — Stability and persistence of performance.
Opportunities: —**tactic** —***strategic***	— Predictive management of actual loan portfolios before being stranded. — *New circular loan portfolios to pursue de-risking benefits.*

Figure 13.3 Risk breakdown in the 3R Model of circular finance.

in the economic cycle. The assumption of a lower level of risk for a circular portfolio, alongside a linear comparable, is the baseline of the investment decision alongside the possibility to generate a superior risk-adjusted performance (refer to the 'Revenue/Return' in the 3R Model) and, perhaps even more importantly, a performance that will be persistent and stable over the forthcoming years. Very often, this strategy must be put in relation with the need to actively manage the existing portfolios of assets, for instance private loans. According to the sectoral composition, parts of existing portfolios, or even a portfolio as a whole, could have their value impaired by the weaknesses on sustainability topics, such as the level of CO_2-equivalent emissions, the dependence from scarce resources, or even the change in the technological paradigm and demand trends. An example of a sector that is heavily affected by sustainability issues and the changing energy model is the oil and gas industry, due to its extraction and refining operations that are currently stranded by both legal limitations to research and drilling on one side and negative externalities, such as greenhouse gas (GHG) emissions, on the other one (Zara et al., 2023). In cases like this one, a bank needs to manage the risk that loans in the portfolio become progressively stranded and finally turn from performing to nonperforming. As a first level of action, a bank could use circular metrics and key risk indicators (KRIs) for monitoring the level of exposure to linear risks and steer the divestment from the stranded positions before they turn into a nonperforming condition. That corresponds to a tactical orientation towards the opportunity. When the bank decides to catch the opportunity with a strategic approach, it will move to an active management for building new portfolios, searching for companies that are investing in the circular transformation (or are circular by origin), and steering and supporting the transition for those counterparties that are already existing clients. With a strategic approach, a bank can obtain a twofold result, as actively supporting the transition also becomes a way to find a solution for the problem of linear stranded assets.

The trigger for financial players to actively seize an opportunity is also dependent on clear and consistent evidence in favour of the assumptions, here viewed as a de-risking effect. For this reason, independent academic research plays an important role in testing the hypothesis, finding possible evidence in its favour through the analysis of empirical fields, and spreading the knowledge among industry players, both financial companies and regulators. In this chapter, we present some findings in favour of the de-risking hypothesis, spreading from our research in empirical finance pertaining to the field of opportunities (3R Model) and provide results regarding the role played by non-financial information disclosure, as an example of transformative topics that affect areas corresponding to the first and the second pillar of the framework presented in the section titled 'The interactions between finance and the CE: A conceptual framework.' Conversely, in this chapter we avoid discussing evidence pertaining to the fourth pillar, which is only indirectly affected by the circular transition.

The Circularity Score

The Circularity Score (CS) is a quantitative and concise metric proposed by Zara and Ramkumar (2022) to measure the degree of circularity at company level, that is, the extent to which companies engage in circular business strategies and operations. By constructing the score, we highlight the relevance of pillar 2 – 'Agreed CE definition and circularity metrics' – in the framework reported in Fig. 13.1. In this regard, the extant literature (e.g., Harris et al., 2021) has seemingly reached a rough agreement on the levels at which circularity may be assessed, which are (a) micro-levels revolving around enterprises and consumers, (b) meso-levels entailing the integration between different economic agents, such as within an industry, and (c) macro-levels centred on cities, regions, and governments. Outside the economic and financial literature, metrics at the

Table 13.1 Components of the Circularity Score

Pillar	*Category*	*Number of Indicators*
Circular Inputs	Emissions	65
	Resource Use	39
	Total Circular Inputs Pillar	**104**
Product Usage	Innovation	27
	Agenda 2030	8
	Community	7
	Total Product Usage Pillar	**42**
End of Life	Product Responsibility	9
	Total End-of-Life Pillar	**9**
Disclosure and Signalling	Disclosure and Signalling	9
	Total Disclosure and Signalling Pillar	**9**
Total Indicators		**164**

product level have also been developed (e.g., Linder et al., 2017). However, lenders and investors in general need to assess their counterparty's standing; hence, they could not rely on anything but company-level indicators. This is why the FS industry needs measures of circularity at the micro-level (company), like the CS, grounded on how an entity performs during the transition of its business model toward a circular one.

The CS results from an algorithm built upon 164 indicators, retrieved from the ESG section of the Refinitiv database (formerly Thomson Reuters – Datastream, ASSET4 module) and selected based on their relevance to measuring a company's degree of circularity. Data were originally downloaded in September 2020. Also, they are classified in seven categories (namely: Emissions, Resource Use, Innovation, Agenda 2030, Community, Product Responsibility, and Disclosure and Signalling), which are organized into four pillars, namely circular inputs, product usage, end of life, and disclosure and signalling. Table 13.1 shows the breakdown into indicators, categories, and pillars (Zara et al., 2023).

The first three pillars reflect those of the CE framework: namely, the introduction of renewable and regenerative resources, the circulation of products and materials in the economy, and the design of products that can be easily separated in their materials and components at the end of their life cycle. The fourth pillar is intended to measure the level of sustainability-related information disclosure with the aim to provide outside data to assess the commitment to the transition toward a CE.

The measurement process follows different steps, based on a bottom-up approach:

1 A score is assigned to each company-indicator combination. In order to account for the inherent barriers that companies operating in certain industries face when transitioning from a linear to a CE (thus, to ensure a level playing field), the score assigned is adjusted for the performance of all the companies operating in the same industry. The indicator score is computed as the ratio between the number of companies performing worse or equal with regard to that indicator (numerator) and the total number of companies having an available value for that indicator on the Refinitiv platform (denominator).
2 Then, a company-category score is computed as the arithmetic mean of the scores of the indicators comprised within that category.
3 The pillar score is computed as the weighted average of category scores. The weight of each category is defined as the ratio between the number of indicators belonging to that category (numerator) and the overall number of indicators encompassed by the pillar to which it belongs (denominator).

4 The ‘plain’ version of the CS is computed as the weighted average of the pillar score. The weight of each pillar is defined as the ratio between the number of indicators encompassed by the pillar (numerator) and the overall number of indicators (denominator).
5 Finally, the plain CS is adjusted to account for the different levels of financial materiality that a given category of indicators takes for different industries. Financial materiality is measured based on the Materiality Map developed by the Sustainability Accounting Standards Board, which identifies the most financially material topics of sustainability issues relative to each industry, as identified pursuant to its proprietary Sustainable Industry Classification System (SICS). Then, after being attached a score for financial materiality that varies across industries, topics are reconciled with circular categories, so that within a given industry, each category is associated with a comprehensive materiality factor, given by the ratio between the materiality score of that category in that industry (numerator) and the materiality score of the industry as a whole (denominator); that is, the category’s relative weight on the industry’s materiality score. Finally, for a company, each category’s (partial) circularity score is adjusted for materiality by multiplying the plain version thereof by the industry-specific factor, yielded by adding 1 to the ratio described previously. Re-performing steps 3 and 4 ultimately yields the materiality-adjusted measure of circularity.

This process results in a materiality-adjusted CS whose value ranges between 0 and 1, growing along with the degree of circularity.

Figure 13.4 presents summary statistics relative to the CS, with respect to SASB SICS industries. Note that direct comparisons between companies, regarding their circularity, may be

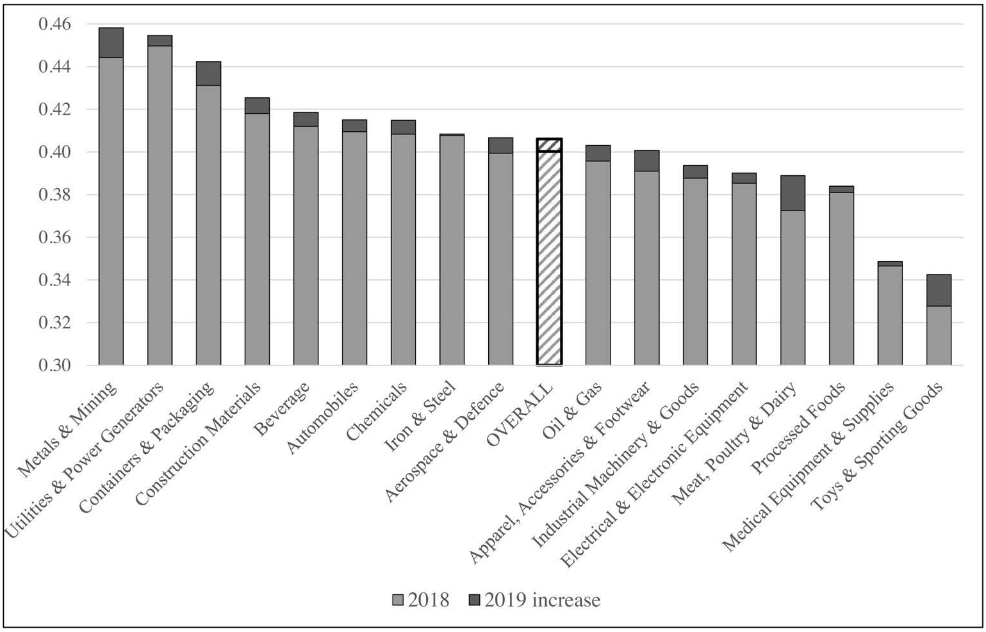


Figure 13.4 Average Circularity score by industry.

Note: These figures should not be used to establish cross-industry comparisons; hence, the above does *not* represent a circularity-based ranking. In fact, the CS may be used to compare only companies pertaining to the same industry.

established only within the same industry but not across industries; hence, we are not allowed to compare industry averages either. Looking at 2019 figures, we can observe that metals and mining exhibits the highest average CS (~0.46), toys and sporting goods the lowest (~0.34), whereas aerospace and defence is the closest to the sample mean (~0.40). In all industries, the CS was higher in 2019 compared to 2018, albeit to a varying extent. However, we should be careful not to read that chart as a 'circularity ranking'.

The circular economy as a de-risking strategy

The findings that we present in this section are a selection of the current research activity on the topic of the relationship between the CE and financial performance. This research has been carried out at the GREEN Research Centre of Bocconi University and has benefited from with Intesa Sanpaolo Innovation Center, ISP Banking Group.

By empirically testing whether there is a greater commitment towards the CE is actually associated with de-risking at a company level, we dig deeper into pillar 3 – 'Opportunities that the transition to a CE offers to the FS industry' – in our framework; hence, we apply and test the 3R Model, with a specific focus on the first R: risk. The selected evidence presented in this section lends support to the thesis designed in the 3R Model, which considers the CE as an effective de-risking strategy.

At an early stage, we collected a sample of European circular and listed entities over a 2013–2018 timeline to investigate the relationship between their degree of circularity – measured by the CS – on the one hand, and equity risk and risk-adjusted returns (Zara et al., 2022a), as well as their default risk (Zara and Ramkumar, 2022), on the other. At a later stage, we enlarged our sample and circumscribed the horizon to the 2018–2020 time span. The following paragraphs refer to the second step of the research programme.

Sample construction

Our sample consists of 644 companies – retrieved from the Orbis database – that match the following criteria, set forth by Zara et al. (2022a):

a Operating in the manufacturing, construction, metal mining, oil and gas extraction, and utilities sectors, pursuant to the Standard Industry Classification (US SIC) system. It is a system that assigns companies a four-digit numerical identifier on the basis of their primary line of business. Thus, each sector has a unique identifier. The SIC system arrays the economy into 11 divisions, divided into 83 two-digit major groups that are further subdivided into 416 three-digit industry groups, and finally disaggregated into 1,005 four-digit industries. Our choice of industries must be traced back to the exposure of these sectors to the promotion and adoption of circular business models, as they are resource-intensive and instrumental to contrasting the climate change.

b Being listed in EU-15 markets (that is, countries that were EU Member States between 1 January 1995 and 30 April 2004) or Switzerland. Such geographical focus acknowledges the pioneering role played by the European economic system in respect of the transition from linear to circular business models, driven by both private and public initiatives. In the public realm, it is worth mentioning the *Circular Economy Action Plan* (European Commission, 2020), which sets forth provisions in respect of products' design, production processes, and sustainable consumption, aiming to improve waste prevention and increasing resources' usage (European Commission, 2020).

c Having non-financial information and data available during 2018–2019; that is, allowing computing their measure of circularity for at least one of the two years.

Regarding the object of a company's business, pursuant to US SIC, we selected 15 two-digit industries from Division D (manufacturing), 2 industries from Division B (mining), 3 from Division C (construction, fully covered), and 1 from Division E (transportation, communications, electric, gas, and sanitary services), for a total of 21 two-digit industries.

By jointly applying (a) and (b), we get an investable universe made of 2,028 entities; then, following the application of (c), we end up with 644 companies in 17 industries pursuant to the SASB SICS classification, as two of them – namely, agricultural products and building and furnishing products – are not populated by any firms. More in detail, we computed the measure of circularity for 622 companies relative to 2018 and 638 companies relative to 2019, whereas 616 exhibit that measure for both years. For a reconciliation between the SIC and the SASB SICS classifications, see Table A1 in the Appendix in Zara et al. (2023).

A description of the sample by country is reported in Table 13.2, where 2018 and 2019 observations on total assets are pooled together and ordered by the number of companies. As for the latter, the four most represented countries, the United Kingdom, Germany, Switzerland, and France jointly constitute an outright majority of the sample: more in detail, Germany slightly exceeds France, whereas the United Kingdom comes up third and, jointly taken with the previous two, sum up to an outright majority of the sample. Such a configuration is quite representative of the reference population of undertakings; the Herfindahl-Hirschman index – which measures how concentrated a population is, on a 0–10,000 scale – denotes an appreciable degree of dispersion (about 1,129 in terms of observations, 1,521 in terms of total assets). The average entity in our sample is worth 13.88 billion euros in total assets, yet there are wide cross-country differences; while Spain's undertakings exhibit an average size (€13.53 bn), French and German entities are by far the largest ones (€31.05 bn and €24.79 bn, respectively), whereas Greek firms lie at the very bottom (€1.63 bn).

Default risk

Default risk expresses the likelihood that a company may fail to fulfil its financial obligations, whether on publicly exchanged securities with an active market (e.g., corporate bonds) or with regard to private transactions (e.g., commercial debt towards suppliers). We express default risk via three alternative dependent variables, all of which are log-transformed (that is, we take the natural logarithm of each figure). They reflect the traditional distinction between short-term measures and medium-to-long term ones, which describe the likelihood of a company defaulting over a 1-year and 5-year horizon, respectively.

- *Probability of default (PD), 1-year;*
- *Probability of default (PD), 5-year*; and
- *Credit default swap (CDS) spread, 5-year.*

More in detail, the PDs are grounded on the ratings externally attributed by large and experienced agencies (e.g., Standard & Poor's, Moody's, and Fitch, the so-called 'Big Three'), given

Table 13.2 Description of the sample

	Numerosity			*Size*	
Country	*Number of companies*	*Observations (% of observations in the whole sample)*	*Cumulative share (% obs)*	*Total assets (% of Total Assets of the whole sample)*	*Average total assets per company (EUR bn)*
United Kingdom	150	23.52%	*23.52%*	18.82%	11.10
Germany	79	12.43%	*35.96%*	22.21%	24.79
Switzerland	67	10.54%	*46.50%*	7.61%	10.02
France	63	9.91%	*56.41%*	22.18%	31.05
Sweden	52	8.18%	*64.59%*	2.44%	4.14
Italy	38	5.98%	*70.57%*	5.40%	12.54
Netherlands	34	5.35%	*75.92%*	6.60%	17.12
Spain	31	4.88%	*80.80%*	4.76%	13.53
Belgium	23	3.62%	*84.42%*	3.42%	13.10
Ireland	23	3.62%	*88.04%*	2.58%	9.87
Finland	22	3.46%	*91.50%*	1.63%	6.55
Denmark	21	3.30%	*94.81%*	0.73%	3.05
Austria	14	2.20%	*97.01%*	0.81%	5.10
Luxembourg	7	1.10%	*98.11%*	0.30%	3.74
Portugal	6	0.94%	*99.06%*	0.42%	6.17
Greece	6	0.94%	*100.00%*	0.11%	1.63
Overall	**636**	**HHI ≅ 1,129.46**		**HHI ≅ 1,520.63**	**13.88**

Notes
Countries are ordered by the number of companies in the sample. *Number of companies* counts the entities for which there is at least one non-missing observation on total assets (i.e., relative to 2018, 2019, or both). The other figures are computed by pooling years 2018 and 2019 together.
HHI = Herfindahl-Hirschman Index

that basically any listed undertaking – hence, every company in our sample – is attached a rating by at least one Big Three agency. The CDS spread rests on the marked-to-market spreads on publicly traded securities of the same kind, relative to a basket of comparable entities, for there might be no active market for a company's CDS, given that this security is usually exchanged only in respect of large entities with significant debt issuances outstanding. Five years is the usual maturity for this kind of securities.

The CDS spread is the risk premium (i.e., additional costs) charged on credit default swaps, which are derivative contracts enabling the holder to be financially immunised against the event of a company defaulting on its debt: if this occurs, the CDS holder receives a payment, just like a policyholder gets liquidated by an insurance company. The 'spread' refers to the difference – conventionally measured in basis points, that is to say units worth 0.01% of the nominal value – vis-à-vis a risk-free contract of the same type, taken as a benchmark.

All these measures are computed and released by Bloomberg and are based on proprietary algorithms. Among the independent, explanatory variables that we include in our models to explain the dependent ones, the CS is the central one we are the most interested in. Also, we include an array of other variables that the literature has often regarded as potentially contributing to explaining the variability of default risk as controls. They express a company's size (i.e., the natural logarithm of total assets), leverage (i.e., the debt-to-equity ratio), debt servicing capability (i.e., the interest coverage ratio), profitability (i.e., the profit-on-sales ratio), and the presence of a capital impairment (i.e.. whether total equity is negative or not). Our models consider two periods of time; dealing with yearly figures, default risk measures are retrieved at the end of 2019 and 2020. Figure 13.5 shows results in the first column of the default risk section at the bottom part of the table.

We found that more circular companies faced a lower likelihood of defaulting on their debt. In the short run, defined as one year, the beneficial effect associated with a higher CS was much stronger compared to the medium-to-long timeframe of five years. The estimate was different from zero at 95% confidence level in both cases. An X% confidence level – where X is usually set at 90, 95, or 99 – means that, in X% of cases in a high number of trials, the outcome lies in an 'interval' centred on the punctual estimate; conversely, in 1 − X% of cases (i.e., the frequency of errors), it would lie outside. A smaller de-risking effect, which in statistical terms is zero, is associated with the CDS spread. Such difference may be explained by noting that PD estimates reflect the outcome of a fundamental analysis performed by rating agencies and reported by Bloomberg, which is able to catch the de-risking embedded in circularity; conversely, the CDS spread is a market-based measure and reflects that investors are less efficient to account for the risk associated with an entity's business model when they have to judge the credit standing of a security issuer.

Equity risk

Unlike the previous paragraph, focused on debt issuances, this field of research features risk in respect of a company's publicly traded equity instruments. In line with Zara et al. (2022a), equity risk is expressed by the following variables:

- *Standard deviation of stock returns, annualized*,
  - it represents the total risk – expressed in volatility terms – that is borne by an investor who held a given stock.
- *Beta against the STOXX Europe 600 index,*
  - it represents the systematic component of the above: that is, the portion that depends on a given stock being exposed to fluctuations in a Europe-wide fully diversified market portfolio and, thus, cannot be erased through diversification.
- *Beta against the MSCI World index*,
  - an alternative measure of systematic risk as benchmarked to a global market portfolio, rather than just a Europe-based one.

The explanatory variables are the same as those described in the 'Default risk' paragraph. However, the perspective is a short-term one and aims to investigate the extent to which more circular companies are also more resilient to a severe shock, exogenous to the financial system: specifically, events such as the outbreak and initial spread of the COVID-19 pandemic. For this purpose, dependent variables were computed not only over the whole 2019–2020 horizon but four shorter ones, too: namely, 2020 and three subperiods thereof, as we identify a pre-shock, a shock, and a post-shock phase. By mirroring Ramelli and Wagner (2020), with a slight adjustment to ensure that the pre- and post-shock phases have the same length, we computed dependent variables out of the following time windows:

1 between Monday, 2 January 2020, and Friday, 21 February 2020 (*pre-shock*);
2 between Monday, 24 February 2020, and Friday, 20 March 2020 (*shock*); and
3 between Monday, 23 March 2020, and Friday, 8 May 2020 (*post-shock*).

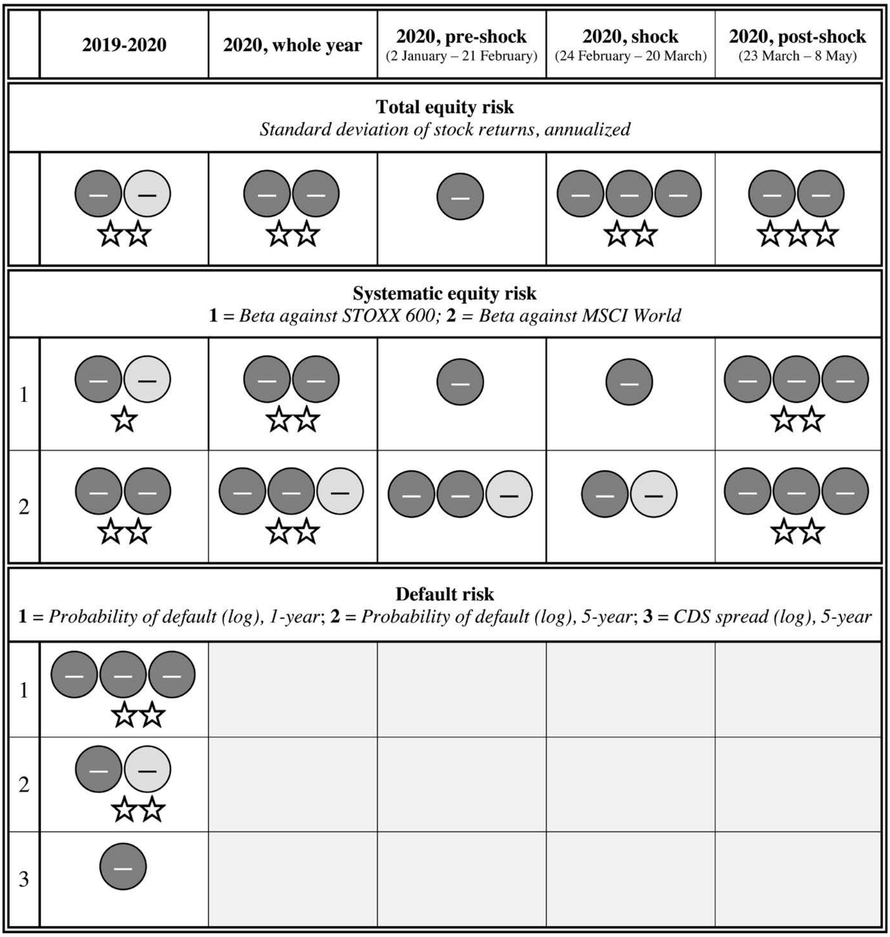


Figure 13.5 The effect of circularity on risk; the magnitude of estimated coefficients and statistical significance.

Note: Circles express the relative magnitude of the effect generated by a 0.05 increase in *Circularity Score* (focus explanatory variable) on the following:

- total equity risk (*Standard deviation of stock returns, annualised*). The effect is expressed in absolute terms; results do not change if we consider a different size of the Circularity Score increase;
- systematic equity risk (*Beta against the STOXX Europe 600 index and Beta against the MSCI World index*). The effect is expressed in absolute terms; results do not change if we consider a different size of the Circularity Score increase;
- default risk, measured as the likelihood of a company defaulting on its debt in the short run (*Probability of default, 1-year*) or the medium-to-long run (*Probability of default, 5-year*), or the risk premium charged by those investors that buy insurance against that event (*CDS spread, implied, 5-year*). The effect is expressed in percentage terms; results are sensitive to the size of the Circularity Score increase that we consider.

The relative magnitude of coefficients can be compared only within models having the same dependent variable or groups of dependent variables, not between them.

For each variable or group of variables, we order all the estimated coefficients from the smallest to the largest; hence, we obtain a scale ranging between 1 (smallest) and 3 (largest), with 0.5 steps. Dark circles count as 1, light circles as 0.5: for instance, one dark circle and one light one denotes a 1.5 score. Approximations are used: for instance, an estimated coefficient comprised between 2 and 2.5, but closer to the former (the latter), is represented as 2 (2.5).

Stars express the statistical significance of coefficients by reporting the confidence level of estimates: i.e., 99% (3 stars), 95% (2 stars), 90% (1 star, which is never the case), or less than 90% (no stars).

Figure 13.5 reports the results. The analysis shows that the de-risking effect played by the degree of circularity did soar along with the COVID-19 virus spreading, peaking in the post-shock phase. In fact, the coefficient associated with CS is never statistically different from zero in the pre-shock phase. During the very outbreak of the pandemic (the shock phase), the estimated effects of a company's degree of circularity on systematic risk remain nonsignificant, whereas the standard deviation of stock returns significantly decreases as the CS increases, the coefficient being statistically different from zero at 95% confidence level. Conversely, after the shock, the negative association between the CS and equity risk measures gets clearly displayed, in respect of any dependent variable, and is consistent across models. The relative magnitude of estimated coefficients is very large, the confidence level being 95% or 99% (relative to systematic and total risk, respectively).

Together, these results potentially suggest that, upon the occurrence of a massive exogenous shock, more circular companies were not only more resilient in terms of equity risk vis-à-vis less circular ones; also, they performed notably better in the post-shock phase, exhibiting a swifter and more effective recovery. This is consistent with the analysis on risk developed in the 3R Model, where enhanced resilience to negative scenarios is presented because of the diversification of business models enacted by the adoption of circular ones.

Bridging the CE with finance: Focus on disclosure

In our CE-finance framework, non-financial disclosure is particularly relevant to carefully investigate the role played by the undertakings' non-financial information disclosure; that is, relative to their sustainability practices and achievements, particularly in its association with the company-level degree of circularity and financial performance.

First, we should consider that the extent whereby an entity releases sustainability-related information does affect the measurement of its circularity, based on the CS methodology; hence, companies that are more prone to make a bountiful disclosure are more likely to get a high CS, also because a Disclosure and Signalling pillar is included within that metric. Therefore, we need to clear the overall circularity from the contribution of disclosure itself, yielding a core CS (CCS) that may provide a more faithful representation of the company's actual transition to CE by structurally changing its business model rather than just conveying information to its stakeholders.

By testing how much of the CS does reflect the contribution of explanatory variables, we ended up discovering that about 80% of the variability of the CS is explained by that of disclosure-related variables. Hence, we could compute the CCS as the nondisclosure component of circularity; reiterating, the nondisclosure component is a measure of circularity once cleared of the influence exerted by disclosure practices. In further steps, we considered the CCS either alone, to compare the effects associated with the full measure of circularity to those associated with the core component thereof, or alongside sustainability disclosure variables. In practice, this provided a decomposition of the 'full' CS. Disclosure-related characteristics are condensed in two variables: namely, *information content*, which expresses both the quantity and the quality of circularity-related non-financial disclosure, and *information integration*, which expresses whether the sustainability reporting is integrated within the financial one and the extent a company is subjected to an Anglo-Saxon, investor-protective legal framework. The two disclosure-related variables have been constructed by applying the Principal Component Analysis (PCA) technique to other variables, used as inputs. Details are available in Zara et al. (2022b). We show the essential results with a focus on equity risk in Figure 13.6.

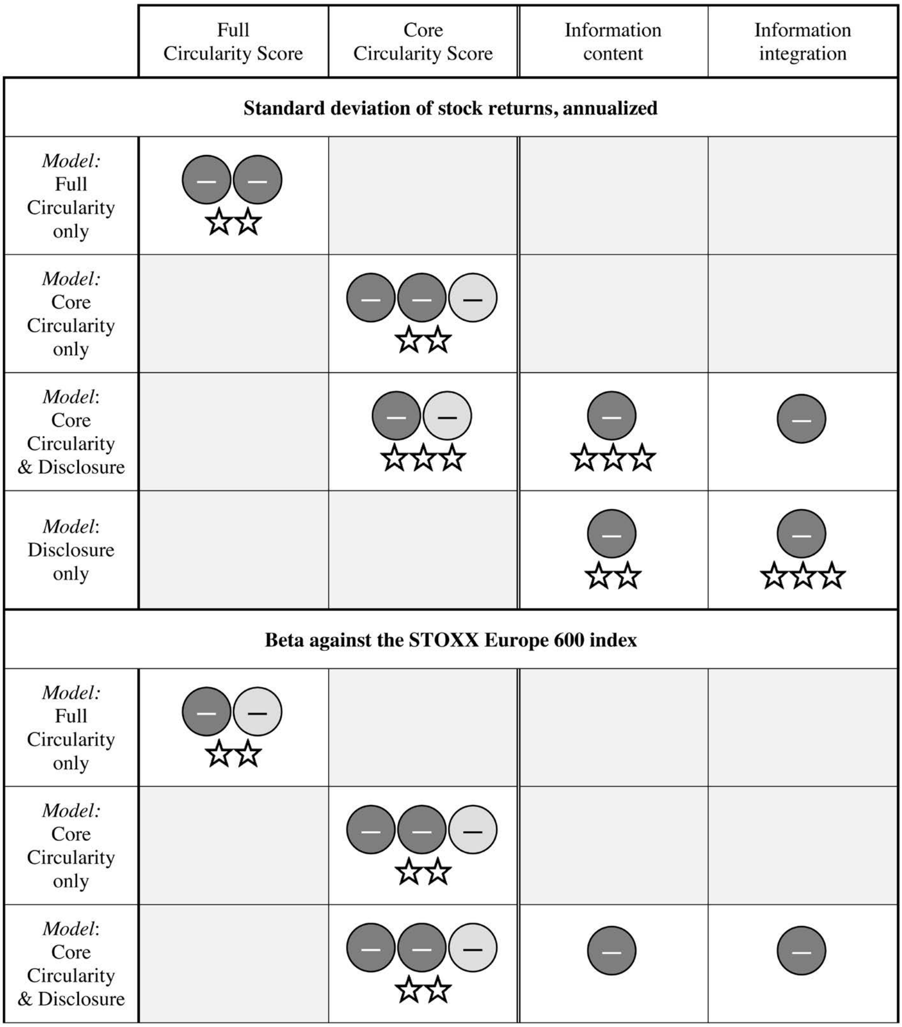


Figure 13.6 The effect of circularity and disclosure on equity risk as magnitude of estimated coefficients and statistical significance.

Note: Circles express the relative magnitude of the effect generated by a unit increase in the focus explanatory variable(s) on each model's dependent variable. Focus explanatory variables are reported in the first row; namely:

- *Full Circularity Score*; i.e., the degree of circularity gross of the effect of disclosure;
- *Core Circularity Score*; i.e., the degree of circularity net of the effect of disclosure;
- *Information content*; i.e., a variable expressing both the quantity and the quality of non-financial disclosure;
- *Information integration*; i.e., a variable expressing whether the sustainability reporting is integrated within the financial one and the extent a company is subjected to an Anglo-Saxon, investor-protective legal framework.

For details on these variables, see Zara et al. (2022b) presented at the 2022 GRETA conference held at Ca' Foscari University, Venice, Italy.

The first column denotes which model the estimations are taken from, based on the focus explanatory variables included.

The relative magnitude of coefficients can be compared only within models having the same dependent variable or groups of dependent variables, not between them.

As for the meaning of dependent variables, as well as the meaning of circles and stars, see the note to Figure 13.5.

In general, sustainability disclosure turns out to be necessary but there are not enough tools for de-risking purposes; in fact, disclosure-related variables alone exert relatively weak and inconsistent effects on equity risk. Moreover, we found no statistically significant effect on credit risk. In this sense, sustainability reporting is a powerful mediator as it can trigger de-risking by helping the relatively more circular companies to make investors aware of the lower risk they embed. Conversely, CCS exhibits a de-risking effect on both realms of risk measures, which is even stronger in magnitude through full circularity, whose benefits for a company's creditworthiness are in line with previous studies (Zara and Ramkumar, 2022).

Jointly taken, these results (Zara et al., 2022b) suggest that the most direct driver of de-risking, for an undertaking, is not its endeavour as of the information given to investors, but the practical actions it takes to move from a linear to a circular way of conducting its operations. Therefore, transparency in financial markets remains an essential tool but cannot achieve, alone, the same benefits as those that a circular transition brings to a company's financial soundness, in terms of lower volatility of its publicly listed equity or increased distance to default.

Furthermore, we investigated the effects played on credit risk by specific disclosure-related behaviours, such as having the non-financial reporting assured by a certified external agency and integrated into traditional financial statements (Zara and Bellardini, 2022). These results suggest that at least rating agencies, as a proxy of private markets, dislike excesses: in their judgment, those companies that engage in overwhelming disclosure (that is, with both integration and external assurance) are regarded as relatively riskier. Conversely, public markets are more appreciative of the information conveyed to the exterior, as non-financial disclosure helps them refine the valuation of potential investment targets. We found that market-based risk measures actually exhibited de-risking in case debt issuers integrated their non-financial disclosure into financial statements and received an external certification relative to the former.

Akin to the divergence in the empirical association between circularity and default versus equity risk, such divergence may be easily explained by noting that public markets essentially rely on widely available information, including on sustainability, for their smooth functioning. Conversely, private markets are longer-term oriented, prefer looking at business fundamentals rather than a company's informational behaviour, and can use more private information vis-à-vis the generality of investors.

Conclusions

This chapter shows the existence of a double-sided association between the CE and finance: not only is the latter a 'catalyst' of the former, but it constitutes an irreplaceable tool to support and accelerate the circular transition. Additionally, the CE is a realm wherein highly valuable financial opportunities may be found. To paraphrase US President J. F. Kennedy in his inaugural address, we should ask not only what finance can do for the CE but what the CE can do for finance. When finance moves towards CE and sustainability in a broader sense, some key areas embedded in our four-pillar framework (see the section 'The interactions between finance and the CE: A conceptual framework') are affected. The pillars are crucial for the management of the transition chain of finance. Pillar 3, which refers to opportunities offered by a circular transition, is the trigger of the process embedded in the chain and influences the speed of the change in the other three pillars. Opportunities arising for the FS industry are developed and explained in detail through the 3R Model.

In this chapter, the first R, risk, is adopted as an archetype of the potential lien in the relationship. As we argued from an empirical standpoint, there can be an economically significant association between the degree of circularity of a non-financial company and its risk, relative to both its publicly traded securities (equity risk) and the likelihood to go bankrupt (default risk). In general, by investing in entities that are committed to changing their businesses and operations in a circular direction, financial institutions may enjoy lower risk, catch superior risk-adjusted returns, and nurture their reputation.

The contribution we offer to the literature can be placed in the fields of both sustainable finance and the relationship between the CE and finance. With regard to the former, our contribution is innovative: by considering the CE as measured through the CS and as a content of sustainability different from the usual ESG framework. Its advancement stands on the fact that circularity is a more 'material' content vis-à-vis ESG. The latter includes sustainability concerns in a business-as-usual model that remains linear, whereas the first involves rethinking the economic paradigm by origin, generating ESG impact as a consequence of the circular transition. Moreover, the evidence reported in the discussion of the de-risking effect is in line with most of the literature on sustainable finance, which is also in favour of an association between the degree of sustainability and financial performance (Friede et al., 2015). Referring to the second field, research on circular finance is a new strand of literature and we contribute to its theoretical design and empirical evidence. The four-pillar framework states which main topics should be taken into consideration when the transition chain toward a circular finance is developed. Moreover, the 3R Model of opportunities provides a comprehensive theory of the drivers that generate benefits for financial players – that is, mainly credit institutions and asset managers – who decide to embrace and actively support a circular transition of the economy. Empirical research shows support for the proposed theory; this chapter is focused on the first array of opportunities, namely risk.

When we refer to our empirical results, it is necessary to observe that the field we hereby present has a limited geographic scope, for we focused only on EU-15 countries, plus Switzerland, and considered only industries that are resource intensive and clustered in the manufacturing, energy, construction, and mining sectors. Nevertheless, our results point toward the circular transformation representing a powerful opportunity for the financial industry, which, concurrently, is a strong enabler of the circular transition. By choosing assets that are more circular, investors would be able to better withstand exogenous shocks, secure their returns over time, and minimize the losses on the capital they disbursed. In other terms, circular assets can be more appealing than linear ones. Theoretically, this should trigger a substitution effect within portfolios, ultimately resulting in the gradual exclusion of linear assets from the market by a free choice of agents, not solely due to regulatory constraints. This substitution effect would affect those assets that are not in line with the ongoing transition, for they are expected to become more and more stranded as time passes.

Symmetrically, this is likely to shed a positive light on more circular companies and business operations. In their financial dimension, it means being able to pursue advantages in terms of a more stable capital structure, thanks to the ability to attract long-term investors, such as institutional ones, which follow a buy-and-hold investment strategy, a lower cost of capital, as these securities have (1) a more prudent risk profile and (2) a broader, better diversified basis of funders. The combination of (1) and (2) should raise the interest of both policymakers and the authorities that oversee the financial system, persuading them that a support to the development of circular and sustainable finance is not only positive for the growth of the economic system but also a relevant element to increase stability. The latter is a fundamental element for the acknowledgement of the lower level of risk, incorporated by the portfolios of circular assets, which should orient and drive regulators to distinguish between linear and circular assets and look at the latter as a positive supporting factor.

For instance, the reduction of capital requirements could represent a tangible reward for that portion of the FS industry that has decided to play the role of catalyst in the circular transformation.

Educational content

1 Reflect on the double-sided relationship between the CE and finance. In your opinion, which of the two aspects prevails? Is finance a catalyst of the CE, or the CE as a source of valuable opportunities for finance?
2 Regarding financial institutions, how could you link the theoretical framework of the four pillars with the 3R Model of opportunities?
3 In your opinion, which are the most prominent features of the CE paradigm that contribute to significantly reducing both default and equity risk?
4 According to the theory and evidence presented in the chapter, is the role played by non-financial information disclosure determinant for fostering the role of finance as a catalyst for the CE adoption? How?

Note

* For those readers who are unfamiliar with the financial nomenclature we use in this chapter, we suggest you familiarize by using the most up-to-date edition of the *Investments* handbook by Bodie et al. (1999).

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14

CORE COMPETENCES AND CORE RESOURCES AS CATALYSTS FOR THE DESIGN OF CIRCULAR BUSINESS MODELS

Davide Chiaroni and Andrea Urbinati

Introduction

The circular economy (CE) is an industrial approach that aims to substitute the linear 'take, make, dispose' model of business (Ellen MacArthur Foundation, 2015), recognising that resources are neither abundant nor easily accessible to satisfy a growing demand for new products and services (McDowall et al., 2017; Zhu et al., 2011). A CE view of business can lead the economy to a new sustainable pattern of growth (Antikainen & Valkokari, 2016) and motivate society at large to adopt more sustainable behaviours (Haas et al., 2015; Miliute-Plepiene & Plepys, 2015).

In existing research, the CE approach is analysed through three main perspectives and units of analysis: the macro-perspective (e.g., regional, national), the meso-perspective (e.g., business network, supply chain), and the micro-perspective (e.g., single company) (Khitous et al., 2020; Ranta et al., 2020). At the macro-perspective level, research focuses on the overall context within which CE initiatives take place between different stakeholders and especially on the formulation of policies to guide governments towards decisions that are beneficial to society (Kirchherr et al., 2018; Murray et al., 2015). At the meso-perspective level, research focuses on business ecosystems and supply chains within which the focal company operates (Wen & Meng, 2015). At the micro-perspective level, scholars focus on how companies design a circular business model by significantly rethinking the anatomy of their (linear) business model and strategic positioning (Urbinati et al., 2021). Accordingly, the concept of circular business models has recently emerged in studies, investigating, from a strategic management perspective, how companies (re)design their business model to become more sustainable and conform to the principles of CE (Bocken & Short, 2020).

Research on circular business models highlights, in particular, how the design of a circular business model requires companies to adopt certain managerial practices (Urbinati et al., 2017). For example, companies are encouraged to make more effective use not only of energy, materials, and resources, but also data and information (Acerbi & Taisch, 2020), and to contextually reduce their environmental waste by adding value along the supply chain (De Angelis et al., 2018). Again, manufacturing companies are called on to develop, distribute, and retrieve products while maintaining product ownership (Tukker, 2015; Tukker & Tischner, 2006). This system is aimed at extending the responsibility of the producer, who maintains ownership of the product while

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allowing the customer to act as a user in the market and no longer as a buyer. The ownership of products implies a shift from product selling to a product-service system (PSS), which is based on the product-as-a-service principle. A PSS can take place through pay-per-use (e.g., leasing or renting) or pay-per-performance (Bocken & Ritala, 2021), and by developing reverse logistics and take-back systems, which are usually designed to take the product back from the customers (Ranta et al., 2018; Engez et al., 2021). Although it is not the only option for circular business models, the product-as-a-service principle is indeed one of the key pillars of the CE (Lacy & Rutqvist, 2015).

However, existing literature in this research area argues that there are no one-size-fits-all practices for circular business models (Palmié et al., 2021), as each company should (re)design its own circular business model by exploiting at best the particular contextual conditions, both internal (such as strategic orientation, company's age and size, etc.) and external (such as geography, level of market competition, etc.) characterising the market where it operates (Ünal et al., 2019; Henry et al., 2020; Zucchella & Urban, 2019).

In recent decades, scholars have predominately neglected the resource-based view of companies in CE studies, although this is among the main theoretical lenses in strategic management studies. The resource-based view of companies aims at addressing the question of how some companies persistently outperform others through leveraging on their core competences and resources (Barney, 2001). Very few studies analyse the relationship between circular business models and the resource-based view of companies (Nandi et al., 2020). For example, Jabbour et al. (2019) highlight a set of core resources, such as input materials, parts, finished goods/ services, machinery, facilities, and infrastructure, which may support cascading circular strategies across supply chains. Core resources can also be represented by digital technologies, such as cyber-physical systems, smart sensors, machine-human interactions, big data, and blockchain-based data transparency systems, which may support design-for-remanufacturing capabilities and resource efficiency in (circular) supply chains (Rosa et al., 2020; Bag et al., 2019, 2020). In addition, Blomsma et al. (2019) emphasise the role of knowledge, skills, and applicability of business processes as core competences that allow companies to plan, lead, organise, and control CE configurations. These competences are at the core of several companies and may enable the design and transformation of their circular business model (Kaipainen & Aarikka-Stenroos, 2021; Re & Magnani, 2022). Core competences and resources are not necessarily already owned by the companies but may depend on external actors. In this case, the company must evaluate the risk of dependency on the value network for these competences and resources (Blomsma et al., 2019; Franco, 2017).

Starting from the premise mentioned previously, the presence of core competences and resources may play a determining role in the way companies design a circular business model, and more interestingly in the way they may remain competitive in the long term once their transition towards CE has taken place (Santa-Maria et al., 2021). Core competences and resources can act as catalyzing factors to drive the transition of companies' business models towards a CE and enable CE implementation in business (Sarja et al., 2021). In the current research literature, however, there are only a very few studies on catalysts for CE and business models, and these are mostly aimed at contributing to the existing research on CE implementation in business organisations by providing understanding of the role of these factors in enabling the transition (Ranta et al., 2021). Further research is needed on this topic.

This chapter examines the relationships between core competences and resources and the concept of circular business model design and develops insights that advance the boundaries of the resource-based view of companies in the studies of CE and circular business models.

Conceptual development

Circular business models

A circular business model can be defined as a business model that is "sustainable only if value can be economically recovered from the product. It might be realised through reusing the product, thereby extending the value of the materials and energy put into the manufacturing process, or by breaking it down into components or raw materials to be recycled for some other use" (Atasu & Van Wassenhove, 2021).

To the best of our knowledge, in the current research on CE there are only a few attempts to analyse the characteristics of circular business models. Some authors provide conceptual taxonomies and focus on the concepts of take-back systems and recycling (Ranta et al., 2018). Other studies propose archetypes of sustainable business models and emphasise the creation of value from waste (Bocken et al., 2014). Further research develops frameworks of business model innovation in a CE, by focusing attention on the efficient use of resources (Planing, 2015). Complementary to these studies, a few scholars have tried to provide a comprehensive set of actions for circular business model design (Urbinati et al., 2017).

Recent research highlights how companies purposively adopt particular managerial practices to (re)design the business model to become more sustainable and conform to the principles of the CE (Ferasso et al., 2020). Managerial practices can be recognised as the actions that top management adopts to allow for the transition from a linear to a circular business model (Del Vecchio et al., 2022). The adoption of these managerial practices can take place within three main dimensions of a business model: value creation, value transfer, and value capture (Centobelli et al., 2020). For example, value creation occurs by adopting Design for X practices (Sassanelli et al., 2020), such as design for remanufacturing or reuse, design for assembly and disassembly, and design for recycling (Vermeulen, 2015); value transfer consists in leveraging multi-channels of communications with clients or exploiting digitally enabled technologies and businesses, such as sharing platforms (Henry et al., 2020); and value capture takes place through the adoption of new revenue stream mechanisms, such as take-back and/or PSSs (Khitous et al., 2022). A recent review conducted by Franzò et al. (2021) provides a summary of relevant managerial practices that companies can adopt in relation with each business model dimension to design a circular business model.

More recent research addressing the micro-perspective of the CE highlights additional company-specific conditions, such as the commitment of managers and the presence of enabling digital technologies, which can support the design of circular business models (Centobelli et al., 2020). For example, research has pointed out that companies can adopt digital technologies, such as big data, cyber-physical systems, and simulation as enablers of circular business models (Pagoropoulos et al., 2017; Rosa et al., 2020; Uçar et al., 2020). For example, big data can be used to assess potential pathways for secondary materials (Davis et al., 2017; Jose & Ramakrishna, 2018), or industrial symbiosis (Song et al., 2017), while cyber-physical systems may enable the life cycle management of products (Caggiano, 2018). Simulation systems can allow for optimising the performance of supply chains and modelling material flows (Schäfers & Walther, 2017). Table 14.1 summarises the presented discussion on managerial practices for circular business model design.

Despite the emerging stream of literature on the topic of circular business models, we believe there is still a lack of understanding within the micro-perspective of CE about the micro-foundations for the adoption of the managerial practices described previously. We thus posit that a powerful, and yet overlooked, theoretical lens for investigating these micro-foundations is the resource-based view of companies.

Table 14.1 Managerial practices for circular business model design

Business Model Dimensions		
Value Creation	*Value Transfer*	*Value Capture*
• Design for X practices. • Resource efficiency measures (REMs) or practices on the supply side, demand side, and life cycle to reduce the resources needed for goods or services, redesign of processes, life cycle assessment (LCA) techniques. • Selection of partners along the supply chain and development of a suitable ecosystem of several stakeholders. • Energy efficiency, use of renewable energy sources, and exploitation of waste as a resource. • Adoption of digital technologies.	• Commercial and promotion initiatives. • Communication of circularity through all channels. • Offering the right value to the right customers. • Management of changes in customer habits (or even changes in customers) due to selling circular products or services. • Adoption of digital technologies.	• Shift from product selling to the product-service system (PSS). • Extension of the product life cycle through collaborative consumption and virtualisation of services. • Building and maintenance of relationships with customers (to achieve waste elimination and closing loops, e.g., incentives and benefits offered to customers for taking back used products). • Adoption of digital technologies.

Source: Adapted from Franzò et al., 2021.

The resource-based view of companies

The broader resource-based view of companies starts from the assumption that competences and resources may be heterogeneously distributed across companies and that these differences may be long-lasting (Barney, 2001). Thus, the resource-based view of companies incorporates traditional strategy insights concerning a company's distinctive and heterogeneous competences and resources (Grant, 1991; Mahoney & Pandian, 1992). This view integrates three different resource-based theories of competitive advantage, which, despite sharing the emphasis on understanding why some companies can consistently outperform others, also show some differences, which need to be emphasised:

- Structure-Conduct-Performance theory of competitive advantage (Porter, 1991).
- Neo-classical microeconomics theory (Ricardo, 2005).
- Evolutionary economics theory (Nelson & Winter, 2002).

The Structure-Conduct-Performance theory adopts the assumption that the company's performance in the market depends critically on the characteristics of the industry in which it competes, as in the structure (Porter, 1991). In addition, this theory argues that some competences and resources can only be developed over long periods of time (i.e., path dependence), being characterised by both a causal ambiguity. This means that it may not always be clear how to develop them in the short to medium term, and as a social complexity, as some competences and resources cannot be bought and sold, at least some of them may be inelastic in supply (Dierickx & Cool, 1989). Supply inelasticity implies that companies that possess these kinds of competences and resources may be able to generate above normal profits and protect themselves from competitors, whose ability to supply the same competences and resources is then prevented. Thus, these kinds of competences and resources can become a source of competitive advantage (Peteraf, 1993). This theory can be especially used by scholars for studying the specific sources of sustained competitive advantage for a company (Barney, 2001).

The neo-classical microeconomics theory adopts the assumption that, in general, competences and resources (called 'factors of production' by neo-classical microeconomists) are elastic in supply. This elasticity means that when demand for a particular competence or resource increases, the price of acquiring either the one or the other will also increase, and the total amount of either made available to the market will also increase. This theory can be used especially by scholars for studying yields generated by the differential ability of companies to develop new competences and resources as the environment changes (Barney, 2001).

The evolutionary economics theory adopts routines – as an example of a company's competences and resources – as the fundamental unit of analysis, and companies vary in the routines they have developed to run their business. According to this theory, some routines may provide more sustainable competitive advantage than others and the performance that a routine generates ensures the survival of the company. This theory can be used especially by scholars when interested in studying how competences and resources evolve over time (Barney, 2001).

In this chapter, we take the perspective of the Structure-Conduct-Performance theory of competitive advantage, as we are mainly interested in studying whether and how companies leveraging on core competences and resources in designing their circular business models have opportunities to succeed in their transition towards, or adoption from scratch of, a CE.

A resource-based view of circular business models

Building on the previous two sections, we argue that the resource-based view of companies can act as a theoretical lens for understanding why companies, in designing their circular business model, adopt a specific managerial practice among those theoretically available. By leveraging on this conceptual development, we maintain that a resource-based view of companies is a necessary antecedent to be addressed in studies about CE catalysts. We take stock of research on the micro-foundations for the design of circular business models, through the resource-based view of companies, and depict the conceptual framework reported in Figure 14.1. According to the proposed framework, core competences and resources may act as catalysts in the design process of circular business models.

The resource-based view of companies focuses on core competences and resources controlled by companies, which can represent a competitive advantage (Barney, 1991). According to Barney (1991), companies may own core competences and resources that cannot be found in others. It is worth mentioning that in relation to core competences, Teece et al. (1997) present

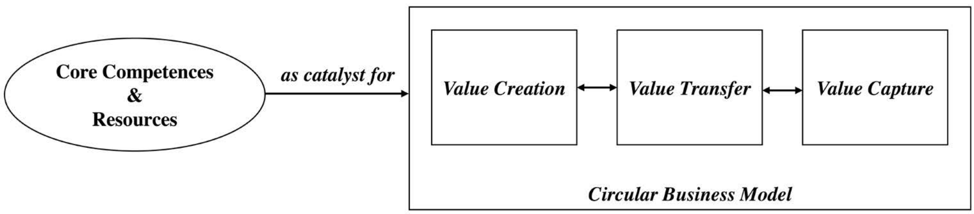

Figure 14.1 Conceptual framework of the resource-based view of companies for the design of circular business models.

the dynamic capability approach, which warns that companies must renew their sources of competitiveness, especially in environments that change rapidly. According to Teece et al. (1997), companies need to integrate, build, and reconfigure their capabilities to deal with these changes in the environment. The concept of dynamic capability expands the traditional resource-based view of companies into the realm of dynamic environmental contexts, where changes and disruptions are the norm rather than the exception. These changes in the environment, in the context analysed in this study, can properly be represented by the transition of companies to circularity. Therefore, understanding what competences and resources may support a company in the pathway towards a CE can help the same companies be competitive with their circular business model (Seles et al., 2022).

Core competences and resources supporting the adoption of managerial practices in circular business models

In this section, we present the relationship between the core competences and resources and the specific managerial practices enabling the design of a circular business model. When reflecting on CE research, the resource-based view of companies can allow us to investigate the core competences and resources that may support the design of circular business models, with reference to each business model dimension, such as value creation, value transfer, and value capture (Kaipainen & Aarikka-Stenroos, 2022).

In the value creation dimension of a circular business model, core competences and core resources are mostly aimed at contributing to the creation of the value proposition, namely a circular product or a circular service. Core competences may be technical or design-related ones, concerning programs for industrial-technical or for eco-sustainable drawing (Romani et al., 2021), while physical resources may concern laboratories or R&D units where the running of the circular production process and the development of circular products and services take place (Ghisellini & Ulgiati, 2020).

In the value transfer dimension, core competences and core resources must address two main aspects: what the circular value proposition to be communicated to the client is and how to communicate it. Here, core competences may be either hard, meaning technological or innovation-related ones, or they may be soft or communication-related, such as storytelling, persuasion, negotiation. Core resources may be composed of digital assets, such as platforms, or human resource assets, for example, marketing managers (Blasi et al., 2021; Wilson et al., 2021).

In the value capture dimension, core competences and core resources address the way companies generate revenue streams through the adoption of PSSs while taking back the products from customers. In this case, core competences may be soft (or collaboration-related), about supplier involvement and customer requirements, while core resources may concern physical assets, such as take-back systems, reverse logistics, and distribution channels (Uhrenholt et al., 2022).

The following section discusses at length the main core competences and core resources supporting the design of each dimension of a circular business model.

Core competences and resources supporting the adoption of managerial practices in the value creation dimension

Core competences and core resources in the value creation dimension of a circular business model are mostly exploited within the boundary of the company, either at product or process level, as they contribute to the creation of the value proposition, i.e., a circular product or a circular service. Core competences are mostly defined as being technical or design-related and technological or innovation-related, and they may concern programs for either industrial-technical or eco-sustainable drawing (Romani et al., 2021), and CAD and modelling skills, respectively. Physical resources may concern laboratories or R&D units where innovation designers run the circular production process and the development of circular products and services takes place (Ghisellini & Ulgiati, 2020).

At the product level, core human resources mostly support the Design for X practices that can be specifically applied to the product, such as the design for assembly, the design for disassembly, and the design out waste. Human resources should be able to pay attention to the selection of materials and tools, and to suggest innovative product-based strategies (van Dam et al., 2020). Research suggests that the creation of the internal role of "product designer" should be able to manage the communication flow within the company and the relationships within the upstream partners of the supply chain, such as suppliers or other intermediaries between the supply and the production phases (Sumter et al., 2017). Here, the adoption of some enabling digital technologies, such as 3D printing, could also be useful for supporting companies in the design for assembly and/or disassembly, by producing modular and customised products for customers in places that are located near them, thus exploiting a geographical advantage (Despeisse et al., 2017). Some required competences for the adoption of 3D printing are related to computer-aided design (CAD) and modelling skills, knowledge of additive manufacturing systems and technologies, and knowledge of the characteristics and behaviours of 3D printing materials (Luiz Mattos Nascimento et al., 2019).

At the process level, core human resources support the Design for X practices that can be specifically applied to the process, such as the design for remanufacturing, the design for refurbishing, and the design for recycling. Companies' designers and engineers should be able to design circular production processes by paying attention to the product's life cycle. Research suggests also the creation of an internal role acting as 'process designer' able to meet the principles of sustainable production, production processes, and material reuse strategies (Bocken et al., 2016). Also here, the adoption of some enabling digital technologies, such as the Internet of Things (IoT), could be useful for the monitoring, analysis, and control of product data to support the product's life cycle and extend their replacement along the entire supply chain (Wang et al., 2014). Some required competences for the adoption of IoTs are related to embedded hardware and software design, and driver development for the nodes that collect data, as well as skills for developing mobile and cloud applications for the IT side of the system (Bressanelli et al., 2019).

Core competences and resources supporting the adoption of managerial practices in the value transfer dimension

Core competences and core resources in the value transfer dimension of a circular business model must address the following two main aspects: what circular value proposition is to be communicated to the client and how to communicate the proposition. The first aspect is mostly related to the managerial practices of commercial and promotion initiatives and the communication of circularity through all channels, while the second one is mostly related to the managerial practices of the offering of the right value to the right customers and the management of changes in customer habits, or even changes in customers themselves, due to selling circular products or services.

The human component is, of course, a core resource. Company employees, especially those in charge of communicating the circular product or service, should be able to help customers perceive the value of the circular product or service. They must develop a core competence that goes beyond the traditional communication or promotional ability, which Settembre Blundo (2017) defines as an “evangelization” of customers. Accordingly, those in charge of external customer communication should be able to pay attention to the expectations of clients, understand their needs, be able to resolve their CE-related issues, and persuade them through storytelling and negotiation of the merits of the circular value proposition (Blasi et al., 2021).

The presence of technological or innovation-related competences related to digital technologies are also expected to play a significant role in the circular value proposition. This applies to product-related competences, such as artificial intelligence (AI). Following the definition of the objectives, the phases of an AI project include the collection of the data, their preparation, the choice and optimisation of the model, its testing and training, the fine-tuning of the parameters, its deployment, and subsequent re-editions (versioning of the software). Some required competences for the adoption of AI are, for example, those of data scientists, data analysts, and data engineers to program the AI, for cleaning and preparing the data, and for managing and processing the data, respectively. The presence of competences related to digital technologies is also useful in relation to the way companies interact with their clients in the market, for example, for software pattern recognition, prediction, optimisation, and recommendation generation (Wilson et al., 2021).

The presence of digital assets, especially digital infrastructure, are designed as a virtual place, are able to allow the connection and virtual interaction of multiple users through integrated interfaces, and are mainly managed through applications or websites (De Reuver et al., 2017). They may play a relevant role for enhancing the commercial and promotional initiatives and during the communication of circularity with clients.

Core competences and resources supporting the adoption of managerial practices in the value capture dimension

Core competences and core resources in the value capture dimension of a circular business model address the way companies generate revenue streams through the adoption of PSSs while taking back the products from customers to guarantee the product’s life cycle extension and the closure of the materials’ loop.

Market-related technological competences about how to design and manage PSSs centres on “tangible products and intangible services, designed and combined so that they jointly are capable of fulfilling specific customer needs” (Tukker, 2004, p. 246), and are of paramount importance for the design of circular business models. In particular, product-oriented PSSs are aimed at supplementing products with additional services such as repair services; use-oriented PSSs are aimed at letting the product remaining under the ownership of the producer, addressing the users through rental or leasing services; result-oriented PSSs are aimed at allowing the producer to sell results rather than products, for example, power by the hour (Khitous et al., 2022).

As highlighted by Isaksson et al. (2009), successfully managing PSSs also requires specific product-related competences, such as “hardware design (including integrated electronics and software), design for manufacturing and assembly, supplier involvement – both component suppliers and sub-system suppliers, and customer requirements on product use (mainly via marketing function)” (p. 340). This claim holds true for the presence of soft skill or collaboration-related competences and the engagement of the other actors of the supply chain, by driving their transition towards the CE (Aarikka-Stenroos et al., 2002; Kaipainen et al., 2022).

Finally, as argued by Uhrenholt et al. (2022), the presence of physical assets constituting an effective take-back system are needed to support “the collection of end-of-life products, transportation, sorting and disassembly, requalification, and re-engagement of the recovered material, components or products in the forward supply chain" (p. 2). Thus, take-back systems are aimed at recovering value from products to be recycled, remanufactured, or refurbished. These systems are fundamental for the adoption of CE principles applied to reverse logistics and distribution, and represent a core resource for the design of a circular business model (Lewandowski, 2016).

Table 14.2 aims to open the black box at the intersection between the resource-based view of companies and the design of circular business models, based on the conceptual framework depicted in Figure 14.1. This table provides a summary of the core competences and resources required by companies for the adoption of the managerial practices enabling the design of a circular business model.

Discussion and avenues for future research

Figure 14.2 provides a visual representation of the framework highlighting the different linkages between the core competences and core resources and the managerial practices they enable in the different dimensions of a circular business model.

First, the complexity of these linkages should be noted. To effectively enable a certain managerial practice, the coexistence inside the company of a defined set of core competences and resources is necessary. For example, Design for X practices require the simultaneous presence of adequate human resources, adequate physical assets, and technical, or design-related, competences related to drawing. This is consistent with the literature on the resource-based view, where resource recombination (Burt & Soda, 2021; Galunic & Rodan, 1998) is considered a key process in allowing the company to turn a set of core competences and resources to competitive advantage by either combination (i.e., synthesis-based recombination) or reconfiguration (i.e., reconfiguration-based recombination). Our framework suggests that this recombination can enable companies to adopt a given managerial practice in their circular business models. At the same time, core competences or resources, through different recombinations, allow the company to adopt different practices. For example, product-related competences inform the adoption of several managerial practices, from the adoption of digital technologies to the shift towards PSSs.

Second, when core competences are addressed in particular, it appears clearly that circular business models require the contemporary presence of the ability to design new products and/or services (technical competences), the ability to innovate (technological competences), with a significant role of digital technologies, the way through which products and/or services interact with the customers, and finally the ability to collaborate and communicate in an engaging way (soft skills) with the different actors of the supply chain, in order to connect with the proper ecosystem for the CE.

Moreover, in reading the framework, it is worth remembering that circular business models are purposeful combinations of managerial practices and, in this respect, as clarified also in Franzò et al. (2021), it is not necessary for all the managerial practices to be simultaneously adopted by the company to become circular. Consequently, different companies with different circular business models require a different combination of core competences and resources. This match between a company's internal core competences and resources, and its strategic positioning – its decision about the circular business model – is of paramount importance for defining the enabling role of core competences and resources. The presence of a certain core competence or resource does not mean that the company should pursue the adoption of a certain managerial practice. On the contrary, once the adoption of a certain practice is considered relevant for the company's circular business model, the presence or lack of the related core competences and resources plays

Table 14.2 An overview of the resource-based view of companies for the design of a circular business model and the adoption of managerial practices

Business Model Dimension: Value Creation				*Managerial Practice*
Core competences	Technical competences (design-related)		Industrial-technical or eco-sustainable drawing	Design for X practices (in general) both at product and process level
	Technological competences (innovation-related)	Product-related competences	CAD and modelling skills, knowledge of additive manufacturing systems and technologies, knowledge of the characteristics and behaviours of 3D printing materials	Adoption of digital technologies (such as 3D printing)
		Process-related competences	Embedded hardware and software design, skills for developing mobile and cloud applications for the IT side of the system	Adoption of digital technologies (such as IoTs)
				Resource efficiency measures (REMs) or practices on the supply side, demand side, and life cycle, redesign of processes, life cycle assessment (LCA) techniques
				Energy efficiency and use of renewable energy sources, and exploitation of waste as a resource
Core resources	Human resources		Product designers	Design for assembly, design for disassembly, design out waste
				Selection of partners along the supply chain and development of a suitable ecosystem of several stakeholders
			Process designers	Design for remanufacturing, design for refurbishing, design for recycling
				Selection of partners along the supply chain and development of a suitable ecosystem of several stakeholders
	Physical assets		Laboratories or R&D Units	Design for X practices (in general) both at product and process level

(*Continued*)

Table 14.2 (Continued)

Business Model Dimension: Value Transfer				*Managerial Practice*
Core competences	Soft skills (communication-related)		Storytelling, Persuasion, Negotiation	Offering of the right value to the right customers Management of changes in customer habits (or even changes in customers) due to selling circular products or services
	Technological competences (innovation-related)	Product-related competences	Programming the AI, cleaning and preparing the data, managing, and processing the data	Adoption of digital technologies (such as AI)
		Market-related competences	Pattern recognition, prediction, optimisation, and recommendation generation	Adoption of digital technologies (such as PSS) Offering the right value to the right customers Management of changes in customer habits (or even changes in customers) due to selling circular products or services
Core resources	Human resources		"Evangelists" of customers	Communication of circularity through all channels Offering the right value to the right customers
	Digital assets		Digital infrastructure, designed as a virtual place, able to allow the connection and virtual interaction of multiple users	Commercial and promotion initiatives Communication of circularity through all channels

Business Model Dimension: Value Capture				*Managerial Practice*
Core competences	Technological competences (innovation-related)	Product-related competences	Hardware design (including integrated electronics and software), design for manufacturing and assembly	Shift from product selling to the product-service system (PSS) Adoption of digital technologies
		Market-related competences	Use-oriented and result-oriented product-service systems (PSSs)	Extension of the product life cycle through collaborative consumption and virtualisation of services Building and maintenance of relationships with customers (to achieve waste elimination and closing loops, e.g., incentives and benefits offered to customers for taking back used products)
	Soft skills (collaboration-related)		Supplier involvement – both component suppliers and sub-system suppliers, and customer requirements on product use (mainly via the marketing function)	Shift from product selling to the product-service system (PSS)
Core resources	Physical assets		Take-back systems, reverse logistics, and distribution channels	Extension of the product life cycle through collaborative consumption and virtualisation of services

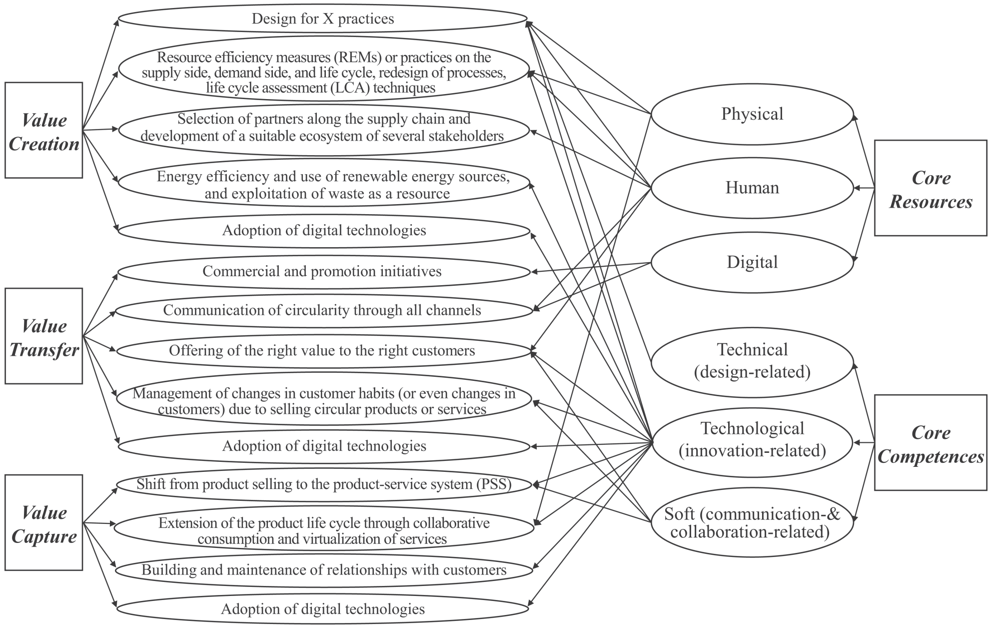

Figure 14.2 Conceptual framework: Visual representation of linkages between managerial practices and core competences and resources.

a fundamental enabling role. This strategic interaction (Seles et al., 2022) is essential, even more so in today's turbulent and dynamic environment, for interpreting the proposed framework by considering both business strategies and company-specific competences and resources.

Finally, an additional lens to put in place in reading the proposed framework is in the nature of the company adopting a circular business model, whether it is a "born circular company" (Zucchella & Urban, 2019) or a "growing circular company" (Chen et al., 2020), where the adoption takes place in this second case through a process of transformation of the existing (linear) business model towards a circular one. In the case of a 'born circular company', the enabling role of the identified core competences and resources for the adoption of a certain managerial practice is even more evident, as it is the lack of these competences and resources in preventing the new company from developing a certain circular business model. In this respect, several contributions (e.g., Razmdoost et al., 2020; Ng et al., 2019) highlight the required combination of ordinary competences and resources with core competences and resources to ensure the successful formation of new ventures in both stable and dynamic environments. Established companies, on the contrary, while embracing a transition towards CE, not only do they need to have the required core competences and core resources for enabling managerial practices, but they must also avoid clashes with other existing core competences and resources tightly related to the existing (linear) business models. For example, the presence of physical assets such as centralised large-scale production plants might prevent the company from embracing a distributed remanufacturing scheme that is more coherent with a CE approach. Or again, the presence of a well-established distribution channel designed for a one-way shipment towards the final customers might prevent the company from putting in place take-back systems. Potential clashes at the level of core competences and resources are already debated in literature, where, for example, Franco (2017) discusses the challenges of incumbents in the textile industry to adopt circularity due to the presence of 'linear' core competences and resources. More recently, Sarja et al. (2021), in their systematic literature review about the transition to CE in business organisations, argue that some competences and resources in an established company may even play an ambivalent role in both supporting and hindering the transition to CE, depending on the situation and circumstances of the company as well as on other contextual factors. Consequently, for established companies, not only must the presence per se of an enabling core competence or resource be verified, but it is also necessary to evaluate that there are no clashes with other existing competences and resources pushing linear business models.

Our framework only touches on all the previous points, which require an in-depth understanding of the phenomenon, thus paving the way for interesting avenues for future research. The opportunity to recombine core competences and resources in an original way might lead to completely new managerial practices. At the same time, investigating the characteristics of knowledge and its social organisation, such as the way competences come to be formed and institutionalised (Galunic & Rodan, 1998), in circular companies might impact the likelihood of such recombination. The role of strategic alignment between circular business models and core competences and resources also requires further investigation, allowing also in this case for the development of completely new typologies of circular business models. Finally, further research is needed to shed light on the ways the proposed framework must be adopted to study incumbent companies versus new ventures, with the interplay of existing competences and resources stemming from linear and circular models deserving a lot of attention.

Conclusions

Our study is based on a conceptual framework at the intersection between the resource-based view of companies and the circular business model literature. We argue that to properly understand the way companies design their business models by adopting some particular managerial practices from among those theoretically available, the presence of specific core competences and resources needs to be investigated. Consequently, core competences and resources can act as catalysts inside the company in enabling the process of circular business model design, guiding managers in the choice of managerial practices regarding CE. At the same time, in line with recent contributions on core competences and resources (Kaipainen & Aarikka-Stenroos, 2022; Sarja et al., 2021; Seles et al., 2022), we argue that a circular business model designed leveraging core competences and resources is more likely to succeed, as to maintain a sustainable competitive advantage over time, in the CE domain.

Therefore, we invite scholars in the field to further investigate the relationships between core competences and core resources and circular business models, as they have the potential to explain, at the micro-level, the decisions taken by companies when adopting managerial practices in their business models.

We are aware of the main limitations of our conceptual study. Besides those already discussed in the previous section, we must admit that having our focus only inside the company is preventing us from considering the potential interplay between internal and external catalysts. Several studies (e.g., Centobelli et al., 2020), for example, have questioned the role of contextual factors, such as the presence of a favourable regulatory framework or of other market-related conditions, in driving the decisions at company level on what managerial practices to be adopted in a CE context. Similarly, the presence of CE catalysts at the meso-level, as in the ones involving the supply chain and the ecosystem of business actors where and with whom the company operates (Kaipainen et al., 2022; Aarikka-Stenroos et al., 2022), should be explored to get the full picture of the factors limiting, or enabling, the managerial space of decisions addressing the circular business model design. At the same time, the core competences and core resources for circular business models considered here should be seen as an initial, exploratory list, given the novelty of the approach we followed. A further investigation, also including an in-depth empirical analysis of the framework, is certainly needed.

Many avenues for further research are therefore available, stemming from our conceptual work, and we are waiting for scholars to take it forward. Nevertheless, we consider our contribution so far to be of great relevance in supporting managers willing to adopt a CE, by suggesting they must carefully scout inside their company for the presence of the most effective core competences and resources to embrace CE, leveraging on their potential role of catalysts in the circular business model design. At the same time, for those companies that have already taken a step into the CE transition, nurturing and fostering the core competences and resources that are antecedents to CE might result in increasing the chances to sustain their competitive advantage.

Educational content

After being sure the audience is familiar with the resource-based view of companies, a potential use of the conceptual framework in this chapter for running a class on CE could be envisioned, supporting a case-based discussion of a circular business model with the following key questions:

1 Analyse the circular business model, sorting the managerial practices adopted by the company into the three business model dimensions of value creation, value transfer, and value capture.
2 Discuss the presence inside the company of core competences and core resources acting as catalysts for the circular business model design chosen by the company.
3 Evaluate and discuss, based on the previously mentioned points, the likelihood of the company creating a sustainable competitive advantage, suggesting potential actions to nurture and foster the required core competences and core resources.

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15

ARTIFICIAL INTELLIGENCE AS A CATALYST IN THE CIRCULAR ECONOMY TRANSITION

Kang Li

Introduction

Artificial intelligence (AI) refers to programming machines to do tasks intelligently and act like humans, including functions such as understanding language, solving problems, learning, and undertaking self-improvement based on previous experiences (McCarthy et al., 2006). AI, as one of the cutting-edge technology representatives, is capable of massive data collection, effective analysis, intelligent learning, and accurate prediction. AI could complete complicated tasks in a friendly and time-saving manner, especially when dealing with high-dimensional datasets. Machine learning (ML) is a type of AI that trains machines to learn intelligently from historic experience and then make decisions based on these learnings. In general, models based on AI/ML are a range of predictive programming algorithms that learn from the known and then can deduce the unknown. Those models have multiple superiorities, including being more objective and accurate, more cost-efficient, more automatic, and involve multiple types of data.

The possibilities and benefits of AI applications in CE have been discussed in the academic world. For instance, it had been suggested that AI approaches provide big data collection, efficient analysis, quick testing and prototyping functions, thus it could function as a valuable tool to improve circular product design (Ghoreishi & Happonen, 2020). The significant role of AI technologies in a CE transition have also been studied in other perspectives, such as in product management practices (Porter & Heppelmann, 2014) and reverse logistics processes (Wilson et al., 2021). Moreover, as indicated by sharing real-time information in industries, AI technologies have the potential to effectively prosper markets and unlock circularity implementation for industries (Bianchini et al., 2019; Bressanelli et al., 2018).

However, many studies only focused on the role of AI in CE transition either from a certain perspective (e.g., in product design, product management or the reverse logistics process) or just concentrated on general discussion. Few studies have deeply investigated both how and which AI technologies could be applied to achieve CE transformation in overall business processes. Presently, there is no thorough overview about how AI could act as a catalyst to accelerate the CE transition, especially through the sub-perspective of the five different circular business stages. Those five circular business stages include circular design, circular production, circular consumption, circular reuse and repair, and circular recycling stages, which Van den Berg and Bakker (2015) suggested.

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To address this research gap, the purpose of this chapter is to conduct a systematic literature review methodology to explore and find evidence from the existing literature on how AI can be a catalyst to accelerate CE transformation in the five circular business stages. The main research question in this chapter is: what is the role of AI in CE transformation? This research question is then divided into five sub-research questions to further investigate the catalyst role of AI in the sub-perspectives of five circular business stages.

This chapter shows that, in general, AI technology is evidenced to be a catalyst of CE transition. AI possesses the superpowers of real-time data collection, effective data processing, precise simulation, and accurate forecasting and analysis of a large amount of both structured and unstructured high-dimensional data. These advanced abilities help to realise circular principles, such as maximising the use of products, components, and materials, while minimising resource consumption and decreasing energy emissions in the entire circular business stages. Accordingly, AI facilitates a CE closed-loop implementation and therefore, catalyses the CE transition. This chapter extends the current CE literature to the interdisciplinary area of AI technologies. Second, it contributes by extending the possible scope of application of AI in AI-related literatures. From a theoretical perspective, these results could be useful in updating research gaps and guiding further explorations of the gaps in this emerging, interdisciplinary topic. From a practical perspective, the results may help entrepreneurs, industry leaders, and policymakers to better understand AI as a catalyst in CE transition.

The remainder of this chapter is structured as follows: The next section gives a background of AI and ML. This is followed by an overview of the methodology used for the literature search. The results are then presented. The last section includes the conclusions of the literature search.

Background

The term ‘AI’ was first proposed by John McCarthy as making machines understand language, solve problems, and undertake self-improvement based on learning experience (McCarthy et al., 2006). The main assumption behind AI is that computers, through their work process, could be built to simulate human intelligence. Since the working process of computers is understood by humans, AI could be used as an instrument to scientifically investigate and reveal the phenomenon of human intelligence, which is otherwise hard or even impossible to explore. The domain of AI is wide, with various subfields. The major subfields of AI include evolutionary computation, natural language processing, expert systems, robotics, and so on (Cioffi et al., 2020). From the 1970s to the 1980s, most studies on AI in literature focused on the dimension of making computers ‘think’ rationally. One of the most representative branches in this dimension is expert systems, which is a system to simulate the decision-making processes of human experts. However, the requirement of a huge and complex knowledge base building and the uncertainty of the reasoning system leaves expert systems out of scope (Negnevitsky, 2005). This leaves another subfield of AI called ML, with self-learning capability, which has evolved into the predominant AI technique because of its more applicable capability in practice (Bartram et al., 2020).

ML refers to a computer learning system where machines can obtain knowledge from experience data and update themselves by learning new knowledge automatically with no need for additional programs (Chanal et al., 2021). ML includes three main categories: supervised ML, unsupervised ML, and reinforcement ML. The supervised ML technique is ideal for learning the relationships in labelled data and enables constructing advanced performing forecasting systems

(Gabrys & Petrakieva, 2004). Labelled data is the data set that has been tagged with labels identifying certain classifications or characteristics of that data set. Once the model has been trained with labelled data, it can be used to elicit a response from unknown data. Therefore, ML can be used to solve problems such as with regression, classification, association rules determination, and prediction, and thus, decision-making. Unsupervised ML can analyse unlabelled or unclassified training data and discovering potential trends, patterns, or rules hidden in the dataset through a unique training system. In addition, reinforcement ML can teach an autonomous learning system to sense, as well as act, in its environment and select optimal behaviours for achieving task goals.

The most commonly used AI/ML models in literature include logistic regression (LR), artificial neural networks (ANN) and deep learning (DL), support vector machines (SVM), decision trees (DT), Bayesian networks (BN), K-nearest neighbours (KNN), gradient boosting machines (GBM), other general models (e.g., random forest and cluster analysis), and hybrid models (Ahmed & Kim, 2017; Akanbi et al., 2019; Ashwitha & Latha, 2022; Bala, 2010; Chachdi et al., 2019; Chakraborty et al., 2020; Gaur et al., 2015; Kharfan et al., 2021; Matino et al., 2019; Nassif, 2016; Rahman et al., 2011; Wang & Dowling, 2022; Wang & Liu, 2021). Generally, AI/ML models are a range of predictive programming algorithms that use the known to deduce the unknown. Models or approaches based on AI/ML technologies have several advantages. Firstly, they are more objective and accurate. They are capable of learning from previous data and determining objectively the rules of association between input variables and target variables. They are especially efficient with nonlinear modelling of highly intricate functions and pattern recognition in high-dimensional datasets. Since AI/ML models do not rely on restrictive assumptions such as previous statistical models, which utilise normal distribution of independent variables or equal variance within each group (Li et al., 2016), they can complete modelling tasks with greater accuracy. Secondly, Brey and Søraker (2009) found that AI/ML models enable computers to extract, calculate, integrate, and analyse large amounts of information in a more expedient manner. Thirdly, AI/ML approaches can deal with more diverse information sources, from both traditional structured data sources and from arranged, unstructured data sources, such as images, text messages, and online news (Sakr et al., 2016). This extraordinary advantage enables many different types of information to be collected and analysed when building the models based on AI/ML approaches. Lastly, AI/ML-based models learn rules by themselves with no explicit programming needed, and also improve themselves automatically without the need for human intervention.

The possibilities and benefits of AI applications in CE have been discussed in literature. Ghoreishi and Happonen (2020) suggested that, with the power of data collection, efficient analysis, fast testing, and prototyping functions, AI can be an accelerator in circular production designing. In addition, AI technologies have an essential role in increasing product circularity and conducting smart product management practices (Porter & Heppelmann, 2014). Wilson et al. (2021) advocated that the application of AI technologies could boost efficiency in reverse logistics and promote reusing materials and goods sustainably. Additionally, Bressanelli et al. (2018) suggested that AI, as one of the representatives in modern technology, can improve the solutions to overcome the challenges towards circularity for all sectors of society. Bianchini et al. (2019) further claimed that advanced technologies such as AI have tremendous impact on our economy, society, and labour markets. AI, with these advanced advantages, has great potential to be a technology catalyst to boost CE transformation as a developing and innovative technology in the fourth technological revolution.

Research methodology

This chapter utilises a systematic literature review methodology to explore existing literature on the role of AI applications in CE transition. Following the review process suggested in previous studies (Chauhan et al., 2022; Denyer & Tranfield, 2009; Toorajipour et al., 2021), the following five steps were performed to accomplish the objective of this chapter (see Figure 15.1), including

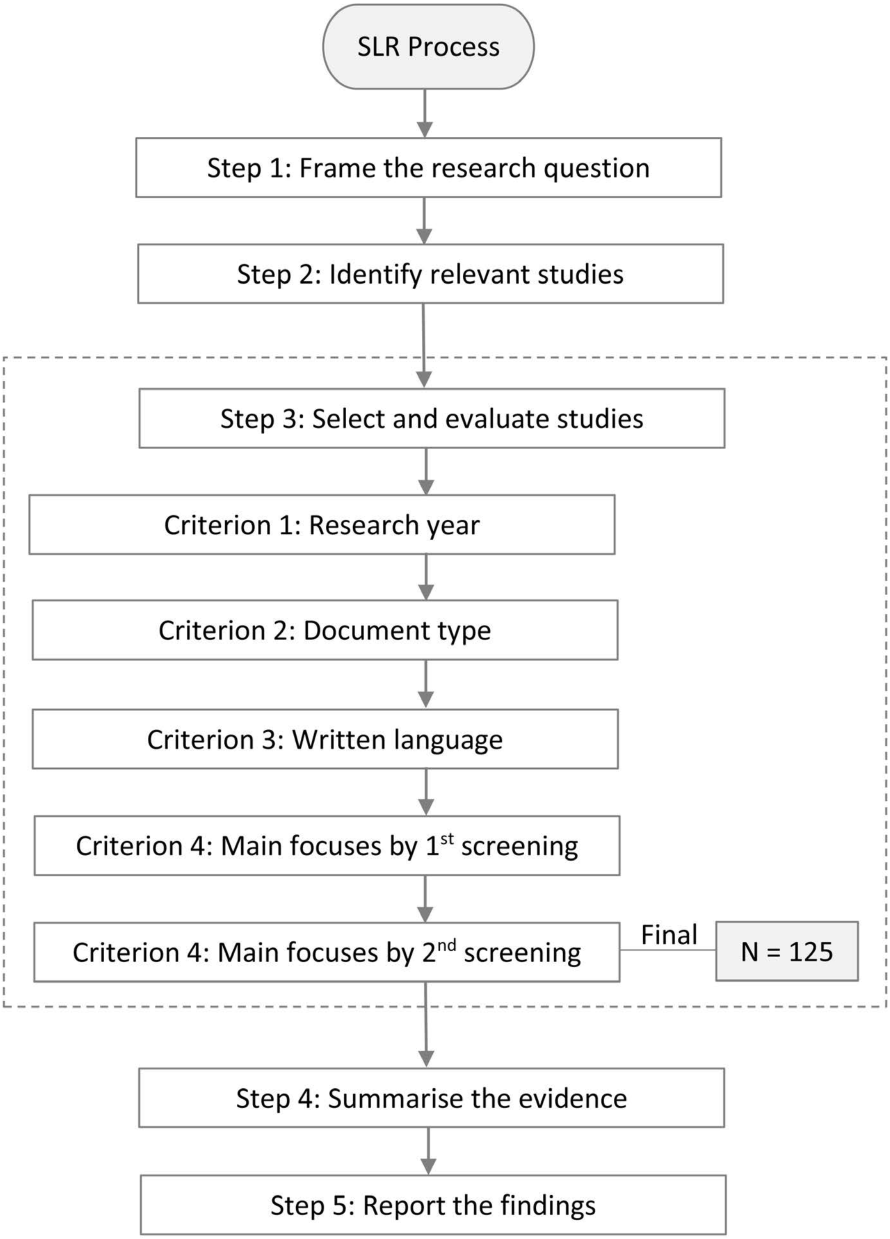

Figure 15.1 Systematic literature review process.

framing the research question, identifying the relevant studies, selecting and evaluating the studies, summarising the evidence, and reporting the findings. The details are discussed in the next sections.

Framing the research question

The first step in the systematic literature review was to determine the proper research question. The main research question (RQ) answered in this chapter is RQ1: What is the role of AI in CE transformation?

The research question draws on a framework by Van den Berg and Bakker (2015), who noted that CE is a model of closing material loops to separate wealth from resource usage. They defined five closing loops, meaning the circular design, circular production, circular consumption, circular reuse and repair, and circular recycling stages. To answer the main research question, the question is divided into the following five sub-questions (SQ):

(SQ1) What is the role of AI in the circular design stage?
(SQ2) What is the role of AI in the circular production stage?
(SQ3) What is the role of AI in the circular consumption stage?
(SQ4) What is the role of AI in the circular reuse and repair stage?
(SQ5) What is the role of AI in the circular recycling stage?

SQs 1–5 enable a review of the relevant literature more closely and thus, to have deeper insights into the knowledge therein to guide researchers, practitioners, and policy leaders.

Identification of relevant studies

To identify as many studies as possible that are relevant to the research questions, five scientific databases were selected as sources: ScienceDirect, Emerald, Wiley, Scopus, and EBSCO. The search strings were as follows: ‘AI-related keywords’ AND ‘CE-related keywords’ AND ‘stages-related keywords’. The AI-related keywords used in the search were the following: ‘artificial intelligence’, ‘machine learning’, ‘logistic regression’, ‘artificial neural network’, ‘support vector machines’, ‘decision tree’, ‘Bayesian networks’, ‘k-nearest neighbour’, and ‘gradient boosting machine’. The CE-related keywords referred to the words ‘circular economy’. The stages-related keywords selected were: ‘design’, ‘product’, ‘consumption’, ‘reuse and repair’, and ‘recycling’; these specific keywords were extracted from Van den Berg and Bakker (2015).

Selection and evaluation of studies

The first criteria that was set for selecting the studies to review was the time scope of the literature. The restriction was to search studies published in the time range of 2007–2022. The focus on the quality of the studies restricted the search to include only studies found in peer-reviewed journals and as conference papers. Additionally, only papers written in English were included. Finally, papers were filtered based on the relevance of the research focus to the previously mentioned search strings. The focus of the papers was checked through two evaluation rounds: first, by reading the title and the abstract, and second, by reading the overall contents and contributions. The final total review sample was 125 papers.

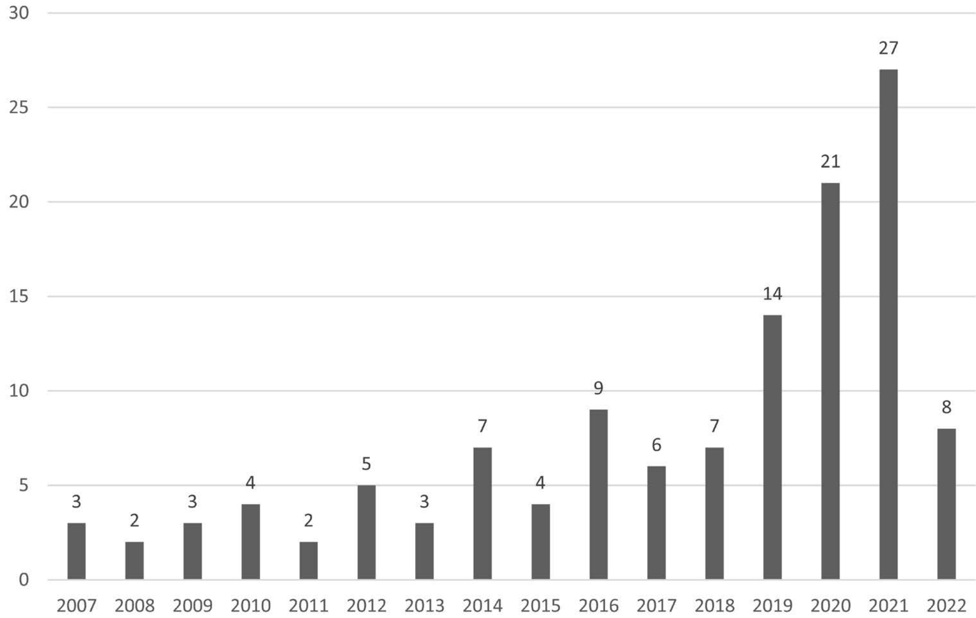

Figure 15.2 Distribution of journal article by year.

Summarising the evidence

After determining the relevant papers, the evidence was extracted and summarised. The aim was to examine the differences between studies and their distributions through descriptive analysis. The distribution and categorical analysis results are presented by year, source, document type, and AI/ML technique as described next.

First, Figure 15.2 shows the distribution of selected papers on CE research by year. The results show that the number of publications increased steadily after 2019 and peaked at 27 in 2021; this was followed by 21 publications in 2020. These results suggest the increasing attention to applications of AI/ML techniques in CE papers in the last four years of the search.

Second, Table 15.1 presents the categorical analysis of the review results pertaining to the design, production, consumption, reuse and repair, and recycling stages of the circular business process. The results show that most of the papers (42.40%) focused on the circular production stage, and only 9.60% were related to the circular design stage. Table 15.1 also shows that the top two search engines were Scopus and ScienceDirect, and the main document type was peer-reviewed journal papers.

Table 15.2 presents a categorical analysis of the studies according to the type of AI/ML methodology of the paper. The results show that the two AI/ML methodologies most frequently discussed in the articles were hybrid or general AI/ML methods (25) and specific ANN methods (24). The least used AI/ML application methodology in the CE papers was KNN (8). This suggests that hybrid AI/ML models and ANN are the current trends of research.

Reporting the findings

The review findings were reported as the main results of this study. To deeper understand the catalyst role of AI in CE transformation from previous studies, the findings were split according to

Table 15.1 Categorical analysis by sources and types

Stages	*Sources*	*Document types*
Circular Design (9.6%)	EBSCO (1) Emerald (0) Scopus (3) ScienceDirect (7) Wiley (1)	Journal (11) Conference (1)
Circular Production (42.4%)	EBSCO (5) Emerald (3) Scopus (27) ScienceDirect (15) Wiley (3)	Journal (48) Conference (5)
Circular Consumption (20.0%)	EBSCO (1) Emerald (4) Scopus (12) ScienceDirect (7) Wiley (1)	Journal (20) Conference (5)
Circular Reuse & Repair (12.8%)	EBSCO (2) Emerald (2) Scopus (7) ScienceDirect (4) Wiley (1)	Journal (12) Conference (4)
Circular Recycling (15.2%)	EBSCO (2) Emerald (1) Scopus (9) ScienceDirect (5) Wiley (2)	Journal (15) Conference (4)

Table 15.2 Categorical analysis by AI/ML technique

AI/ML technique	*Circular business stages*										
	Circular design		*Circular production*		*Circular consumption*		*Circular reuse and repair*		*Circular recycling*		*Total*
Linear regression (LR)	0	0%	5	4%	3	2%	2	2%	1	1%	11
Artificial neural network (ANN)	3	2%	8	6%	5	4%	2	2%	6	5%	24
Support vector machines (SVM)	2	2%	7	6%	3	2%	2	2%	4	3%	18
Decision tree (DT)	1	1%	8	6%	2	2%	1	1%	1	1%	13
Bayesian networks (BN)	1	1%	7	6%	3	2%	4	3%	1	1%	16
K-NEAREST neighbours (KNN)	0	0%	3	2%	2	2%	1	1%	2	2%	8
Gradient boosting machine (GBM)	0	0%	6	5%	3	2%	1	1%	0	0%	10
Others	5	4%	9	7%	4	3%	3	2%	4	3%	25
Total	12	18%	53	64%	25	34%	16	26%	19	19%	125

the five circular business stages and further divided into AI/ML technique used in the research. The results of this chapter are presented and discussed in next section.

Results and discussion

Figure 15.3 presents the role of AI/ML techniques in the five circular business stages as indicated by the reviewed studies; it was shown that AI/ML is an innovative technology that could catalyse a CE transformation. In summary, the advantages of AI/ML are that it can greatly assist circular design experts (in terms of the method, time and process, and system and environment), efficiently improve circular production procedures (i.e., in terms of planning, manufacturing, quality, and inventory control), smartly enhance the circular consumption process (by matching demand and through logistics and sharing/renting/leasing platforms), and intelligently help implement reuse, repair, and recycling (of products, parts, and materials from waste).

AI as a catalyst in the circular design stage

Figure 15.4 Appendix summarises the main research findings. Twelve of the reviewed studies discussed the use of AI in the circular design stage. The evidence generally suggested that AI technology could be a catalyst to assist and accelerate circularity transition in the design stage. Specifically, with the sophisticated data processing and analysis capabilities of AI, it can impressively improve circularity design methods and optimise the overall design time and processes. In addition, AI can upgrade ineffective design systems and improve the design environment.

Through the use of AI/ML technology, experts and designers can be offered innovative methods of finding and inventing more possible circular products and materials. For example, Wang and Liu (2021) proposed an innovative approach, based on AI technology, which helped designers consider design experiments more comprehensively, adjust design parameters faster, and evaluate potential circular materials more accurately. Second, AI/ML technology could be an effective tool for reducing the design time and simplifying the design steps in the circular design process. López-Guajardo et al. (2021) suggested that AI-based intelligent technology could dramatically accelerate the design process, reduce the design time, and reduce the complexity of the design steps. Third, AI/ML technology offers the possibility of making smart recommendations to experts and designers to assist them in the circular design stage. Huang (2021) introduced a new AI design tool that could provide recommendations and assist designers in finding possible circular materials from waste. Fourth, AI/ML technology can help build digital design platforms and avoid unnecessary harmful experiment environments in the circular design stage. Ghoreishi and Happonen (2020) indicated that AI-based applications could support designers in connecting data in a virtual experiment environment, so that harmful experiment environments or materials can be avoided. More related studies on the role of AI in the circular design stage are presented in Figure 15.4 Appendix.

AI as a catalyst in the circular production stage

Most (53) of the articles on AI/ML applications in CE were on the circular production stage. Overall, they showed that AI technology could serve as a catalyst in the circularity transition during the circular production stage. These studies further showed that AI has advanced real-time data collection and forecasting capabilities that can help manufacturers achieve circular production in four ways: by optimising the production planning process, improving the production

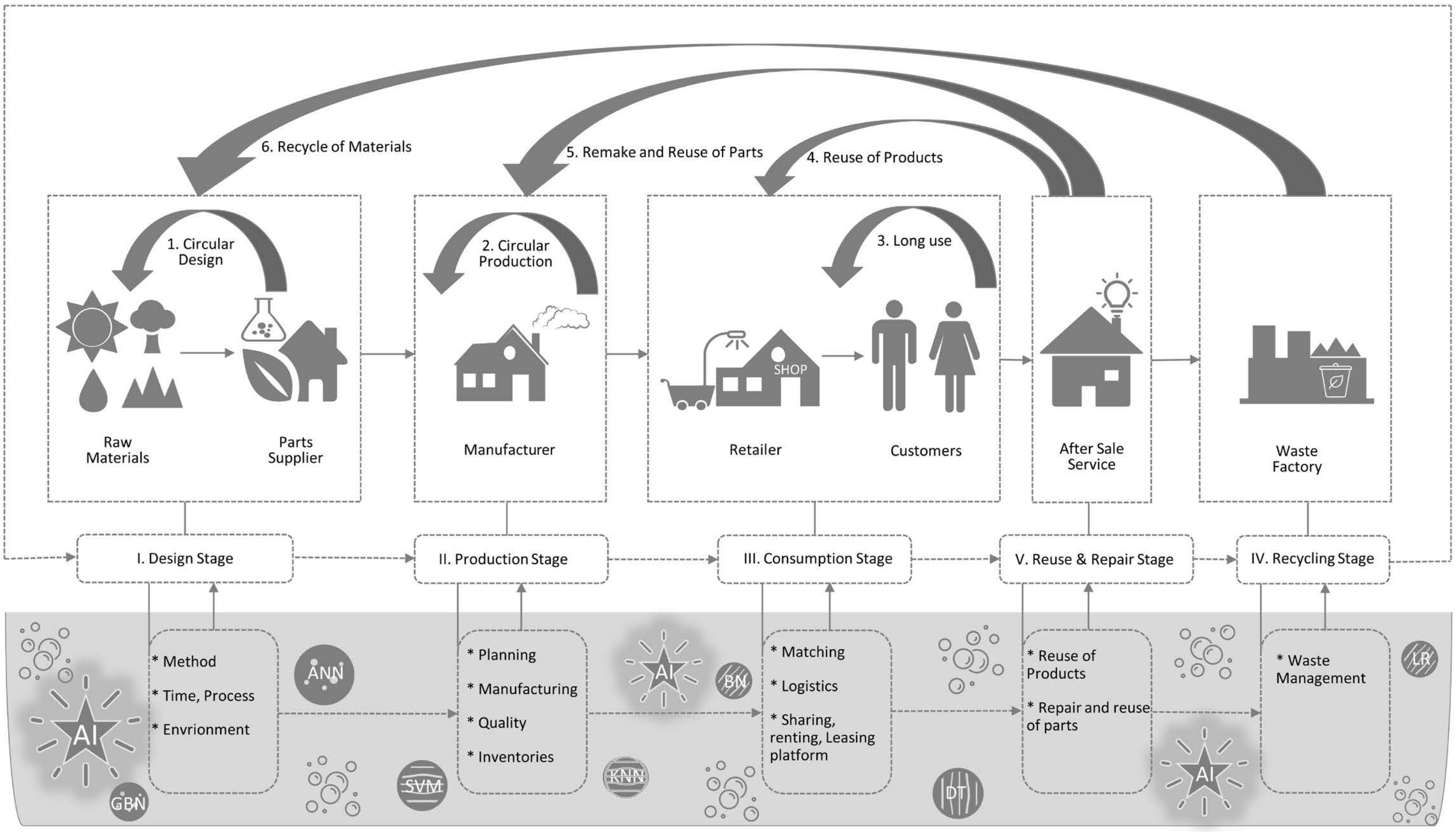

Figure 15.3 The role of AI in circular design, production, consumption, reuse, repair, and recycling stages.

efficiency of manufacturing equipment, enhancing product quality control, and minimising inventory management costs.

Specifically, AI/ML technology can accurately forecast demand in real time allowing for production planning with a minimum waste of materials and energy. AI/ML can also be used to rank and forecast preferences for future products, which could effectively guide current production planning by minimising the overproduction of non-preferred products. In addition, AI/ML technology can formulate optimal schedule policies based on dynamic real-time data. Several studies focused on the role of AI/ML technology in circular production planning. For example, Matino et al. (2019) introduced ANN-based models to forecast blast furnace gas demand, which allowed for continuous and optimal production planning. Second, in the management of manufacturing equipment, AI/ML techniques offered the advantages of monitoring the production process of manufacturing equipment. AI/ML can maximise the efficiency of manufacturing equipment by minimising their energy consumption and gas emission, and by maximising stability in the circular production process. For instance, Luo and Oyedele (2021) suggested a building energy consumption forecasting system based on AI that has been proven to play an important role in reducing energy consumption and CE implementation in the circular production stage. Third, most of the common AI/ML algorithms have been proven to provide tremendous assistance in controlling the quality of manufactured products. Yang and Lee (2012) recommended an AI model for the semiconductor manufacturing process that accurately monitors and identifies production failure. Fourth, in the field of warehouse or inventory management, Jackson et al. (2019) showed that AI/ML technology can assist manufacturers in implementing intelligent inventory management. More findings on the application of different AI/ML methods in the circular production stage could be found in Figure 15.4 Appendix.

AI as a catalyst in the circular consumption stage

Twenty-five studies investigated the benefits of AI/ML in the circular consumption stage. The results in Figure 15.4 Appendix show that AI technology could generally also be a catalyst in the promotion of a circularity transition in the consumption stage. More clearly, AI can realise the circularity principle in the consumption stage by accurately matching demand with potential customers, assisting in intelligent logistics or transportation activities, and providing sharing, renting, and leasing platforms.

AI/ML technology supports tools or platforms for accurately matching demand with potential customers, so that minimum energy and materials will be wasted due to changes, returns, and extra packaging in the delivery process in the circular consumption stage. For example, Salehinejad and Rahnamayan (2016) built an AI-based prediction model for forecasting customer shopping patterns that could be used in intelligent recommendation systems. Most AL/ML algorithms can provide intelligent assistance in logistics management in the circular consumption stage, such as by predicting the nearest pickup point and the shortest delivery route (Zhang et al., 2019). Sun and Shi (2021) explored an SVM-based prediction model for efficient and smart planning of transportation schedules by logistics firms. In addition, common AL/ML algorithms have been found to be the main technical support for building and operating sharing, renting, and leasing platforms, which improve the implementation of circular business models (Jia et al., 2019; Kim & Hong, 2020). For instance, Chen et al. (2020) applied an AI algorithm to build a rental and return demand prediction model to solve bike shortage and unbalanced distribution problems in bike-sharing systems. Figure 15.4 Appendix summarises other studies on various AL/ML approaches.

AI as a catalyst in the circular reuse and repair stage

As presented in Figure 15.4 Appendix, 16 of the reviewed papers focused on the role of AI in CE transformation in the reuse and repair process. Overall, the results suggest that AI technology could act as a catalyst to facilitate the circularity transition in the circular reuse and repair stage. More specifically, with AI's precise analysis, simulation, and forecasting superpowers, AI could enhance the intelligent maintenance of circular products in use and improve smart, reverse logistics of obsolete products or parts. Accordingly, AI can maximise the usage of products, components, and materials and, thus, advance CE transformation in the reuse and repair stage.

AI/ML technology can provide an intelligent maintenance system in the circular reuse and repair stage, which could monitor product performance, predict the likelihood of faults, and suggest optimal maintenance schedules. For example, Daniyan et al. (2020) proposed an AI system for monitoring and predicting railcar wheel-bearing failures. This system efficiently optimised the time spent related to railcar intelligence maintenance. Most AL/ML algorithms can intelligently enhance reverse logistics in the repair and reuse of parts. Govindan et al. (2019) used AI/ML technology to build a hybrid model for intelligent selection of a logistics provider in the reverse logistics process. Other related studies are presented in Figure 15.4 Appendix.

AI as a catalyst in the circular recycling stage

Nineteen articles in the review concentrated on AI/ML implementation during the recycling stage. Overall, the articles presented evidence that AI technology could be served as a catalyst to advance circularity transition in the circular recycling stage. AI is capable of processing and analysing large amounts of both structured and unstructured data (e.g., images, videos, and audio) in high dimensions. This characteristic could largely improve automatic waste recognition and classification; greatly assist smart waste collection location, route planning, and time scheduling; and tremendously increase the quality of intelligent prediction of the amount of waste (Abbasi et al., 2014; Jull et al., 2018; Vu et al., 2019).

AI/ML technology enables accurate waste recognition and classification in the recycling stage. For example, Sakr et al. (2016) introduced an AI-based image recognition model to automate waste sorting. Based on their sample, the classification accuracy of the model could achieve approximately 95%. Other researchers found that AI/ML technology supports the finding of an appropriate waste collection location and optimises the collection route and the scheduling of the collection time. Nowakowski and Pamuła (2020) used an AL/ML algorithm to develop a model for identifying and classifying waste from electrical and electronic equipment in photos with high accuracy. The model could also be used for smart and efficient scheduling of waste collection. AI/ML technology also greatly improved waste amount prediction. Akanbi et al. (2020) developed AI-based models for forecasting the amount of salvageable and waste materials from buildings set for future demolition. The AI-based models were effective tools for demolition engineers and project managers and allowed for them to implement a circularity transition in the recycling stage. The details of other studies on different AL/ML methods are shown in Figure 15.4 Appendix.

Conclusions

This chapter was a systematic literature review on how/which AI can catalyse the CE transition in the circular design, circular production, circular consumption, circular reuse and repair, and circular recycling stages. One hundred twenty-five published papers from five scientific research databases were selected based on four preset criteria. The findings showed that AI/ML approaches have been proven to tremendously catalyse CE transition in the five circular stages by providing innovative and advanced techniques to fully implement the main CE principles, such as maximising the use of products, parts and materials, minimising waste generation, and reducing environmental pollution. In other words, there is evidence that AI is an enabler and catalyst of the CE transition.

This chapter contributes to both CE and AI literature as a comprehensive and deep systematic literature review on the role of AI as a catalyst in CE transition. Previous studies generally focused on a certain perspective of the CE transition topic at a more general level. This chapter is one of the nascent studies of CE proposing that AI could be a catalyst of CE transformation implementation. This study is one of the emerging reviews that explored the intersection between CE and modern AI/ML technologies; this combination could efficiently and intelligently complete complex tasks by analysing all kinds of structured or unstructured data in a high dimension. This premise extends the field of CE to the new and interdisciplinary area of AI technologies. The results of this review could be used to further explore this emerging interdisciplinary topic and to map the boundaries of existing knowledge so that knowledge gaps can be identified for future research. This chapter also contributes to AI literature by extending the possible scope of the application of AI. The results presented in this chapter may be used in a practical manner to help entrepreneurs, industry leaders, and policymakers to better understand AI as a catalyst in CE transition.

Two potential future research directions were suggested in this chapter. First, CE is a broad topic, and the implementation of AI in this field can penetrate different aspects at all levels. Therefore, splitting the current topic into different sub-perspectives, for example, splitting the topic in more stages or by industries, may be a valuable way to uncover further knowledge on the catalyst role of AI in CE transformation. In addition, most of the articles reviewed in this chapter predominantly focused on the circular production stage of the CE. This indicates that current literature is composed of an unbalanced research distribution. Future research could continue the investigation of the catalyst role of AI in the CE transition in other circular stages, enriching the literature base.

Educational content

Consider and discuss the following questions:

1 What are the advantages of models or approaches based on AI/ML technologies?
2 What are the five circular business stages mentioned in this chapter?
3 How could AI act as a catalyst in five circular business stages? Can you think of other examples?

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APPENDIX

Stage	AI as a Catalyst in CE Transition	Field	Subfield	Role	AI/ML Technique	Study
Circular Design	AI/ML Technology as a Catalyst to Accelerate Circularity Transition in Design Stage	Design Method		Enable Innovative Designing Methods of Circular Materials or Products	Artificial Neural Network (ANN)	Wang and Liu (2021)
					Support Vector Machines (SVM)	Ibrahim et al. (2018)
					Decision Tree (DT)	Ahmed and Kim (2017)
					Bayesian networks (BN)	Wang and Dowling (2022)
					Others	Cheng and Yu (2019)
		Design Time & Process		Reduce Designing time and simplify Designing process	Others	López-Guajardo et al. (2021); Van Fan et al. (2020)
		Design System & Environment	Recommendation and Assistance in Design System	Offer Smart Recommendations and Assistances in Designing System	Artificial Neural Network (ANN)	Huang (2021); Paraschos et al. (2022)
					Support Vector Machines (SVM)	Akanbi et al. (2019)
					Others	Ada et al. (2021)
			Standard and Condition in Design Environment	Avoid Harmful Designing Experiment Environment	Others	Ghoreishi and Happonen (2020)
Circular Production	AI/ML Technology as a Catalyst to Accelerate Circularity Transition in Production Stage	Production Planning	Predicting Demand	Enable Accurate Real-time Demand Forecasting	Linear Regression (LR)	Chachdi et al. (2019)
					Artificial Neural Network (ANN)	Matino et al. (2019)
					Support Vector Machines (SVM)	Ashwitha and Latha (2022)
					Decision Tree (DT)	Bala (2010)
					Bayesian networks (BN)	Rahman et al. (2011)
					K-Nearest Neighbors (KNN)	Gaur et al. (2015)
					Gradient Boosting Machine (GBM)	Nassif (2016)
					Others	Zhu et al. (2021); Kailasam et al. (2022); AL-Musaylh et al. (2021)
			Planning Preferances	Enable Accurate Products Preference Ranking and Forecasting	Linear Regression (LR)	Chakraborty et al. (2020); Cao and Zhang (2021)
					Artificial Neural Network (ANN)	Chen et al. (2021)
					Support Vector Machines (SVM)	Lieder et al. (2020)
					Decision Tree (DT)	Van Wezel and Potharst (2007)
					Bayesian networks (BN)	Chanpariyavatevong et al. (2021)
					K-Nearest Neighbors (KNN)	Li et al. (2009)
					Gradient Boosting Machine (GBM)	Pineda-Jaramillo and Arbeláez-Arenas (2022)
					Others	Khayyam et al. (2021)
			Scheduling Priorities	Make Dynamic Optimal Scheduling Policies	Artificial Neural Network (ANN)	Weckman et al. (2008)
					Support Vector Machines (SVM)	Shiue (2009)
					Decision Tree (DT)	Shahzad and Mebarki (2016)
					Others	Carastan-Santos and De Camargo (2017)

Figure 15.4 Appendix. Summary of research results. (*Continued*)

Stage	AI as a Catalyst in CE Transition	Field	Subfield	Role	AI/ML Technique	Study
Circular Production	AI/ML Technology as a Catalyst to Accelerate Circularity Transition in Production Stage	Manufacturing Equipment Mangement	Energy Consumption and Gas Emission	Monitor and Reduce Energy Consumption and Gas Emission	Artificial Neural Network (ANN)	Luo and Oyedele (2021); Khayyam et al. (2021)
					Support Vector Machines (SVM)	Shine et al. (2019)
					Decision Tree (DT)	Schmidt et al. (2015)
					Bayesian networks (BN)	Pérez-Miñana et al. (2012)
					Gradient Boosting Machine (GBM)	Tan et al. (2021)
					Others	Nalla and Pothabathula (2021)
			Equipment Efficiency and Stability	Improve Equipment Efficiency and Stability	Artificial Neural Network (ANN)	Xu and Liu (2014)
					Support Vector Machines (SVM)	Pani and Mohanta (2015)
					Decision Tree (DT)	Kuo and Lin (2010)
					Bayesian networks (BN)	Borunda et al. (2016)
					Gradient Boosting Machine (GBM)	Yu et al. (2020)
					Others	Raghuvanshi et al. (2022)
		Quality Control		Enable real-time Smart Quality Control	Linear Regression (LR)	Jin and Shi (2007)
					Artificial Neural Network (ANN)	Masood and Hassan (2013)
					Support Vector Machines (SVM)	Demetgul (2013)
					Decision Tree (DT)	Karabadji et al (2014)
					Bayesian networks (BN)	Yang and Lee (2012)
					K-Nearest Neighbors (KNN)	Zhou et al. (2016)
					Gradient Boosting Machine (GBM)	Baghbanpourasl et al. (2019)
					Others	Islam et al. (2020)
		Warehousing/Inventories Mangement		Allow intelligent Warehousing/Inventories Monitoring, Controlling and Forecasting	Linear Regression (LR)	Hua et al. (2007)
					Artificial Neural Network (ANN)	Jackson et al. (2019)
					Support Vector Machines (SVM)	Jiang et al. (2021)
					Decision Tree (DT)	Rahim et al. (2018)
					Bayesian networks (BN)	Boutselis and McNaught (2019)
					Gradient Boosting Machine (GBM)	Islam and Amin (2020)
					Others	Bala (2012)

Figure 15.4 (Continued)

Stage	AI as a Catalyst in CE Transition	Field	Subfield	Role	AI/ML Technique	Study
Circular Consumption	AI/ML Technology as a Catalyst to Accelerate Circularity Transition in Consumption Stage	Matching Demand		Enable Accurate Matching Demand with Potential Customer	Linear Regression (LR)	Yanfang and Chen (2017)
					Artificial Neural Network (ANN)	Salehinejad and Rahnamayan (2016); Safa et al. (2014)
					Support Vector Machines (SVM)	Gordini and Veglio (2017)
					Decision Tree (DT)	Fang et al. (2016)
					Bayesian networks (BN)	Xu et al. (2008)
					K-Nearest Neighbors (KNN)	Gaur et al. (2015)
					Gradient Boosting Machine (GBM)	Fathian et al. (2016)
					Others	Morgan et al. (2013)
		logistics Process		Assist Intelligent logistics/transportation activities	Artificial Neural Network (ANN)	Zhu et al. (2021)
					Support Vector Machines (SVM)	Sun and Shi (2021)
					Decision Tree (DT)	Zhang (2021)
					Bayesian networks (BN)	Zhang et al. (2019)
					K-Nearest Neighbors (KNN)	Albadrani et al. (2020)
					Gradient Boosting Machine (GBM)	Khiari and Olaverri-Monreal (2020)
					Others	Lim et al. (2022)
		Sharing & Renting & Leasing Transform		Improve and Assist Sharing & Renting & Leasing Platform	Linear Regression (LR)	Wang et al. (2020)
					Artificial Neural Network (ANN)	Zhou et al. (2021); Chen et al. (2020)
					Support Vector Machines (SVM)	Kim and Hong (2020)
					Decision Tree (DT)	Zhang et al. (2019)
					Gradient Boosting Machine (GBM)	Jia et al. (2019)
					Others	VE and Cho (2020); Das et al. (2020)

Figure 15.4 (Continued)

Stage	AI as a Catalyst in CE Transition	Field	Subfield	Role	AI/ML Technique	Study
Circular Reuse & Repair	AI/ML Technology as a Catalyst to Accelerate Circularity Transition in Reuse & Repair Stage	Reuse of Products		Make Intelligence Maintainance	Linear Regression (LR)	Robles-Velasco et al. (2020)
					Artificial Neural Network (ANN)	Daniyan, et al. (2020)
					Support Vector Machines (SVM)	Cheng and Hoang (2014)
					Decision Tree (DT)	Matzka (2020)
					Bayesian networks (BN)	McNaught and Chan (2011)
					K-Nearest Neighbors (KNN)	Bagheri et al. (2010)
					Gradient Boosting Machine (GBM)	Aziz et al. (2020)
					Others	Liao et al. (2021)
		Repair and Reuse of Parts		Improve and Assist Smart Reverse Logistics	Linear Regression (LR)	Vijayan et al. (2014)
					Artificial Neural Network (ANN)	Govindan et al. (2019)
					Support Vector Machines (SVM)	Sun and Shi (2021)
					Bayesian networks (BN)	Pochampally and Gupta (2012); Duta et al. (2014)
					Others	Awan et al. (2021); Schlüter et al. (2021)
Circular Recycling	AI/ML Technology as a Catalyst to Accelerate Circularity Transition in Recycling Stage	Waste Management		Enable Accurate Waste Recognition and Classification	Artificial Neural Network (ANN)	Mater et al. (2022); Xu et al. (2021)
					Support Vector Machines (SVM)	Sakr et al. (2016)
					Decision Tree (DT)	Kambam and Aarthi (2019)
					Bayesian networks (BN)	Liu et al. (2017)
					K-Nearest Neighbors (KNN)	Jull et al. (2018)
					Others	Alidoust et al. (2021)
				Make smart Waste Collection Location, Route and Time Plan	Linear Regression (LR)	Chen (2022)
					Artificial Neural Network (ANN)	Vu et al. (2019); Nowakowski and Pamuła (2020)
					Support Vector Machines (SVM)	Aziz et al. (2018)
					Others	Nowakowski et al. (2018); Amal et al. (2018)
				Enable Accurate Waste Amount Evaluation and Prediction	Artificial Neural Network (ANN)	Akanbi et al. (2020); Ali Abdoli et al. (2012)
					Support Vector Machines (SVM)	Abbasi et al. (2014); Corral Bobadilla et al. (2018)
					Others	Baby et al. (2017)

Figure 15.4 (Continued)

16

GAMIFICATION AS A CATALYST TO THE CIRCULAR ECONOMY

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Introduction

Economic models of production, coordination, and consumption that are based on circularity have been postulated to remedy many of the ills of economic activity that are detrimental to the environment and all beings in the biosphere, and, more holistically to economic, social, and cultural interactions among individuals and communities (Ellen McArthur Foundation, 2021; Hamari et al., 2016; Kirchherr et al., 2017; McDonough & Braungart, 2002). However, several barriers have stopped or slowed down cyclical economic models from being adopted and integrated across different value networks (Ghisellini et al., 2016; Jaeger & Upadhyay, 2020; Ritzén & Ölundh Sandström, 2017). Changing the methods in how economic activity is coordinated on a global market requires a global will, and while cemented practices cause major friction, so does a lack of human awareness, motivation, engagement, and attitudes for shifting towards more sustainable models of economic coordination where the design of processes, products, services, (re)use, repurposing, repairing, access, and sharing of resources, both tangible and intangible, is maximised.

It has been widely postulated that motivational information systems, and chiefly gamification, are able to transform many of the systems, services, and practices towards being able to bring about similar positive experiences, motivation, and attitudinal shifts witnessed in the context of games and game culture (Hamari, 2019). The main inspiration of this development, games, has been shown to bring about cognitive, emotional, social, and motivational benefits; the premise of the use of gamification is based on the ability to translate these benefits to positive changes in motivations, attitudes, and behaviours towards a sustainable praxis. While gamification has been extensively applied and researched throughout several domains of human activities (Koivisto & Hamari, 2019a) such as in education (Majuri et al., 2018; Nah et al., 2014), health care (Johnson et al., 2016; Koivisto & Hamari, 2019b), consumption (Guillen et al., 2021), governance and citizen engagement (Buheji, 2019; Hassan & Hamari, 2019), mobility (Köse et al., 2019; Morschheuser et al., 2019), business development and enterprise systems (Humlung & Hadara, 2019; Raftopoulos et al., 2015), and workplaces (Riar et al., 2021; Warmelink et al., 2020), its research and application have been growing perhaps slower in the context of cyclical models of

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economic coordination, which albeit would hold insurmountable impact potential on net sustainability and resilience.

It is also relevant to highlight that the design and application of games and game-like affordances entails processes where critical thinking skills are honed, while also enabling a sense of responsibility and learning (Kafai & Burke, 2015) as part of an experiential, innovation-oriented, collaborative process, just as the ones needed for the circular economy (CE) to happen. Disciplines such as citizen science (Kimura et al., 2021; Milburn & Wills, 2021), collaborative design methods (Kolpondinos & Glinz, 2020), and even policy design (Kim & Nam, 2022) present examples of how gamification plays a relevant role for the execution of their processes, ultimately providing insights that can facilitate the application of gamification across different areas and activities of the CE. Building upon the learning on sustainability-related communication strategies (Guillen Mandujano et al., 2021), it is possible to identify how gamification, as a catalyst to CE, can be considered both a tool and an approach.

As a tool, gamification is a way to generate a particular understanding of CE. Through games and gamification conveying knowledge and sensitizing, a specific topic can be fun and engaging (Hamari et al., 2016; Sailer & Homner, 2020). Further, research shows that game-like and playful design can foster creativity (Arnab et al., 2019), thus it can bring about circular-oriented innovation, defined as a combination of product design, business model, and value networks that operationalise CE strategies connecting the expertise from upstream and downstream actors to develop a circular-oriented value model (Brown et al., 2021). Roth et al. (2015) explore the ways in which the forms and functions of gamification bring together different actors and stimulate creativity for business model innovation and design thinking processes, such as ideation, creation of products, services, and corporate identities. Moreover, facilitating a value-based understanding of CE is necessary for integrating the still missing human dimension in the CE needed to tackle the existing top-down policy measures inhibiting self-organisation and local, autonomous efforts to go beyond today's market and income-centred approaches on which current CE strategies are cemented (Schröder et al., 2020).

As an approach, gamification strategies are about CE, enabling actions for CE to happen and addressing some of the critical challenges related to the generation of value through circularity. Gamification can engage behavioural change as a mediation model (Nivedhitha & Manzoor, 2020), providing performance feedback, and intrinsically motivating individuals and organisations through challenges and incentives. For example, realising or even visualising life cycle–related risks and rewards in terms of individual actions and accountability can serve as a means to incentivise collaboration through reflective and adaptive actions. Ultimately, these actions lead to habit formation, effecting awareness, decisions, and preferences, such as consumption choices (i.e., water) (Gregory & Di Leo, 2006), or other activities that range from recycling (Kasioumi, 2021) to the creation of entire ecosystems of alternative markets via collaborative schemes (Botsman & Rogers, 2011). Despite these possible favourable outcomes, there seems to be a lack of overarching understanding and overview in terms of how and in what phases of CE gamification can be applied and which sustainability goals are incorporated.

To address some of these shortcomings, this study focuses on the following three questions: 1) How is gamification discussed in existing CE literature? 2) What kind of gamification approaches have been taken and studied across the different facets of CE? 3) What are the potential areas for further application of gamification in relation to CE? We will investigate what kinds of results the current literature corpus holds, as well as derive future avenues for both research and practice in the application and study of gamification in CE.

Review procedure

To draw an overview of the state-of-the-art research on gamification in the CE context, we conducted a systematic literature review (SLR). This review method is particularly useful to systematically and explicitly identify, aggregate, evaluate, and synthesise "the existing body of completed and recorded work produced by researchers, scholars, and practitioners" (Fink, 2019, p. 3). SLRs enable researchers to grasp emerging phenomena in their broader scale, to flesh out conclusions of the research corpus existing in academic publications by comparing individual qualitative and quantitative findings, and to derive conclusions based on the generated overview both to inform practice and to produce new knowledge in the field of research (Moher et al., 2009; Petticrew & Roberts, 2006; Ridley, 2012).

Depending on their objectives, SLRs can present a summary of knowledge, aggregate data from empirical studies, build an explanation, or present a critical assessment of existing literature (Templier & Paré, 2015). The present review mainly falls into the categories of knowledge summarisation and critical appraisal, as it maps the existing literature on the topics of gamification of and for the CE while providing an overview of how both fields of research (gamification and the circular economy) are intertwined and have been studied in previous research. According to Victor (2008, p. 1), a systematic literature review follows transparent and rigorous processes, thoroughly covering the literature and emphasising the quality of the included evidence to take a systematic approach to synthesise the data. We created a comprehensive analytical framework that facilitated coding the information according to the approach to the CE and gamification strategies and characteristics explored.

The coding process

Besides elements to classify the articles according to their type of publication, the domain of study, objective, and type of action where gamification to catalyse the CE was presented (i.e., project, prototype, tool, etc.), we focused on analysing the aspects related to the CE and gamification. The former is structured according to the elements of sustainable circular business models (Antikinen & Valkokari, 2016; Lewandowski, 2016; Smith-Gillespie, 2018), allowing to highlight the approach to circularity explored in the documents. Additionally, we included the areas of education, policy-making, and organisational change for and stemming from CE, which are also relevant for catalysing the CE. Table 16.1 explains these elements.

For the latter (gamification aspects), our review follows a conceptualisation of gamification in the extant literature and separates between three areas: 1) the design of the gamification approach implemented, 2) the sought-after or investigated psychological outcomes of gamification, and 3) the sought-after or investigated behavioural outcomes of gamification (Koivisto & Hamari, 2019a).

Data collection

To ensure the clarity of the results and the rigour of the literature search process (Pare et al., 2015), we used SCOPUS as our primary database since it has one of the most extensive coverage and accuracy in citation counts accessible worldwide. The literature search took place on 9 November 2021, using the query: TITLE-ABS-KEY (gamif* AND ("repair" OR "recycling" OR "remake" OR "re-make" OR "re-condition" OR ("circular" AND "Econ*") OR ("sharing" AND "Econ*") OR ("resource" AND "recovery") OR ("circular" AND "sourcing") OR ("co-product" AND "recovery"))) (ALL (gamif*) AND TITLE-ABS-KEY (("repair" OR "recycling"

Table 16.1 Components for catalysing the CE

Component	*Description*	
Education	Drawing from similarities with Education for Sustainable Development (ESD), education for CE prepares learners for transdisciplinary challenges by encouraging holistic, systems thinking – including boundaries, internal and external influences, causality, complexity, and multi-stakeholder perspectives. When using games, it entails active experimentation and concrete experience (Whalen et al., 2018).	
Policy-making	Policy instruments and mechanisms that, for instance, decouple resource dependencies, facilitating resilience to external shocks while respecting nature and people's health. The focus is on policies that enable the existence of services, production, and commercialisation of goods designed to last longer, that are easier to reuse, repair, and recycle, and that incorporate as much recycled material as possible instead of primary raw material. These measures include restricting single-use, tackling premature obsolescence, and banning the destruction of unsold goods (European Commission, 2022, n.d.).	
Organisational change	Defined as a continuous process aiming at renewing the capabilities, direction, and structure of an organisation (Moran & Brightman, 2000), these processes aim at overcoming the challenges related to introducing the CE in an organisation, such as restructuring and rebuilding systems and processes of societal acceptance, effectiveness, supporting infrastructure, multi-stakeholder involvement, technological, and operational actors (Sarja et al., 2021).	
Design	Besides considering the environmental aspects at all stages of the product development process, the act of striving for products that make the lowest possible environmental impact throughout the product life cycle – also known as eco-design. Design for CE also integrates the economic and environmental value of materials by looping them back in the system, lengthening their life, and keeping them in the economic system. Design for CE entails preventing and reversing obsolescence at the product and component level (design for integrity) and preventing and reversing obsolescence at a material level (design for recycling).	
Production patterns*	Sourcing	Sourcing recycled or renewable materials that can be returned to either the technical or biological cycle.
	Recovery	Residual/secondary outputs from one process (or value chain) become inputs for another process (or value chain).
	Remake	Manufacturing steps acting on an end-of-life part or product to return it to like-new or better performance, with a warranty to match.
	Recondition	Fixing of a fault/aesthetic improvement of a product, but with no new/additional warranty on the entire product. Includes repair and refurbishment.
Use**	Access	Providing end users with access to the functionality of products/assets, instead of ownership.
	Performance	Focus on guaranteed performance level or outcome based on the functionality of a product/asset. Typically provided as a product-service bundle.
End of cycle (in literature also presented as end-of-life)	Recovery (upcycling, downcycling)	Materials or products at end-of-cycle are incorporated into different products or used as feedstock/inputs for another process (or value chain).
	Recycling	Relevant component to prevent resource waste, it is an alternative to landfill disposal that sometimes downgrades the material and could be very energy intensive.

Notes

* Adapted from the Circular Economy Business Models guideline produced by the European-funded project "From linear to circular project R2Pi"

** This includes sharing and collaborative economies. The sharing economy presents an alternative to individual ownership, giving participants access to products and services through different economic arrangements such as flea markets, secondhand shops, and garage sales (Botsman & Rogers, 2011; Hamari et al., 2016).

OR "remake" OR "re-make" OR "re-condition" OR ("circular" AND econ*") OR ("sharing" AND "econ*") OR ("resource" AND "recovery") OR ("circular" AND "sourcing") OR ("co-product") AND "recovery")))

Besides the identifiers of author, title, year, and keywords, both author and index, the fields also included the language of origin, document type, and publication stage; this facilitated the removal of publications in other languages than English and for the selection of peer-reviewed conference papers, journal articles, reviews, book chapters, and articles in press. Moreover, the terms related to different processes of the CE were also introduced to identify literature that, without explicitly talking about the CE, brought about relevant information on how gamification contributes to the particular aspect of CE. The term 'gamif*' was used to cover all entries with the verb gamify or noun gamification.

Data selection

All the selected papers were analysed author-centrically and concept-centrically (Watson & Webster, 2022). The former comprised predefined units of analysis that were corroborated and coded for each manuscript. The concept-centric approach helped to facilitate the creation of frequency tables, which helps describe the landscape of research about gamification as a catalyst for the circular economy.

Once the database was completed, the chapter authors, who represented an interdisciplinary team with different backgrounds, first performed individual reviews to be compared and discussed with the others during group meetings. To reduce bias, the reviewers coded the same number of articles at the same time; therefore, any existing disagreement was discussed among the four researchers to reach a consensual coding (Hill et al., 1997). Figure 16.1 illustrates the process followed to consolidate the database and commence the analysis of content.

Gamification and circular economy: Findings and discussion

Landscape

The initial database was comprised of 82 documents, of which 46 publications were excluded following our assessment criteria. Four documents were discarded because they were duplicate entries, 26 papers were not related to either the CE or/and gamification, 13 were introductions to proceedings, 2 entries referred to full books, and 1 of the articles was not written in English. This exclusion reduced the final pool of considered literature for our review to 36 papers. Of the remaining papers, 13 were journal articles, 20 were conference proceedings, 1 was a book chapter, and 2 consisted of lecture notes. We noted that most of the papers were presented at conferences; this implies that this topic of interest is still relatively new. Most publications were from 2021, with 10 of them already available by the time of our search. One paper was already marked for publication in the year 2022, presenting a clear growth of research in this field.

When it comes to fields of research, the most predominant was education with nine publications, followed by human-computer interaction and information systems (with seven and five papers respectively). Twelve of the analysed papers presented preliminary work or concepts under development.

The research presented in the reviewed publications seems to pursue similar objectives, mainly promoting recycling behaviours, with thirty-one papers explicitly looking into "sustainable behaviours". Twenty-two of these papers feature recycling-related actions while three analyse

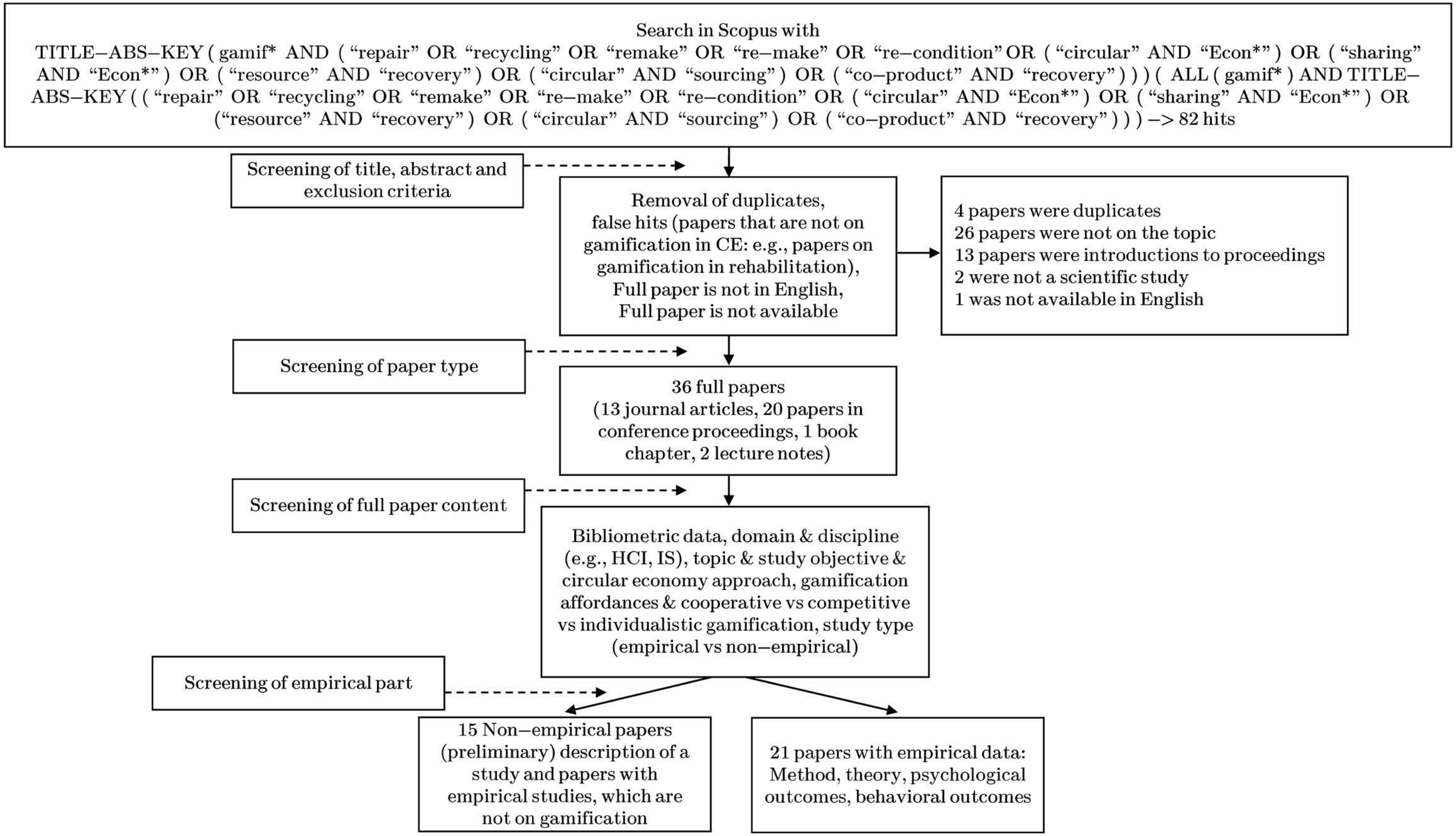

Figure 16.1 Database consolidation and analytical process.

Table 16.2 Publications per CE phase

CE Phase	*Articles*	*Total*
Design	Gera & Hasdell, 2020; Helmefalk & Rosenlund, 2020; Kragić Kok et al., 2020	3
Production	Jääskä et al., 2021; Kragić Kok et al., 2020; Whitaker, 2021	3
Use	Akasaki et al., 2016; Gera & Hasdell, 2020; Kragić Kok et al., 2020; Morschheuser et al., 2019; Pasca et al., 2020; Prabowo et al., 2019; Shevchuk et al., 2019; Tan et al., 2017; Tomé Klock et al., 2021	9
End-of-life (end-of-cycle)	Aguiar-Castillo et al., 2018, 2019; Berengueres et al., 2013; Cheng et al., 2020; Comber et al., 2013; del Campo et al., 2018; Delnevo et al., 2021; Ekundayo et al., 2022; Gibovic & Bikfalvi, 2021; Gizzi et al., 2019; González-Briones et al., 2019; Helmefalk & Rosenlund, 2020; Hsu & Chen, 2021; Keivanpour, 2021; Kragić Kok et al., 2020, Leitão et al., 2022; Lessel et al., 2015; Naskova, 2017; Ponis, 2021; Santti et al., 2020; Shevchuk et al., 2019; Sreelakshmi et al., 2015; Stengos et al., 2019	23

behaviours in different aspects of the collaborative economy, such as the use of sharing solutions or motivations to partake in crowdsourcing. There were also four papers related to recycling; they had little to no mention of CE. Most of these papers included process optimisation (i.e., via artificial intelligence or sensor application) as their focus.

Zooming into the different stages of the CE, the articles were distributed as shown in Table 16.2. It is relevant to note that some publications touched upon several phases of CE.

In general, most studies reported behavioural outcomes related to the end-of-life stage, having recycling as the objective of implementing gamification. Use was the second most addressed stage of CE, equally presented in terms of access or performance, as these publications investigated different elements of the sharing economy, particularly studying collaborative consumption platforms (Gera & Hasdell, 2020; Prabowo et al., 2019). Also, a total of nine articles presented games, six of them still in their prototype and testing stages. Of these nine games, two were presented as serious games, while one was described as a simulation. All but two of the papers presenting games reviewed recycling.

Regarding the type of study, 83% of the papers reported empirical research, 36% were nonempirical, and 5.5% were not determined, mainly because they were reporting work in progress. Of the papers presented, 30% had experimentation as its primary research method, often linked to surveys or interviews; 25% of the papers analysed reported mixed methods. Systematic reviews featured in 15% of the papers, whereas case studies and other types of studies (i.e., idea proposals) represented 22% of the sample; 11% of the documents did not report a specific method.

The strong presence of empirical studies allowed us to identify some of the most applied theories across the field. While 22 documents did not report a particular theory, 5 of them emphasised Self-Determination Theory, followed by Flow Theory, and the Technology Acceptance Model (TAM) (3 mentions each), and to a lesser degree, theories of experiential learning and social learning (1 document).

Gamification applied in CE research

Considering that gamification elements (affordances) are implemented to a system or service with the purpose of evoking psychological and behavioural outcomes within a certain context (Koivisto & Hamari, 2019), gamification design conveys meeting individual motivational needs

Table 16.3 Affordances per publication

Type of affordance	*Articles*	*Total*
Points	Aguiar-Castillo et al., 2018; Aguiar-Castillo et al., 2019; del Campo et al., 2018; Ekundayo et al., 2022; Gera & Hasdell, 2020; Helmefalk & Rosenlund, 2020; Jääskä et al., 2021; Kragić Koc et al., 2020; Leitão et al., 2022; Lessel et al., 2015; Prabowo et al., 2019; Shevchuk et al., 2019; Santti et al., 2020	13
Leaderboards	Akazaki et al., 2016; Ekundayo et al., 2022; Helmefalk & Rosenlund, 2020; Jääskä et al., 2021; Santti et al., 2020; Shevchuk et al., 2019; Stengos et al., 2019	7
Badges	Akazaki et al., 2016; Cheng et al., 2020; Ekundayo et al., 2022; Gera & Hasdell, 2020; Jääskä et al., 2021; Leitão et al., 2022; Shevchuk et al., 2019	7
Levels	Cheng et al., 2020; Gera & Hasdell, 2020; Jääskä et al., 2021; Sreelakshmi et al., 2015	4

in varying contexts influenced by factors and situations where the gamified system is being used. Therefore, we identified the most used affordances to map out existing evidence about the gamification elements chosen in the context of the CE, and if possible, to identify the reasons behind these choices. After all, one of the objectives of applying gamification is to transfer motivational effects into different environments, building upon systems that support the users towards a specific behaviour or activity (Koivisto & Hamari, 2019).

The reviewed body of literature presents diverse concepts of using gamification in CE. Point-giving is the most used reward system (13 documents), followed by leaderboards (7 documents), badges (7 documents), and level counts (4 documents). Table 16.3 illustrates these publications. Some of the non-point/badge awards include suggestions for physical rewards, most of them monetary (Santti et al., 2020; Shevchuk et al., 2019) and even penalisation (Gonzáles-Briones et al., 2019). This finding leads to several questions about the motivations behind engaging in actions for CE. For example, the potential economic value that recycling conveys, despite its limitations in facilitating the circulation of materials, seems to be one of the main appeals for companies engaging in end-of-life cycle activities (Ranta et al., 2018). The papers analysed reveal that the same notion seems to hold for individual households. However, 'pro-environmental behaviours' are intrinsically motivated because individuals are aware of their responsibility and the impact of their actions, for example, when using apps designed for activities such as recycling (D'Arco & Marino, 2022). Therefore, it is relevant to question why the strong reliance on extrinsic reward structures, as these can be counterproductive as well (Aguiar-Castillo et al., 2019), thus calling for gamification designs that reinforce intrinsic motivation, giving more meaning to the action itself than receiving additional rewards.

Mostly we encountered the application of games as educational tools, with 67% of the papers focusing on end-of-life activities; of these papers, 92% investigate recycling, and the other 8% are about product recovery. All these games were presented as prototypes or in the initial stages of their implementation. Four studies (del Campo et al., 2018; González-Briones et al., 2019; Ponis, 2021; Stengos et al., 2019) propose applying gamification in combination with Internet of Things (IoT) technology. Specifically, these studies propose using gamification in relation to waste management, from marine littering control (Ponis, 2021; Stengos et al., 2019) to waste management simulations (González-Briones et al., 2019; Jääskä et al., 2021). The proposed solutions involve the use of sensors to capture the amount and increase of waste in waste disposal containers by which users are credited for having used the recycling container (del Campo et al., 2018; González-Briones et al., 2019). Two studies propose the involvement of government or city councils, where gamification is understood as a form of subsidising or penalising users with an increase or decrease in the rate of garbage tax imposed by the local government (del Campo et al., 2018; González-Briones et al., 2019). One paper (Silva et al., 2021) brings forward the issue of how gamification enables reflexivity to connect CE organisational actions with local contexts and stakeholders, giving gamification an instrumental role in communication and trust building. In four of the papers analysed (Aguiar-Castillo et al., 2018; Gera & Hasdell, 2020; Kelly et al., 2020; Prabowo et al., 2019), the latter relays one of the main psychological outcomes of introducing gamification to platforms and activities promoting the CE. Despite being a minority, the studies presenting gamification as a tool that shared similar objectives: improving the participation in collaborative schemes via online platforms, where gamification also helps to generate pride and the perception of added value to the users, like the case of 'superhosts' for Airbnb (Gera & Hasdell, 2020). What these studies highlight are the relationships between service providers and users, in some cases even presenting opportunities for co-creation and customisation.

While most of the papers aim at motivating user participation, attitude change also features as one of the desired outcomes to influence the formation of new habits, even though in some instances, attitude change is not even needed for shifting behaviours (Ro et al., 2017), because the users may only need support for turning their existing awareness into tangible actions. However, the issue of awareness was brought up only by six of the studies. It can be argued that more research is needed to identify existing needs and opportunities to bridge the current gaps between awareness and the strategies to engage in activities that facilitate CE. Quite possibly the need is about raising awareness in the first place; for example, widening the designers' and developers' understanding that, in addition to recycling, end-of-life alternatives include options like reducing or reusing via upcycling or downcycling.

When it comes to mechanics, most papers presented competitive (15) and individualistic (14) approaches. Cooperative designs were present in 7 publications while only 3 of them had inter-team possibilities. Only one example (Santti et al., 2020) presents the four approaches; in addition, there is only one paper presenting an individualistic, cooperative, and competitive design (Jääskä et al., 2021) meaning that while individuals play on their own, they can also form groups to play together and compete against other groups. It is worth noting that most of the cases presented in the analysed papers seem to emphasise the skills that users can gain by engaging in CE activities rather than by having an emotional involvement. This situation could be because of the prevalence of gamified approaches that examine resource management tasks, leaving a void for games in other areas (Scurati et al., 2020). Most of the papers reported the results of very small samples comparing gamification features (i.e., Aguiar-Castillo et al., 2018; Akazaki et al., 2016; Leitão et al., 2022), opening the floor to follow-up questions concerning issues such as the outgrowth of the studies, or what the outcomes would be when applied on a larger population. Only one of these publications presents a preliminary analysis in 2018 expanded through an empirical study with the specific target group of tourists in 2019 (Aguiar-Castillo et al., 2019). Moreover, a question that lingers is: what kinds of messages are being communicated through the game mechanics applied?

Figure 16.2 summarises the objective of gamification in the context of the CE as analysed in the systemic literature review.

Gamification in relation to transition management

CE catalysts should investigate facilitating the transition that different societal actors must go through to make CE happen. Therefore, we took Loorbach's Transition Management Cycle

Figure 16.2 Visualisation of the most addressed topics in the analysed literature.

(TMC), a "governance typology used to develop systemic instrument and process strategies" (Loorbach & Wijsman, 2013) as a reference to further analyse the implications that the findings of this literature review entail for implementing gamification as a CE catalyst. This framework was originally developed to contextualise actors' behaviour in societal transitions and has also been applied to business transition management analyses with the understanding that current sustainability problems are persistent and require systemic changes (Loorbach & Wijsman, 2013). The TMC has four types of governance activities, as Figure 16.3 presents.

By analysing the objectives for implementing gamification in relation to CE, our study intends to depict the TMC elements that are identified in our systemic literature search as currently being explored and to point out further opportunities to facilitate transitions towards CE through gamification.

Of the studied papers, 25% presented activities of an operational nature, reporting the results of experiments and prototypes with the intention of supporting everyday decisions; eight of these papers also presented reflective actions as part of the studies' objectives. Five of the publications were both operational and tactical, and four were operational with strategic actions.

The second most present activities had a reflexive nature (16 papers); most of these papers are literature reviews or studies meant to analyse the effects of applying gamification in certain

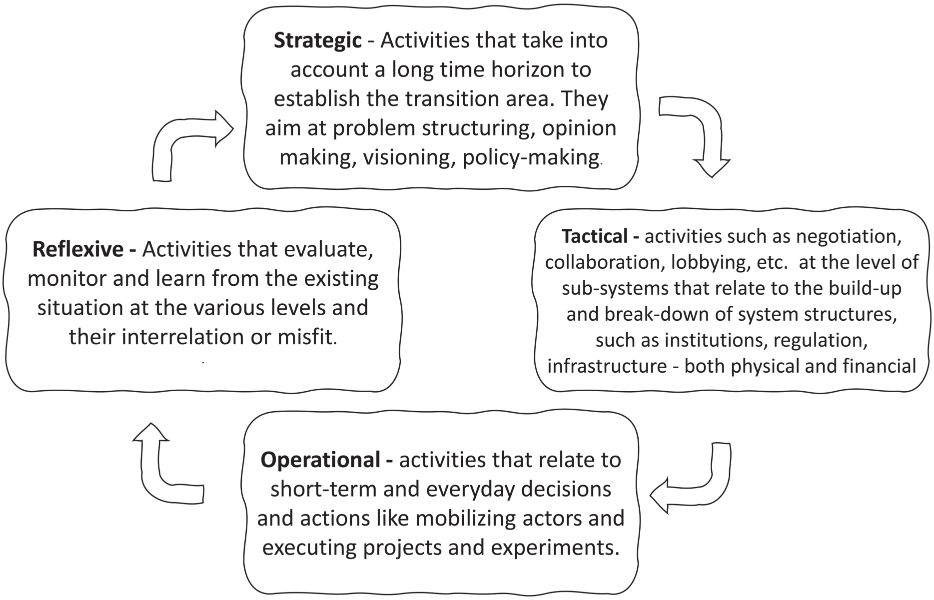

Figure 16.3 The transition management cycle.

Source: Loorbach, 2007; Loorbach & Wijsman, 2013.

contexts, mainly recycling and use-related activities (both access and performance). Two of these papers also present strategic objectives, whereas only one reports gamification as a form of tactical activity for CE transitions, namely communication (Silva et al., 2021). Strategic and tactical actions featured in almost the same number of papers (eight and seven, respectively) and normally in combination with operational and reflexive activities, as detailed previously.

Figure 16.4 presents the TMC types the papers addressed in relation to the encountered CE phases and the expected impact area of gamification as a CE catalyst. There is a strong

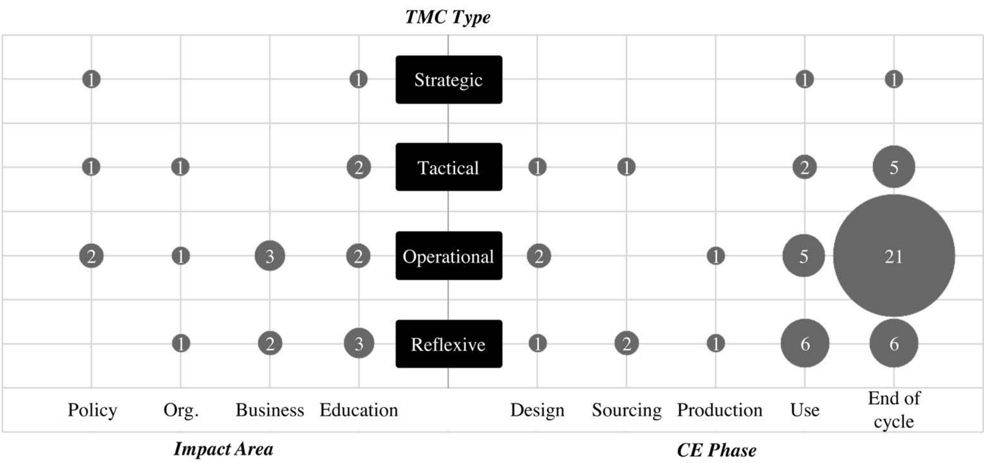

Figure 16.4 TMC type concerning impact area of gamification and CE phase.

predominance of operational papers, particularly among those studying topics related to end-of-life cycle activities. It is important to note that Figure 16.4 only depicts the papers where the impact area (policy, organisational change, business development, and education) is a core part of the study. The papers where the impact area is marginally mentioned as a potential beneficiary or as a background argument are not included in the graph. This visualisation shows how none of the papers that reflect a strategic approach to transition management apply gamification for organisational change or business processes, as most of the papers are concerned with applying gamification for education or policy-making. This is quite a significant finding, as businesses and organisations should have processes to manage their transitions to the CE; however, the evidence of this study indicates that none of them are using gamification as part of their CE execution, a potentially missed opportunity considering the existing evidence of gamification applications. Another interesting observation is that papers that have business development at their core are also lacking gamified tactical activities to support their CE transition processes.

Gamification in relation to the United Nations Sustainable Development Goals

While there is no doubt that the United Nations Sustainable Development Goal 12 (United Nations, n.d.), responsible consumption and production, is the one that closely attains a CE, the goal is barely mentioned in the literature. This is noteworthy because 24 publications address the topic of waste management with 22 papers featuring recycling as its main objective, thus directly contributing to Target 12.5: "By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse" (United Nations, n.d.). The other goals that feature quite clearly in the literature studied are Goal 6 – Ensure access to clean water and sanitation – (Kragić Kok et al., 2020) and Goals 14 and 15 – life below water and life on land respectively – (Ponis, 2021; Stengos et al., 2019), as these papers talk about the problematics of sea littering and the opportunities to tackle the problem. These studies present a technology-oriented approach to the regenerative eco-innovation notion (restore, renew, and revitalise natural systems), which is often linked to CE. There seems to be a lack of perspective on the social and collective potentials of gamification encountered in the present study is in accord with indications of previous broader-scale gamification reviews (e.g., Koivisto & Hamari, 2019; Riar, 2020). Some relevant exceptions to this trait highlight the relevance of having access to proper infrastructure that facilitates "deep civil deliberation in global and multi-regional debates" (Whitaker, 2021), the need for a "critical mass" for the success of sharing platforms (Gera & Hasdell, 2020), and the importance of collaborative elements to increase the willingness to use crowdsourcing platforms (Morschheuser et al., 2019).

Gamification in relation to CE in different domains and sectors

Gamification concerning the policy-making domain presented a skewed picture, as gamification is presented as a tool that facilitates some aspects of the circular economy, with only a few mentions of policy-makers being the beneficiaries of these processes rather than their enablers (Gibovic & Bikfalvi, 2021; Tomé Klock et al., 2021). Of the six papers that touch upon policy implications, three do so as part of the papers' background (Aguiar-Castillo, 2018; Naskova, 2017; Stengos et al., 2019) and only 1 had policy-making at the core, as it is about a system motivating citizen participation through the application of garbage tax reductions (González-Briones et al., 2019), an action that only local governments can undertake.

A similar situation appeared regarding organisational change, except for two publications that presented gamification as a means to enable organisational change (Prabowo et al., 2019; Tomé

Klock et al., 2021), the other three publications that touched upon organisational change presented it as an area of potential application (Kelly et al., 2020; Gera & Hasdell, 2020; del Campo et al., 2018).

Despite being the most relevant topic for education, with nine publications addressing it, business development was also marginally present as a contextual element (Aguiar-Castillo, 2018; Morschheuser et al., 2016; Naskova, 2017; Pasca et al., 2020; Prabowo et al., 2019;) but not as the focus of the study as such. Of the four publications that had business development as a focal cornerstone, gamification was presented as an educational tool to teach about project management and entrepreneurial applications (Jääskä et al., 2021); with two papers analysing the business implications of gamifying CE, mainly from the business model perspective (Gibovic & Bikfalvi, 2021) and a product-service perspective (Hsu & Chen, 2021; Tan et al., 2017).

It is worth noting that the gamification strategies, and even the games presented in the studies analysed in this review, present a picture of open possibilities to explore the CE as a system, encompassing emotional elements with technological possibilities, shifting the ways that we perceive the interactions between individuals, nature, and societies. In this vein, it is also relevant to highlight that the analysed literature unequivocally presented gamification in a positive light, emphasising its potential for engaging individuals and facilitating the implementation of different processes. However, it is important to remember that gamification is a design approach that leads to ethical concerns due to its primary objective of affecting individual psychological states and behaviour (Thibault & Hamari, 2021). Therefore, designers, policy-makers, managers, educators, and all stakeholders involved in developing gamified strategies for whatever purpose – the CE in this case – should bear in mind issues ranging from transparency for data management to potential psychological harm.

The way forward

Although there is no doubt that games, and to some extent gamification, are playing a role in different fields of study and action of CE, what this systemic literature review and analysis highlighted is the need to further explore other aspects of circularity than end-of-cycle recycling approaches. There is also a need for more empirical evidence to present the practical challenges for researchers, designers, practitioners, policy-makers, and industry that gamifying CE might help to overcome.

In practice

When it comes to the expected areas of impact of implementing gamification towards circularity, we found extensive focus on education and recycling, while there is little to no evidence about the intention to contribute to policy-making or business development, a situation that reflects the current criticism of the lack of action in the implementation of policies towards circularity, for example in the European Union where "there is a dichotomy between the EU discourse – talk – and EU policies – actions – on the CE […] EU *talk* is in the optimist and holistic framing of Reformist Circular Society discourses, while EU *action* falls within the segmented and optimist typology of technocentric CE discourses" (Calisto Friant et al., 2021). To portray different approaches to CE, it is necessary to confront existing notions of what these processes are for in the first place.

A similar situation appears in relation to organisational change processes. While literature reveals that firms transitioning or transforming themselves to the CE need changes in their strategies, capabilities, and organisational structures (Chizaryfard et al., 2021), there is an information void about the role that gamification plays – or could play – for these purposes. It is worth highlighting that this finding applies solely to gamifying organisational change for the CE, as literature related to gamifying organisational change is a growing field of research (Alexandrova & Rapanotti, 2020; Deterding, 2019; Jacob et al., 2022; Krath et al., 2022; Morschheuser et al., 2022) and can serve as a reference for organisations transitioning towards more circular processes.

Another future research avenue this study found relevant and necessary is the potential of gamifying communication of, for, and about CE. While evidence of the effects of gamifying communication processes is still in an early stage and mainly applied for internal processes or corporate social responsibility programs (i.e., Maltseva et al., 2019), current research points to increasing efficiency and understanding of the topics at hand, such as project management (Muszyńska, 2020). In the case of CE, gamifying may help to address some of the ambiguity around current discourses related to the topic (Rödl et al., 2022).

This literature review showed how the convergence towards a CE may also depend on an effective combination of gamification with contemporary technologies, such as IoT. While some of the reviewed studies point toward promising ideas for using IoT (González-Briones et al., 2019; Stengos et al., 2019), there are further technological trends that can be relevant for accomplishing sustainable practices such as big data, blockchain, artificial intelligence, augmented reality (AR), and virtual reality (VR) (Demestichas & Daskalakis, 2020). For example, gamification could be used in combination with artificial intelligence with the prospect of creating smarter gamified sustainability apps and intelligent virtual characters that may assist users with accomplishing sustainability goals.

Another technological trend topic that is gaining attention for its potential to establish cost-effective and sustainable solutions is the use of immersive technologies. AR and VR can be utilised to create virtual environments or simulate processes and ideas, which can prevent the use and waste of physical resources. AR/VR can be used in diverse stages within the supply chain, such as in e-procurement (Korbel et al., 2022) or at the factory level (Rocca et al., 2020), as well as by consumers as a try-on technology (Riar, Xi et al., 2022), resulting in critical environmental benefits such as reducing returns of articles due to prior virtual trying and by avoiding a build-and-waste culture. While these and similar technological trends have taken a foothold across several domains, attempts to understand if and how these technologies can be afforded with gamification to produce unique advantages for a CE system remain unassuming. Therefore, future research should explore the potential of using gamification in combination with contemporary technologies in CE practices.

Implementing gamification or any other approach to circularity also requires a thorough understanding of social and economic contexts, presenting a systemic picture where experimentation plays an important role. Practitioners and designers must be aware of the consequences of both the intended and the unintended gamification strategies they implement in their activities, particularly the impacts that may occur in the mid and long term. This also means that not all gamification design interventions pose crowning solutions in all circumstances. Rather, it is necessary to shed more light on where and especially how gamification should be employed. The analysed studies present different views on CE, showing both the complexity of the topic and the challenges of providing holistic gamification strategies. Yet, it is possible to decide on the mechanics that designers and practitioners believe can meet the objectives of the task at hand and incorporate elements for potential follow-up. The choice of gamification affordances and strategies may challenge conceptions of 'business as usual,' taking the users (and potentially the designers) out of their comfort zone and presenting a picture of limited scientific ambition. For example, the gamification mechanics portrayed in most of the studies – competition, individualism, and the pursuit of efficiency – are the defining characteristics of the classical economy that the CE challenges. The findings of this review accentuate that, currently, there seems to be uncertainty in terms of how gamification should be applied and towards what underlying motivational sentiment (e.g., extrinsic or intrinsic, collectivistic or individualistic, etc.) for the promotion of a positive demeanour towards CE practice. For example, open questions remain to what degree gamification should be used to motivate individuals on an extrinsic or intrinsic level. Interestingly, several studies (i.e., Aguiar-Castillo et al., 2019; Helmefalk & Rosenlund, 2020; Shevchuk et al., 2019) propose gamification to provide tangible rewards, such as prizes that can be redeemed for collected points, or even approaches to subsidise tax payments as a reward structure for sustainable behaviour, thereby opting for extrinsic motivational routes. However, sustainable behaviour may be an inherently intrinsic-driven behaviour and gamification has established itself as an approach that can tap into the intrinsic motivation of people (Xi & Hamari, 2019) and even eliciting altruistic sentiment (Riar et al., 2020, Riar et al., 2023). One study within the reviewed body of literature indicated that the expectation of prizes could be counterproductive (Aguiar-Castillo et al., 2019), thus extrinsic rewards may be perceived negatively by individuals that engage in sustainable behaviour for intrinsic reasons. Empirical investigations into possible negative side effects and more holistically, how different oriented design options prompt engagement in CE action based on extrinsic and intrinsic motivation remain modest. Therefore, future research should empirically investigate and compare the effectiveness of gamification design interventions that address extrinsic and intrinsic reward structures, as well as a combination of both, to shed light on which doctrine is more favourable for accomplishing sustainable behaviour. Moreover, cooperative mechanics remain far behind individualistic and competitive mechanics when it comes to the proposed design options. As discussed previously, sustainable behaviour and efforts to create a CE are a global endeavour that requires communication, communal awareness, and the mobilisation of society as a collective. However, the underrepresentation of studies that use gamification to motivate collective efforts in the realm of CE is striking and requires more attention in future research.

In enquiry

While research about gamification and innovation continuously shows examples of team spirit, consensus building, creative thinking, productivity, knowledge transfer, and engagement, particularly for new product development and market integration (Patrício et al., 2018), it is noteworthy that most of the reviewed studies did not draw on a particular theory to investigate gamification as a catalyst to CE. This is staggering, considering that solid theoretical groundwork is indispensable to our understanding of how gamification may give rise to diverse cognitive and affective outcomes that can ultimately result in a desirable behaviour. Depending on the theme, the future scientific enquiry ought to find it appropriate to draw on theories of need satisfaction (Xi & Hamari, 2019), theories of collective intentionality (Morschheuser et al., 2017; Riar, Morschheuser et al., 2022), as well as on personality-related concepts, and reinforcement theories that consider both the effects of reward, and punishment structures, and that have previously been considered in the context of sustainable behaviour (Bergmann et al., 2017). These are only a few examples, and more diversity in terms of conceptual exploration is necessary to move the field forward in understanding how gamification can motivate engagement in CE action based on theoretically sound assumptions.

Considering that the CE represents a systemic innovation leading to transitions at all levels (Kirchherr et al., 2017), change processes within organisations, public institutions, and even interactions with consumers must be planned and managed. Gamification has long been recognised as an approach to simplify management processes, as it enables higher participation, interaction, knowledge generation, and utilisation of resources (Markopoulos et al., 2017; Perryer et al., 2016). Therefore, gamification's potential to catalyse the CE across organisations and public institutions is an opportunity worth analysing and developing further. The literature review also pointed to the emergence of another function of gamification: communicating the concept of CE (Silva et al., 2021). The fact that only one study approached this topic shows a relevant research avenue as communication lies at the heart of any transition process, such as the ones required for catalysing the CE.

Most of the reviewed papers seem to have a narrow focus to the present sustainability challenges and themes. Besides the lack of systemic approaches to the issue of CE, when it comes to the big picture of sustainability, the ethics of using gamified approaches or implementing gamification as a tool is another notable absence from the overall discourse presented by the studies. Although sustainability and CE are a series of global efforts that require collective actions, most gamification design interventions focus on individuals and households, which somewhat neglects social components that could motivate people to form and achieve sustainability goals collectively. The absence of the United Nations Agenda 2030 across the reviewed literature also opened several questions about how research on CE is contextualised, from general framing: why is the Agenda 2030 largely underrepresented in the current research that aims to contribute to sustainable development through CE? To the expected impact that these studies (particularly the ones presenting prototypes) want to achieve, are they considering the transition dynamics from linear to circular models? In what ways are these studies portraying potential trade-offs when switching from 'as usual' behaviours to circular ones? To harness the potential of gamification about and of the CE, there is a need to be pragmatic, acknowledging existing and potential limitations to create holistic, coherent, and interdisciplinary strategies. In the context of open innovation, research on gamification is scarce. It has been studied mainly from the perspective of facilitating ideation or the inflow of ideas to the firm by involving key stakeholders such as customers, consumers, and other communities and ideation platforms through crowdsourcing or co-creation (Morschheuser et al., 2017; Stieglitz et al., 2017). The results of this study also highlight a strong tendency to rely on technology-driven approaches to facilitate CE, therefore, to develop these interdisciplinary strategies, gamification scholars and designers could explore other approaches, such as bringing the elements of the IPAT equation into their co-creative endeavours. The IPAT expresses I (environmental impact) as a function of P (Population), A (Affluence), and T (Technology) (Zhang et al., 2018) therefore, providing a wider context to where and how gamified CE strategies could take place, whether entirely facilitated by the T or not. Although the formula has been the subject of much debate (Holdren, 2018), it provides a basis for considering several other factors that impact and can result from transitioning to circularity. In general, drawing from gamified experiences in collaborative design methods, citizen science, and policy design can help broaden the horizon to address some of the identified shortcomings. This study shows the potential to strengthen multi-stakeholder, playful, catalytic actions that can bring us closer to CE.

Conclusions

This systemic literature review revealed a strong tendency towards applying gamification as an approach to motivate recycling behaviours. Among this line of study, there seems to be a consensus on the strategies that facilitate understanding the core concepts of recycling while not necessarily explaining this activity as one of the various elements that comprise the CE nor presenting some of the most critical issues related to recycling, like energy intensity and CO_2 emissions needed for these processes. Moreover, within this group of studies, games are presented as a series of educational tools with little to no relevance for raising awareness or communicating a bigger picture of the CE beyond one or two elements of the CE.

The application of two analytical frameworks for reviewing existing literature on gamification and the CE led to an unpacking of the intention, dynamics, and potential impact of applying gamification to the CE, creating awareness about existing gaps in the field as well as clear avenues for further action. For example, it is an invitation to explore opportunities such as introducing the IPAT equation in CE and design implementation processes to consider the population and affluence elements of CE, not only the technology and environmental impact. Gamification can play a relevant role as a strategic tool to facilitate the inclusion of these two elements throughout the development and deployment of solutions.

Although gamification is shown to gain or strengthen skills, the lack of elements that tap into emotional aspects related to individual agency, for example, the recognition that one is contributing to a circular process, leaves room for further exploring the possibilities that gamified approaches can bring. This is particularly relevant to overcoming the pitfalls that using gamification for repetitive resource management tasks, as is currently the case, may convey. Transitioning from a linear to a CE is a joint, progressive effort that requires decision-making and adoption of new habits and practices at all levels; if properly designed and applied, gamification as a catalyst of the CE has the potential to support the efforts along this journey.

This systematic literature review of 36 documents allowed for the development of an overview of how gamification is presented in academic work related to CE. Figure 16.5 shows a summary of these findings, comprising the results associated with research (theories explored, types of study), implications for application in other domains (Sustainable Development Goals, transition management), and potential avenues of practice and enquiry to pursue to maximise the potential that gamification conveys as a catalyst for CE.

Educational content

Research about the role of gamification as a catalyst for CE is full steam ahead. Our findings point to several avenues that researchers and practitioners can take. Bearing these in mind, this chapter poses the following reflective questions to its readers:

- What kind of gamification approaches could be designed and adopted in different scenarios of CE?
- What motivational forces both enable and disable CE, and what type of gamification may help catalyse them effectively, and for whom and in what contexts of CE?
- What tensions exist between different enablers and disablers of CE (e.g., economic, environmental, technological, societal, cultural) and how can gamification be differently incorporated in alleviating them?
- In what ways can CE business models be gamified?
- Why and how can gamification become an enabler of participatory policy-making processes?

Acknowledgments

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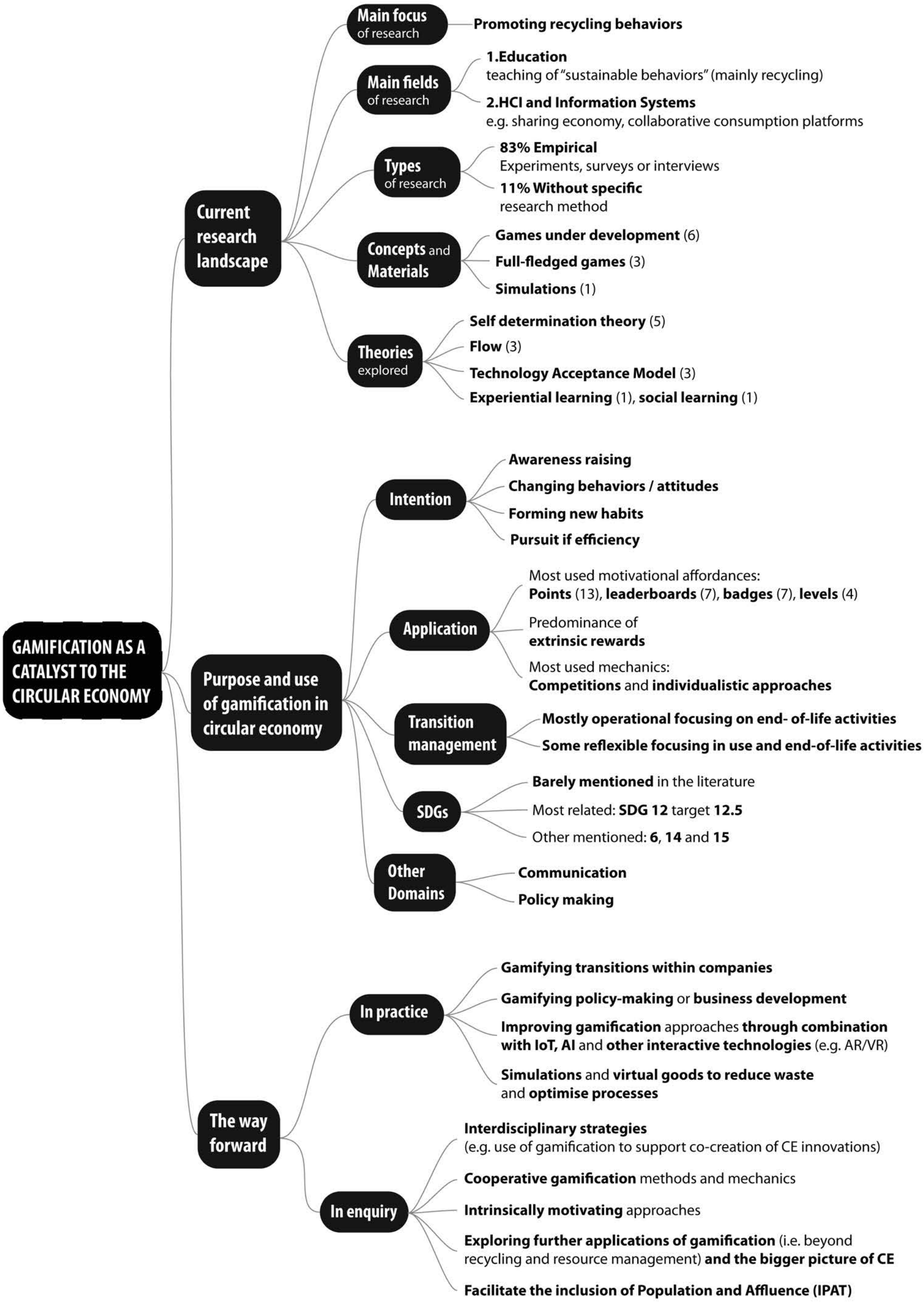

Figure 16.5 Graphic summary of the chapter.

Source: The authors.

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PART III

Methodological approaches for catalysing

17

MID-RANGE TRANSITION ARENAS AS CATALYSTS IN A CIRCULAR ECONOMY

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Introduction

The circular economy (CE) actualises through trajectories that permeate economic sectors, policy institutions, and geographical scales. CE solutions evolve, and are maintained, by multi-layered networks, which have components that do not easily reach the policy agenda, with some needing to be developed from scratch to have a bearing on socio-technical change. Catalysis of CE calls for practical tools to support the identification and linking of critical components for the implementation of CE solutions, and transition management (TM) is one such tool.

TM is developed as a transformative governance approach to identify change dynamics and align interests towards long-term implementation of policies and actions to catalyse various agendas (Frantzeskaki et al., 2012; van de Kerkhof & Wieczorek, 2005; Loorbach & Rotmans, 2010). Its aim is to create deliberative spaces for searching for, learning about, and experimenting towards a desired transformation goal with 'front-runner' stakeholders, engaged in innovating novel constellations of technologies and practices (Kemp et al., 2007; Loorbach & Rotmans, 2010; Rip & Kemp, 1998). The methodology connects contextually embedded experiments with global and regional developments, while facilitating broad and iterative strategy-making processes (Beers et al., 2019; Loorbach & Rotmans, 2010). A central facet of TM is the establishment of transition arenas (TAs) that comprise a series of knowledge co-production workshops, in which problem identification, vision building, and the construction of future pathways take place in a facilitated process with diverse and carefully selected stakeholders (Frantzeskaki et al., 2012).

There has been a resurgence of TM-related activities in Finland's science-policy interface during recent years. The Finnish Strategic Research Council (SRC), established in 2015, has redirected state funding towards transdisciplinary research with strong stakeholder interaction across society (e.g., policy-makers, civil society, and industry actors) and direct policy relevance (topics including digitalisation, sustainable energy, food system, and governance renewal) (Heino & Hautala, 2021). The 78 scientific projects (by May 2022) have been positioned as intermediaries in creating legitimacy and transparency for sustainability agendas (cf. Kivimaa et al., 2019) as well as developing methodological innovations and evaluative perspectives to navigate the transition policies across the sectors and regions (cf. Loorbach et al., 2018). This also reflects the more

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general development at the EU level, where transition approaches are becoming increasingly institutionalised at the science-policy interface (EEA, 2019; Turnheim et al., 2020). Many of the projects have also focused on CE topics and policy agendas either explicitly in research designs or implicitly by connections to policy developments.

TM facilitates technical, social, and conceptual learning (Bos & Brown, 2012) that support the operationalisation of transition topics on a longer term. The earlier TA processes have often focused on timescales of 30 years or more (e.g., van de Kerkhof & Wieczorek, 2005); however a mid-range focus, a strategic 5- to 15-year time span, is required to address sustainability challenges in convergence with ongoing policy development (Hyysalo et al., 2019a). To support relevance in future actions and to develop more reflexive strategic processes, Finnish researchers have developed a *mid-range transition pathway design toolset* (MTPT) to enable more structured and direct involvement to TA work (Hyysalo et al., 2019b). In this chapter, we draw on experiences from three recent mid-range TAs in SRC-funded research projects that have had methodological interests in sustainability transition research, a common methodological setting, and also ephemeral connections with CE policy developments. With the analysis, we aim to broaden the understanding of TM as a method to catalyse transitions toward a more CE. Consequently, we pose the following questions:

- How does the mid-range TA methodology support facilitating and navigating changes within, and across, societal sectors and spatial scales?
- What are the practical implications of TA work to cater to transitions towards the CE?

This chapter is structured in six sections. The following two sections clarify the conceptual and methodological basis of TA design. The fourth section outlines an analysis of the three TA cases. The final two sections provide discussion, conclusions, and implications to this book's focus on catalysts for a sustainable CE.

Transition management in the context of the circular economy

The CE is very much a policy-driven concept (Murray et al., 2017) promoted through successful narratives in policy-making, and the concept's ambiguity enables the coexistence of mutually exclusive interpretations (Lazarevic & Valve, 2017). For the CE transitions, TM can help to align interests towards the implementation of policies and actions (Frantzeskaki et al., 2012), and TA as a methodology offers a procedural approach that can be applied by engaging stakeholders in a context-specific and embedded framing, while also including conflicting meanings of implementation.

Applying transition management in a circular economy context

Based on the TM literature, we identify four key levers to consider when experimenting with TM in different contexts relevant for CE. First, according to Frantzeskaki et al. (2018), the TM application can be divided into three categories – *theoretical*, *operational,* and *heuristic* – that emphasise different types of dynamics of societal change. The theoretical focus advocates TM as a novel governance framework for systemic change, the operational focus emphasises application and adoption of TM process tools and designs, and heuristic focus applies TM as a lens in existing governance challenges and processes to increase the understanding of transition dynamics. In the different disciplinary frameworks, perspectives, and agendas in CE research, these categories become increasingly intertwined, as agendas on different levels, assessment, and practical action connect.

Second, TM has been viewed as a means of systematically "solving" *moderately structured problems*, where active mediators are needed to produce new knowledge and structure ongoing discussions (van Poeck et al., 2017). Too loose problem-framing hinders the meaningful and concrete iteration of future developments, while too strict framing elevates the predefined policy agendas and fixed stakeholder positions. However, the commonly used long-term timescales in TM (30–50 years) include a risk of distancing the discussions from current practices and interests, potentially leaving the conceptual ambiguities and difficult actions and trade-offs insufficiently addressed. Transitions towards a CE call for changes on a relatively short time perspective. A closer connection to policy cycles operating on mid-range timescales is necessary to provide more concrete lessons related to the implementation of policy pathways and critical reflection on stakeholder positions (Hyysalo et al., 2019a).

Third, regarding the real-world impact of TAs, another consideration relevant for CE has been how well TA processes are coordinated in relation to *policy windows* (Harlow et al., 2018). Governance institutions may be ill-equipped to adapt to transformative agendas (Valve et al., 2013). The explicit focus on forerunner actors and experimentation is necessary for the epistemological coherence of transitions thinking but can also be expanded in terms of policy implications (Hyysalo et al., 2019a; Voß et al., 2009). In terms of longer-term intangible outcomes, the TAs are expected to operate in three main domains. In the pragmatic domain, envisioned *new initiatives and projects* can create impulses and nudge transitions in the specific sectoral or spatial contexts (Ernst et al., 2016; Frantzeskaki et al., 2016). In the collaborative domain, *changes in actor-networks* create reflexivity towards roles and help to destabilise existing practices (Wittmayer et al., 2018). Last, in the institutional domain, the *reconfiguration of institutional rules and organisations* can become a long-term outcome cascading with reflexivity created through governance experimentation (Frantzeskaki et al., 2018, p. 3), albeit emerging in a slow and nonlinear way (Schäpke et al., 2017).

Finally, TM aims to *create space for systemic engagement,* where relations between multiple dilemmas and viewpoints can be approached simultaneously to reconstitute the 'public' of sustainability policies (Chilvers et al., 2018). The construction of *transition pathways* is a key means for cross-pollinating diverse views on change and supporting engagement, and in the CE context they also allow for improved regional and material assessments. There are always multiple pathways, and depending on the transition topic, they can be oriented towards, for example, *governance transition*, *socio-technical transition*, or *socio-ecological transition* (Frantzeskaki et al., 2016) – acting not only as mere illustrations but also material devices for arranging the potential actions. However, too rigid and straightforward interpretations on core concepts and required actions can have connotations of siding too closely with social engineering (cf. Shove & Walker, 2007; Voß et al., 2009), and in the regional setting they can also induce criticism.

TAs act as transition initiatives that aim at constructing an engaged public around specific topics (Chilvers & Longhurst, 2016). However, transition processes differ with regards to how the initiative for change is defined. For example, engaged stakeholders participating in co-creation processes can directly take initiative, but a wider impact often requires assigning responsibilities and aligning of more complex stakeholder relations beyond the local context. For the purposes of a CE transition, TM can operate *in diverse forms*, for example projects on specific topics (Frantzeskaki et al., 2016), knowledge co-production processes and arenas (Hölscher et al., 2019), or experiments, such as in urban living labs (Nevens et al., 2013). These interpretations differ in emphasising systemic understanding, shared future view, cross-context knowledge, or

Table 17.1 Types of arena work and potential focus in outputs

Type of TA process	*Focus of outputs*	*Reference*
Early transition frameworks	Establishing the method; Policy assessment and support	Kemp et al., 2007; van der Brugge et al., 2005
Urban transition labs; living labs	Connecting to pilots, experiments; Networking	Nevens et al., 2013; Baccarne et al., 2014
Local-regional transition initiatives	Long-term visions and strategic insights; Trans-scalar considerations	Frantzeskaki et al., 2012; Poustie et al., 2016
Strategic mid-range transition arenas	Strategic agendas and action points for the near future	Hyysalo et al., 2019a, 2019b; Valve et al., 2022

immediate means and actions for change. In connection with the development of the TA method, these different orientations underline the variety in TA-type interactions, and the potential it can tap into (see Table 17.1).

Connecting arena work to a mid-range timeframe

The impacts of TA work can be assessed regarding the resulting propositions for actions and their implementation, or as the emergent outcome of deliberative interactions and processes generated over the long term (Schäpke et al., 2017). There are tangible outputs (e.g., reports, blogs, policy briefs) and intangible outputs (e.g., individual and social learning, network building, novel agendas) that require different evaluative approaches (Schäpke et al., 2017). However, the evaluation of outputs, outcomes, and participant appraisals has proven to be a complex task, as the contextually different arenas produce different kinds of results depending on, for example, timing in relation to policy cycles, institutional embedding, and existence of competing processes (Hölscher et al., 2019).

TAs have traditionally been geared towards a long-term focus of 30–50 years (e.g., van de Kerkhof & Wieczorek, 2005), and the expectations of the output as well as the consequent transition pathways have remained relatively broad (Frantzeskaki et al., 2017; Loorbach & Rotmans, 2010; Roorda et al., 2014). Whereas long and broad pathways may be conducive for achieving convergence among participant views, they are not suited to the identification of difficult societal trade-offs and discussions over fine-grained actions, opportunities, and responsibilities relevant to CE transitions. To better address the strategic 5- to 15-year short- and mid-range actions, the TA process has been iterated towards a mid-range focus; supporting more reflexive strategic processes that are better connected with future action (Hyysalo et al., 2019a, 2019b). The more detailed pathway descriptions and timeframes of action also facilitate making TA outputs relevant for the audiences and connected to existing policy continuums, to create stakeholder integrity both within and outside the process.

The TA processes build on knowledge integration, and this process is also influenced by the quality, frequency, and directness of interactions (Dóci et al., 2022). The mid-range TA approach (Hyysalo et al., 2019a, 2019b, 2019c) introduces a more structured design of TA facilitation with consistent workshop activities, key materials, and external communication. This also enables more rigid analyses of the implementation choices, stakeholder reflections, and produced outputs across topical and spatial contexts (Hyysalo et al., 2017, 2019a). The earlier occasions of TA work have often relied on the facilitator and analyst team ('TA team') to turn results from collaborative work into refined pathway depictions (see e.g., Ferguson et al., 2013; Roorda et al., 2014).

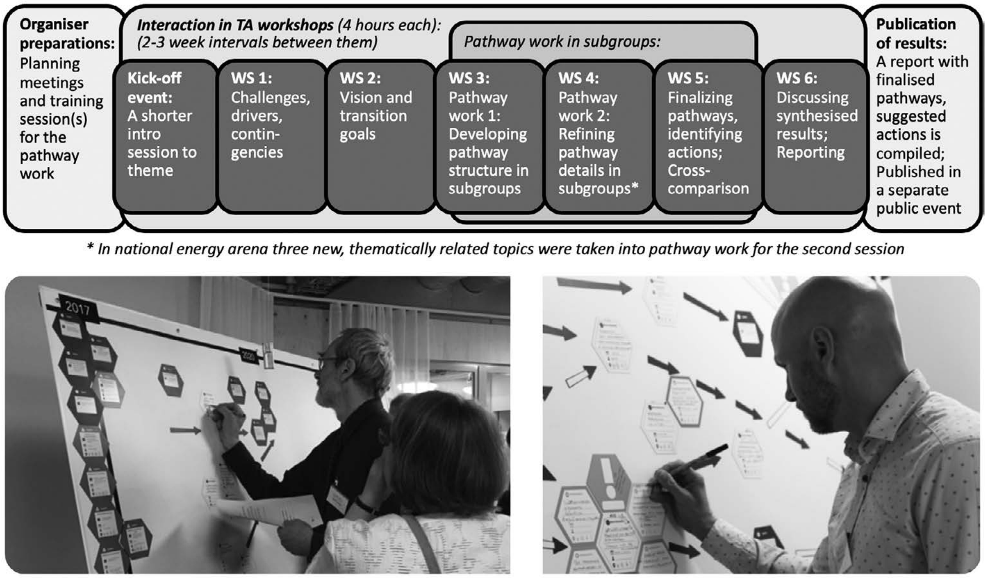

Figure 17.1 The general structure in the mid-range TA workshop series, and photos of actual transition pathway co-creation supported with the MTPT canvas.

However, in the mid-range TA process, the participating experts work on the pathway designs with the help of the MTPT in a strongly facilitated and materially supported process drawing from participatory design (Hyysalo et al., 2019c; see Figure 17.1; see also Botero et al., 2020; Simonsen & Robertson, 2012). This also allows for the reduction in the number of TA workshops prescribed in methodological guidelines (cf. Ferguson et al., 2013; Roorda et al., 2014), for the benefit of enabling better engagement of busy change makers, experts, and policy actors (Hyysalo et al., 2019a, 2019b).

In assessing TA impacts, a focus on outputs and expected outcomes is an effective starting point for analysis (Schäpke et al., 2017). This dynamic between the outputs and outcomes is connected to replicability of governance experimentation and can help to understand the potential of new means of governance and strategy making also relevant to CE.

Method experimentation: Presenting three mid-range transition arenas

Our analysis focuses on three full mid-range TA series that were organised between 2017–2019, focusing on energy transitions on a national scale and blue bioeconomy on a regional scale. At least three of the authors were present in each of the TAs from the early design phases to the communication of the results. The mid-range TA process consists of 6–7 workshop days with 2- to 3-week intervals (see Figure 17.1). In the pathway creation phase, a large metallic pathway board and magnet pads and arrows for notation are utilised. The participants fill in 'pathway steps' aiming at a collaboratively developed transition goal. Next, they prioritise these steps and study them in greater detail, attaching 'determinants' to them that refer to, for example, policy, technology, and business (see further detail in Hyysalo et al., 2019a, 2019b).

The first mid-range TA series using the MTPT toolset was organised in the *Smart Energy Transition* project in 2017. Besides aiming to develop an energy and climate strategy counter-agenda, the *national energy (transition) arena* acted also as the starting point to disseminate the MTPT toolset further. The *BlueAdapt* project's *blue bioeconomy (transition) arenas* developed the methodology in a policy area with considerations linked more closely to socio-ecological dynamics. These two TAs were opened in diverging regional contexts of North Savo and Southwest Finland (see Table 17.2).

Each of the three mid-range TAs spanned over several months, during which the operation shifted iteratively between shared sessions, small group work, broader arena reflections, and written commenting. The steps in the process were structured according to the conventional

Table 17.2 Cases in focus

TA series	*National energy transition arena (2017)*	*Blue bioeconomy transition arena North Savo (2018)*	*Blue bioeconomy transition arena Southwest Finland (2019)*
Aim of the TA	National energy and climate strategy counter-agenda 2017–2030	Regional blue bioeconomy agenda for North Savo 2019–2035	Regional blue bioeconomy agenda for Southwest Finland 2019–2035
Organisers and participants	Smart Energy Transition project, Aalto University, Finnish Innovation Fund Sitra; 21 participants across the energy policy field.	BlueAdapt project, Finnish Environment Institute, Savonia University of Applied Sciences; 14 participants with diverse regional expertise.	BlueAdapt project, Finnish Environment Institute, Valonia Service Centre for Sustainable Development; 18 participants with diverse regional expertise.
Produced transition pathways	• Coal is phased out by 2030. • Creating 2000 MW demand-response capacity in electricity. • Creating 2000 MW demand-response capacity in heating. • Halving building net-energy use. • Reducing household energy use 15% by behaviour-change. • 750,000 alternatively powered vehicles (electricity, gas) by 2030. • Reducing total mileage driven by 10% through mobility as a service. • Doubling the cleantech exports.	• Positive fish balance • In 2035, the region's sustainable fish production larger than demand. • North Savo presents an active network of water expertise that produces knowledge on water protection and experiments with new solutions. • At least 30–40% of the region's bovine manure is managed by advanced fractionation. • The networking of sustainable lake tourism actors in the region is supported by developing a holistic management approach.	• In 2035, new blue bioeconomy food products from Southwest Finland will reach markets; food-related use of Baltic herring will double to 10 million kg annually. • In 2035, the organic biomass of the region will be effectively turned into resources; half of domestic animal manure is processed with energy content being utilised and nutrients recycled. • Aquaculture output in Southwest Finland will triple by 2035 without increasing nutrient discharge.
Reporting	Hyysalo et al., 2017; Hyysalo et al., 2019a	Valve et al., 2019a; Valve et al., 2022	Valve et al., 2019b; Lukkarinen et al., 2023

TA process leading from vision-building to the development of transition pathways and actions (see Roorda et al., 2014). The pathway development to which participants were directly involved was mainly undertaken in subgroups, followed by cross-referencing to iterate policy messages. Moreover, based on the workshop recordings, the organising team conducted work between the workshop sessions to improve detail, display pathway dynamics, and iterate timing of the actions and steps.

In each of the studied TAs, a research-driven project organiser took care of the process facilitation and iteration of the main outputs and results, and a context-specific organiser (or 'host') took more explicit ownership of the actions. In the *national energy arena*, the Finnish Innovation Fund Sitra operated as the legitimising host under their thematic area *carbon-neutral circular economy*. In the *blue bioeconomy arenas* in North Savo the host was Savonia University of Applied Sciences, a developer of different water management and analysis technologies with networks within blue bioeconomy sectors. In Southwest Finland, the host was the Valonia Service Centre for Sustainable Development, with established connections to key public authorities and role as a knowledge intermediary in sustainability-related topics. In each case, the participants were selected through a careful and iterative process (ref. Roorda et al., 2014; Voß et al., 2009), where the most relevant topics were identified in the ongoing policy and planning developments, interviews, and reflective dialogue with the institutionally and/or regionally embedded host.

Various datasets were collected. First, the documentation of establishing the arenas, implementation of workshop interaction, and external communication provides a paper trail on how transition agendas were formulated and how the TA method has 'travelled' to new contexts. Second, the co-created outputs that include the pathway visualisations, narrative documents, action lists, blogs, and press releases form the basis on how the transformative agendas were mobilised. Finally, diverse types of reflections were utilised to understand stakeholder dynamics and perspectives, including a total of 37 participant interviews (between 16–90 minutes), 10 organiser interviews (between 32–87 minutes) and 53 replies to feedback surveys. The interview data was transcribed to be utilised as textual material along with the other documents. Additionally, an estimated 150 hours of non-transcribed workshop recordings were collected during the dialogues as supporting material.

The analysis proceeded in three main steps with at least two of the authors contributing to each step. First, we focused on the emergence of the TAs in an interplay between policy development, contextually embedded stakeholders, and research intermediaries. The aim here was to capture the relational work of the transition experts in establishing the co-productive arena. Second, we identified key similarities and differences between the cases regarding what tangible outputs and longer-term intangible outcomes emerged as relevant in the arena processes and stakeholder reflections. Here, the aim was to better understand the catalysing work of the completed TAs. Finally, we jointly reflected the implications of the TAs from a CE perspective to draw methodological, conceptual, and practical lessons relevant for the book.

Analysis: The mid-range transition arenas as catalysts in the circular economy

The three TA processes were carried out in different CE-related contexts, where socio-technical dynamics, spatial conditions, and stakeholder networks had implications on the process, developed pathways, underlying actions, and means of mobilising the actions in practice. Consequently, the findings help to understand how design variances and contextual shifts shape pathway design and tangibility of proposed actions, as well as the potentials and limitations of the mid-range TA method to catalyse CE transitions.

Mid-range transition arenas expanding dialogues on the circular economy

In the studied TA series, there were moments when the CE concept was touched on explicitly. Already the work in the *national energy arena* resulted in a pathway on scaling up the Finnish cleantech and bioeconomy sector. In this context, the CE was referred to as a loose 'go-to' concept catching focus of diverse participant views. In both *blue bioeconomy arenas,* however, more detailed discussions addressed, for example, nutrient circularity, the integration of recirculating aquaculture facilities, and industrial symbioses through new technological innovations. More circular solutions could increase resource efficiency (e.g., by utilisation of excess heat) and reduce nutrient loading (e.g., using waste nutrients as fertilisers). Here, the circularity was approached as a technical 'end-of-the-pipe' solution, which directed the discussion on critical aspects of technology development and commercial profitability. Both *blue bioeconomy arenas* also produced regional transition pathways to serve as catalysts for the nutrient CE in the region (Valve et al., 2020). Since both regions are characterised by intensive livestock farming and manure accumulation poses a risk for water protection, new technological solutions (e.g., local processing) and investments in resource recovery (e.g., manure, biogas, fertilisers) are needed. With farmers as potential investors, and governmental authorities as re-organisers of markets (among others), the pathway dynamics also enabled improved assessment of responsibilities and roles.

In the *blue bioeconomy arena* in North Savo, the transition vision of providing welfare from common clean water and the economisation of water protection was derived from a shared water vision developed a year before (see Koski-Vähälä, 2017). Although the CE was not explicated in the transition vision, it became important in relation to nutrient CE (Valve et al., 2020) and the bioeconomy opportunities around side streams (e.g., animal manure, fisheries). The workshop structure was further revised to give additional emphasis on the cross-pollination of actions, to create a basis for policy discussion. However, there were difficulties in finding regional ownership of the results.

In the *blue bioeconomy arena* in Southwest Finland, the developed transition vision viewed the region as a forerunner in food production combined with efficient nutrient recycling and utilisation of blue bioeconomy innovations. New CE developments, such as emerging markets for recycled fertilisers and regional innovation experimentation with recirculation technologies in fish aquaculture were considered important. There were also further adjustments to the workshop structure. A more open process with a broader stakeholder group was established to enable adaptation during the process. Further, the amount of time spent on constructing transition pathways was extended.

The potentials and limitations of agility in TA methodology was demonstrated in internal variations of facilitator and participant dynamics, connected to transition pathways in focus. In the *national energy arena*, the eight pathways varied in terms of novelty and depth; some built on a large body of existing knowledge introduced by engaged participants and expert facilitation. For example, a pathway on halving building stock net-energy use in a 14-year time span required deep transdisciplinary discussions to devise policy actions supporting systemic change. Yet, ambiguous framing of transition goals or missing expert understanding on an issue led to the pathway exercise operating rather as a space for collective ideation and testing of what steps might be sufficient and feasible (Hyysalo et al., 2019a). A pathway on multiplying national cleantech exports is a telling example here, as a vague target directed participants to focus on very broad ideas rather than actual transformative policy processes to support change.

Similar variation can be identified in the seven transition pathways of the *blue bioeconomy arenas;* quantifiable targets, facilitator expertise on topics, and motivated participant groups translated into coherent pathways. This was visible in the pathways focusing on nutrient-loading from agriculture that were developed in both arenas. Despite operating under the same challenge that requires novel circular solutions, the pathways offered different kinds of cross-spatial dynamics. The North Savo solution would rely more on farmers' agency on building regional manure processing hubs for biogas production, while the Southwest Finland solution anticipates a bigger role for the energy companies. An example of a less iterated pathway is focused on defining opportunities for lake tourism. The pathway starts with a clear challenge of Finnish lake environments being economically and socially underutilised. However, the facilitation of the pathway was directed towards identifying infrastructure needs and innovations around new services rather than tackling persistent problems of lake environment being dominated by industrial resource needs and the recreational use of water environment being culturally a very individualised and privatised tradition.

Overall, the variances in the TA processes reveal three core features for successful pathway work: 1) clear goal explicating a traceable transition from the current situation, 2) deep and varied topical expertise of selected participants, and 3) engaged and critical facilitation to discuss systemic interactions beyond narrow innovations and conflicting perceptions. Moreover, the redesign of the arena process resulted in shifts in two main areas – regarding the process design and outputs, and the intended societal outcomes towards broader aims (see Table 17.3). These two axes can be considered central, when the mid-range TA methodology travels to new CE contexts.

Table 17.3 Developments in the mid-range TA methodology and the MTPT process

TA series	*MTPT process and materials*	*TA outputs, (intended) societal outcomes, and impacts*
Socio-technical transitions in the national energy arena	• Mid-range temporal focus until 2030. • Process design of six workshops. • Facilitation guidelines on pathway work. • MTPT toolset with specified action magnets and board. • Six topical background memos.	Outputs: • Eight sectoral transition pathways. • List of 100 immediate policy actions. Outcomes and impacts: • A counter-agenda to national energy and climate strategy. • Institutionalising energy transition terminology to Finnish energy policy. • Several actions to the government programme (Marin, 2019).
Socio-ecological transitions in the regional blue bioeconomy arenas	• Temporal focus until 2035. • Extended time for pathway creation in process design. • External commentators in the process. • Explicit cross-pathway comparisons. • New action magnets for land use and production. • Single context-oriented memo.	Outputs: • Four (North Savo) and three (Southwest Finland) transition pathways. • Lists of 32 and 28 immediate policy actions. Outcomes and impacts: • Stimulating discussion on sectoral blue bioeconomy developments in agriculture nutrient recycling and fish aquaculture. • Improving regional capabilities to engage in sustainable transitions.

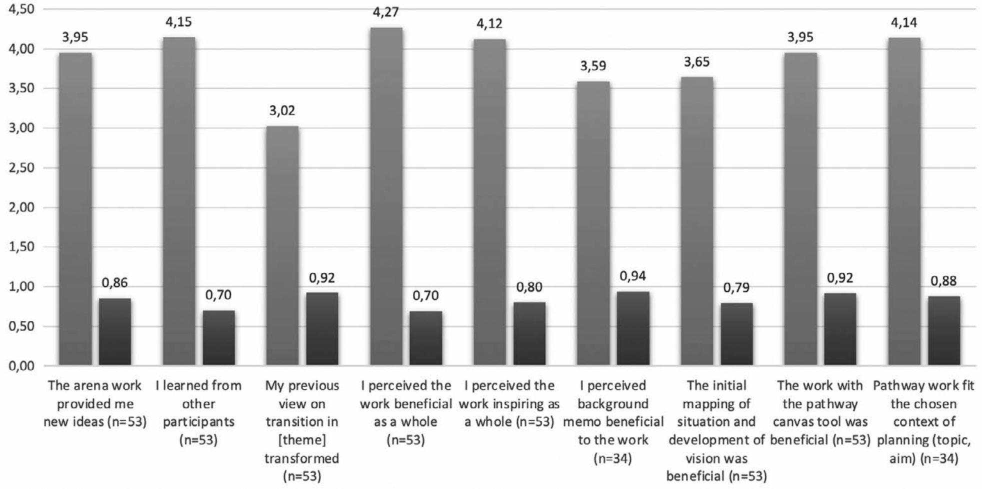

Figure 17.2 Collected answers from the follow-up participant survey (1–5 scale, the dark columns on right marking standard deviations).

Participant and organiser feedback on the arena work

Experiences of the mid-range TA process were collected via follow-up participant surveys, supported with analyses of participant and organiser interviews. The survey results show that overall, the mid-range TA work was perceived as beneficial and inspiring (see Figure 17.2) with broad support also from the supporting interviews. After the workshops, the participants thought they had learnt from others and gained new ideas on various topics. However, the process's impact on their views on transition was less significant and with the highest standard deviation. This suggests that the process broadened, rather than altered, the participants' personal views, and learning focused on expanding and linking previous understanding rather than transforming it.

In the follow-up interviews, the participants discussed learning new perspectives in relation to the focus themes, along with reflection on their justifications and reasoning, and the creative collaboration in pathway design as a mode of interaction. These aspects were also mentioned worthy of transporting to other networks and domains of action. The pathway work with the MTPT canvas supported both temporal and material assessment of actions and responsibilities especially relevant for regional CE transitions. According to organiser interviews, the mid-range TA process was also perceived positively; it worked both as a research tool for studying broad cross-sectoral concepts, themes, and transitions, and as a method to interact with contextually relevant networks to produce tangible outputs. From the facilitators' point of view, the process was perceived to support learning, offer refreshing perspectives, and help to develop a shared understanding regarding the complex whole.

Overall, the interaction was perceived to help strategy work in sectoral policy settings of individual transition pathways, more generally as a counter-agenda for established policies (*national energy arena*) and in regional development and planning (both *blue bioeconomy arenas*). However, due to complex stakeholder dynamics and regional and topical details that were difficult to predict beforehand, the collaborative and iterative process required continuous attention from the TA facilitators. The facilitator workload substantially varied in different process phases, with very intense periods of refining outputs (e.g., working memos, pathway report) and collecting findings (e.g., digitalisation of pathway work output, facilitating commentaries) (see also Hyysalo et al., 2019b).

Potential and limitations of the arena interaction

The TA series had different connections to their policy settings, directing the operationalisation of outputs, outcomes, and impact. Here, the orientation toward policy cycles is of value, as finding the right opening for policy-impact is not straightforward. In the *national energy arena*, which was an intervention within the science-policy interface on national climate targets timed to follow the publication of the energy and climate srategy (TEM, 2017), the binary positioning towards the newly published official strategy created initial policy interest for knowledge co-production. The main outputs (pathways, final report, the list of 100 actions; see Table 17.3) were supported by the publication of press releases, 10 action-oriented blog posts and meetings with a diverse set of energy sector stakeholders, to impact national policy processes. The dissemination of results benefited from the EU's post-2020 energy governance framework (European Commission, 2017) that brought the TA discussions to mainstream policy-making. Furthermore, the initially 'too early' timing regarding the next election cycle turned out to be beneficial because the arena's key message on increasing the pace of energy transition was eventually appropriated by most political parties.

The *national energy arena* was an experiment demonstrating the potential for a systemic change away from fossil fuels, while identifying opportunities for innovative technology and service developers and citizen participation. The eight co-created pathways connected to several energy policy topics (see Table 17.2 for details), and the core principle in the guiding vision was that more circular solutions combined with novel technologies will not only lead to a carbon neutral energy system but also reduced energy demand. For example, the heat capture technologies at the building scale and at the system scale of district heating networks (based on heat pumps on different scales) would transform the operation of building energy networks and enable disconnection from fossil energy. In essence, the identified energy policy opening enabled methodological experimentation in developing systemic solutions that the stakeholders considered to be overlooked in the energy policy context.

The *blue bioeconomy arenas* were more open-ended processes related to emergent policy topics. The concept of the 'blue bioeconomy' was coined in Finnish policy implementation only in 2016, when the government introduced a development plan on the blue bioeconomy sector combined with an innovation program (MMM, 2016). Consequently, there was little tangible meaning to the concept at the time of the TAs, and the arenas aimed at concretising this through co-created transition pathways. Additionally, the arenas attempted to promote the view of turning environmental protection into a source of economic value. The regional orientation connected the arenas closely to specific forms of resource utilisation, which required a more place-specific orientation. As a result, the stakeholders also had stronger ties (and potential biases) towards the selected topic, making dialogue more sensitive with a less appealing institutional focus. In both *blue bioeconomy arenas*, the introduction of national policy developments contributed to the temporal relevance of the arenas. However, the primary orientation was on local experimentation in the regional contexts to open opportunities for economic renewal and to catalyse innovation activities in the areas. This became evident also in the follow-on actions especially in North Savo, where arena outputs contributed to tackle the shortcomings in the regional lake tourism networks, and to experiment with biogas production from manure to regulate excess nutrients on farms. In Southwest Finland, the arena process was followed with activities to identify systemic solutions for utilising currently under-valued fish stocks, but the actual experimentation proved complex. Furthermore, the trans-scalar nature of transition policies became evident in this context, as the discussions were focused on politicised targets for good ecological status of waterbodies set in the European Water Framework Directive (Directive 2000/60/EC). Especially the incumbent stakeholders in fish farming questioned the legitimacy of the targets unfairly limiting their economic activities.

All the arenas have proven impactful in their contexts – although not necessarily through the actions explicated in the transition pathways. The *national energy arena* reached the target of normalising the energy transition approach to the national policy forum, and many of the actions have ended up in the government programme (Marin, 2019). Furthermore, in retrospect, the transition goals of phasing out coal and enrolling 750,000 electric vehicles by 2030 seem conservative although other goals, such as reducing household energy consumption by 15 percent with behavioural changes or creating capacity of up to 2,000 MW of heat demand response seem rather challenging. The *blue bioeconomy arenas* succeeded in providing more concrete examples of blue economy sectors and communicating the message that blue bioeconomy is not only about what happens in water. However, the idea of overcoming the opposition between environmental protection and economic value creation remains marginal. More importantly, the pathways, especially regarding the improved agriculture nutrient control in North Savo in central Finland and in coastal Southwestern Finland, and sustainably tripling fish aquaculture output in Southwestern Finland have been important contributions to complex policy developments.

Discussion

The transitions towards CE can be catalysed by opening spaces for explicit interaction to assess systemic links and policy implications. To meet this challenge, TM has been suggested as a model to "bridge the gap between top-down planning and bottom-up incrementalism" in policy and governance for sustainable development (Kemp et al., 2007, p. 3). Furthermore, the mid-range TA process supported with MTPT can help facilitate multi-stakeholder dialogues to the co-design of transition pathways by directly channelling participant action and ideation (Hyysalo et al., 2019b; 2019c). In this chapter, we have reflected upon three TA processes in different policy and spatial contexts to better understand success factors of such an approach. We discussed how the mid-range TA becomes meaningful in approaching changes in the societal systems. Then, we discussed this potential and relevance in a CE context.

The process, outcomes, and potential framings of the arena interaction

Schäpke et al. (2017) note that the outputs of TA work can contribute directly to policies, but the broader systemic transitions are contingent on indirect changes and learning in actor-networks, which is more difficult to trace. The mid-range adaptation of TA (Hyysalo et al., 2019a) has proven applicable and adaptable to various contexts with diverging power relations and cultures, but the success of pathway work is contingent on several elements – namely, the identification of policy openings, selection of stakeholders and development of contextually embedded ownership, clarity of the process and transition vision, and understanding the impact dynamics. The methodological adaptability between the contexts has required design alterations to maintain policy relevance; the alterations can be illustrated by three distinct framings for TA work – *project, strategic,* and *spatial* – that are implemented in the knowledge co-production processes (see Figure 17.3). The framings are not exclusive and each of them carries implications for the

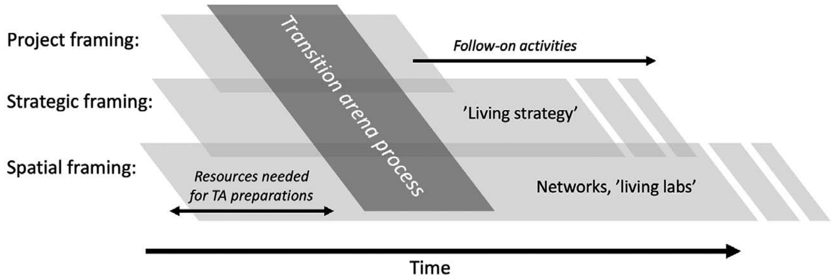

Figure 17.3 The mid-range TA process with different 'framings' as the focus, with differences in the necessary resources and time for preparation, and follow-on activity.

stakeholder constellation, the type of generated knowledge, and required effort in the preceding work and follow-on activities. The three framings also carry implications for CE transitions, as project framing is linked to expansion and scale-up pathways for technical and societal innovations, strategic framing to alignment of policy actions, and spatial framing to development of place-based processes and interactions to support circularity.

As understanding on CE solutions mature, often in small niches, the work within a thematic *project framing* is often the starting point of TA action, and it enables the further development of initial strategic thinking into action connecting to an increasing number of stakeholders. While project framing is often evident in research-related arenas, the *national energy arena* and the *blue bioeconomy arenas* extend this towards *strategic framing*, where policy focus is more explicitly on developing, problematising, or challenging the actions or initiatives across the multiple and often contradictory stakeholder interests. The strategic framing implies the politicisation of transition topics, or the formulated future pathways, can take place either within the arena space or in the wider societal communication also relevant for near-future CE transitions. The future actions can take a form of a living strategy that provides space for iterating and reflecting the actions as the change processes unfold. Finally, *spatial framing* is related more closely to the implementation of activities and operationalising of the pathways in the diverse territorial contexts, aligned with lessons from experimentation and stakeholder emancipation in developing grassroots initiatives for more sustainable practices. The implementation of these actions can take the form of, for example, novel networks or living labs that support the reconfiguration and transformation of established practices in production and consumption networks. However, for the CE context the spatial considerations should not be considered as containers of action but rather relational perspectives on the more diverse societal policy developments, which was especially evident in the regional TAs on the blue bioeconomy.

These three framings are crucial, when considering the implications for complex sustainability transitions that require coordination of heterogeneous societal dynamics, and the follow-on activities after the TA process (see Table 17.4). First, project framing implies a *heuristic orientation*, where the transition dynamics are being tested, deepened, or even sketched out by the specialists to create a more comprehensive understanding of the socio-technical, socio-ecological, and institutional future dynamics around the issue (cf. Frantzeskaki et al., 2018; 2016). Therefore, the emphasis on the follow-on work is less imminent and can be shaped by the created understanding and feedback from the societal actions. Second, strategic framing is connected to *operational orientation* and work on emerging policy openings – such as shifts in power and agendas – to utilise discursive power on the science-policy interface or tease out dormant societal contradictions.

Table 17.4 Potential framings and orientations for mid-range TA exercises, and implications on follow-on action

Framing	*Definition and focus*	*Orientation and implications for follow-on actions*
Project framing	Project-based networks and legitimation in the implementation of knowledge co-production.	Knowledge on systemic sustainability dynamics in socio-technical or socio-ecological context [heuristic].
Strategic framing	Strategic openings to unpack societal 'lock-ins' on complex issues and legitimate science-policy interventions.	Systemic connections and strategic pathways to uncover societal discrepancies and mobilise systemic change [heuristic-operational].
Spatial framing	Defining regionally or locally specified challenges and opportunities to understand dynamics of change.	Co-producing pragmatic connections and activities to transform sectoral and institutional practices [operational].

The stronger politicisation also emphasises the need to orient follow-on actions to relevant policy processes and institutional contexts to maintain the relevance of the produced transformative policy lessons. Finally, spatial framing builds more on the evidence-based implementation of outcomes by *operational orientation* on distinct initiatives, experiments, and pathway steps. The shelf life of such activities is potentially much longer, but also requires more engaged ownership and management of the follow-on activities within the transition context.

Mid-range transition arenas catalysing changes for the circular economy

Addressing the persistent problems of unsustainable resource governance calls for fundamental, structural transformation of societal systems (e.g., agri-food, housing, energy) and rethinking how resource use and sharing arrangements are tied to economic development and well-being. CE has become a key governance framework to reconfigure how value is extracted from resources (Hobson, 2021). While the CE circulates as an ideal, the practicalities and actual engagements or forging CEs are limited and fragile (Corvellec et al., 2021; Gregson et al., 2015). The actualisation of an economic system that aims at the minimisation, in view of total elimination, of resource extraction and waste generation is often presented in terms of 'R' strategies (Lazarevic & Brandão, 2020), such as: refuse, reduce, reuse; repair, remanufacture, repurpose, recycle, and recover (energy) (cf. Reike et al., 2018; see also European Commission, 2015). However, such strategies and circular business models are often presented as acontextual, apolitical, and aspatial solutions that merely need to be implemented, circulated, and scaled up (e.g., Bocken et al., 2014).

How can TAs help support the material circulation and value extraction and the reconfiguration of resource intensive systems? Considering the previous analysis and discussion, we suggest four ways in which TAs may act as catalysts in transformation processes.

First, mid-range TAs may help to render the CE as a governance problem in new and innovative ways, allowing participants to break free from institutional lock-ins and spatial boundaries. The material circuits of production and consumption are deeply embedded in global and national regimes, structured by existing, and path-dependent, sectoral (e.g., chemical product, waste, trade, planning policy) and multi-level governance mechanisms, incumbent actor-networks and material infrastructures. TAs encourage participants to explore visions and pathways beyond the confines of institutionalised policy domains and incumbent power relations, thus providing a space to empower a more diverse array of actors in co-deliberation of contextually relevant CE visions and goals. Consequently, TAs can act as catalysts for the deliberate re-politicisation of transition goals, questioning of dominant win-win, growth via decoupling, and other ecological modernist narratives of the CE (see also Lazarevic & Valve, 2017).

Second, mid-range TAs can act as a catalyst for CE transitions by bringing experiments, niches, and CE strategies to be explored in new settings. For example, one of the transition pathways in the national energy arena focused on novel mobility services relying on the interplay between economic incentivising and social experimentation with new technologies in an urban space – a development that is currently in full motion. TAs can act as spaces to identify experiments and pilots, immediate actions, and the assignment of responsibilities, protected from mainstream markets and selection pressures (Schot & Geels, 2008). Collective TA pathway building can be a tool in which active and passive shielding policy instruments (see Smith & Raven, 2012) can be identified and linked to experimental interventions to overcome hinders and showcase for CE developments.

Third, mid-range TAs can support the discussion and analysis of niche expansion and mainstreaming. Scaling up CE experiments and niches requires active value creation and the development of business strategies. Transforming waste materials into new raw materials requires economisation and marketisation work (Gregson et al., 2013). These modes of work are carried out in institutional and material circumstances that need to be changed to support reorganisation of production systems and markets. For example, in the studied cases turning waste heat into energy resource requires reconfiguration of heating network technology to enable lower temperatures, while turning waste manure into energy and fertilisers requires new technological intermediaries to restructure markets.

Last, mid-range TAs can act as a catalyst for identifying and addressing collective action problems. Transition pathways open new questions related to the allocation of roles and responsibilities, such as identifying the central role of the public sector in creating demand for locally produced biogas to support excess-nutrient processing from agriculture. Knowledge co-production processes have been shown to empower actors, enhance the legitimacy of actions and stakeholder commitment (Wyborn et al., 2019). CE solutions also call for horizontal and vertical policy coordination to scale up CE solutions and minimise unwanted rebound effects (e.g., Valve et al., 2021).

While the previously mentioned points show the potential value of TAs in catalysing CE transitions, there are limitations. Whether TAs are connected to local, regional, or national objectives, the mid-range solutions are limited to the sphere of influence of arena stakeholders, although many of the challenges are connected to the persistent global sustainability problems and production systems. For example, the sustainable fish aquaculture development in the Southwest Finland region is restrained by Norwegian salmon farming that sets the market price level in global trade. Moreover, while mid-range TAs may be able to identify areas for policy development, the space is not sufficient to provide detailed designs. For instance, the Finnish energy TA formulated emergent ideas on circular energy systems to a coherent narrative that the political interest groups could later pick up and develop to more detailed policy initiatives.

Conclusion

In this chapter, we have studied how TM processes can support CE transitions, and how the mid-range TA can be operationalised within various framings and with different orientations of work and expectations of results. The recent TA projects in Finland offer a fruitful context to study the adaptability of the mid-range methodology, as well as assess connections between the TA interactions, their outputs, and more long-term developments potentially connected to the local context of action. Since the initial use of the methodology, the utilisation has been continued in a range of contexts including citizen energy (Lukkarinen et al., 2020), national biodiversity strategy (Hyysalo et al., 2022), Agenda 2030 roadmaps (Lähteenoja et al., 2022), regional sustainable mobility (Enell-Nilsson et al., 2019), and low-energy buildings and district planning (Grönroos et al., 2022). The methodology and toolset have also been redesigned to support online use (see http://murrosareena.fi/english/).

In pursuing the CE, "there is a need for civil society and consumers, the private sector, as well as the policy framework within which it operates, to align their goals" (Brandão et al., 2020, p. 506). Key actors need to work together on "commonly shared objectives for the circular economy," and develop means of implementation and become informed about the impacts (Brandão et al., 2020, p. 506). The mid-range TA process offers one window to observe how reflexive processes of collaborative knowledge production can help strategy and policy-making processes for CE developments. On a regional level, mid-range TAs can help to align strategic near-future goals and existing spatially dispersed networks.

Overall, TAs can orientate co-creation of actions in various kinds of transitions, whether in a governance, socio-technical, or socio-ecological systems setting (e.g., Frantzeskaki et al., 2016). As a method to support more reflexive governance for CE transitions, the mid-range TA process adds an iterated orchestration of exchanges between diverse kinds of actors. Furthermore, the MTPT supported pathway co-creation provides an additional interface to assess complex systemic dynamics to speed up the necessary near-future actions.

Educational content

1 CE transitions often require assessment and mediation of differing views and interests. The mid-range TA process supports collaborative synthesising of diverse knowledge on complex topics and helps facilitate critical dialogues on future action.
2 The mid-range TA process along with the MTPT contributes directly to the toolbox for more deliberative, reflexive governance. It acts as a constructive method to facilitate knowledge co-production, helping to structure understanding and future action in relation to various contexts and areas of interest.
3 Mid-range TAs can also act as catalysts for identifying and addressing collective action problems. If properly anchored to the context through relevant materials, participants, and facilitation, they can help shape ideas into action between different actors, organisations, and networks, also helping to bridge temporal and sectoral gaps when seeking new CE collaborations.

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18

DESIGN THINKING TOOLS TO CATALYSE SUSTAINABLE CIRCULAR INNOVATION

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Introduction

In recent years, 'design thinking' emerged as a new approach for organisations aiming to solve complex and open-ended innovation problems. Innovation management scholars have discussed this extensively (Brown, 2008; Kimbell, 2011; Liedtka et al., 2013; Martin, 2009; Stacey et al., 2000). According to Brown (2008), design thinking is an iterative and experimental approach to develop innovations that are desirable for people, financially viable, and technically feasible for organisations. Boland and Collopy (2004) stated that managers should learn to think in the way designers think, approaching business problems in a more holistic and open-ended way. The British Design Council (2007) and Plattner et al. (2009) proposed a conceptual design thinking model. Making an additional step, Liedtka and Ogilvie (2012) listed ten design thinking approaches and tools that can be leveraged to operationalise the conceptual model (e.g., rapid prototyping and journey mapping).

In parallel, design thinking approaches have been increasingly discussed also for addressing complex challenges, with a specific focus on achieving sustainable development and a circular economy (CE) (e.g., Baldassarre et al., 2019a; van Dam et al., 2020). Circular innovation is about the technology, product, value chain, business model, and ecosystem changes to break away from a linear economy paradigm where products are disposed of after a limited number of uses, to a system where products and materials are reused, and the natural environment is regenerated. Several scholars claimed that design thinking can and should play a significant role in transitioning to a CE by rethinking not only industrial products and processes, but also the businesses and socio-technical systems around them (Dobers & Strannegård, 2005; Papanek, 1971). Ceschin and Gaziulusoy (2016) suggested that it can be instrumental in designing business models to enable and foster a CE. Baldassarre et al. (2020a) proposed a framework to implement existing sustainable design thinking theory into business practice at four levels, from products to business models and collaborative ecosystems, as well as a design thinking process for industrial symbiosis (Baldassarre et al., 2019b). Diehl and Christiaans (2015) highlighted the changing role of designers from the creation of industrial products to co-creating sustainable business models with multiple stakeholders and integrating their various demands and proposed several tools for

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developing future-oriented scenarios and roadmaps and visualising potential solutions to create a shared understanding among team members and stakeholders.

Despite these developments, how design thinking can be concretely leveraged by organisations to perform circular innovation and more broadly catalyse the transition toward a more sustainable society remains relatively under-explored. Although there is now a better understanding of how design thinking and proposed tools can be used for addressing complex innovation problems (Dorst, 2011; Liedtka et al., 2013), we still know little about how these tools can contribute to the development of sustainable and especially circular innovations (e.g., Bocken et al., 2021a). Research in this regard is emerging rapidly. For example, Brown et al. (2021) proposed a design thinking tool to support multiple organisations in collaboratively ideating a circular value proposition, while Bocken et al. (2021a) explicitly stated that design thinking tools can be leveraged to ensure desirability, feasibility, and viability of circular innovation, without, however, diving into this specific subject. This research has the potential to be concretely applied by organisations and accelerate the transition to a CE. However, for the time being, it is in its infancy. Aiming to advance it, with this chapter we explore the following research question: How can design thinking tools catalyse sustainable circular innovation?

We address this question by first reviewing the contemporary conceptualisations of design thinking, mapping the extant tools, and consequently illustrating how these tools have been applied in several sustainable and circular innovation projects. This is functional to build on former research (e.g., Guldmann et al., 2019; Prendeville & Bocken, 2017) and explain with more specificity when and how design thinking tools might be applied to develop sustainable circular innovations that are simultaneously desirable for people, and financially viable and technically feasible for businesses.

Conceptual background

What is circular economy innovation?

Circular innovation is about developing and making conscious changes to technologies, products, value chains, business models and ecosystems to support the move away from a linear 'take-make-dispose' paradigm to a system where products and materials are continuously reused, and nature is regenerated (Brown et al., 2019; Rashid et al., 2013). Key strategies include slowing, closing, narrowing, and regenerating resource loops (Bocken et al., 2016a; Konietzko et al., 2020). Slowing the loop is about long-life products and design for product life extension, supported by design for attachment and trust (emotional durability), and reliability and physical durability (Bocken et al., 2016a). For example, several companies selling anything from clothing to furniture and household equipment, are including a lifelong warranty to ensure longer use of their products (see e.g., Button, 2018 and buymeonce.com). This is often accompanied by a more premium business model to make this 'value over volume' model viable. Closing the loop is about recycling, which may be facilitated by designing for a technological or biological cycle (McDonough & Braungart, 2010) and easy dis- and reassembly. Recycling is a widely known practice for household waste and packaging. However, there is still ample work to do, because in 'leading' places like Europe recycling of household waste, packaging and electronics is still below 50% (2016 data, European Environment Agency, 2021). Narrowing the loop is about using less material or resources per product or service. For example, smaller shared cars use less fuel and require less cars in total. Since 2013, the car-sharing company DriveNow has made available the small electric BMWi in its sharing model in several German cities. Regenerating is about cleaner loops and ensuring the environment is in a better state than how it was found (Bocken et al., 2021b). For example, companies like Nestlé and Unilever are working on biodiversity issues such as reviving bee populations and regenerating the soil together with collaborators to secure their future supply of ingredients such as strawberries and tomatoes for their products (Bocken & Geradts, 2022).

Developing innovations for the CE is a complex endeavour, as they are embedded in a larger innovation system and influenced by a multitude of factors, such as technological and market developments and the institutional environment, including norms, values, culture, and policies (Buhl et al., 2019; Han et al., 2022). Therefore, it is often challenging to develop and implement sustainable circular innovations for several reasons. First, circular innovation requires organisations to think differently due to increased product responsibility (Bocken et al., 2016a). It requires them to consider the whole life cycle of products (Den Hollander et al., 2017), as well as the related infrastructure and actors to enable slowing, closing, narrowing, and regenerating resource loops (Konietzko et al., 2020). Second, to develop desirable, viable, and feasible circular strategies, the needs and values of different users and stakeholders must be understood more deeply (Guldmann et al., 2019). Third, the most relevant circular principles and strategies for the company need to be identified and implemented (Sumter et al., 2018), and the innovation outcomes from environmental, social, and economic perspectives need to be assessed (Santa-Maria et al., 2021). Finally, even if a product is designed with the intent of increasing efficiency and reducing negative environmental impacts, rebound effects might occur (Castro et al., 2022; Chitnis et al., 2013; Zink & Geyer, 2017). In practice, this means that a positive environmental impact is not achieved because the efficiency gains are lost due to other unexpected factors. A simple example to illustrate the concept is the installation of a more energy-efficient light bulb, which leads users to a less careful behaviour and ultimately to higher energy consumption. Another example could be a car-sharing service that optimises the use of vehicles but at the same time encourages to drive more instead of walking short distances. The best designs would seek to build in mechanisms to avoid such rebound effects where possible.

What is the role of design thinking?

Design thinking has gained popularity as a new paradigm for dealing with problems in various domains and professions, such as information technology, innovation, and business (Dorst, 2011) and more recently, sustainability and CE (e.g., Ceschin & Gaziulusoy, 2016; Guldmann et al., 2019; Sumter et al., 2018). For example, design thinking can catalyse circular innovation through the creation of products that can be disassembled and recycled (Vanegas et al., 2018), or through a more environmentally conscious material selection (Virtanen et al., 2017). Also, design thinking can contribute to a CE by influencing user behaviour (Wastling et al., 2018), and integrating business model considerations (Bocken et al., 2016a). In this respect, design thinking as a user-centred, collaborative, and iterative approach is considered to be highly relevant for circular innovation (Guldmann et al., 2019). Moreover, the role of designers needs to change more profoundly, for example, towards designing for multiple life cycles, assessing, and comparing the environmental impact of different circular strategies, engaging users in the use and return of products, and understanding the interlinkages between the product and the business model (Bocken et al., 2016a; Sumter et al., 2020). Next, we discuss the core aspects of design and then introduce our conceptual framework for mapping the extant design thinking tools proposed by several scholars.

Design thinking, as popularised by management scholars, can be understood as a problem-solving approach that "uses designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (Brown, 2008, p. 2). Three important aspects come forward in this definition: 1) the designer and his/her way of thinking and acting, 2) the success criteria of a design, and 3) the design process.

The first aspect is the designer or design thinker, who is argued to have a different way of thinking than, for example, a manager (Boland & Collopy, 2008). Cross (1982), in this regard, referred to "designerly ways of knowing", as the way that designers operate to first understand and frame the problem they are dealing with, and then move on to approaching it and solving it. Lawson (1980) and Schön (1983) extensively explored the way designers think and act as well. In turn, management scholars attempted to better understand how the main insights of these seminal pieces of literature could be useful in other contexts of business innovation, strategy, and organisational design (Brown, 2008; Hassi & Laakso, 2011). Several definitions of what constitutes design thinking, design thinking principles, and related skills and practices have been proposed within the design and management discourse. According to Brown (2008), for instance, the characteristics we should look for in design thinkers are empathy, integrative thinking, optimism, experimentalism, and collaboration. Hassi and Laakso (2011) distinguish between practices, thinking styles, and mentality in conceptualising design thinking. The authors propose: 1) a human-centred approach, thinking by doing, visualising, combining divergent and convergent approaches, and collaborative work style as design thinking practices, 2) reflective framing, abductive thinking, taking a holistic view and using integrative thinking as design thinking styles, and 3) experimental and explorative, ambiguity tolerant, optimistic, and future-oriented as design thinking mentality. In a similar vein, Diehl and Christiaans (2015) highlight the expanding role of designers by expanding the traditional skill set of designers to include human-centeredness, experience design, future-orientedness, visualisation, and integration. Furthermore, the design process is often co-creative involving frequent interactions with multiple customers and stakeholders (Guldmann et al., 2019).

The second aspect includes the criteria to define the success of a design. These aspects include desirability, feasibility, and viability (Brown, 2008; Martin, 2009). The desirability criterion refers to what people need and/or want; feasibility refers to what is doable from a technical, technological, and/or operational standpoint; viability refers to what is possible financially and/or economically for the innovating organisation (Calabretta et al., 2016). These three criteria are central to design thinking and relevant to circular and sustainable innovation as well (Baldassarre et al., 2020b). Besides these three criteria, circularity is a crucial criterion for circular innovation, which requires business organisations to focus on retaining the value embedded in used products by narrowing, slowing, closing, and regenerating resource loops (Bocken & Geradts, 2022; Guldmann et al., 2019). Therefore, following the logic of design thinking and applying it to sustainable circular innovation, we define four criteria for sustainable circular innovation development, namely desirability, feasibility, viability, and circularity.

The third aspect is the design process, which uses the desirability, feasibility, viability, and circularity criteria to create customer value or market opportunity. Several design thinking process frameworks explain what constitutes a design process. Brown (2008) conceptualises the design process as a system of spaces rather than a predefined series of orderly steps. The three spaces proposed are inspiration, ideation, and implementation. Ries (2011) discusses the iterative steps of building, measuring, and learning in the Lean Startup approach. In a similar vein, several frameworks conceptualise design processes for sustainable or circular business model innovation. Frankenberger et al. (2013) define the process stages of business model innovation. These entail initiation, ideation, integration, and implementation of new business models.

Finally, the fourth aspect relates to the level of innovation: at the technology, product, business model, or ecosystem level (Konietzko et al., 2020; Rashid et al., 2013). Whereas designers have been involved in technology and product design, the interaction between products, services, and business models is becoming a more prominent area of work in business and design research and practice (Diehl & Christiaans, 2015). The reason is that a business model determines the impact of a product in terms of customer success (Chesbrough, 2010), and environmental impact (Tukker, 2004). Design is even linked to supporting the transition of broader ecosystems, to circular cities through redesigning the products and business models used in the cities and using design thinking to realise new projects (Prendeville et al., 2018).

Method

In this section, we describe the method employed to address the research question of how design thinking catalyses sustainable circular innovation. We identified a set of relevant sources presenting a wide spectrum of design thinking tools. These sources included primarily the books *This Is Service Design Thinking* (Stickdorn et al., 2011) and *The Delft Design Guide* (van Boeijen et al., 2020), as they emerge from the need for a comprehensive overview of perspectives and tools to guide designers in the development of products, services, and other creative processes and are being used for both educational and practical purposes around the world. We consulted these sources in combination to derive a selection of five essential design thinking tools that we found to be commonly used in design innovation practice (Table 18.1). In parallel, we identified a set of relevant sources presenting design thinking tools that can be used specifically to innovate for circularity. These sources are included in the review by Bocken et al. (2019), including an overview of circular business model tools and later tools at the intersection of CE developed by the authors. Initial tools were selected from the review by Bocken et al. (2019) to focus specifically on CE and design thinking but were also restricted to the tools that the authors were familiar with and were used with companies in practice. A review by Pieroni et al. (2019) on sustainable and circular business model innovation highlighted over 90 approaches (tools, frameworks, etc.) but of those, only around 50% were experimental rather than theoretical, and only a handful of tools had been used with(in) companies. In this study, the authors drew on tools that encapsulate design thinking and have been applied with(in) companies. We added newer (post-2019 review) tools; circular tools the authors co-developed and applied in practice. These newer added-circularity tools and frameworks include the ones by Baldassarre et al. (2020b), Brown et al. (2021), and Konietzko et al. (2020). We eventually selected five conventional and seven circularity tools. The 12 tools that we selected are briefly described in the following paragraphs and categorised in Table 18.1.

The first five rows of the table show, highlighted in light grey, five essential design thinking tools that we selected, namely: future visioning, personas, system map, service blueprint, and (sustainable) business model canvas. The remaining rows show, highlighted in dark grey, design thinking tools created specifically for circular and/or sustainable innovation, namely: circularity deck, circular collaboration canvas, circular business model pilot canvas, environmental value proposition framework, rapid circularity assessment, product journey map, and value mapping. Although this is not a complete list of all the existing tools that can be used to design in circular and sustainable innovation projects, we selected these because we have worked with them and aim to provide empirical evidence on how they can be applied in practice. Accordingly, in the next section, we illustrate how the tools listed previously can be applied in practice using a set of illustrative cases from sustainable and circular innovation projects (Siggelkow, 2001, 2007; Yin, 2011).

Table 18.1 Synthetic overview of the design thinking tools and methods, categorised according to sustainable and circular design thinking principles, criteria, phases, and level of circular innovation

	Sustainable and circular design thinking															
	Tools and methods	*Principles*					*Criteria*				*Phases*			*Circular innovation*		
		Human centred	*Future oriented*	*Holistic systemic*	*Collaborative*	*Experimental*	*Desirability*	*Feasibility*	*Viability*	*Sustainability, Circularity*	*Ideate, Design*	*Implement, Test*	*Evaluate, Improve*	*Product / Technology*	*Business model*	*Ecosystems*
1	Future visioning		X		X	X	X			(X)	X			X	X	
2	Personas	X				X	X				X			X		
3	System map			X	X			X			X			X	X	X
4	Service blueprint	X			X	X	X	X			X	X		X	X	
5	(Sustainable) Business model canvas	X	X		X	X	X	X	X	(X)	X	X			X	
6	Circularity deck	X		X	X	X	X			X	X			X	X	X
7	Circular collaboration canvas	X			X	X	X			X	X				X	X
8	Circular Business model Pilot canvas				X	X		X	X	X		X	X		X	
9	Environmental value proposition framework			X	X			X		X	X		X		X	
10	Rapid Circularity Assessment			X					X	X	X		X	X	X	
11	Product Journey Map	X			X	X	X		X	X	X		X	X		
12	Value mapping		X	X						X	X			X	X	X

Source: Based on Brown (2008), Bocken et al. (2019), Ries (2011), Frankenberger et al. (2013), Konietzko et al. (2020), Stickdorn et al. (2011) and van Boeijen et al. (2020).

Results

Tool 1 – future visioning

Future visioning is a method used for expressing a desired future that serves as a strategic reference point and motivates innovators in an organisation (van Boeijen et al., 2020). A vision aims to establish a tension between 'what is' and 'what could be', to provide long-term direction for innovations. It can be presented using text, drawing, and video content. Future visioning is typically used in the innovation strategy development of an organisation.

One example of future visioning is the case of Sagar Energy Solutions and fishermen on Lake Victoria in Tanzania, which deployed over 600,000 kerosene lanterns for night fishing (see Figure 18.1). These lanterns consume 900,000 litres of kerosene per day. The current solutions have a high negative environmental impact and health risk for the fishermen. Sagar Energy Solutions is a social enterprise developing renewable energy solutions for off-grid communities. To guide their innovation strategy, they developed their future vision: "Transitioning niche and artisanal businesses away from fossil fuels, towards modern and renewable energy solutions" (see sagarenergysolutions.re). This future vision (Figure 18.1) gave directions to the design team that developed a new floating lantern powered by solar energy. This new design will not only eradicate the use of kerosene, but it will also significantly decrease the environmental impact, create a safer and healthier working environment for the fishermen, and pay itself back because of its low operational costs.

Tool 2 – personas

A 'persona' is a fictional profile used to represent a particular user or group to ensure human-centredness in innovation and make sure that such innovation will be desirable (Stickdorn et al., 2011). Personas are usually developed by combining research insights into a visual and textual representation of the archetypical user, encompassing key traits, needs, and wishes, which are functional to catalyse ideation and further design.

In a study on a large UK-based clothing retailer (Miller et al., 2016), the following was investigated: How can sustainable behaviour personas be developed and used to stimulate sustainable business model innovation? As part of the study, five personas were developed based on an initial survey in the UK, which was further enriched through in-depth interviews and video/photographic material. The resulting personas included: Selfish Impulsives (24%), Savvy Economisers (24%), Casually Conscious Customers (19%), Progressive Purchasers (19%), and Committed Caretakers (15%) (Miller et al., 2016). Full-sized personas were used during workshops to stimulate creativity. The personas were designed to avoid stereotyping, but in a way that they looked like real people. By using real faces and matching clothing, the customers came to life more, which catalysed brainstorming because they "felt like real people that we connected to implicitly" and "in a way that business could create and deliver to them" (Miller et al., 2016, p. 15).

Tool 3 – system map

A 'system map' is a visual representation that depicts in a holistic way the entire innovation system, including the stakeholders involved (e.g., customers, organisations, etc.), their interactions (e.g., financial flows and transactions, service exchanges, etc.) as well as boundary objects (e.g., new products, etc.). The result is a map that shows the various socioeconomic actors that form part of the system and their interactions, which becomes more and more detailed as the project

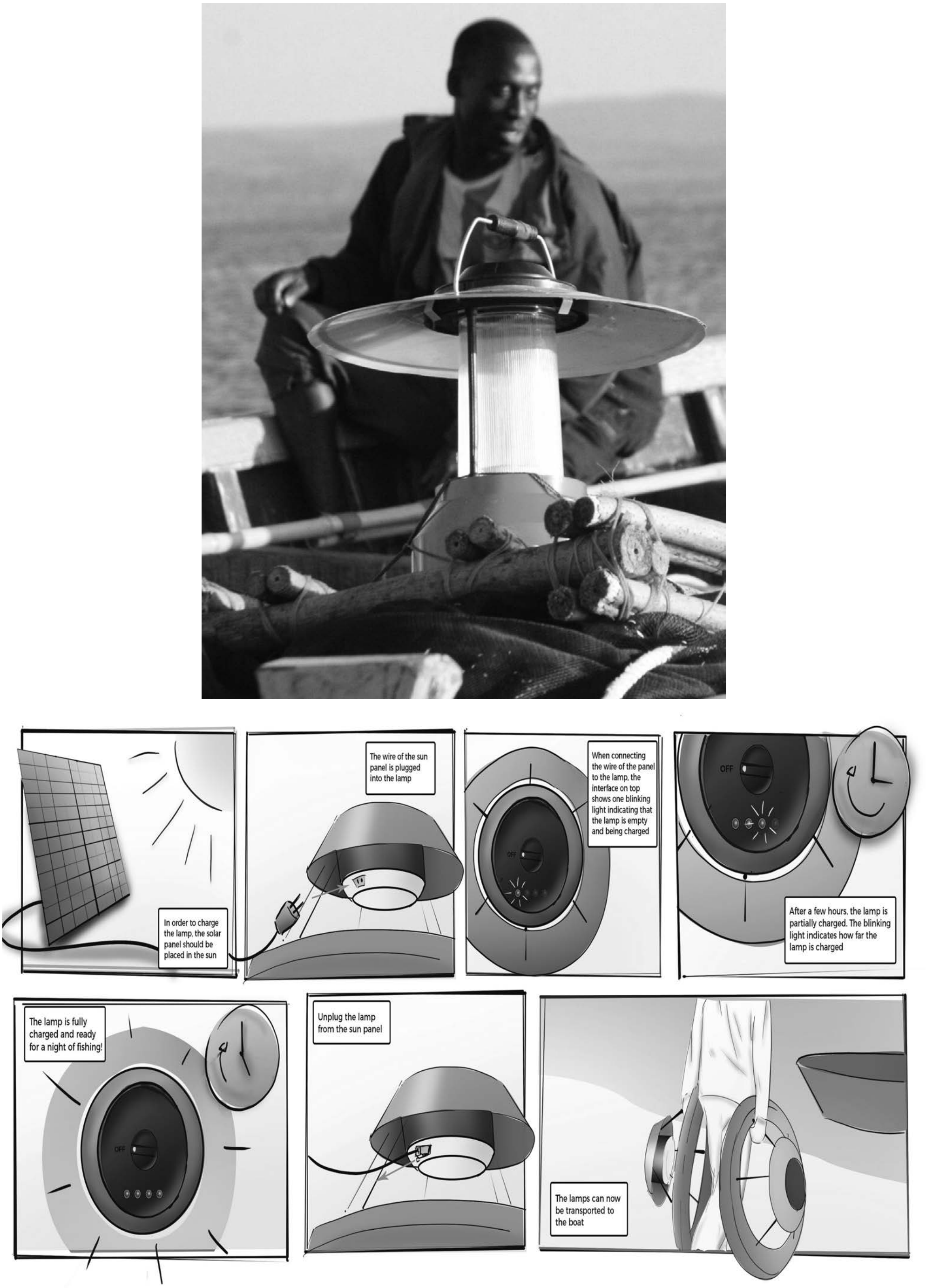


Figure 18.1 Kerosene lanterns and design of a solar energy-powered lantern as a sustainable alternative driven by the future vision of the company.

Source: Blok et al. (2019).

evolves (Vezzoli et al., 2017). System maps can be used to support the (co-)designing and visualisation of the system structure, to keep track of the feasibility of an innovation during the ideation and design phase or to benchmark and learn from similar product-service systems.

To compare the business model of two grocery home delivery companies, a system map of both business models was created. This visual way of mapping information, as well as financial and product flows, made it easy to understand the differences between the two concepts. In Figure 18.2, the system map of the company Pieter Pot (reusable packaging supermarket offering) in which not only the shopping crates are returned and reused, but also the primary packaging is on the left side. The food supplies are delivered in reusable glass pots, which, after emptying, are returned to Pieter Pot, cleaned, and reused by the next customer. On the right side of Figure 18.2 is the system map of a more traditional home delivery by PicNic. The system maps demonstrate clearly that the more circular concept of Pieter Pot also involves more financial, products, and information flows, and more actors.

Tool 4 – service blueprint

A 'service blueprint' is a visual schematic representation of the sequence of actions that are necessary for a service offering to be delivered (Stickdorn et al., 2011). It incorporates the perspective and actions of users, service provider(s), and third parties (if any), thus fostering *human-centred* and *collaborative* innovation. Service blueprints are typically used to *ideate* and *design* new services, but also to experimentally *implement* and *test* them to mainly ensure their *feasibility*.

In a study in collaboration with Philips Design, the question was: How can we engage hospital patients to send back the Healthdot (a medical device) after home use following hospital discharge, in order to foster a circular service model for the device? The service blueprint was used as a design tool to visualise and discuss with key stakeholders (i.e., patients, the hospital, Philips, etc.) their roles and actions needed for the circular service model to take place. Figure 18.3 visualises this in a service blueprint.

Tool 5 –sustainable business model canvas

A 'business model canvas' (Osterwalder & Pigneur, 2010) is a schematic representation of how a business functions, including details on the value proposition it offers, the targeted customers, relationships, and channels to reach them, key activities, resources and partners, cost structures, and revenue streams. Business model canvases allow to experimentally ideate, design, implement, and test new business model concepts, to ensure that they are desirable for customers as well as technically feasible and financially viable.

Business model canvasses (and the sustainable business model canvas version of it; see Figure 18.4) have been widely used in practice to develop circular business models (Bocken et al., 2018, 2021; Guldmann et al., 2019). The strength of these types of tools is that they bring together the key elements of a business model, starting with the value proposition or product-service offering, elements of value creation (key activities, stakeholders, resources, and capabilities), value delivery mechanisms (e.g., channels), as well as value capture mechanisms (cost structure and revenue streams). Different cases on companies experimenting towards a (more) circular business model, such as Philips, Peerby, and MUD Jeans were mapped according to these different elements to evaluate the changes of aspired business model changes (Bocken et al., 2018). Figure 18.4 includes an illustrative example for 'circular fashion'.

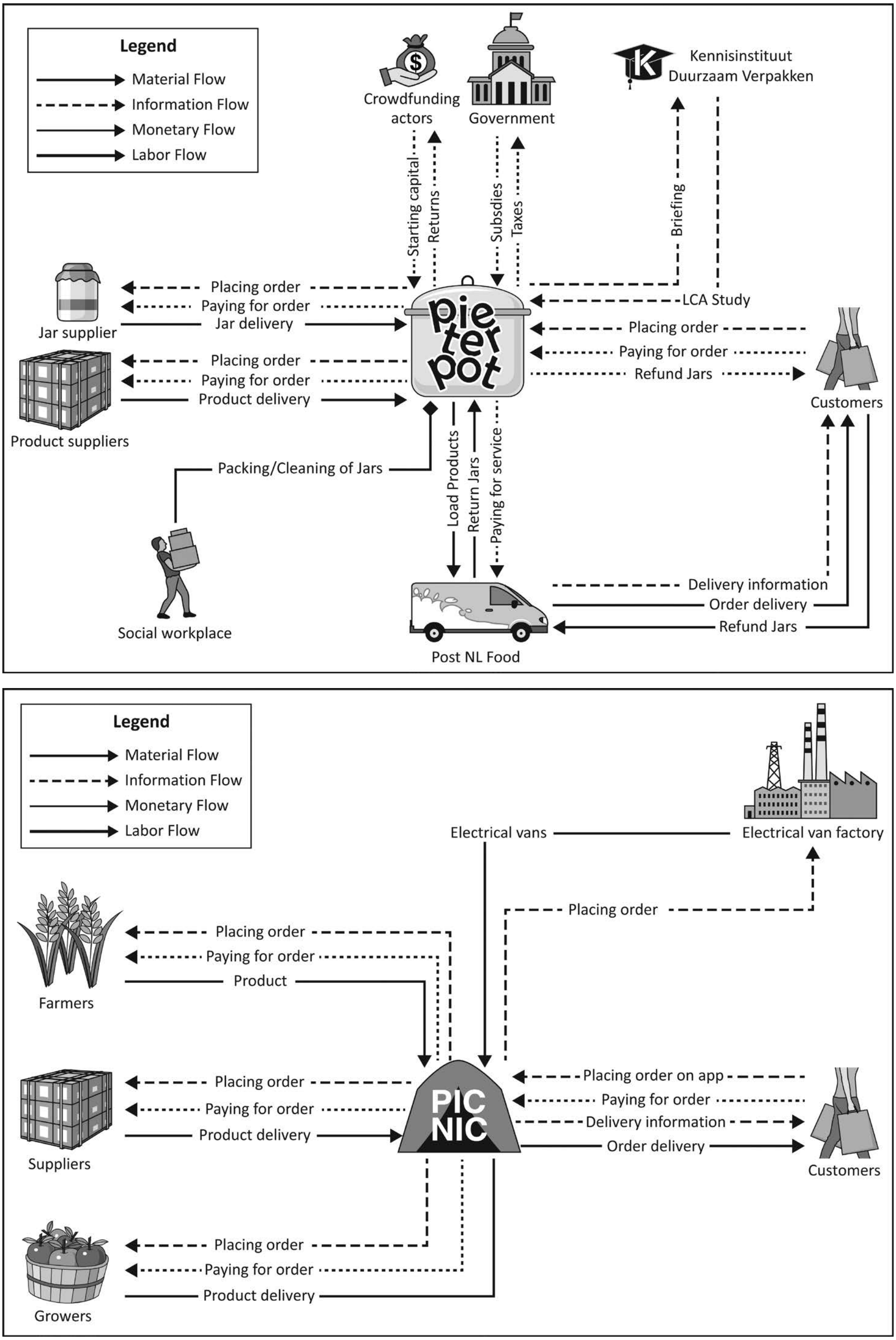


Figure 18.2 System maps of two different grocery home delivery business models.

Source: Ville et al. (2021).

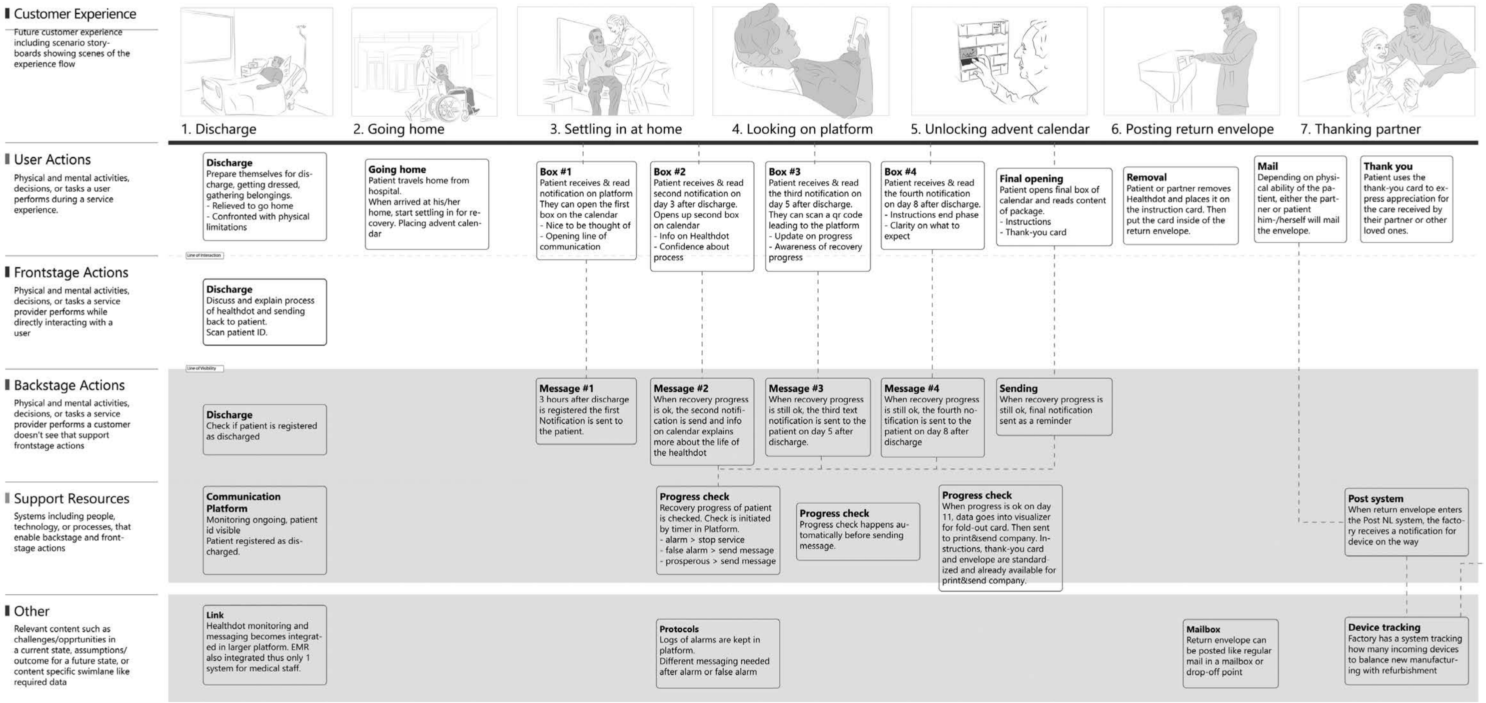


Figure 18.3 Service blueprint tool applied in a project with Philips Design, supporting the design of a circular service model in a health-care context. For more information, see van Hamersveld (2019).

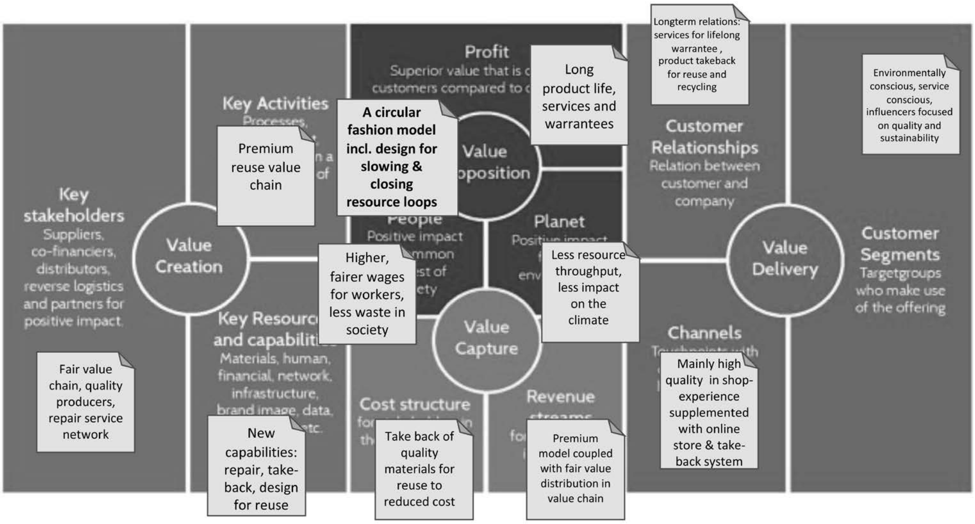


Figure 18.4 Sustainable business model canvas for circular fashion.

Source: Bocken et al. (2018).

Tool 6 – circularity deck

The circularity deck is a set of cards containing different strategies, approaches, and examples to innovate for a CE in a more systemic and collaborative way (Konietzko et al. (2020). The tool is intended to support brainstorming workshop sessions where participants can ideate and design ways to narrow, slow, and close material and energy flows through new products, business models, or cross-organisational interactions. This is important to foster circular and sustainable innovation concepts that are more desirable for business customers and partners.

In a study in collaboration with innovation consultancy Innoboost and the multinational Philips, the question was: How can the lifetime of electronics products for personal care be extended? The circularity deck was used in a physical workshop to facilitate innovators from different departments within Philips in a brainstorming session about multiple possible actions entailing product redesign (e.g., design for repair and refurbishment) as well as changes in the company's business model (e.g., transitioning from a one-off sale to a lease model) and by establishing collaboration with other parties (e.g., delivery companies). The resulting ideas were used internally by Philips to steer the corporate's circular innovation strategy.

The circularity deck may be used in the online platform Miro to facilitate online brainstorming (see https://miro.com/miroverse/circularity-deck). An excerpt of the cards was used for a virtual brainstorm using Miro in a process combined with Lean Startup and effectual thinking, building on what knowledge, networks, and resources are available (Bocken & Coffay, 2022). The aim was to help industry develop CE experiments.

Tool 7 – circular collaboration canvas

This circular collaboration canvas tool is a template containing a set of key questions to trigger collaborating organisations in ideating and designing a joint value proposition for a circular innovation. It is typically used to negotiate key features of the value proposition while negotiating around key challenges, to ensure its desirability and circularity.

In a study in collaboration with Behaviour Works Australia, Monash University, and the Australian Fashion Council, the question was: How can we collaboratively boost circularity in the fashion industry within Australia? The circular collaboration canvas was used in an online workshop setting to help six different (large and small) companies in the fashion industry and one charity organisation to define a collaborative circular innovation idea to be pursued together, within the broader framework of upcoming circularity policies established by the government. The outcome was the creation of *Circular Stories*, a graphic booklet summarising the typical life cycle of an apparel product in the country, complemented by circularity principles and guidelines that may support other companies in collaboratively transforming their supply chains. Figure 18.5 is a snapshot of the canvas used during the workshop, where the participants discussed key questions (e.g., What challenge do you want to solve? How will you improve circularity?) as a way to converge toward the aforementioned outcome.

Tool 8 – circular business model pilot canvas

The circular business model pilot canvas tool is a template that supports experimentally implementing, testing, and iteratively evaluating a circular business idea in terms of a prototype that has to be defined, built, and delivered to customers while generating profit and measuring the circular impact that is achieved by doing so. Due to its nature, it is typically used once a circular business idea has been already defined, mainly to move forward with the validation of its feasibility, viability, and sustainable circularity.

In a study conducted within the EU Horizon 2020 project 'Zero Brine' as a collaborative effort with 20 organisations from ten different countries, the question was: What is a possible circular business model for recovering and putting back on the market resources and minerals recovered from industrial wastewater in the Port of Rotterdam? The circular business model pilot canvas was used in a set of 19 individual contacts as well as three collaborative sessions with project partners, in order to iteratively refine the circular value proposition (i.e., What is the idea and the impact?), creation (i.e., How do we make it happen?), delivery (i.e., How does it work?), and capture (i.e., How do we profit?) elements of the business model to be piloted before moving into full-scale rollout. Figure 18.6 is a snapshot of the canvas, filled in with the final business model proposal defined at the end of this process.

Tool 9 – environmental value proposition framework

The Environmental Value Proposition (EVP) tool consists of a visual (Figure 18.7) containing five process steps, as well as a guiding EVP table developed on the basis of the ReSOLVE framework of the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015). With the EVP, companies can design new circular business models or verify intended environmental benefits (Manninen et al., 2018). The core of the framework is the environmental value propositions of the company, which are developed in the first step, and assessed and verified in the subsequent steps together with relevant stakeholders linked to the different life cycle stages of products or services (i.e., the beginning of life [BOL], middle of life [MOL], and end of life [EOL]). The idea of the tool is to follow the five-step process with stakeholders and explore how they can have a role in the joint development of the EVP to create a more positive impact.

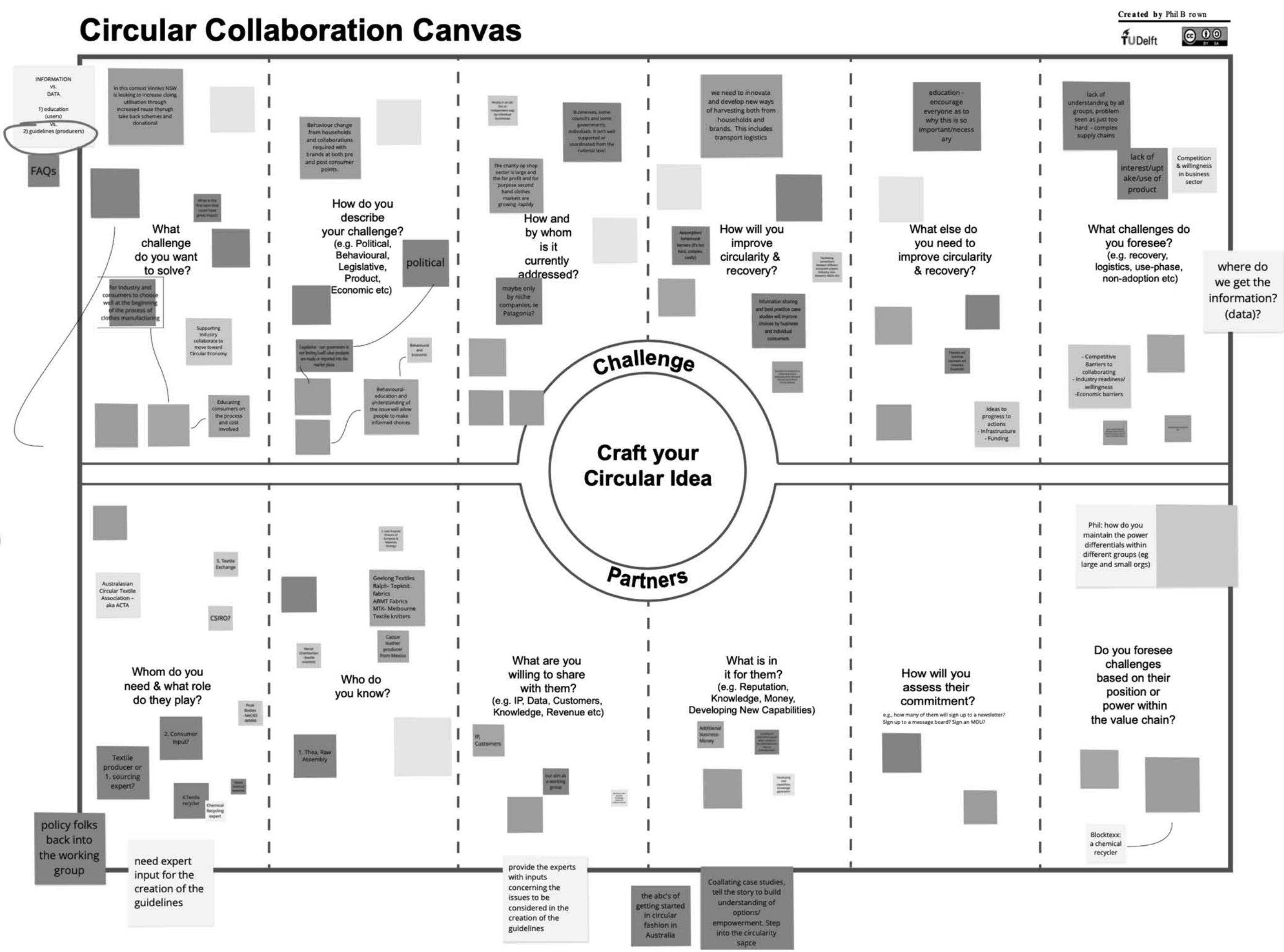


Figure 18.5 Circular collaboration canvas applied with multiple stakeholders working together to boost circularity in the fashion industry in Australia. For more information, see https://www.monash.edu/circular-fashion/who-we-are.

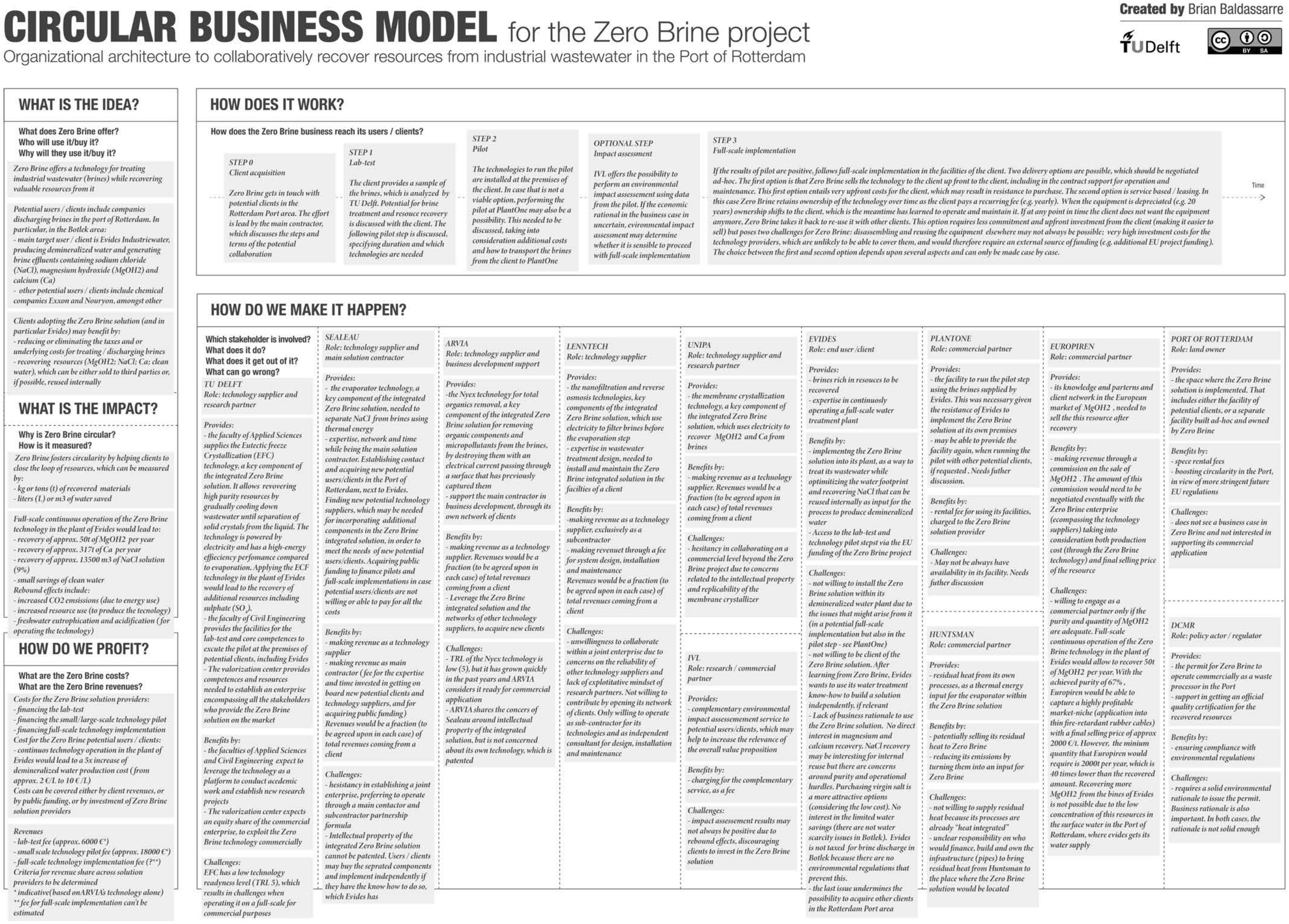


Figure 18.6 Circular business model pilot canvas applied in the Zero Brine project. For more information, see https://zerobrine.eu.

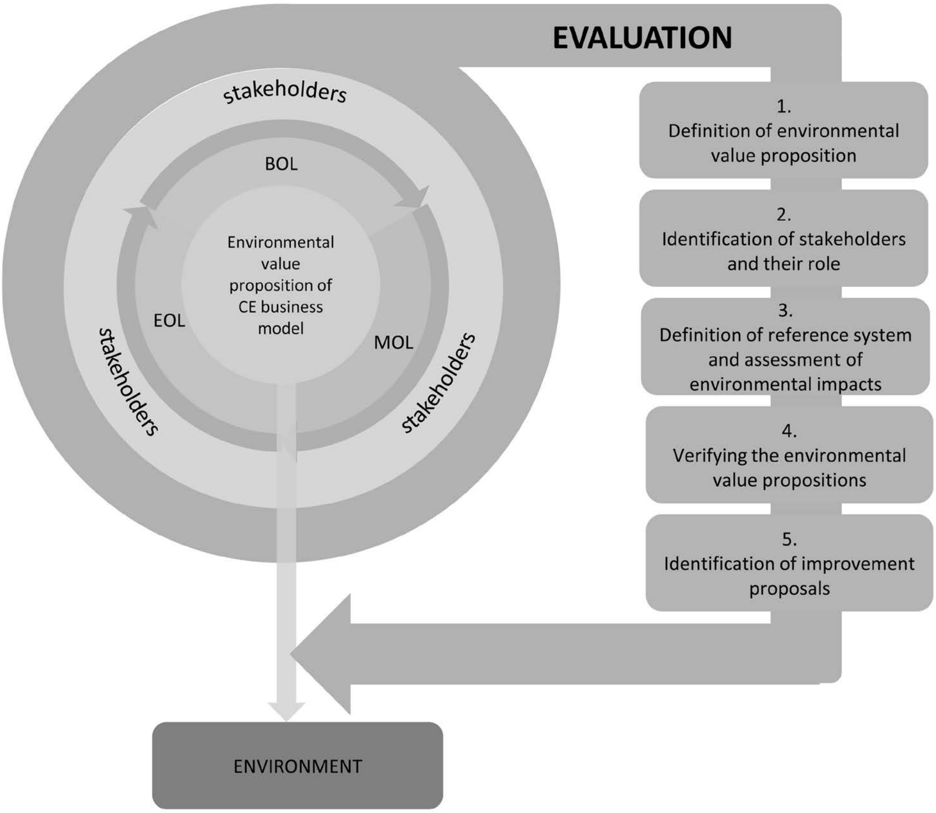


Figure 18.7 Environmental value proposition canvas.

Source: Manninen et al., 2018.

The tool has been applied in a case study on three companies: 1) Deastaclean, a material recycling company producing wood stone, 2) Coreorient, a tool renting company for battery-powered tools and house-cleaning equipment, and 3) Homie, a home appliance renting company. Typically, the process involves ranking the company's environmental priorities based on key environmental impacts, followed by reaching agreement on the main EVPs being targeted by the company. Table 18.2 shows the environmental value propositions for each case. The EVP provides a systemic approach to help companies understand their own activities.

Tool 10 – rapid circularity assessment

The Rapid Circularity Assessment (RCA) aims to assess the environmental impact of new circular business model ideas and concepts (Bocken et al., 2016b). The aim is to help companies consider the most environmentally beneficial options and make changes to the design where feasible. It considers stocks of existing products (e.g., clothing) and new flows (new production of clothing) as well as closing (e.g., recycling), slowing (e.g., longer product life), life cycle impacts (e.g., consumer use), and wider systemic effects (e.g., negative rebound effects) in a visual table (see Table 18.3).

Table 18.2 Three cases and their environmental value propositions

Case-specific environmental value propositions	*Cases*		
	Wood stone	*Tool renting shed*	*Pay-per-use washing machine*
Increasing the life span of wood fibre	X		
Avoiding the use of natural stones	X		
Minimising the use of natural resources through tool sharing		X	
Long-lasting products		X	
Supports travelling without a car		X	
Long-lasting quality washing machines with maintenance contracts			X
Stimulation of sustainable usage of washing machines			X
On a longer time scale, the focus on (design for) remanufacturing and refurbishing to prolong the usage of washing machines			X

Source: Manninen et al., 2018.

Table 18.3 Rapid circularity assessment

	Flows *(number of items sold annually by company: influx of NEW products)*	*Stocks* *(number of goods nationally or number of goods per person nationally: products ALREADY IN USE)*
Slowing effects (long-lasting products and extending product life, slowing consumption)	Design to 1 extend the useful lifetime of existing or new products 2 reduce total new items produced	Design to 1 reduce total items in the country 2 increase the total number of goods given away for reuse (e.g., secondhand markets) 3 reverse overall trends of total goods going to landfill (e.g., by repurposing the materials and increasing recycling rates)
Closing effects (recycling)	Design for 1 increased recyclability of a new product 2 increased recycling rates for new goods	Design for 1 increased recyclability of existing products 2 increased recycling rates for existing goods
Regenerating effects (cleaner production, renewable inputs, no toxic substances, net-positive strategies)	Design for 1 increasing positive impact on the environment, such as increasing biodiversity, for new products and services 2 increasing positive impact on society, such as improved education and health, for new products and services	Design for 1 increasing positive impact on the environment, such as increasing biodiversity of products and services already in use 2 increasing positive impact on society, such as improved education and health of products and services already in use

(*Continued*)

Table 18.3 (Continued)

	Flows (number of items sold annually by company: influx of NEW products)	*Stocks (number of goods nationally or number of goods per person nationally: products ALREADY IN USE)*
Life cycle effects (effects across raw material sourcing, production, transport, use and disposal – not yet captured)	Design for 1 efficiencies (e.g., less material per product) 2 manufacturing efficiencies throughout the production chain 3 transport savings 4 more efficient or less cleaning 5 cleaner forms of recycling 6 efficiencies not yet captured	Design for 1 transportation savings in the handling of current goods in the country 2 increase the total number of goods given away for recycling 3 to reverse overall trends of total goods going to landfill (e.g., by repurposing the materials and increasing recycling rates)
System effects (wider impacts of the innovation)	Key questions to consider: 1 Does it lead to negative rebound effects (e.g., consuming more) or positive ones (e.g., from fast to slow fashion)? 2 Are there any unintended consequences by upcycling the value of waste? 3 Does it lead to radical changes for stores and employees? What are the impacts on those stakeholders and others? Who are the winners/losers? 4 What is the effect of multiple coexisting business models? 5 What the does this innovation have on society? 6 What is required for other companies to follow – is that considered in this new business model?	

Source: Bocken et al., 2016a, 2021b.

The circular strategies on the left column have been used by a clothing company to identify and assess business model ideas to slow and close resource loops (Bocken et al., 2016b). Then, during a workshop with a clothing retailer, the RCA helped to refine ideas and improve the environmental side of the value propositions.

Tool 11 – product journey mapping

In a circular product service system, products naturally change hands. A product will have multiple use cycles. To get people comfortable with transferring and receiving products from and to others, these transitions should be carefully designed. The Product Journey Map is a circular design method that helps organisations preserve and capture the maximum value of a product of the multiple use cycles over its lifetime. Product journey mapping is like customer mapping but with a focus on the product. It is a method for mapping and visualising the life cycle of a product over multiple use cycles (Van Boeijen et al., 2020). Product journey mapping is used in the early stages of development. It helps designers plan a product's journey over consecutive use cycles, identify potential service touch points, and opportunities for capturing value.

Product journey mapping can be useful in the case of, for example, the development of a washing machine lease system with multiple 'use cycles'. In the example in Figure 18.8, the washing machine has three use cycles over its lifetime (premium, economy, and budget). Each use cycle has a different pricing strategy to attract different user groups. For a viable business

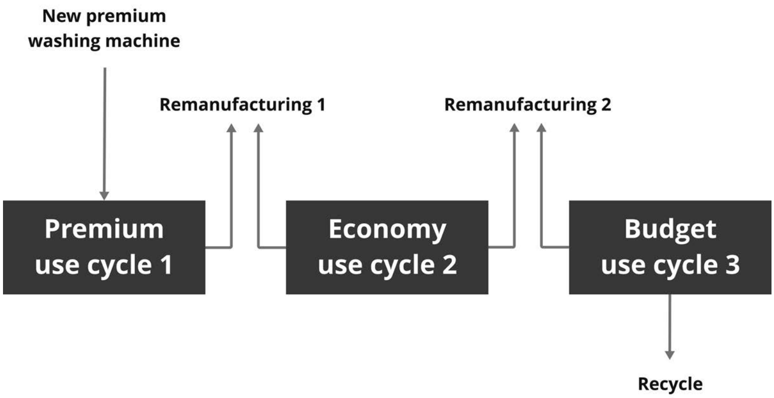


Figure 18.8 Product journey mapping by mapping the use cycles of the life cycle of a washing machine in a lease system.

case, the same amount of premium, economy, and budget customers are needed. In between each use cycle, the product must be partly remanufactured before the washing machine can go to the next user. In most cases, the rubber gasket must be replaced, which is costly because it is not easy to replace. Product journey mapping can help identify these types of challenges for each use cycle in advance and to plan or develop solutions to overcome them.

Tool 12 – value mapping tool

The value mapping tool (Figure 18.9) is a visual tool and an accompanying process that helps businesses to create value for the company, society, and environment by enabling them to rethink their existing business models. It provides a systematic approach to brainstorm new sustainable business model ideas where negative and positive forms of value creation are explored using a multi-stakeholder perspective. The tool facilitates companies to consider different forms of value (i.e., value captured, value missed, value destroyed, and new value opportunities) and how the company and its stakeholders capture value (positive benefits for stakeholders) or destroy value (negative outcomes of the business) (Bocken et al., 2013). By reflecting on different forms of value for all stakeholders, the tool aims to reduce conflicts and trade-offs among stakeholders and align positive outcomes for all.

Figure 18.10 shows how the visual mapping tool has been applied in a course setting at a higher education institute for the redesign of the business model of a Dutch poultry farm that puts animal health and welfare first and aims to create an environmentally sound business and close cycles by using leftovers from other sources to feed chickens. Design students followed the suggested process steps to use the tool and developed various value creation opportunities for relevant stakeholders and ranked these ideas based on a feasibility-impact matrix to select the most promising ideas for redesigning the business model of the farm.

Discussion

This study addressed the question: How can design thinking tools catalyse sustainable circular innovation? For this purpose, we developed a unifying framework for design thinking and circular sustainable innovation based on extant literature. Subsequently, we mapped existing design

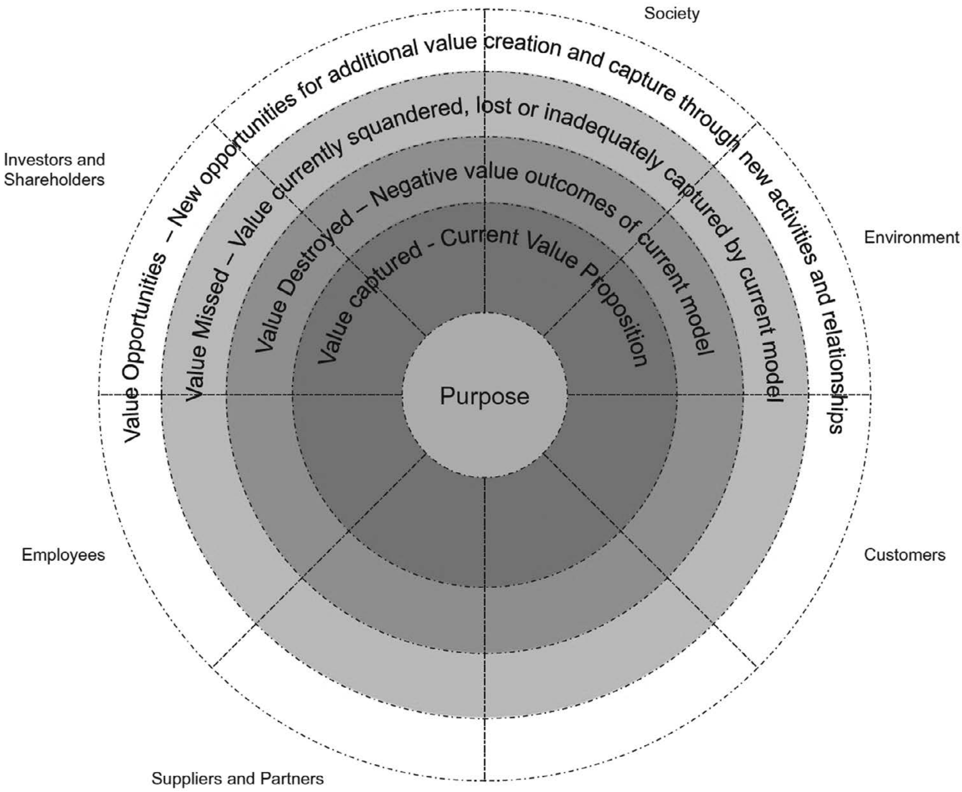
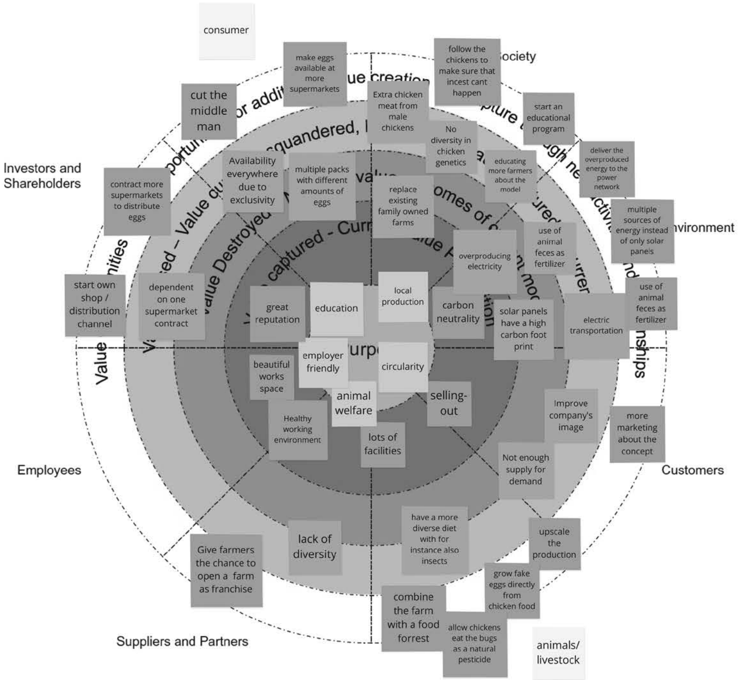


Figure 18.9 Value mapping tool.
Source: Bocken et al., 2013.

thinking tools and illustrated how they have been applied in several sustainable and circular innovation projects. Our goal was to explain how design can catalyse sustainable circular innovation by providing specific tools that can be applied to support and improve processes and outcomes within circular and sustainable innovation projects. In the results section, we presented a list of ‘traditional’ design thinking tools, and a list of tools created specifically to innovate for sustainability and circularity. For each one of these tools, we provided an illustrative case (Siggelkow, 2001, 2007; Yin, 2011), showing how it has been applied in the context of a circular innovation project.

First, we found that the more traditional design thinking tools such as personas and systems maps allowed for the application of all design thinking principles in varying degrees: systemic thinking, collaboration, future-oriented thinking, within a human-centred and experimental approach to innovation. This is not surprising as these tools emerge from the design discipline, where the design thinking principles build upon by studying the professional practice of designers. This, in turn, shows how design thinking and tools cover the part of the needs of designing for a CE, which is said to require systemic solutions co-created with future customers in mind (Baldassarre et al., 2020b; Bocken et al., 2016a). On the other hand, the CE-specific tools predominantly focus on the principles of systemic thinking, collaboration, and



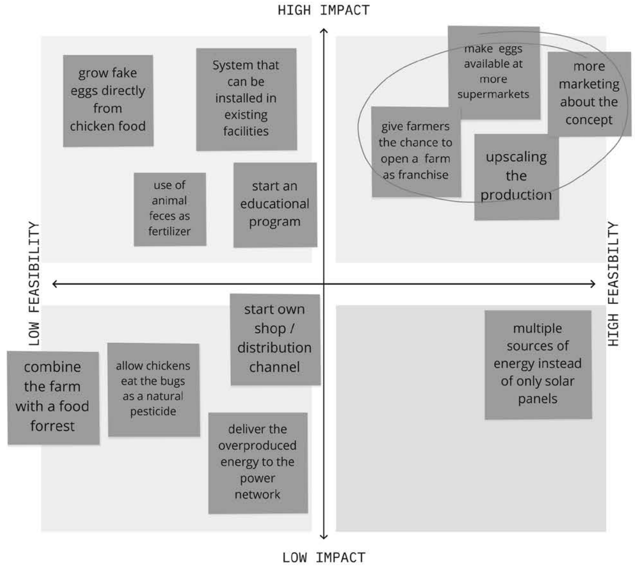


Figure 18.10 Populated value mapping tool.

experimentation with multiple stakeholders and are to a lesser extent user-centred and future-orientated. CE-specific tools target gaps where current design tools are lacking, but often lack the typical aspects of the original design tools (e.g., being human-centred or focusing on desirability). Hence, it is suggested that both types of tools are still used in conjunction, or that more hybrid integrated tools are used to better encapsulate design-driven and circular aspects. For example, there is a need for the integration of user-centred and futuristic thinking approaches into the CE-specific tools.

Second, with respect to the *success criteria* (i.e., desirability, feasibility, viability, and circularity) we observe that the traditional design thinking tools predominantly build upon desirability and feasibility of new ideas and less on viability (except the business model canvas), or circularity and sustainability, whereas the CE-specific tools build upon feasibility, viability, and circularity criteria. In particular, circularity issues have not been widely integrated into traditional design tools. Hence, traditional tools might lack important aspects such as a focus on the business case and evaluation of environmental impacts, which might hamper the implementation of sustainable and circular innovations, or will not result in increased circularity. A focus on sustainability and circularity is observed in the CE-specific tools we analysed. The CE-specific tools all evidently target the missing circularity and sustainability focus of the traditional design thinking tools. In addition, they cover the organisational aspects to a greater extent with a focus on value creation processes and the viability of product and business ideas.

Third, through our analysis, we observe that two categories of tools differ in terms of their usefulness during the different *phases of the innovation process*. Most of the traditional design-thinking tools are focused on ideation and some on implementation, while few focus on evaluation and continuous improvement. On the other hand, the CE-specific tools cover the phases of innovation process more holistically. In particular, the 'evaluate' and 'improve' phases of the innovation process is crucial for the successful implementation of CE innovations and ensuring their sustainability. In that regard, only a few traditional design tools can be applied in circular innovation projects to deal with complex operational issues (e.g., logistics and changing value chains), multiple life cycles (Rashid et al., 2013; Sumter et al., 2018), and rebound effects (e.g., Castro et al., 2022; Zink & Geyer, 2017). Even though previous studies have hinted at the importance of designers being able to cope with these challenging issues, the gaps in existing tools we identified reinforce the need for better foundations. This highlights the risk of designers continuing to use 'traditional' design tools in isolation when seeking to pursue circular innovations. Some emerging tools start to address issues like rebound effects (e.g., Das et al., 2022). Yet, a greater awareness and education on what circular innovation entails is needed to prepare future designers for circular rather than linear design, as this cannot be captured in single tools and methods.

Fourth, with respect to the different *levels of innovation*, a distinction can be made between the traditional design thinking tools and the CE-specific tools. While more traditional design tools cover predominantly the product and service levels of innovation, the CE-specific tools focus more on the business model and ecosystem levels of innovation. Apparently, this relates to the tools stemming from different streams of research. While traditional design thinking tools are developed based on research in product and service design, the CE-specific tools emerge from organisation and innovation management research, which focuses more on business and collaboration aspects, and require the involvement of a more diverse set of internal and external stakeholders. In that regard, the CE-specific tools appear to cover more diverse aspects of the innovation spectrum, and some tools such as the circularity deck and value mapping are inclusive or flexible enough to cover the different levels of innovation (e.g., product, business model).

Table 18.4 Focus of design thinking (light grey) and circular (dark grey) tools and methods

Circular Design Thinking														
1 Principles					**2 Criteria**				**3 Phases**			**4 Levels of innovation**		
Human centred	Future oriented	Holistic, systemic	Collaborative	Experimental	Desirability	Feasibility	Viability	Sustainability, Circularity	Ideate, Design	Implement, Test	Evaluate, Improve	Product / Technology	Business model / Value chain	Ecosystems (e.g., cities)

Source: Building on Baldassarre et al. (2020b), Brown (2008), Castro et al. (2022), Frankenberger et al. (2013), Guldmann et al. (2019), Rashid et al. (2013), Ries (2011), and Sumter et al. (2018).

The different focuses of traditional design tools and circular tools have been highlighted with light grey and dark grey, respectively, in Table 18.4.

In Table 18.5 we highlight the entire spectrum of circular design thinking principles, criteria, innovation phases, and levels of innovation and skills for circular innovation, aiming to inform the development of future tools that might aid organisations in navigating the circularity transition. Thus, the table provides a novel unifying framework for circular design thinking, based on the literature and cases. The proposed table and framework were developed by combining insights from literature on design thinking and circular innovation with empirical insight and gaps emerging from the illustrations of the tools that we selected. Columns 1, 2, 3, and 4 of Table 18.4, presenting the principles, criteria, and phases, and levels of innovation, are based upon extant literature. In turn, Table 18.5 points to the need for a set of essential skills for circular design thinking: design for multiple use cycles (e.g., durability and remanufacturability); integration of product design with business model (re)design and value chain (re)design; design for sustainable product use (e.g., avoiding rebound effects); and design for material recycling or recovery. These skills are highly interlinked; design for multiple life cycles requires an understanding of business models and value chains because products need to be returned to allow for multiple product life cycles. Moreover, design for sustainable product use to avoid rebounds potentially also requires business model rethinking as it is about consumer behaviour also after the initial ‘sale’. Service business models like rental, lease, or pay per use are known to have more touch points with the customer and have been linked to proven sustainability impacts (Bocken et al., 2018; Lindahl et al., 2014). This type of awareness, and the types of knowledge and skills are important for future designers to help them develop more circular and sustainable designs.

We therefore suggest that future tools for circular design thinking should support the use of these important skills. Furthermore, we note that these skills are based on insight and gaps emerging from the empirical illustrations of the tools that we selected. We would like to emphasise that these illustrations are largely related to circular design thinking work conducted by

Table 18.5 Unifying framework for circular design thinking

Circular Design Thinking																		
1 Principles					**2 Criteria**				**3 Phases**			**4 Levels of innovation**			**5 Skills**			
Human centred	Future oriented	Holistic systemic	Collaborative	Experimental	Desirability	Feasibility	Viability	Sustainability, Circularity	Ideate, Design	Implement, Test	Evaluate, Improve	Product/ Technology	Business model/ value chains	Ecosystems (e.g., cities)	Design for multiple use cycles (e.g., durability and re-manufactur-ability)	Design for integration: product design with business model (re) design and value chain (re)design	Design for sustainable product usage (e.g., avoiding rebound effects)	Design for material recycling or recovery

Source: Building on Baldassarre et al. (2020b), Brown (2008), Castro et al. (2022, Frankenberger et al., (2013), Guldmann et al. (2019), Rashid et al. (2013), Ries (2011), and Sumter et al. (2018).

researchers in the Netherlands. However, we note that important efforts are emerging in other parts of the world as well. For example, the British Design Council recently published a *Beyond Net Zero* report (British Design Council, 2021) developed in collaboration with the Ellen MacArthur Foundation, where circular design thinking and principles are discussed in relation to, among other sustainability paradigms, circularity. Other examples of the emergent focus on circular design thinking projects and tools are provided by the DO school in Germany, the design thinking community in Asia as well as the renowned design consultancy IDEO, which recently developed a circular design guide. We encourage researchers to conduct a more systematic study of these global efforts to expand Table 18.5 with additional insights and gaps underlying circular design thinking skills to be catalysed by future tools.

Conclusions

In this conclusion section we would like to add some final reflections to pave the way for future research. Around 50 years ago, Victor Papanek urged designers to "design for the real world" by taking full responsibility for the artefacts they put on the market, bearing in mind the resources needed to produce them, as well as all the waste generated after people threw them away (Papanek, 1971). Today, as a new generation of 'circular designers' is more than ever needed to deal with the increasing pressure of these issues, in Europe and all over the world (European Commission, 2022), it is crucial to look behind the tools, to better understand the people who use them. Although ideas on how to use design to address environmental issues are not new and go all the way back to Papanek (Baldassarre et al., 2019a, 2020a), the research field of circular design has been emerging only recently (Van Dam et al., 2020) but building on areas such as eco-design, Design for X (recycling, durability, etc.) and sustainability more broadly (Bocken et al., 2016a; Den Hollander et al., 2017). So far, scholars have explored what circular design is about (e.g., Bocken et al., 2016b), and how it can be practiced through specific skills (Sumter et al., 2018), and through the tools discussed in this study (e.g., Brown et al., 2021; Konietzko et al., 2020). Nevertheless, limited research is available on who these "circular designers" are, and what traits and skills they might possess. Better understanding of who they are, thus their motivation, their challenges, and their personality, is essential if researchers want to create tools that are effective in truly supporting their work. Furthermore, understanding who 'circular designers are' is also important for educational purposes, to ensure that the next generation of circular designers will be equipped with the right tools to deal with the environmental crisis. This type of research is already present in other fields. In the field of sustainable entrepreneurship, for example, scholars have analysed and identified different typologies of sustainable entrepreneurs, distinguishing the social engineer from the social constructionist and the social bricoleur (Zahra et al., 2009). Despite their relevance, similar insights are not yet present in the field of circular design.

The framework in this study provides a starting point for addressing these questions by highlighting circular design thinking skills, as well as gaps in traditional design tools. Accordingly, we encourage future research using the following questions: What characterises the profile of a circular designer in terms of personal motivations and professional challenges? What tools are currently most needed by circular designers? How can the next generation of circular designers be effectively trained? When addressing these questions, there is also another important issue to consider. In circular innovations, users play an active role beyond the traditional notion of 'consumption', becoming circular value creators and deliverers as well. Therefore, next to circular designers, future research should also seek to better understand 'circular users' who may even be the co-creators of novel products and services (consider secondhand or sharing platforms). While insights on who they are and what their motivations are is present, insights on how these relate to the creation of new circular design thinking tools is scant. We also encourage future research in this direction. Finally, we note that focusing on circular designers alone might not be sufficient, because in circular innovation, users play an active role as circular value creators and deliverers. This will open new areas for circular design and innovation research and practice.

Educational content

- This chapter proposes principles, criteria, phases, and levels related to sustainable circular innovation through a design thinking approach.
- Skills for circular innovators are outlined, including design for multiple life cycles, design for integration, design for sustainable product use, and design for material recycling or recovery.
- Future research might go beyond these skills to better understand the professional profile of 'circular designer' in a more thorough and holistic way.
- Education may leverage these insights in order to further develop and nurture the skills of innovators capable to deal with the challenges of the current and aggravating environmental crisis.
- The design thinking tools proposed in this chapter may provide a starting point for teaching circular innovation to students in design, architecture, engineering, and management schools.

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19

SCENARIO METHOD FOR CATALYSING CIRCULARITY AND LOWERING EMISSIONS IN THE CONSTRUCTION SECTOR/ REAL ESTATE, NIGERIA

Olumide Ayanrinde and Jeffrey Mahachi

Introduction

The Earth's planetary limits show the extent of its resiliency and ability to tolerate abuse, such as CO_2 emissions into the atmosphere. In accordance with the Paris Agreement, many industries such as the construction sector/real estate industry, must change the default procedures (Dzebo et al., 2019). Otherwise, the world's climate will reach a tipping point where we find ourselves with a runaway climate and overstretch the ecosystem's limits. Eco-friendly residential buildings, also known as green buildings, are becoming increasingly popular, but scenario methods have been widely applied from the representation of ranges of future global climate change under alternative greenhouse gas emission models to the interpretation of these futures for local communities (Butler et al., 2020). Science-based methodological approaches, such as scenario methods, are useful simulation tools to prevent global warming since they are tied to the local ecosystem, which has a limited threshold (McElroy & Baue, 2013), and they uphold the basic idea of context-based sustainability. One way to decarbonise buildings is to arbitrarily list things to change about residential estates (Ayanrinde & Mahachi, 2021). For instance:

1 Materials: ensure the building's furnishings, fittings, fixtures, gadgets, etc. are locally made and climate friendly, and reuse and remodel instead of demolishing.
2 Energy: residence is powered with natural lighting and solar/wind energy systems.
3 Water: harvest rainwater, treat it for use, and install water-saving systems.
4 Site: residence is easily accessible and has vegetation within the compound.
5 Waste management: recycle (solid and/or liquid) waste generated in residential buildings.
6 Indoor environment: ensuring buildings are well-ventilated and without health hazards such as dust, smoke, noise, or foul smells.
7 Documentation: ensure easy access to a resident's user guide, manuals, emergency plans, etc.

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These initiatives support circular economy (CE) adoption principles because they can reduce the amount of CO_2 released into the atmosphere, but some have more of an emissions reduction impact than others (Timperley, 2020). It is easy for some high-impact initiatives to be missed when creating a personalised plan. Hence, this chapter presents how to cover the gaps when setting personalised emission targets for residential buildings. To do so, we leverage CE material reduction principles in the design stages of residential buildings' development, particularly in a context of resource efficiency and in the setting of Nigeria, Africa, to avert foreseeable climate change. Environmentally friendly real estate development can help mitigate climate change by limiting global emissions. To plan for such decarbonisation, key questions addressed in this chapter are: How can we assess buildings' CO_2 emissions in the design phase? How can science-based scenarios be adopted to force 2DC emission paths through the selection of efficient materials to use in the development of residential real estate?

Although the sector is currently underpinned by profit margins, this chapter seeks to change practices towards conscious context-based circularity by linking buildings' decarbonisation scenarios to their immediate ecological limits. This chapter seeks to encourage homes to adopt context-based circularity targets; implementing these will be huge in terms of homes doing their part to avoid harming the planet, marking a tremendous change. Applying the recommendations of this research will also enhance the reputation of real estate firms, supporting them to attract new customers.

The scope of this chapter covers a pilot real estate project in Abuja, Nigeria. We analyse the greenhouse emissions of the dwelling units using the EDGE buildings app (online open-source software). The dwelling units contain four semidetached buildings, three detached duplexes, 16 terraced units, 16 units of two blocks of flats, and a commercial zone. Information extracted from the buildings design drawings (architectural, structural, electromechanical, and plumbing designs) were inputs to the EDGE buildings app, and the corresponding output simulation was the CO_2 emitted per building, quantified in tonnes of carbon dioxide emitted per year (tCO_2/year). After that, we applied sectoral decarbonisation scenarios according to the occupants' income levels to produce a fair share emissions reduction forecast.

Literature review

Sustainability needs in Africa and Nigeria

Climate change and CE issues are most often studied in Europe and Asia (Ranta, Aarikka-Stenroos, et al., 2018a); now, we examine these aspects in an African context. Nigeria is a fast-growing African country and, therefore, a fruitful context to study climate change and CE adoption, particularly in relation to residential buildings. In line with the new Federal Solid Waste Management Policy, the National Policy on Plastic Waste Management, and the *CE in Africa-EU Cooperation-Country Report for Nigeria* (FGN & EU, 2021), proposals are sought to tackle resource efficiency and sustainable production and consumption in non-oil productive sectors.

Interventions will be coordinated with the Nigeria CE Working Group (NCEWG) under a multi-partner and multi-year Nigeria CE Program (NCEP), with the government of Nigeria and the Ministry of Environment in the lead and several EU member states and other development partners participating (FGN & EU, 2021). Nigeria is one of the cofounders of the African CE Alliance (ACEA) and a supporter of the Global Alliance on the CE and Resource Efficiency (GACERE).

Nigerian and African contexts for catalysing sustainability and CE

The challenges facing rapidly urbanising developing economies such as Nigeria are inherently social (Esther, 2021). They include inadequate water supply, youth unemployment, poor public education and health systems, poor sanitation, poor habitation, inequality, and energy inequity. The CE ecosystem is becoming increasingly vibrant, with fresh players appearing each year. There is a growing understanding not just of the need to implement a CE but also of the associated business gains. Nigeria has had circular activities for many years (Ministry of Foreign Affairs & Naijalink Ltd, 2020), often within the informal economy and driven by poverty rather than green thinking. The formal sector is coming on board, and its capacity is expanding. Afghanistan, Lao PDR, Israel, Kenya, Mauritius, and Nigeria are currently in the early stages of implementing CE concepts. Today, much resource recycling still takes place based on individual initiatives (Ghosh, 2019). With the right enabling circumstances, the CE could provide new opportunities for economic diversification, value creation, and skills development (Preston et al., 2019). Developing countries are in a great position to benefit from the opportunities the new economy offers. For instance, their robust informal sectors currently practicing 'circular' activities – such as phone repairs and refurbishing electronic waste (WEEE), among others – could engage in higher-value CE supply chains.

African presidents have been participating in global efforts to define collective directions for sustainable development to ensure mankind's success, such as the Millennium Development Goals (MDGs). In recent times, the Sustainable Development Goals (SDGs) (Esther, 2021) and the Intended Nationally Determined Contributions (INDCs) resulted from the 2015 Paris Conference on Climate Change, which witnessed 195 countries accept individual obligations to limit greenhouse gas emissions. Yet, as indicated by several indices that include the Human Development Index (HDI), African countries still find it challenging to reach a level of development that provides an equitable existence for the citizenry.

In 2017, the ACEA was inaugurated with the mission of stimulating Africa's transition to a CE that delivers economic growth, jobs, and positive environmental outcomes (World Economic Forum, 2021). The ACEA was inaugurated with three founding co-chairs: South Africa, Rwanda, and Nigeria. In 2019, Côte d'Ivoire and Ghana agreed to join the coalition, bringing the total nations to five. The charter was endorsed at the 2019 African Ministerial Conference on the Environment (AMCEN) in South Africa. At the same gathering, the African Development Bank (AfDB), with support from the World Economic Forum, declared that it would charge its secretariat to strengthen the alliance's aim more broadly on the continent. Since then, other countries such as Cameroon, Niger, Senegal, the Democratic Republic of the Congo, and Malawi have expressed an interest in joining the alliance (World Economic Forum, 2021).

The success of CE in developing countries will be critical to global efforts to ensure sustainable growth (Panshak et al., 2020). Yet, today, the payment balance constrains Nigeria's economic development process. Even though monetary strategies improve its growth performance, Nigeria grows faster and more sustainably when applying strategies aimed at reducing the import components of its demands or improving the external balance, keeping budget deficits within generally acceptable limits, and increasing the export shares of products with high elasticity of demand.

Overview of Nigeria as a research context for climate change reduction and the circular economy via science-based target scenarios

The Community Climate System Model (CCSM) is a coupled climate model for simulating the earth's climate system, while the Beijing Climate Center Climate System Model (BCC_CSM1.1) is a fully coupled global climate–carbon model including interactive vegetation and global carbon cycle. Suppose the atmospheric temperature of Nigeria increases by 3°C or more. Here, we present data forecasting the severity of localised warming using CCSM4 and BCC-CSM1-1 models. The possible impacts are:

- Global warming will affect people beyond the average temperature change as that will impact other variables such as water supplies.
- The most substantial climate impacts regionally are likely to be poor water availability, and subsequently, drought.
- Based on satellite imagery trends from NASA and the Transaqua project, northern parts of the country have become drier over time, and they are predicted to get even drier in a warming world.
- A deficit of rainfall in the continental interior relative to the pre-warming case is likely; however, the two climate models used in the assessment make it hard to accurately predict regional climate changes.

Different environment simulation models do not always agree precisely on what they expect to happen in different locations, but some coherence often emerges, especially if the models are underpinned by science-based targets. What is evident is continued predicted drying in areas where it is anomalously dry today; for example, the Lake Chad Basin has reduced in size and volume over the years (Ross, 2018).

A country-specific set of fifteen meteorological stations representing all climate zones within the nation was selected. Their average was computed as the national mean temperature, and its evolution over the past decades was compared with the IPCC global mean estimate. CCSM4 and BCC-CSM1-1 show how climate models are driven by historical and natural climate forcing, based on which they make hindcast estimates.

When comparing the predicted impacts of climate change on rainfall patterns, soil moisture, and atmospheric temperature between the CCSM4 and BCC-CSM1-1 climate models, we observed that Nigeria's climate has been changing; this observation is consistent with other authors' findings and official government reports. The finding is evidenced by temperature increases; variable rainfall, sea levels, and flooding; drought and desertification; land degradation; more frequent extreme weather events; affected freshwater resources; and biodiversity loss (Haider, 2019). Looking to the future, climate projections for the coming decades forecast a significant increase in temperature over all the ecological zones.

How regulation, norms, and people's knowledge affect the circular economy and climate change prevention, particularly in the construction sector

Nigeria's built environment can be made circular and generate economic opportunities if we explore opportunities to use the following four CE catalysts or activities: a) make design the core of a circular built environment, b) use environmentally friendly construction materials, c) support the construction of green buildings to increase their sustainability, and d) use reform approaches to manage household rubbish and wastewater (World Economic Forum, 2021). To achieve those goals, what will catalyse a paradigm shift from acquiring knowledge to instigating a sustainable society underpinned by CE principles? The World Economic Forum (2021) reiterated the need for enablers. The roles of such enablers include improving and implementing policies and guidelines, providing business support, creating funds for quality infrastructure, increasing access to financing and technology, and widening the availability of data and information.

To achieve a CE truly and entirely in Nigeria, each stakeholder in the value chain must play their part optimally as lagging implementation by any stakeholder will affect the entire system. Dutch technology may serve as an innovation catalyst to support the scientific foundation for CE innovations in Nigeria (Ministry of Foreign Affairs & Naijalink Ltd, 2020). Yet, initiatives and platforms envisioned for that purpose have been delayed by the impacts of COVID-19 (European Commission, Directorate General for Environment, Rajput, J., Potgieter, J., Aigbokhan, G., et al., 2020). Even though the COVID-19 crisis hit Nigeria hard, there is now a window of opportunity to implement economic reforms aimed at diversification, and the CE can play a guiding role in that process (European Commission, Directorate General for Environment et al., 2020). Networking events are crucial for building relationships that will be valuable in such regards, many of which are organised by catalysts such as the Climate Innovation Centre, foreign diplomatic missions, and government entities.

Surprisingly, people living in lower-income economies tend to display more ‘circular’ behaviour than those in higher-income countries (Preston et al., 2019). Moreover, despite the considerable variation, per capita resource consumption is generally lower in developing countries than in developed ones (Preston et al., 2019) The digital revolution in emerging economies paves the way for harnessing technologies to move drastically to more resource-productive business standards. Thriving start-up scenes are cropping up in Nairobi, Bengaluru, and São Paulo; for example, companies such as Huawei, Alibaba, Tencent in China, and Flutterwave in Nigeria are champions of digital innovation and new enterprise model deployment. Hence, encouraging efficient use of resources underpinned by the 3Rs of ‘reduce, reuse, and recycle’ (Ranta et al., 2018b).

Recycling is easier to implement than reducing or reusing waste due to its lesser impact on current business models (Ranta et al., 2018a). Accordingly, it dominates economic value creation in the CE when compared with the ‘reduce’ and especially ‘reuse’ principles, even though recycling has a limited ability to keep materials in circulation. Policy-makers must find ways to facilitate value creation through the principles of ‘reduce’ and ‘reuse’ for the CE to reach its full potential. Ghaffar et al. (2020) demonstrated how government regulation of the recycling and reuse thresholds for every new project can significantly improve circularity within the built environment. Through various regulations and the adoption of the CE model, concerted efforts are being made by governments to extend the life span of building materials and thus conserve the embodied energy of the materials (Akanbi et al., 2020). Otherwise, the CE risks evolving into a hypothetic-normative (but self-serving) utopia that derails actual and well-intended efforts to reorganise production, consumption, and more largely, material flows in ways that are respectful of planetary limits and that work in favour of sustainability (Corvellec et al., 2022).

How circularity manifests in Nigeria

CE highlights a rethinking of our current economic model at a global level (Chime, 2021). The idea is gaining popularity with governments across the globe and among manufacturing industries and strategists given its ability to offer solutions to 21st-century social, environmental, and economic difficulties (Akpata et al., 2021). In solving those problems, shared efforts will be required to integrate the CE into several core business principles. In Nigeria, Ezeudu et al. (2021) posit that informal recycling/resource recovery activities, waste management policies, and functional institutions are in place, with the potential to serve as internal enablers when implementing CE. Yet, the absence of state-of-the-art waste disposal facilities such as engineered landfills, incinerators, and anaerobic digestion plants are external barriers to implementing CE (Ezeudu et al., 2021).

Akpata et al. (2021) noted that Nigeria has seen international and local companies invest in new business models that are eco-friendly, efficient, and sustainable. The growing trend is expected to gain momentum, considering the pandemic and its impact on traditional production systems. In the coming years, Nigeria hopes to see more indigenous firms embrace the concept of circularity through recycling and repairs (Akpata et al., 2021). However, adopting more advanced practices such as eco-design will be slow to gain traction because the necessary understanding and expertise are scarce. In line with the EU's Green Deal and with the objective of a green recovery from the COVID-19 crisis, the Nigerian Green Economy Alliance Team Europe Initiative is set to support the Nigerian government's efforts to diversify the economy by enhancing access to renewable energy for productive uses, integrating CE principles into the economic development model, and boosting the development of the agricultural sector. Collectively, these actions should help Nigeria achieve the SDGs and put the country on a sustainable development path. Furthermore, the EU will support investments in renewable power sources, energy efficiency in energy-intensive sectors, and a CE for better resource utilisation (FGN and EU (2021).

Nonetheless, change is not expected to be straightforward. Waste is a design flaw (Medkova & Fifield, 2016); yet, the challenges facing municipal waste management in Nigeria are numerous and diverse, related to economic, technological, psychological, and political barriers (Ghosh, 2019). Moreover, Ayanrinde and Mahachi (2021) propose that the adoption of green/efficient residential buildings will continue to stall if significant social/psychological barriers persist.

Technologies and practices advancing sustainable, circular, and low-emission buildings

Diverting to a circularity growth pathway will require significant replacement of primary resources with secondary materials – those recovered from waste streams and repurposed or re-manufactured for further use – and substantial improvements in the efficient use of primary resources (Ghaffar et al., 2020). Using building information modelling (BIM) to enhance projects' efficiency is a well-known practice advocated by many governments (Charef, 2022). This presents opportunities in terms of smart building design and the CE (Preston et al., 2019). Material consumption may be reduced if we can maintain buildings for the full duration of their design life. To that end, data analytics, intelligent machines, embedded sensors, and connectivity are supporting a host of changes in how buildings are maintained, which can prolong their useful operational lifetimes. Drones and robots can provide maintenance and retrofitting services. Sensors embedded throughout a building can deliver data to a central management system, reporting on the structural integrity, energy use, and operational health, as well as highlighting issues as they crop up, such as the need to replace or refurbish a particular component. The use of tracking technologies such as BIM or radio frequency identification (RFID) can help to optimise the performance of materials, support design for disassembly, and enable preventative maintenance. These technologies also support the use of buildings as effective 'material banks' – identifying materials for potential reuse after a building is decommissioned or demolished.

Although CE methodologies vary, they revolve around a similar goal. Yuan, et al. (2006) described resource reduction, high technological requirements, and benefits for communities, organisations, and individuals as crucial features of the CE. Similarly, Ellen MacArthur Foundation (2022) listed the source-economised economy (minimising new material use during production), the ecological economy (the ecological chain supported by partnerships between industries), and the high-tech economy (reduced use of virgin material and energy sources) as fundamental characteristics of CE (Emmanuel et al., 2022).

Promoting the construction of eco-friendly buildings to increase their circularity is another method to create contemporary trends in construction, with such facilities designed to consider circularity. The conventional structure of these buildings must incorporate restorative and regenerative designs that conserve the energy generated, along with green roof skins and rainwater harvesting. Buildings' environmental impact will thus be reduced by maintaining bio-nutrients in the ecosystem and reducing energy use. Moreover, applying CE models for efficient fittings and building fixtures – such as clean energy technologies, product-as-a-service, and leakage monitoring – will reduce resource consumption, consequently lowering the cost of running buildings, mainly commercial and institutional buildings (World Economic Forum, 2021). In addition, multi-stakeholder collaboration is essential to CE implementation in developing countries such as Nigeria. Multinational companies implementing CE business models may form a beneficial symbiotic relationship with local businesses. The benefits revolve around technology transfer and organisational learning, which are essential for resource efficiency, and clean technology: a foundation of CE (Ministry of Foreign Affairs & Naijalink Ltd, 2020).

Corvellec et al. (2022) stated that it is time for the government and producers to salvage the concept of circularity and thereby create "a closed, material cycle limited in space and size, based on the principle of fair distribution of resources". Yet, cyclical systems still consume resources and create waste and emissions. Therefore, with energy required to operate a CE, we must also call for a shift to renewable energy if a transition to circular material flows is to be realised.

How the real estate sector in developing countries can transform towards circularity

Low-income countries will continue to experience rapid urbanisation rates for decades, and primary resources will be needed to fill the infrastructure gap since, unlike developed countries, developing countries have minimal stocks of in-use buildings and materials for reuse (Preston et al., 2019). In a further prediction, the demand for consumer goods is also expected to rise; experience from developed and emerging countries suggests that new goods and individual ownership are likely to be preferred over 'second-life' goods and asset-sharing (Preston et al., 2019). Currently, the built environment is poorly planned, with a lack of coordination between systems the norm and service provisions scarce and highly unreliable (Esther, 2021). Against this background, there are ample opportunities to implement CE strategies to reduce construction costs and contribute to affordable housing (European Commission, Directorate General for Environment et al., 2020).

Circular construction not only involves resource recovery, reuse, and recycling; it is a much broader concept. Construction and demolition waste (C&DW) management requires tools and protocols that compel the stakeholders to invest in closed-loop construction. This involves bringing together industry, research, civil organisation, public authority, and policy-maker (Ghaffar et al., 2020). To achieve this vision, a body should be set up to evaluate the current environment and identify the loopholes and ways of closing them, and to concurrently address environmental and health issues. An ethical CE (ECE) strategy should be developed, integrating bottom-up systems for urban planning instead of using static top-down urban planning methods (Esther, 2021). Spatial planning for current and future needs must be conducted, avoiding unplanned developments that obstruct roads, pathways, and human progress.

Table 19.1 Stepwise guide to the proposed methodology

Data input	*Data source*	*Analysis*	*Expected output*	*Tools*
Journals, e-books, magazines, newspapers	Library, internet	Qualitative reasoning	Literature review	ATLAS.TI
Services drawings: architectural, structural, electrical, mechanical	Private consulting firm	Programming, climate modelling	CO_2 emissions report	EDGE app, internet
EDGE report quantitative data	EDGE app building emissions report	Carbon emissions forecast	The best part of 2DC forcing and the estimated carbon emissions for selected buildings	Excel spreadsheet
Rainfall patterns, soil moisture, atmospheric temperature	Meteorological stations in all national geopolitical zones	Visualisation/graph plot over time	Climate change patterns	CCSM4 and BCC-CSM1-1 climate models

Applying scenario methods to a real estate pilot project (CAGR, exponential decay constant, and absolute contraction)

For the pilot real estate project, the proposed method promotes energy saving and environmental benefits due to efficiency measures alone rather than inventing new energy sources in residential buildings. For the economic and environmental aspects of the proposals, the methods used are based on quantitative data sources, as shown in Table 19.1. This helps to achieve the research objective of identifying how residential buildings can fit into CE. The energy savings and environmental performance of residential buildings (eco-profiles) strictly depend on factors such as the choice of construction materials, technical equipment, and their installation/use.

Figure 19.1 shows the process designed to improve the thermal performance of the proposed residential buildings. The energy and environmental assessment methods adopt a life cycle approach. Estimates of the embodied energy and the ecological impacts of the required materials and components of the production, transportation, and installation phases are based on the EDGE app.

This study set out to limit the emissions or consumption levels of the 39 dwelling units within the carrying capacity of the relevant ecosystems they impact. The real estate pilot project contains four semidetached buildings, three detached duplexes, 16 terraced units, 16 units of two blocks of flats, and a commercial zone. The occupants' actions were considered in the context of Apo District ecosystems. To do so, we aimed towards the following objectives:

- Use climate models to analyse data from different meteorological stations in the country to determine the national mean temperature evolution over the years and compare it with the global mean estimate from the IPCC to justify the need for CE adoption.
- Use the EDGE app to estimate CO_2 emissions for different residential apartments based on their proposed architectural, structural, mechanical, and electrical designs.
- Use Excel to calculate these buildings' future 2DC emission forecasts or pathways.
- Adopt water, energy, and material efficiency measures to achieve residential circularity.

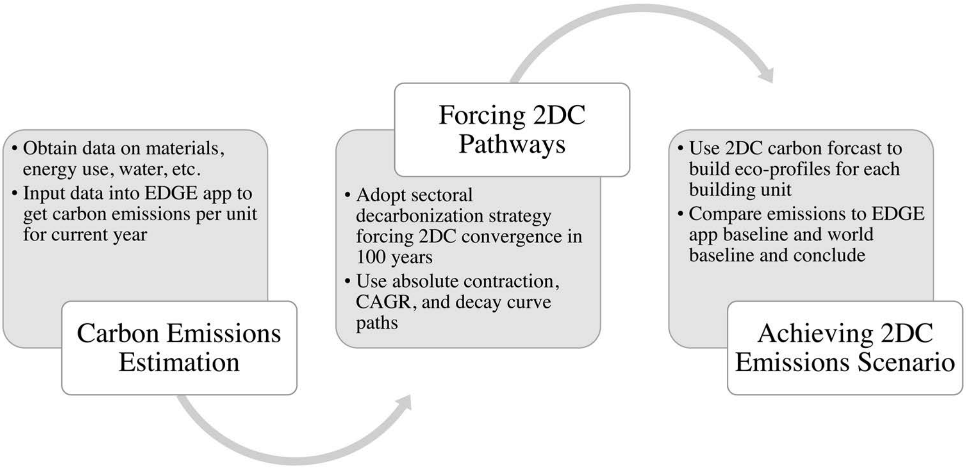

Figure 19.1 Decarbonisation scenarios process chart.

Future emissions 2DC pathways used

Based on the scenario today and the likelihood of future changes, fossil fuel emissions can be projected using the Kaya identity formula (Kaya & Yokobori, 1997). This is a simple formula to project future carbon emissions based on expected (or hoped-for) changes in the population (in billions), economic activity as the GDP per capita in $US 2000/person/year, energy intensity in watts/year/$US, and the carbon intensity of the energy sources (Gton C) in CO_2/terawatts/year.

The Kaya identity formula's usefulness to forecast future emissions is due to its broad perspective. The carbon emission rate $C(0)$ is equal to the human population (with the expectation that it will grow in future times) multiplied by the GDP per capita (because economic activity and energy attributes are fossil-fuel-based) and other energy parameters, as shown in Figure 19.2.

Using the Kaya IDENTITY Scenario Prognosticator, the authors extrapolated the present-day trends by forecasting the size where the Earth's population will plateau to be at nine billion people. The average income/capita increases with time, and USD 2000/person/year best fits the trend. Energy use is getting more efficient. So, the energy intensity decreases with time, with

1. $C(0) = Carbon\ emissions \left[\frac{Gton}{Year}\right] = Population\ (persons) \times GDP \left[\frac{\$}{Person\ Year}\right] \times Energy\ intensity \left[\frac{Watts}{\$}\right] \times Energy\ source \left[\frac{Ton\ Carbon}{Watts}\right]$
2. $C(t) = C(0) \times e^{-kt}$ ……………………………………………Decay curve pathway
3. $C(t) = C(0) \times (1 + CAGR)^t$ ………………………………No-value-added CAGR pathway
4. $C(t) = C(0) \times (1 + g)^t \times \frac{(1 + CAGR)^t}{(1 + G)^t}$ ……………………Value-added CAGR pathway
5. **Absolute contraction pathway……………………………Constant annual % decrease**

where

- **C (0) = present carbon emissions**
- **C (t) = future carbon emissions**
- **e = exponential constant**
- **k = decay constant**
- **t = duration**
- **CAGR (compound annual growth rate of carbon emissions to reach 2DC global target) =** $\left(\frac{C(t)}{C(0)}\right)^{\frac{1}{t}} - 1$
- **g = the household's annual growth rate of gross profit**
- **G = the yearly growth rate of national GDP**

Figure 19.2 Proposed decarbonisation scenario equations for residential buildings.

–0.75 watts/USD best fitting the trend. The recent move away from coal because of lower prices for natural gas brought about by improvements in extracting natural gas, known as fracking, induces changes in the carbon source concerning the efficiency, and –0.4% ton carbon/watts best fits the trend. Based on all of this, the projection under business as usual means that with no efforts to avoid climate change, the rate of carbon emissions, which today is about 11 gigatons per year, could grow to about 25 gigatons per year by 2100 (Pielke et al., 2022).

Results and discussion

The proposed pathways shown in Figure 19.3 are better for the real estate sector than others because they satisfy early criteria that science-based targets should depend on. A building must demonstrate a 20% reduction in projected operational energy consumption, water use, and embodied energy in materials to meet the EDGE standard compared to typical local practices (base case). EDGE defines an overall standard while contextualising the base case to the building functions and location (IFC, 2021). As evidenced in Figure 19.4, all the pilot buildings demonstrate 20% savings except those in the lower-income building design categories, which narrowly miss the 20% EDGE baseline for water efficiency. Efficiency measures contribute to the performance of the pilot buildings, resulting in lower utility costs, extended equipment service lives, and eased pressure on natural resources.

The pilot buildings' eco-profiles satisfy the 2DC pathway since the required minimum CO_2 savings are achievable theoretically. "A simple pass/fail system indicates whether the building project has demonstrated the minimum 20% savings in operational energy, water, and embodied energy in materials compared to the base case model" (IFC, 2021, p. 14). Actual percentage savings for each project can be found on the EDGE certificate and project case studies on the EDGE website. The CO_2 emissions per building unit show a reduction for 30 years due to the efficiency measures.

The 2DC target criteria were adopted for the pilot buildings as indicators of the CE for the following reasons:

- There are recognised 2DC pathways.
- Sectoral decarbonisation reflects different income levels of carbon intensity for the four pilot building types, and all paths converge in the year 2100.

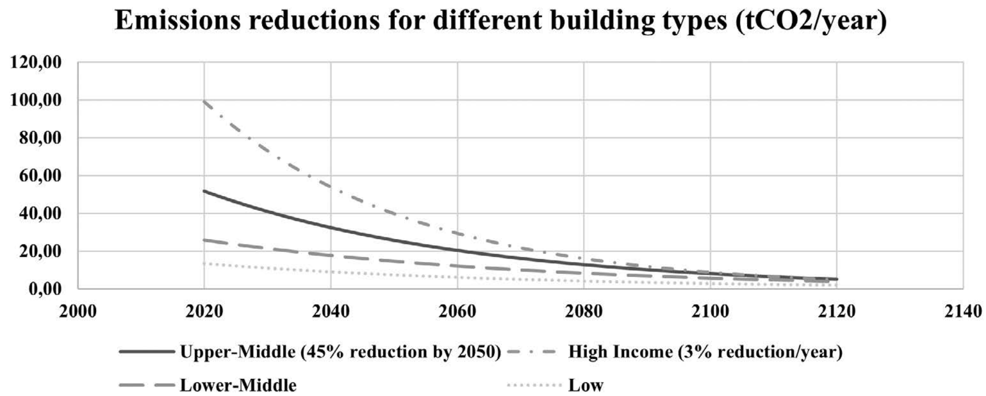

Figure 19.3 Proposed 2DC paths for residential buildings.

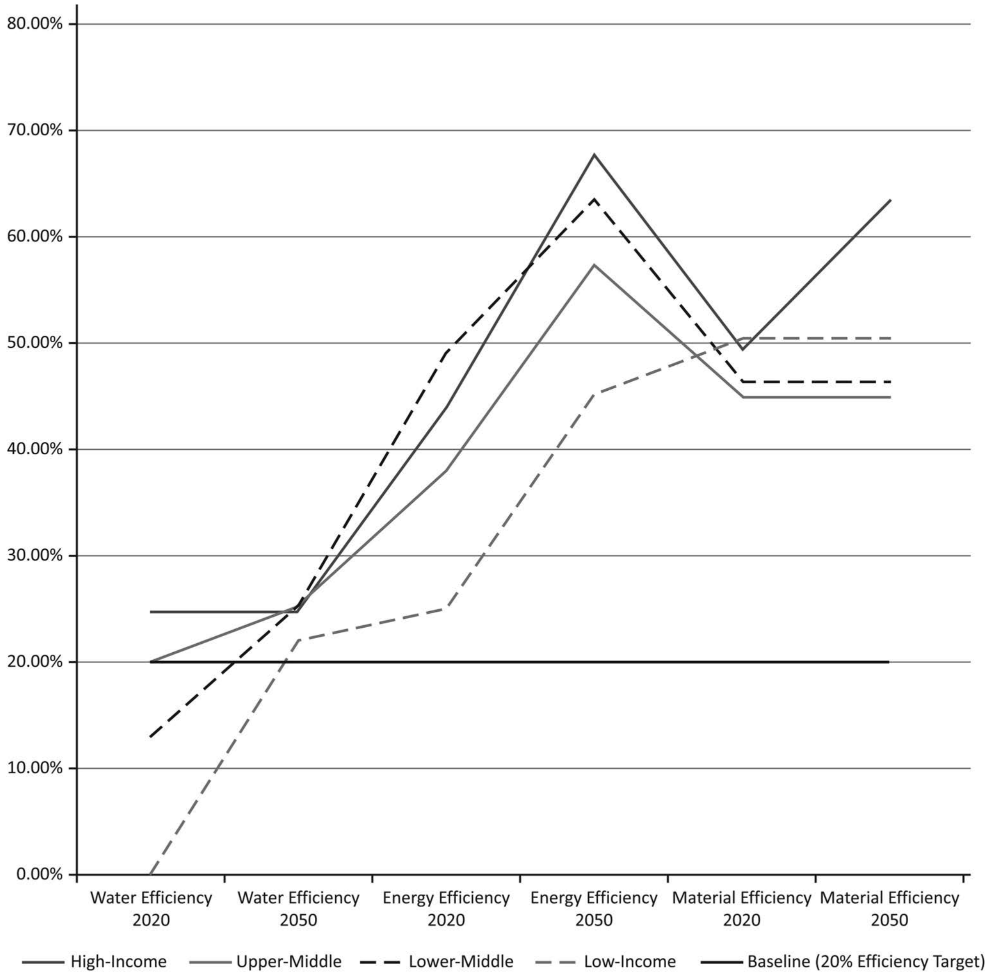

Figure 19.4 Energy, water, and material savings diagrams for pilot real estate buildings.
Source: The authors.

- This ensures high emitters clean up more (absolute emissions vary per income level/design).
- Scope 1–3 emissions are covered (EPA, 2014).
- It is fair and cost-efficient.
- The approach adapts to growth and mitigation opportunities.

In Table 19.2, the science-based targets in role three align with context-based sustainability, which immediately applies as an allocation issue here. The context is the carbon budget from now through 2050 or 2100. According to the sectoral action plans for Nigeria's nationally determined contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) report, Nigeria's carbon budget is about 500 million metric tons of CO_2 or CO_2 equivalents by 2050. The accumulated emissions matter so reducing emissions eventually is not the aim; instead, it is how we get there and what we emit in the meantime.

Table 19.2 2DC target criteria

Building type	*Terrace*	*BOF*	*Semidetached*	*Detached*
Income level	High	Upper-middle	Lower-middle	Low
2DC pathway	Absolute contraction: Converges at a 3% annual reduction	Decay curve: Converges at a 50% reduction	Value-added CAGR: Converges at a 45% reduction	No-value-added CAGR: Converges at a 45% reduction
Scenario	30 years	30 years	30 years	30 years
Convergence	100 years	100 years	100 years	100 years
Emissions/unit in 2020	6.19 (tCO_2/year)	4.31 (tCO_2/year)	6.47 (tCO_2/year)	4.40 (tCO_2/year)
Emissions/unit in 2050	2.51 (tCO_2/year)	2.35 (tCO_2/year)	3.72 (tCO_2/year)	2.77 (tCO_2/year)

Efficiency: The key way to diminish emissions and increase circular principles in the Nigerian climatic context

Emitted CO_2 from residential buildings may not be visible to the naked eye, but the subsequent local climate change due to atmospheric temperature increase is a global concern (Stokes et al., 2015). A natural response by the federal government is to work towards temperature targets. So, what will it take to keep Nigeria's temperature stable or below a benchmark? Rather than make arbitrary decarbonisation decisions for real estate, this chapter will help real estate firms make science-based emissions decisions that will catalyse circular and low-emission buildings' introduction by leveraging state-of-the-art emissions estimation technologies (EDGE building app) and ambitious emissions reduction scenario methods (CAGR, exponential decay constant, and absolute contraction), in alignment with the Paris Agreement.

We hope the results of this study will catalyse CE business activities in the real estate sector. We envision a scenario where occupants will set greenhouse gas emission targets in the context of the region's water supply and the planet's ability to absorb carbon dioxide and other greenhouse gasses.

Conclusion and recommendations

In this chapter, we applied four scenario methods when estimating and validating decarbonisation based on energy, water, and material efficiency for residential buildings in Nigeria. The aim was to promote context-based sustainability. To that end, we presented how to reduce emissions and catalyse CE principles in buildings through the novel method of efficient material use considering the local ecosystem's limits.

The work presented here adds value to the existing body of knowledge since the novel method supports energy saving and environmental benefits through efficiency measures alone rather than by inventing new energy sources in buildings. The application of our sectoral decarbonisation strategy to selected residential buildings supported projections of a fair share of carbon emissions in the future. To make such predictions, it helps to estimate the future carbon emissions/unit and force different (2DC) pathways by establishing building service designs for four income levels.

Theoretical carbon savings were demonstrated even with the current energy, water, and material sources. Natural upgrading to carbon-efficient equipment will be key, with carbon neutrality viable if key stakeholders adopt the CE principle of efficient resource use. As such, carbon neutrality for dwelling units in Nigeria is achievable if we ensure the strict adherence to sustainability plans during municipal development. In particular, the introduction of a CBL certification may support great efforts to be made to achieve carbon neutrality.

Accordingly, the recommendations of this chapter are as follows:

1 Climate change and CE movements are gaining increasing exposure daily. Governments, organisations, and even individuals have started setting science/factual-based targets to reduce their carbon footprints. While one option for Nigeria to endure climate change is mass migration from the north to the south; however, this may lead to other humanitarian crises if not appropriately managed. As an alternative, the low-hanging fruit is to implement sustainable building practices in Nigeria's geographic context by adopting the CE principle of efficient resource use.
2 To reduce buildings' emissions, the construction industry/real estate sector should adopt four income categories when making projections, to ensure a fair share of the decarbonisation budget goes to each; this practice will contribute to avoiding market failures.
3 By investing in carbon-efficient equipment, our production and consumption may become leaner and more conservative. Policy-makers should also learn the importance of the 2DC decarbonisation timeline, specifically for building estates, and the need to avoid greenwashing.

In this research, the emission targets were based on the EDGE global baseline. Further research should incorporate the actual budget for the real estate sector in Nigeria. Plus, a key insight that emerged from this study is the need for a CE business strategy of adopting emission reduction scenario methods for individual homes within proposed real estate projects, an option that should be explored further in future studies.

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Educational content

Although various environmental certification schemes exist for buildings, this study inspires context-based sustainability thinking for dwelling units by applying business decarbonisation targets to residential apartments. Now consider:

1 The key tasks are to develop a CE label certification scheme for buildings and improve on various environmental certification schemes void of science-based decarbonation targets. How can real estate firms instigate these targets' application?
2 Adopting the CE principle of efficient resource use is posited as the low-hanging fruit to implement sustainable building in Nigeria's geographic context. What existing policy instruments support efficiency and how can it be enforced?
3 Can key stakeholders fast-track the business of natural upgrading to carbon-efficient equipment supporting carbon neutrality by simply adopting the CE principle of efficient resource use?

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DIGITAL AFFORDANCES FOR A CIRCULAR ECONOMY TRANSITION

A multiple case study of digital technology-enabled circular business models

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Introduction

The transition from a linear to a circular economy (CE) requires a complex economic and societal shift in which the firms implementing circular business models (CBMs) have an important role. Currently, digital technologies are used to enable CBMs to mitigate the 'friction' businesses may have endured in the past when they were organising and matching supply and demand or orchestrating the governance of the marketplaces (Bocken & Ritala, 2022). Affordances can be defined as the "behaviours that are afforded by an object, place or event" (Michaels & Carello, 1981, p. 17; see Gibson, 1977, p. 67) and can also be found in the digital environment. Digital affordances enable firms to embed rules, algorithms, and mechanisms for self-governance. Although scholars have highlighted the importance of digital affordances for sustainability transitions (Seidel et al., 2013), recognising the role of digital technology in the shift from a linear economy to a CE (Chauhan et al., 2022), there is still little research that demonstrates exactly how digital affordances are used to implement CBMs.

In this chapter, we study how firms use digital affordances to implement digital technology-enabled CBMs. To investigate this, we have adopted the socio-technical systems (STS) lens, which helps us identify the role digital technology has in overcoming some of the challenges firms face in the markets (Bostrom & Heinen, 1977; Geels, 2019; Markard et al., 2012; Ropohl, 1999). The STS framework assists us in investigating the relationship between both the organisational and technical systems (see Seidel et al., 2013), which helps us avoid merely listing descriptions of technical features. Digital CBMs allow stakeholders to participate in the value creation activities (e.g., exchange, collaboration, and transactions) that are predetermined in the business model design (Rajala et al., 2018) and that depend on the firm's circular resource strategy (Bocken & Ritala, 2022); here, the designed activities contribute to the circularity transition. For clarity and to better understand what these socio-technical matters are, we address the following two research questions:

1 What types of digital affordances are used to facilitate digital CBMs?
2 How do firms use digital affordances to enable circular resource strategies?

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The chapter proceeds as follows: first, we conceptualise digital CBMs as socio-technical systems and review the main CBM implementation challenges found in the literature. Then, we describe the data collection and methods used to identify four digital affordance categories for firms overcoming the challenges in implementing digital CBMs: information provision, market intermediation, supply chain enhancement, and institutional legitimation. Then, we present selected empirical evidence for four main circular resource strategies (i.e., narrow, slow, close, and regenerate). Finally, we discuss the implications for theory and practice while highlighting potential avenues for future research.

Theoretical framework

Socio-technical systems lens

Digital technologies play an important role in CE discussions (Chauhan et al., 2022) because they have been recognised as the key enablers for CBMs in implementing circular resource strategies (Konietzko et al., 2020b). Digital models and CBMs can be viewed as socio-technical systems designed to manage a firm's circular resource strategy and value creation. This requires examining the relationship between social and technical elements (Appelbaum, 1997), in other words, managing how these systems allow actors, institutions, knowledge, and materials to operate in close interaction (Markard et al., 2012). The socio-technical system has two sides: (1) the technical system side, which consists of technical and task levels, and (2) the social system side, which consists of the actor and structure levels (Dremel et al., 2020). The technical level (i.e., the technology) is the core enabler of the CBM, whereas the task level manages meeting the overall goals, for example, by incentivising actors participating in value creation (Lyytinen & Newman, 2008). The social system side, on the other hand, considers the roles of various social actors in value creation, and here, the overall social structure is built based on social norms, boundaries, and authority to keep the whole system in balance (Lyytinen & Newman, 2008). There is a process-like relationship between the two sides and all four levels: the CBM strategy influences the technical, social, and structural levels, and the digital affordances we are interested in are *actualised* at the task level (Henningsson et al., 2021).

The concept of an affordance was originally theorised as the action potential of an object an individual experiences in the natural world (Gibson, 1977); however, in recent digital affordance studies, the authors have been referring to the action potential for a range of actors in digital work systems, for example, entrepreneurs and organisations operating in interdependent ecosystems (Autio et al., 2018) and large-scale collaborations (Malhotra et al., 2021). Scholars have defined firms with digital platforms as meta-organisations that have a system-level goal (e.g., Ciborra, 1996; Gawer, 2014; Gulati et al., 2012), strongly referring to them as socio-technical systems. Malhotra et al. (2021) studied socio-technical affordances in a large-scale collaboration context by looking at the challenges organisations face while pursuing their efforts. Also, taking a socio-technical system-level view will offer a useful lens to investigate digital affordances where firms implement their CBMs; a similar approach will be applied in the current study using empirical evidence.

Circular business model implementation challenges

Firms face various challenges at different stages of CBM implementation. We have identified the main areas residing within the supply chain, market, institutional, and information sharing contexts by reviewing the business model literature. We also viewed how Vermunt et al. (2019) identified several external challenges between organisations and markets in organising the circular resource supply chain and exchange. The most typical supply chain challenges were the problems in identifying and bringing excess resources to markets and connecting supply with demand. In the markets, the main challenges are related to price and the rejection reaction of the markets towards a recycled or refurbished resource (e.g., inadequate resource quality causing lack of trust or products not seen fashionable enough). Naturally, some industry- and resource-specific challenges also exist. Various multi- and interdisciplinary studies have covered a range of industry-relevant problems, for example, legal (i.e., institutional) issues that include food (Mor et al., 2021) and construction (Adams et al., 2017) industry firms must overcome when establishing circular resource flows (Bocken et al., 2019). Also, digital CBMs have implementation challenges: a group of issues were found to slow the implementation speed related to information sharing (e.g., firms' and shareholders' reluctance to share knowledge or integrate information sharing) and access to accurate and trustable data between the firms (Antikainen et al., 2018). Also Berg and Wilts (2019) highlighted the need for further integration and automation of digital platforms for circularity. Hence, compared with earlier studies, the studies of digital CBMs have indicated a new group of challenges related to information and data sharing among the actors in digital business networks. Based on the reviewed literature, the main CBM implementation challenges are related to the supply chain, markets, and institutional and information sharing contexts. By looking at these locations and the tasks firms have allocated, we can obtain an idea of how digital affordances are designed to overcome these challenges. CBMs are resource strategy-specific socio-technical systems by their design, and the choices firms have taken assist in filling this purpose, for example, by closing, slowing, narrowing, or regenerating resource loops to create value (see Bocken & Ritala, 2022; Bocken et al., 2016).

Circular resource strategies and digital business models

Scholars have defined a broad set of circular resource strategies that firms use to meet the circularity goals of the business ecosystem (Bocken et al., 2016). The circular resource strategy and its supporting processes define the firm's final CBM design and actors involved. For example, Bocken et al. (2016) have categorised circular resource strategies into four groups aiming at narrowing, slowing, closing, and regenerating the firms' resource flows.

'Narrowing' the resource flows is also referred to as resource efficiency, which aims "at using fewer resources per product" (Bocken et al., 2016; Konietzko et al., 2020a). For decades, the manufacturing industry has practised resource efficiency (mainly for financial reasons). Narrowing requires comparing the time or speed at which the resource passes through the manufacturing process and the products being consumed. The development of less resource-required manufacturing techniques (e.g., less resources used in the process) and new product designs are required. Practical examples of digitally enabled CBMs utilising the narrowing strategy are the AirFaas platform, which allows industrial-scale manufacturers to share and maximise the use of their excess resources within its ecosystem. Also, FLOOW2 enables internal and external sharing of resources within its closed platform ecosystem. The agri-food industry produces many residues that could be remanufactured and used by the food industry as natural ingredients. Agrosingularity matches vegetable producers, residue handlers, food manufacturers, and distributors via a digital platform. However, narrowing as the sole strategy for circularity might not be enough to reach eventual gains in sustainability. For instance, if fewer resources are being used per product but the production phase and quantity are higher than before, the actual benefits for sustainability are questionable. Therefore, the narrowing strategy is often used simultaneously with other resource strategies, which we discuss next.

As a circular resource strategy, 'slowing' means extending the product's life or utilisation time with a design that results "in a slowdown of the flow of resources" (Bocken et al., 2016). For CBM, this means a design of better, longer-lasting products and adding repair or remanufacturing services or product-as-a-service functions to the business model. Various forms of additional services are becoming a popular choice for CBMs, and the product-as-a-service (Bressanelli et al., 2018) and servitisation practices (Parida et al., 2019) have been recognised as some of the main design choices. Practical examples of digitally enabled CBMs utilising the slowing strategy are Varusteleka (Finland) selling excess military clothing with a buyback option of the products, and the clothing brand Reima selling children's clothing-as-a-service with a monthly subscription model.

'Closing' the resource flow strategy means generating value of waste, for example, recycling, and reusing goods. This is defined as "closing the resource loop between post-use and production" (Bocken et al., 2016). The product design must support resources returning to the technological (or biological) system at the end of the product's life (Konietzko et al., 2020a). Practical examples of recycling and reuse strategy–based digital CBMs are peer-to-peer sharing platforms (Schwanholz & Leipold, 2020). Sharing has an impact on resource efficiency; however, its real environmental effects are quite complex to calculate. For example, secondhand P2P platforms can increase impulsive buying and consumption (see Parguel et al., 2017; Townsend & Coroama, 2018). Completely closing the resource loop requires robust and measurable practices, for example, including waste buyback schemes and remanufacturing processes. Practical examples of digitally enabled CBMs utilising the closing strategy are the Legwear Company, Swedish Stockings, and Teemill, all of which offer these services by taking back their products for remanufacturing. With CBM design utilising online marketplaces, waste buyback programmes, and in-house remanufacturing processes, these firms close the nylon and cotton raw material cycles. Some firms offer services for just specific sections in closing the resource cycle: for example, plastic waste collection specialised organisations like Coliba orchestrate urban waste removalists for collection and recycling tasks via a mobile app.

As a resource strategy, 'regenerating' refers to "cleaner loops and leaving the environment in a better state than previously" (Hofstetter et al., 2021). This may, for example, mean the use of nontoxic materials and regenerative energy to power the use of the products (Konietzko et al., 2020b). The term 'net positive' (Rainey et al., 2015) is often used in this context to define how well firms positively affect biodiversity. Regenerative practices require a lot of information (i.e., data), and many digital firms attempt to exploit the data generated during business processes and operations to understand their real impact. In the agricultural sector, regenerative farming is becoming a trend: process data utilising firms like BioCode have monetised this development by tracing and alerting clients about possible challenges and improving the climate impact of the whole food production chain. Data has value at various (if not in all) stages of the regenerative process planning (see, e.g., dairy company Valio's regenerative agriculture e-college). In the construction sector, SundaHus collects material data and offers digital consulting services for building projects. It is notable that neither BioCode or SundaHus are participating in farming or building; they simply collect data to fill in the possible information gaps in specific industries.

Methodology

Research design

To understand digital affordances helping to implement firms' CBM, we follow Malhotra et al.'s (2021) example of integrating socio-technical systems and affordance lenses to study digital CBMs. Given that the prior literature of digital affordances in the context of CE has been relatively limited, we adopted an exploratory multiple case study approach (Eisenhardt & Graebner, 2007) to examine what specific types of digital affordances are linked to enabling a case firm's circular resource strategies.

In the analysis, we build on the socio-technical systems view, which plays a critical role in understanding different types of digital CBMs – given that digital business models in general are active systems depending on technologies (Tykkyläinen & Ritala, 2021; Zott & Amit, 2010). In particular, we utilise the socio-technical systems lens as an analytical template to empirically investigate the interactions between the actors (the key stakeholders who make sure the firms' work gets done), technical aspects (the technical core designed for CBM), and structural levels (e.g., the authoritarian and organisational boundaries), and tasks (the alignment of systems, goals, and purposes) (Kapoor et al., 2021; Lyytinen & Newman, 2008).

A group of 20 firms with a digitally enabled CBM was systematically selected: we used a theoretical sampling strategy (Eisenhardt, 1989, p. 537) to choose cases from a diverse population of firms with a digital technology-enabled CBM for value creation. This allowed us to collect data in the context of the CE and focus on the challenges in implementing the CBM. The sampling was done by first conducting an extensive online search using the SITRA Circular Economy and Ellen MacArthur Foundation webpages to find potential cases. Then, the final group of companies was chosen based on the business model, technology, physical location, and maturity. We noted that Europe has a strong position and political support in the shift from linear to CE, in addition to a high level of platformisation and digitalisation among the firms, which resulted in most of the firms being from the EU area (European Union, 2020). The socio-technical system theory assumes that variances in inputs, processes, and outputs exist in all work systems (Trist & Bamforth, 1951); therefore, we chose a sample from different markets and industrial settings to generate novel and interesting insights and to see the variance between CBMs. The final set of anonymised cases representing digital CBMs is shown in Table 20.1.

Data gathering

Semistructured interviews were used as the primary data collection method. Data were generated in the interviews together with the case company CEOs or founding partners. The interviews lasted approximately an hour each and were conducted between December 2020 and March 2021. Interview recordings were transcribed, resulting in 281 single-spaced pages of data. In addition, company websites, news articles, and platform information (FAQs, user instructions) were stored as the secondary data source to complement knowledge gaps.

Data analysis

We look at digital affordances as options to action through the socio-technical lens to solve the CBM implementation-related challenges. By using the four identified CBM implementation

Table 20.1 Description of the cases in the order of interviews (n=20)

Business model	*Resource strategy*	*Resource*	*Specialised industry*	*Digital system*	*Markets*
#1 Remanufacture and sell plant-based products	Close	Vegetable waste	Food manufacturing	Transaction platform	B2B
#2 Allow excess resource sharing	Narrow	Industrial data	Industrial manufacturing	Digital platform	B2B
#3 Allow food companies to track and improve environmental perf	Regenerate	Food and agricultural industry data	Software	Digital platform	B2B
#4 Food-as-a-service, manufacturing platform	Close	Food ingredients	Food	Digital platform	B2B
#5 Digitally connect waste pickers to resource and recycling markets	Close	Urban waste removalists	Waste removal	Mobile app	B2C
#6 Resell excess food products	Slow	Excess food products	Retailing	E-commerce	B2C
#7 Allow excess resource sharing	Regenerate	Resource sharing data	Software services	Digital platform	B2B
#8 Allow car sharing	Slow	Shared cars	Mobility	Web app	B/C2C
#9 Allow selling excess resources	Slow	Various goods	Public sector organisations	E-commerce	G2C/B
#10 Smart metering of water, electricity, and gas	Regenerate	Utility data	Software services	Digital platform	B2B
#11 Allow selling excess resources	Slow	Construction materials	Construction	Digital platform	B2B
#12 Enable food sharing	Slow	Excess food	Digital services	Mobile app	B/C2C
#13 Enable car sharing	Slow	Shared cars	Mobility	Mobile app	B2C/B
#14 Allow restaurants to sell surplus meals to consumers	Slow	Prepared excess meals	Food service, bakeries	Mobile app	B2C
#15 Enable digital CBMs	Regenerate	Online platform	Digital	Digital platform	B2B
#16 Allow boat sharing	Slow	Shared boats	Mobility	Mobile app	B/C2C
#17 Enable sourcing environmentally friendly materials	Regenerate	Built environment data	Software services	Digital platform	B2B
#18 Used ICT equipment refurbishment and resales	Slow	Waste from electrical and electronic equipment	Retailing	E-commerce	G2C
#19 Circular fashion e-commerce	Close	Sustainable fashion	Fashion, clothing	E-commerce	B2C/C
#20 Refurbish and resell surplus clothing	Slow	Army clothing	Retailing	E-commerce	B2C

challenge categories, we created an a priori coding template for the NVivo analysis. The challenges found in the data were organised in NVivo under information, institutional, market, and supply chain contexts. The information context consisted of descriptions of the problems and solutions the interviewees had noticed in managing things like resource traceability, information about the supplier, clients, products, or product use. The market context consisted of codes like accelerating data transfer and building an ecosystem by connecting stakeholders to support the core, enabling hard to reach resources to markets and growth channels for the business, and increasing customer and resource (or product) acceptance and competition resistance. The supply chain context consists of definitions of how digital CBMs may improve inefficiencies, manage product returns and waste processing, and match supply with demand. The institutional context describes how technology enables local business opportunities, improves resource legitimacy and awareness, and follows local regulation to coordinate business operations. Once the digital affordances had been identified and categorised from the raw data, we conducted a cross-case comparison (Eisenhardt, 1989) and examined how firms had used digital affordances to facilitate the circular resource strategy at the core of their CBM by narrowing, closing, regenerating, or slowing down the resource loops (Bocken et al., 2016).

Digital affordance categories

To answer the main research question, What types of digital affordances are used to facilitate CBMs? we viewed the CBMs as socio-technical systems and explored the digital affordances for each resource strategy by looking at the business model implementation challenges they solve. Next, we introduced a summary of the main categories of digital affordances by using the socio-technical systems lens (see also Table 20.2.). The socio-technical systems model has four levels: structure and actor forming the social system and task and technology forming the technical system. Hierarchically, affordances, which are the activities designed to be taken at technology, actor, and structure levels, are realised at the task level.

Information provision category

The information provision affordance category consists of the collection and distribution of relevant information between actors and incentivising them to share data with others in the business ecosystem. Activities are designed to build trust through resource-centric information and data flows. At the STS social system side, the actor's expected role is to consent and participate in various types of data sharing. Based on data, a key component in this affordance category is trust building, which is also defined as a form of value in digital business (Kracher & Corritore, 2004). According to Levine (2019), microforms affect trust building in digital business communities; however, the findings indicate that a much broader context is needed to investigate trust building at the system level. At the structure side, the firms orchestrate a safe and reliable digital business ecosystem that enables detailed and timely information provision between the actors. The technology level consists of various digital solutions such as digital platforms, mobile applications, e-commerce websites, software integrations, IoT technology (hardware and software), and the use of AI. The task level was built to encourage trust building and data and information sharing between stakeholders. Firms also incentivised actors with data-generated insights, market information, and orchestration to align actors' interests; hence, they were likely to gain more by agreeing with information sharing.

Table 20.2 Categorised digital affordances through the socio-technical systems lens

Socio-technical system		*Digital affordance categories*: *1) Information provision*	*2) Market intermediation*	*3) Supply chain enhancement*	*4) Institutional legitimation*
Technical system level	**Technology**	Technological infrastructure tracing, collecting, storing, analysing, and sharing resource (and other) data and information.	Technological infrastructure connecting stakeholders, participating in resource exchange and transactions.	Technological infrastructure connecting supply and demand.	Digital information channels for promoting and convincing and sharing trust, generating organisational information.
		Digital solutions identified: e-commerce, digital platforms, mobile applications, websites, software integrations, IoT technology (hardware and software), AI			
	Task	Encourages trust between stakeholders to connect for data and information sharing. Incentivises actors with data-generated insights, market information, and orchestration to align actors' interests.	Encourages stakeholder acceptance and participation in the transaction and/or exchange activities. Incentivises and governs the digital marketplace with a value proposition.	Encourages existing stakeholders to continue aligning their interests with systemic goals. Incentivises more suppliers to join with the economic value, which, in turn, attracts demand.	Encourages stakeholders to participate in the markets and decision-making to align or utilise the market legislation with the firms' systemic goals. Incentivises decision-makers with positive externalities and network effect-driven expansion.
Social system level	**Actors**	… consent to data and information sharing and connections between actors/stakeholders in the ecosystem.	… join the marketplace structured by the focal firm's software development team.	… (individuals or organisations) change behaviour and participate in generating circular resource flows.	… become active members of the network supporting system-level goals that influence local institutions.
	Structure	The firm builds a safe, reliable, and specified business ecosystem that enables detailed and timely information provision between the actors.	The firm orchestrates, sets rules and boundaries (e.g., for the market entry) and intermediates value creation and competition in the markets.	The firm manages and enhances supply and demand matching in the digitally managed value chain.	The firm legitimises itself with design choices that generate value with a circular resource strategy.

Source: Lyytinen and Newman (2008); Kapoor et al. (2021).

The market intermediation category

The identified market intermediation affordance category refers to those actions that lower the actors' barriers to joining and becoming active in circular resource markets. Market challenges can be solved with digital systems that enable the CBM and are used to build trust with the resource- and actor-specific information sharing. At the social system level, the actor's role is to consent to data sharing, while the structure of the digital community enables it. Firms do this by increasing customer acceptance and resource value rates, connecting, and measuring the overall system performance. Actors typically join the marketplace structured by the focal firm's software development team. At the structure level, the firm orchestrates, sets rules and boundaries (e.g., for the market entry), and intermediates value creation and competition in the markets. The technical infrastructure connects stakeholders participating in resource exchange and transactions. At the task level, STS incentivises actors participating in exchange activities while governing the digital marketplace.

Supply chain enhancement

The supply chain enhancement category refers to an STS design that enables the sourcing of circular supply, bringing resources to markets and matching with demand. The market challenges are solved with digital system integrations with real-time information sharing like supply location, logistics, availability, quality, and price. At the social system level, the actor's expected role is to participate in exchange by taking on the role of a resource supplier or demand. The key component in this category is behavioural change: individuals or organisations need to change their purchase behaviour and participate in generating circular resource flows. At the structural level, the firm manages and enhances supply and demand matching in the digitally managed value chain. At the technology level infrastructure is designed to connect supply with demand. The task level encourages existing stakeholders to continue aligning their interests with systemic goals by incentivising more suppliers to join with the economic value, which, in turn, attracts demand.

Institutional legitimation

This category refers to actions levelling out the firms' market entry and establishing the firms' CBM by using technology-enabled CBM as the leverage. The challenges are solved by using network effects and externalities, convincing the sustainable development demanding markets with a business model that supports the wider transition from a linear model economy to a circular one. At the social system level, the actor's expected role is to become an active supporter of the CBM and its legitimacy within the business environment; naturally, the broader the impact, the greater the influence the firm has. Active circular resource exchange actors and networks may support meeting the system-level goals given to local governments. At the structure level, firms legitimise themselves with design choices that generate value with a circular resource strategy. At the technology level, digital channels are used for promoting, convincing, and sharing trust-generating organisational information. The task level encourages stakeholders to participate in the markets and decision-making and to align or utilise the market legislation with the firms' systemic goals by incentivising decision-makers with positive externalities and the promise of rapid expansion.

Circular resource strategies

To answer the second research question, how do firms use digital affordances to enable circular resource strategy? We defined the case firms' resource strategy and analysed how technology was used to overcome previously identified challenges in the markets.

Narrowing

Both investigated firms, cases #2 and #7, operated in the B2B markets, enabling the sharing of various resources from manufacturing plants (#2) and parking spaces to intraorganisational medical equipment (#7). By doing this, the firms could reduce the number of new factories, parking spaces, or heavy vehicles being built. Both firms also represented the slowing strategy (as previously mentioned, narrowing strategy is not enough), and because they had very similar large-scale CBMs, the firms have been analysed in the narrowing category to provide practical examples for this group.

The identified platform technology was designed to manage internal and external information and resource sharing between large-scale organisations through software integrations with strict boundary conditions designed to regulate and enable safe interaction. Consequently, the most notable challenges were in the information provision category. B2B market participants are not typically aware of other organisations' resources, such as excess parking space, machinery, or tools. This can be traced to organisational culture and trust-related barriers resulting in an unwillingness to share information (see Table 20.3). Technology was used to afford safe and coordinated resource and information exchange, hence leading to higher levels of trust.

The affordances in the market intermediation category were also related to the lack of a reliable and efficient marketplace. Platform design enables innovation, transactions, and exchange between organisations. The challenges in the supply chains resulted from a lack of motivation and unwillingness to share resources with others. Technology was specifically designed for resource sharing by connecting to actors' internal systems. The actors were becoming aware of the new value creation (financial gains from renting equipment); hence, the case firms developed internal control and 'nudging' systems for actors to further improve their environmental performance. The affordances in the institutional legitimation consisted of regional areas' challenges in expanding and improving economic activities. The circular platform business ecosystem enables innovation and growth, which is important, especially in remote, slow-growth areas.

Slowing

The ten firms in this category operated in the B2B and B2C markets, allowing various resources from military surplus clothing to excess food products to be used responsibly and efficiently. Regardless of the case firms' CBM specifics (sharing or changing ownership), digital technology was used to slow down resource flows with extended and more efficient resource use. This curbed the need for new resource intake into the production–consumption cycle. The used technical solutions, e-commerce sites, and platforms allowed the demand side to make affordable purchases, while the supply side generated itself an additional source of income.

The technical solutions found were e-commerce sites and digital platforms, which both enable affordable purchases, while suppliers could gain an additional source of income. The affordances in information provision resulted from a lack of market awareness about the availability, features, and quality of the excess resources (see Table 20.4). The investigated e-commerce and platform technologies allowed multiple actors to simultaneously view the resource information

Strategy to narrow Resource flows

Table 20.3 Selected evidence for narrowing the resource flows *(cases #2 and #7)*

Solution category	*Challenge specified*	*Technology identified*	*Digital affordance purpose detailed (the socio-technical solution)*	*Outcome*
Information provision	Organisations unaware of other organisations' resource availability	Digital platforms, integrations between the organisations	Enables organisations to communicate, monitor, and share information directly	Circular resource information exchange builds new regional ecosystems
	Organisations unwilling to share internal information		Enables boundaries and rules that allow secure activities and information change	Organisations are reassured to trust in sharing information with technology
Market intermediation	Organisations missing a reliable and efficient marketplace		A digital platform marketplace allows fast transactions and exchange between organisations	Organisations build trust-based relationships and create new value in the circular resource marketplace
	Lack of trust		Trust building with strict technological rules, boundaries, and monitoring of all market functionalities	Build trust and enhance cooperation in the markets
Supply chain enhancement	The organisations incapable to start resource sharing because of lack of tech capabilities		Design enables exchange and transactions, rewarding and punishing according to the organisation's policies and targets	Normalising excess resource sharing; internal systems modified to support circular resource strategy
Institutional legitimation	Markets missing sustainable 'growth engines'		Enables innovation and circular market growth (i.e., industrial symbiosis, sharing practices)	Regional circular market growth leads to institutional trust and acceptance

Strategy to slow Resource flows

Table 20.4 Selected evidence for slowing the resource flows *(cases #6, #8, #9, #11, #12, #13, #14, #16, #18, and #20)*

Solution category	*Challenge specified*	*Technology identified*	*Digital affordance purpose detailed (the socio-technical solution)*	*Outcome*
Information provision	Markets are unaware of the excess resources (often generating costs for the owners)	Merged e-commerce and in-house stock management systems with resource data	Inform the markets about the availability of shared, excess, near out of date, reused or refurbished, and typically more affordable products	Increases market awareness, purchases are more economical for buyer while generating additional income for seller
	Markets lack information about the resource features	Websites, blogs, and digital platform-specific product pages with additional resource data	Detailed digital resource information (e.g., user instructions)	Reassures and informs markets how to use the circular resource
	Markets miss information about the resource quality	Collaboration platforms, e-commerce sites with detailed resource data	Product images, video, details, and labels; users' comments, ratings, and feedback	Builds trust and assists in the purchase/transaction decision-making by rating or specifying the resource quality
Market intermediation	Markets miss a reliable, fast, and scalable place to trade excess resources	e-commerce, collaboration, and innovation platforms forming the marketplace	Allowing several actors to view resource information and feedback, performing exchange, and transaction activities while the firm monitors marketplace performance	Enables exchange and transactions via digital technology between the resource owner and demand
	Already used products have a lower customer acceptance rate	Social media platforms, forums, e-commerce-designed loyalty programmes	Social media campaigns and movements, events, and promotion building to encourage consumers to believe already used is fashionable	Enables elevating customer acceptance rate and activates change in consumer behaviour
Supply chain enhancement	Missing efficient supply chains	APIs, ERP system integrations for real-time supply chain management	Allows real-time stock management and resource availability listings	Accelerates the efficiency of the circular supply chain
	Circulating is not the resource owner's priority	A digital platform or e-commerce site	Digital excess resource distribution channels can enable legal/regulatory changes	Circulating becomes a viable option and is made one of the priorities for the resource owner
Institutional legitimation	The resource is under tight regulatory monitoring	A digital platform or e-commerce structured and designed according to legal boundary conditions	Regulation-based actor, resource, market, and technology data collection to monitor the legality of digital activities	Allows reliability with internal reporting systems and immediate penalties if misconduct detected
	Lack of end user's responsibility in circulating resources	E-commerce site designed for reporting and crediting returns	Allows reversed value chain: resource or product returns, or maintenance, are credited back to customers' online accounts	Manages product during use with maintenance, and end-of-life returns by upcycling, recycling, and remanufacturing

and make transactions. For example, enterprise resource planning system integrations were used to display supply data from multiple sources in real time. The markets previously lacked an efficient marketplace and a low acceptance rate for the used products. In the studied digital marketplaces, suppliers were able to influence markets and resource acceptance rates with detailed information and open feedback. The affordances in the supply chain tackled end users' missing responsibility to send resources back to the production–consumption cycle and improve supply chain efficiency. Technology was designed to afford a reversed value chain: firms had built crediting systems if resources were sent back to the suppliers, for example, for recycling or reusing. In the institutional legitimation category, resource-specific legislation caused most of the challenges (e.g., rules for car sharing, food safety, lack of end users' responsibilities). Case firms' technologies were designed to meet specific legal boundaries, making them reliable and highly efficient. This had positively influenced institutions, leading to a higher decision-maker acceptance rate.

Closing

The four firms identified in this category operated in the B2B markets, either sourcing excess resources of other firms or taking back their own products to be processed again. The CBMs ranged from industrial-scale ingredient manufacturing to providing fashion and clothing industry services with a closed supply chain.

The identified technologies were e-commerce sites and platforms with integrations to actors' internal systems, allowing actors to view, share, and buy resources from other organisations. In the information provision category, the affordances tackled monitoring, measuring, and reporting environmental performance-related challenges (see Table 20.5). The case firms used internal data management systems to monitor, record, inform, and alert about the performance based on the given parameters. The market intermediation related to changes in markets (firms either changing consuming behaviour or wanting to meet the changing needs of the markets) and finding optimal channels to bring resources to markets. Technology-driven, closed-loop resource strategy may be an answer to circularity demands in the markets: behaviour change can be managed with digital crediting systems, but the emphasis was on sustainable production practices. The affordances in the supply chain were related to poor resource sourcing efficiency (e.g., getting resources back). Via integrated systems and an interface, the actors could make resources visible and review, compare, and purchase them. As a result, the markets saw products made with circular resources. In addition, resource returns and pickups were afforded online and credited based on their quantity and quality. The affordances in the institutional challenge category were related to local lack of capabilities in retaining the value of waste and excess resources. The identified technologies, including various digital platforms, offered a solution for the local decision-makers and business environment to integrate into the case firm's business ecosystem and become more sustainable. The case firms also sparked innovation, which further enhanced the local economy. In general, the more deeply rooted and empowering the CBM is in an area, the easier it is to convince the decision-makers on the firm's side.

Regenerating

The case firms in this category operated in the B2B markets, allowing various manufacturing and industrial-scale organisations to measure, monitor, and report their environmental performance. Their CBM utilised client's data (instead of circulating resources) to create value. The

Strategy to close resource flows

Table 20.5 Selected evidence for closing the resource flows *(cases #1, #4, #5, and #19)*

Solution category	*Challenge specified*	*Technology identified*	*Digital affordance purpose detailed (the socio-technical solution)*	*Outcome*
Information provision	Evaluating supply chain sustainability	Internal systems with integrations	Takes back and reprocesses the excess resources allowing full access to process data. Systems manage the supply chain and process data in real time	Supply chains sustainability monitored, and information provided
Market intermediation	Finding the right channels for closed-loop resources	Digital platforms with internal system integrations	Connects the dots in the markets	Creates reliable, efficient, and operational large-scale channels
	Changing 'fast consuming' behaviour	Closed, collaboration, and innovation platforms for marketplace building	Enables normal consumption with a closed-loop circular supply chain	Eases the need for behavioural change
Supply chain enhancement	Inefficient sourcing of sustainable resources	Closed digital platforms with internal system integrations	Organisations (e.g., large manufacturing firms) can review, compare their ingredient list, and purchase natural ingredients (processed out of specific plant waste or residue) via an online platform marketplace	Markets are offered products made with circular resources
	End users responsible for recycling the growing number of excess resources	E-commerce (digital platform) solutions with app configurations designed for returning and crediting	Resource/product returns/pickups ordered online, credited based on the quantity and/or quality of the resource	End users credited for returning resources to the production cycle
Institutional legitimation	Excess resource has no use or demand in its current form	A digital platform enabling the BM and resource distribution	Remanufacturing and/or refurbishing the resource/product to add value (e.g., drying adds a longer expiry time), then data used to convince markets and decision-makers	The end-of-life/excess resource is taken back to the production–consumption cycle and remanufactured into new products
	Undeveloped local business environment	A digital platform enabling local businesses to join	Partnerships with local authorities (public and private), integration to the business model assists in acceptance and innovation in the area	The local business environment developing and innovating with the CBM firm

case firms informed client organisations and suggested improvements in their attempts to form regenerative production–consumption cycles and improve the sustainability of the business environment.

The technologies used – integrated software, mobile application, IoT, and digital platform solutions – led to CBMs that allowed for measuring and following environmental performance to the detail (see Table 20.6). The reason why these digital CBMs exist is because of the information provision category. An efficient and reliable medium for measuring the real-time environmental impact was required, but because of complexities and undeveloped technical solutions, this was missing. These data-collecting systems can generate insights and warn and suggest actions when programmed to do so. The affordances identified in the market intermediation category were identified as missing links between the client's core activities and environmental reporting demands. The technology allowed the client organisations to monitor a specific part or the whole value chain, depending on the business requirements. The same challenges had resulted in affordances identified in the supply chain enhancement category: the organisations' insufficient measuring capabilities had led to unreliable measuring and, in some cases, false claims. The technology enabled organisational integrations within all members in the client's value chain to monitor and later improve the production–consumption cycle. The affordances in the institutional legitimation category reflected large-scale challenges and societal changes. The case firms used technology to enable environmental performance measurement, and at the same time, the whole data industry was developing, allowing decision-makers to tighten sustainability regulations even further, create standards based on best practices, and improve overall environmental requirements for all industries.

Implications and conclusions

This multiple case study has viewed digital CBMs through a socio-technical systems lens and expanded the understanding of the use of digital technologies in the CE context. Our findings demonstrate how firms with a circular resource strategy used digital affordances to overcome implementation challenges in the markets. This complements the literature at the intersection of digitalisation and CE transition (e.g., Chauhan et al., 2022; Demestichas & Daskalakis, 2020; Gauthier & Gilomen, 2016), along with the literature that has highlighted the role of technologies in enabling CBMs (Konietzko et al., 2020a; Bocken & Ritala, 2022).

The findings of the current study also offer several implications for practitioners. First, the managers of digital CBMs may use our findings as a guide to innovate, design, and select suitable socio-technical solutions for a particular circular resource strategy to overcome typical external challenges in their business environment. Our cases were divided into circular resource strategy-focused categories. Second, our findings have demonstrated how digital technology use improves market efficiency by building resource- and service-specific circular marketplaces that offer all actors enhanced resource traceability, information provision, supply and demand matching, and scalability. For practitioners, this means greater opportunities for innovating CBMs that further improve circular resource market development. Third, our study shows how firms design CBMs to meet market-specific legislation with digital technology affordances. For practitioners, this is highly important because these flexible design opportunities and choices can also lead to an expansion to new markets.

Last, a few key takeaways from our chapter. With the rest of the world, the EU is preparing for the TWIN transition – the digital and circular economic shift (European Union, 2020) – and we can expect technology-based CBMs to play a greater role in the transition. We believe that

Strategy to regenerate Resource flows

Table 20.6 Selected evidence for regenerating the resource flows (*cases #3, #10, #15 and #17*)

Solution category	*Specific challenge*	*Technology identified*	*Digital affordance purpose detailed (the socio-technical solution)*	*Outcome*
Information provision	Organisations challenged with strict measuring and reporting requirements	Combination of software integrations, mobile applications, IoT, and digital platform technology	Enables detailed data collection, early warning and problem detection systems and generating data insights for internal and external reporting needs	Knowledge about organisations' environmental impact and means for more accurate reporting
Market intermediation	Mismatching of the external measuring requirements and organisational capabilities		The combination of ICT solutions enables matching the information-providing needs of external (i.e., governmental) organisations and production-focused organisations	Organisations capable of monitoring a specific part or a value chain based on business needs
Supply chain enhancement	Organisations not able to measure their environmental impact (e.g., carbon footprint), products life cycle, or production		Enables software integrations with value chain participants to measure all steps in the production–consumption cycle	Organisations and beyond gain a data-based reliable indication of the environmental performance
Institutional legitimation	Decision-makers need organisations to perform cohesively and efficiently to regenerate instead of just extract		Enables institutions requiring reliable measuring practices and develop whole industries based on the best practices	Institutional decision-making (e.g., industry regulation) is data-driven, and robust, technology-enabled measuring practices will become the norm

understanding both the technical and social sides of the new digital CBMs is the most important managerial skills in the future for firms to be able to orchestrate and design sustainable business operations. Founders and managers of digitally enabled CBMs can use the findings of this study as an affordance benchmarking list to innovate, design, and select the best fit for a particular resource flow strategy in a specific industry. Our findings help demonstrate how digital technology can improve traceability and provide better information of resources and materials, match supply and demand between material users and providers, and scale up quickly by using digital platforms. We conclude that interdisciplinary studies are needed now more than ever to understand where technological development can take us and how it should be integrated into the core strategy and business model design.

Educational content

We would also suggest scholars and practitioners reflecting what was discussed in the chapter with the following questions:

1 Is there a clear market need for the business idea? For instance, are there underutilised or excess resources that might be valuable to someone but the marketplace or the matchmaker for those resources and materials is missing?
2 What are the key resource or market-related barriers that hinder circular business model implementation? How can digital technologies be used to overcome these barriers?
3 How can we utilise platform technology for strategic decision-making, for example, based on environmental impact calculations and predictions? Could the technology be used in advance to prevent negative impacts?

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21

ACCELERATING THE ADOPTION OF A CIRCULAR ECONOMY

An extended diffusion model for understanding consumer perceptions of circular economy products

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Introduction

Current-state economic systems are characterised by normalised over-production and over-consumption, linear supply-chain and production infrastructure, and consumer decision-making processes that are grounded in risk avoidance. The current economic system is vast and complex, and, most importantly, it is fundamentally self-organising. It is this self-organising characteristic that allows for the aspiration, and eventual evolution towards a more circular version of itself. Despite having a clear vision of what a circular economy (CE) could be, it is unrealistic to expect that the technology, infrastructure, and behavior needed to operationalise CE will simply emerge and be adopted without strategic, systematic intervention (Russell, 2018). Yet, at the most fundamental level we must acknowledge that even the most perfectly designed circular system, if not also accepted and adopted by consumers and users, will be ineffective. Accordingly, the day-to-day decisions and choices of individual consumers and users – about what behaviours to engage in, products to use, and/or technologies to adopt – may be just as important for catalysing the CE transition as the technologies themselves. Thus, alongside many other factors across policy, technology, infrastructure, market, cultural, and behavioral domains, the transition to a CE is dependent upon broad-scale, collective acceptance, adoption, and use of CE technologies, behaviors, and products, in lieu of conventional linear options. For these reasons, an enhanced, granular understanding and appreciation of how consumers evaluate and differentiate circular versus linear options, and make the decision to engage (or not) in CE, are critical.

The redesign or transformation of global consumption-production systems is central to the concept of a CE, with key objectives of increasing material efficiency, and reducing negative environmental impacts associated with primary material extraction and processing (International Resource Panel, 2018). Further, eco-innovation, which includes new technologies, processes, and approaches that target improved sustainability performance, has been identified as an important driver and catalyst of economic development and the achievement of the UN Sustainable Development Goals (Jové-Llopis & Segarra-Blasco, 2018; Machiba, 2010; OECD, 2009; Pujari, 2006; Rennings, 2000). As part of the CE, activities including direct reuse, repair, refurbishment, and remanufacturing (hereafter referred to as value-retention processes, or VRPs) can be employed to ensure product life extension and multiple product service life cycles through both

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product- and system-design innovation (International Resource Panel, 2018). Accordingly, VRPs can be considered life-extending eco-innovations of technology, product, and process that are key to transforming the traditional linear system of production and consumption into a more competitive, circular model of economy (Demirel & Danisman, 2019; Scarpellini et al., 2020). To accelerate the adoption of VRPs, as one aspect of an emerging CE, we must understand the factors that influence the individual's consideration and evaluation of non-new options, compared to new versions.

Given that the successful transition to CE requires a scaled adoption of VRPs and CE practices, the goal of this chapter is to expand upon conventional notions about the factors that influence mindsets, paradigms, and perceptions regarding the attractiveness of VRPs and other eco-innovations relative to new versions of a product. This chapter presents a review of the literature regarding relevant factors that are known to influence consumer perceptions of products, and the ways in which these factors can interact with one another. For example, when VRP businesses adopt a low-price focused sales strategy, they can also inadvertently signal a discounted level of product quality and a higher level of functional risk to their potential customers (Atasu et al., 2008; Hamzaoui Essoussi & Linton, 2010; Hazen et al., 2012).

Integrating relevant and diverse factors of influence from the literature, a robust VRP-specific diffusion model is then developed to provide insight into the factors that influence the desirability and attractiveness of VRPs from the consumer's perspective. Beyond price, consumer perceptions of non-new products are influenced by the individual's personal level of risk aversion, the cultural norms for being more (less) similar to others in one's personal network (e.g., heterophily vs. homophily), the inherent transactional risk (e.g., asymmetric information between seller and buyer), and how the absolute value of a product is portrayed (e.g., low price is inconsistent with high quality). Comparative case study analyses from the United States and China are then used to demonstrate the model, and to showcase the variety of factors that can be strategically leveraged by CE business leaders, including business developers, product developers, marketers, and strategists, to improve the perceived value and adoption of VRP product options in the marketplace.

Background

Value-retention processes within the circular economy

In today's increasingly globalised and growing industrial economy, traditional linear models of production and consumption, often referred to as 'take, make, and dispose', allow for the materials, components, and embodied value of products to be lost from industrial and commercial systems, most notably at the end of life (EOL) (McDonough & Braungart, 2010; Sundin & Lee, 2012). As a result, these linear production models require continuously high levels of new (primary and recycled sources) resource input and production activity to meet ongoing demand, and thus create negative environmental impacts (Franzò et al., 2021; The Ellen MacArthur Foundation, 2013).

In contrast to linear production modes, VRPs inherently and effectively preserve the functional form and integrity of product and/or components, enabling marginal benefits of material, energy, and cost-efficiency to be accrued at the unit level. By maintaining the functional form of the original product or component, consumer demand can be satisfied using fewer resources for production (e.g., material inputs, electricity), and generating fewer wastes (e.g., emissions, residues) (International Resource Panel, 2018; Russell & Nasr, 2022).

The following definitions for VRPs are used for this assessment:

- *Direct reuse* refers to the collection, inspection and testing, cleaning, and redistribution of a product back into the market under controlled conditions (e.g., a formal business undertaking) (Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, 2017 Document UNEP/CHW.13/4/Add.2).
- *Refurbishment* refers to the modification of an object that is waste or a product in order to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, with the result of making a fully functional product to be used for a purpose that is at least the one that was originally intended (Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, 2017 Document UNEP/CHW.13/4/Add.2).
- *Comprehensive refurbishment* differs from standard refurbishment in that it involves a more rigorous process within a factory setting, and is only undertaken by certain sectors including, but not limited to, industrial digital printers, medical equipment, and heavy-duty and off-road (HDOR) equipment parts (*Note: this VRP is not part of the case studies presented in this chapter).
- *Remanufacturing* refers to a standardised industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance or better (International Resource Panel, 2018).

The potential for CE largely emerges from the relative increased material efficiency that stems from the use of already manufactured goods as inputs to production, offsetting the requirement for primary materials and their associated life cycle impacts, for example, via VRPs. The reverse-system model that is necessary for VRPs can also be modified into a CE business model for which value creation, delivery, and capture can be more innovatively performed. However, it is important to note that, while VRPs enable product life extension, without an explicit goal of circularity, drawbacks may exist: these activities may be performed via relatively less efficient open-loop systems; they do not necessarily displace new production activities; and, they may lead to the creation of additional markets rather than the transition of existing markets (Russell, 2018).

The diffusion of value retention process innovation

To achieve net-positive impact, VRPs must be scaled significantly and must displace a meaningful share of new/primary production activities (International Resource Panel, 2018; Russell & Nasr, 2022). Thus, the diffusion of VRPs and VRP products into marketplaces around the world, catalysed via adoption by customers and users, is of key importance for informing CE implementation strategies at micro-, meso-, and macro-scales. The adoption of new innovations depends on the interaction of a variety of factors that can differ across and even within economies, including: supply-side factors such as the availability of information, the perceived relative advantage of the innovation, and information asymmetry between the buyer and seller, demand-side factors such as customer/user perceptions and incentives for adoption, and economy-wide factors such as social norms, culture, religion, and politics (Kimura & Hayakawa, 2008; McPherson et al., 2001).

Traditional diffusion modeling involves framing the market from the perspective of consumers considering a branded ‘new’ product (or technology) that is competing against other branded new products (Dev et al., 2020; Peres et al., 2010; Rogers, 2003). Diffusion models commonly assume a continuous probability distribution curve for product adoption, deconstructed into five key adoption stages: innovators, early adopters, early majority, late majority, and laggards (Bass, 1969; Rogers, 2003). Taking the form of an S-curve, the early period after a product arrives on the market consists of accelerating adoption rate increase, until a threshold market saturation level (inflection point) is reached; after this, the adoption rate declines at a declining rate until it becomes obsolete (Rogers, 2003; Sterman, 2000). Bass (1969) noted that two primary coefficients explained the majority of observed adoption: 1) the *coefficient of innovation*, also called the advertising effect, or the attractiveness of marketing, and 2) the *coefficient of imitation*, also called the word-of-mouth effect or network effect (Bass, 1969; Rogers, 2003). A variety of modifications and extensions of the Bass diffusion model have been proposed (Peres et al., 2010; Rogers, 2003), including the application of life cycle dynamics modeling in the case of new versus remanufactured products (Debo et al., 2009), as well as analysis of the environmental and economic performance of reverse logistics (Dev et al., 2020; Kazancoglu et al., 2021).

However, the innovation itself is also an important factor, and in the case of eco-innovations like VRPs there is limited evidence that adoption can be predicted according to traditional innovation diffusion models on the grounds that: (1) there is insufficient evidence to support the assumption that traditional diffusion theory is appropriate for eco-innovations (Karakaya et al., 2014), (2) eco-innovations cannot be treated like other innovations, and instead require their own specific theory and policy guidance (Rennings, 2000), and (3) in the context of the structural transformation necessary for CE, a systems-level view of markets, cultures, and other interdependent factors must be considered (de Jesus & Mendonça, 2018). In the specific context of VRPs, Dimoka et al. (2012) found that previously used products generate more complex perceived quality concerns than new products. Further, Abbey and Guide (2017) noted that consumer perceptions and behaviors related to remanufactured products (an example of VRPs) do not fit with the norms found in the literature on new products. In accordance with these observations regarding research gaps for both eco-innovations and VRPs, an extended diffusion model was developed to account for and reflect the conditions and considerations unique to VRP-product adoption, particularly consumer decision-making, adoption behavior, and CE market transformation.

Consumer perceptions of value-retention processes: Price, perceived quality, and risk

Literature on demand modeling for VRPs largely accepts two important aspects of traditional economic theory: 1) that the dominant pricing strategy for non-new products is to offer a price discount relative to the market price of the new alternative (Atasu et al., 2008), and 2) that the lower-priced product option will attract relatively greater demand. These are expected in a dynamic environment (Scarpellini et al., 2020; Tsai & Liao, 2017).

The perceived quality of the product is also a primary driver of the relative attractiveness of that product. However, regardless of the objective/absolute quality of a non-new product (e.g., as in the case of an as-new remanufactured product), market participants continue to assume and perceive a discounted, lower level of quality (Atasu et al., 2008; Hazen et al., 2012). Consumer sensitivity towards quality is often associated with the level of perceived functional risk associated with the product (Hamzaoui Essoussi & Linton, 2010), and this sensitivity can vary by both the product type (e.g., when considering a vehicle engine versus a production printer), and the production process (e.g., traditional manufacturing versus remanufacturing). Cultural values, as held by a specific group of people, refers to the acquired knowledge that people use to interpret experience and to generate social behavior (Bao et al., 2003; Hofstede, 1980, 1991). As such, the cultural values of networks, organisations, and communities become relevant to this study, as perception and attitudes towards VRPs, influenced by the degree of homophily and/or heterophily within the culture and network, will likely affect customer decisions to adopt or not adopt VRP products.

A consumer's intention to purchase is typically tied to their predominant behavior, perceptions and attitudes, as well as the context of the decision (Mirabi et al., 2015). Purchase intention has been used as an effective tool to predict the buying process (Ghosh, 1994) and is shown to be influenced by price, perceived quality, and perceived value, including internal and external motivations of the consumer during the decision-making process (Gogoi, 2013; Wang & Hazen, 2016). In this way, product attractiveness can ultimately behave as a proxy for market share: the relatively more attractive one product type, the relatively greater market share it will secure (Sterman, 2000). The antecedents to 'intention to purchase', a proxy of relative product attractiveness to buyers, are the perceived value of the transaction (PVT) and the perceived risk of the transaction (PRT) (Hazen et al., 2012, 2017; Lin et al., 2016).

Prospect theory is often applied in terms of product evaluation and purchase intention, in which it is assumed that consumers assign value to both perceived gains and losses associated with product choices (Kahneman & Tversky, 1979). A central understanding from prospect theory is that people are significantly more sensitive to the risk of loss than they are to the potential for gain, and they assign greater weighting to a perceived or objective potential loss, than to a perceived or objective potential gain (Kahneman & Tversky, 1979; Thaler & Sunstein, 1999). Applied to remanufacturing specifically, product characteristics of price, perceived value, and perceived quality are often framed relative to the newly manufactured version of the product directly from the original equipment manufacturer (OEM). According to prospect theory, since customers prefer a 'known risk' to an 'ambiguous risk', information is key; better knowledge leads to better assessments of product value (Hauser & Lund, 2003; Wang & Hazen, 2016). Further supporting the prospect theory approach are the findings by Wang and Hazen (2016) that perceived value and perceived risk are complementary predictors of purchase intention related to remanufactured products.

Ambiguity and information asymmetry

In the case of VRP products, there is often a significant ambiguity of product information that interferes with consumers' assessment of quality (Russell, 2018). This information asymmetry presents as the seller of the VRP product having more knowledge and information about the product than the potential buyer. In the remanufactured product market, this information gap constitutes a meaningful imbalance (Bittar, 2017) that accrues throughout the VRP value chain. VRP producers and distributors often do not understand the consumer values or concerns related to VRP products, retailers are not clear on how to market remanufactured products effectively, and consumers typically lack credible sources of good information needed to properly inform their purchase decision (Hazen et al., 2017; Russell, 2018).

Product knowledge refers to the level of awareness of specific product information that a buyer requires to make a purchase decision. There are different types of information/knowledge about a VRP product that help to inform the customer's perception of value and risk and are relevant to the buyer, as further clarified here:

- **Cost Knowledge of the Product:** The consumer's conscious knowledge of the relative gains and losses inherent, suggested and/or signaled in product price. (Guide & Li, 2010; Wang & Hazen, 2016).
- **Quality Knowledge of the Product**: The extent of the consumer's access to product quality information, product age (remaining utility), and their understanding of the quality of VRP products (Wang & Hazen, 2016).

- **Green Knowledge of the Product**: The consumers' understanding of environmental implications of a product, including resource and energy savings associated with 'green' products, and the sustainable practices of producers (Michaud & Llerena, 2011; Wang & Hazen, 2016).

Information asymmetry across each of these forms of product knowledge is most likely to present as a function of uncertainty and risk for the buyer in their evaluation of the product (Wang & Hazen, 2016). The high cost to both buyer and seller to acquire necessary product information, as well as the proliferation of counterfeit and low-quality products in the marketplace, contributes to the common tendency for VRP products to be perceived as 'higher-risk' than traditional new products (Wang & Hazen, 2016). For consumers with high risk aversion, products with uncertain and/or unknown performance and quality are seen as 'risky', and these consumers often refrain from adopting new products and technologies until they have been 'proven' in the marketplace (Bao et al., 2003; Steenkamp et al., 1999). Where a consumer does not have direct access to quality information but knows that many colleagues and peers have purchased VRP products, this may offset or mitigate concerns about the perceived risk of the transaction.

Figure 21.1 presents a summary descriptive model of the influence that these geographically, culturally, and individually diverse factors can have upon the consumer's perception of VRP product attractiveness, and thus, intention to purchase.

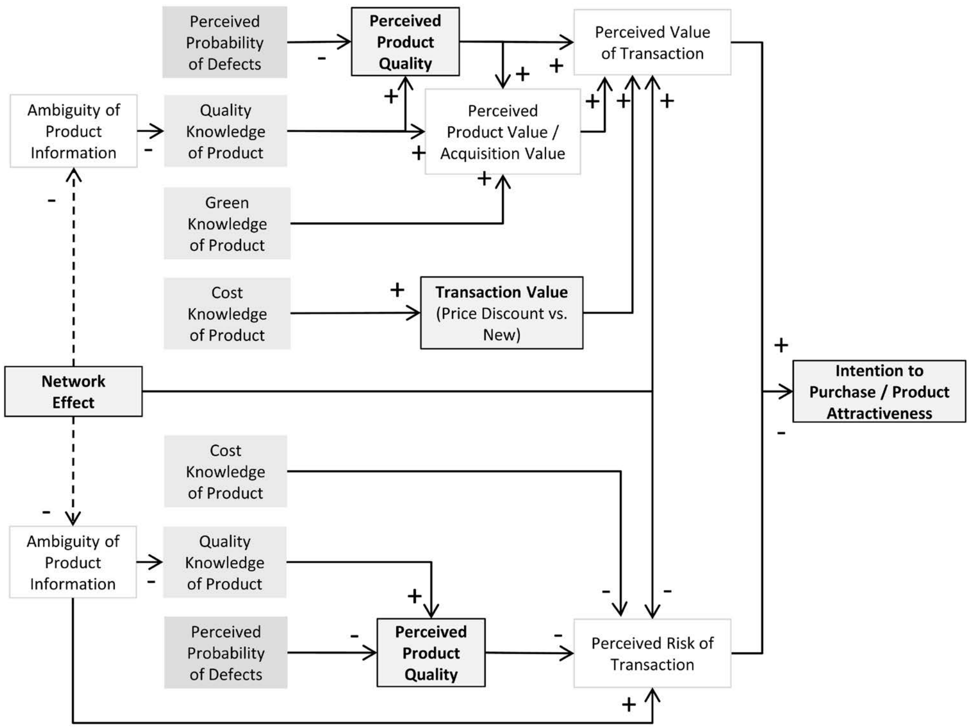

Figure 21.1 Summative model of factors affecting intention to purchase.

Source: Adapted from Wang and Hazen (2016); Hazen et al. (2017); Abbey et al. (2016); Monroe and Dodds (1985); Monroe and Chapman (1987); Ovchinnikov (2011); Abbey et al. (2015); Dimoka et al. (2012).

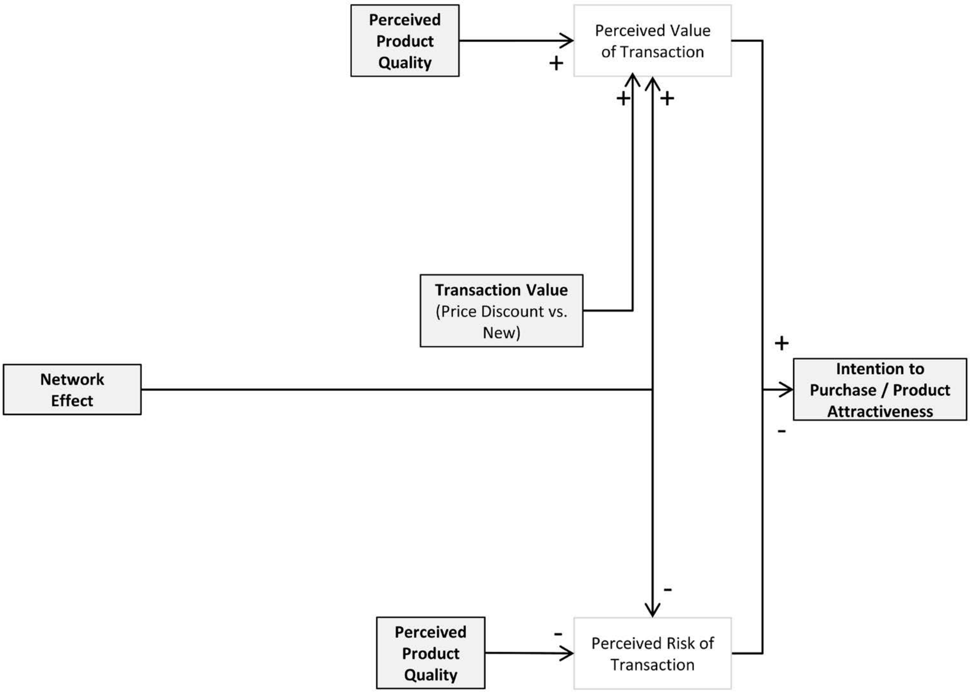

Figure 21.2 Simplified model of factors affecting intention to purchase new and VRP products.

Model methodology

The model presented in the following sections proposes a descriptive, extended diffusion model reflective of market condition and consumer behavior parameters that more realistically reflect the factors influencing the relative attractiveness of VRP products, in accordance with the literature. Accordingly, the parameterised approach presented in this section incorporates factors that are recognised as having influence upon the adoption and diffusion of VRP options (differentiated from new products) within the market (Abbey et al., 2015; Hazen et al., 2017).

For the purposes of developing a generalised model for the diffusion of VRP products, and in the absence of micro-data, a simplified descriptive model is presented in Figure 21.2. This simplified model retains primary factors of perceived value and perceived risk of the transaction (per Figure 21.1). Directionally, described by +/- notation, the simplified model relies on closely related, but more easily quantified measures of perceived product quality, transaction value, and network effect (Hazen et al., 2012; Wang & Hazen, 2016).

To test the relationships and logic of this extended model (hereafter referred to as the VRP diffusion model), simulation was completed via the demand modeling approach used for the International Resource Panel (IRP) model, and with the data provided for test cases of industrial digital printers in both U.S. and China markets (International Resource Panel, 2018). Once developed, the VRP diffusion model was evaluated using variance-based sensitivity testing across three first-order perspectives: 1) The directionality and magnitude of impact that potential uncertainty in select parameter values may have upon model outputs was evaluated to test the logic and robustness of the model; 2) High-level outputs of the model for the United States and China were evaluated relative to the results of a straight-line constant growth model, in which a simplified straight-line sector growth rate and constant relative market shares for new and VRPs were assumed; and 3) High-level outputs of the model for the United States and China were compared to assess the relevance of economy-specific parameters and insights for informing strategic insights and interventions.

A summary table of notations used throughout this model is provided in Appendix Table 21.1, along with additional case study data sets that are used to demonstrate the model later in this chapter.

Modeling product attractiveness

In lieu of micro-data specific to the extended model and products, relevant relationships and existing adoption/diffusion models have provided the foundation for the development of the VRP diffusion model. Using a modified version of a common market share modeling form (Sterman, 2000) (Equation 21.1), the estimated market share output is approximated based on the relative 'attractiveness' of the product. This reflects a simplified approach to modeling 'utility' as a proxy for consumer preference; however, in the absence of micro-data, the term 'attractiveness' is used instead.

$$\textit{Absolute Product Attractiveness}\left(APA\right)_t^j = \textit{Network Effect}_t * (\textit{Noise Factors}) \tag{21.1}$$

The primary driver of absolute product attractiveness (APA) is the network effect, with some influence from other 'noise' factors (Equations 21.1 and 21.2) (Sterman, 2000). Noise factors refer to random or other effects that might influence perceived product attractiveness, and which are not already accounted for in the network effect model, such as consumer values, product knowledge, perceived value, and perceived quality of the product.

As described in Equation 21.1, the absolute attractiveness of the product can be evaluated relative to the absolute attractiveness of all other product options of interest. Thus, *absolute* product attractiveness can be used as a proxy for relative product attractiveness to represent a reasonable estimate of resulting market share (Sterman, 2000). It is important to note that the VRP diffusion model incorporates multi-period capability to reflect how changing levels of the installed base (IB) (or quantity of product (j) via process *(i)* in the market (k)) can affect the attractiveness of the product over time (t).

$$\textit{Modified VRP Relative Product Attractiveness}_t^{j,i,k} = \frac{APA_t^{j,i,k}}{\sum_j (APA_t^{j,i,k})} \ \forall \ j \tag{21.2}$$

Modeling the effect of the network

The influence of the network effect is reflected using an exponential curve to account for the interdependence between the prevalence of VRP options in the marketplace, consumer awareness of the actual versus perceived quality of VRP products, and their participation in collection or reverse-logistics programs. The parameter 'Sensitivity to Network Effect' (Sc^k) accounts for the strength of the network effect upon the attractiveness of the product, and reflects key social and cultural conditions of an economy (k) (Peres et al., 2010; Sterman, 2000) (see the section on sensitivity to the network effect). Sterman's formula for network effect (2000) (Equation 21.3) is modified to account for the type of VRP product options (*i*), and corresponding perceptions of those options (Equation 21.4).

$$Network\ Effect_t^j = \left(e^{Sc^k \left(\frac{IB_t^j}{IB\ Thresh} \right)} \right) \tag{21.3}$$

$$Modified\ VRP\ Network\ Effect_t^{i,j,k} = e^{Sc^{k,j} \left(\frac{IB_t^{i,j,k}}{IBThresh} \right)} \tag{21.4}$$

The inflection threshold (*IBThresh*) reflects the 'relative market saturation' point in the diffusion curve, and has been extensively validated across a variety of diffusion models (Bhushan, 2012; Kumar & Kumar, 1992). Based on multiple studies of industrial products and processes in diverse markets, an assumed inflection point value between 20% and 35% accurately aligned with predictions of the top complexity-accounting diffusion models (Skiadas, 1985). As the installed base approaches the threshold ($IB_t^{i,j,k} \rightarrow IBThresh$), the network effect will increasingly contribute to the increasing attractiveness of the product. Please refer to Appendix Tables 21.2 and 21.3 for supporting case study datasets.

Sensitivity to network effect

The sensitivity of an individual's decisions to the decisions and attitudes of the others within their network is analogous to the concept of network homophily (Holme & Newman, 2006; McPherson et al., 2001). This sensitivity parameter (Sc^k) is a normalised impact factor that moderates the effect of the network on the diffusion and relative attractiveness of a product. Measured on a scale, the degree of homophily (strong influence of opinions and attitudes of those within the network, and thus greater expectation of conformity) (e.g., >1.0) versus heterophily (0–1.0) characterises the social norms and cultures of both markets and organisations (e.g., corporations). Adopting this parameter, the model assumes that sensitivity to the network effect in highly homophilic cultures (e.g., China) is >1.0, or relatively *more sensitive* to the network effect (Hofstede, 1991, 2011) (Appendix Table 21.4).

Prospect theory: The balance of perceived benefits and sacrifices

The relationship between perceptions of value and consumer preference and/or willingness to buy a product are well-documented (Dodds & Monroe, 1985; Monroe, 1990). Given the relevance of perceived value in the context of VRP products, the measure of absolute product attractiveness (Equations 21.1 and 21.2) is extended to explicitly incorporate perceived value (Equation 21.5).

$$APA_t^{i,j,k} = Modified\ VRP\ Network\ Effect_t^{i,j,k} * Perceived\ Value^{i,j,k} \tag{21.5}$$

A customer's perception of the value of a product ultimately reflects a trade-off between what is received and what is given; this is further clarified as the trade-off between benefit and sacrifice (Equation 21.6) (Dodds & Monroe, 1985; Monroe, 1990; Monroe & Chapman, 1987; Wang & Hazen, 2016).

$$Perceived\ Value^{i,k} = \frac{Perceived\ Benefits}{Perceived\ Sacrifice} = \frac{f(Acquisition\ Value, Transaction\ Value)}{f(Perceived\ Risk)} \tag{21.6}$$

Extending and formalising Monroe's original (1990) perceived value model (Equation 21.6), Equation 21.7 reflects the inclusion of VRP products and processes, and related considerations of perceived quality ($PQF^{i,j,k}$), perceived risk, and sensitivity to that perceived risk (e.g., risk of loss).

$$\textit{Modified VRP Perceived Value}^{i,j,k} = \left(\frac{\textit{Transaction Value}^{i,j,k} + \textit{Perceived Quality Factor}^{i,j,k}}{\left(1 + \textit{Sensitivity to Risk of Loss}^{k} * \left(1 - \textit{Perceived Quality Factor}^{i,j,k}\right)\right)} \right) \forall\ i, j, k \qquad (21.7)$$

From Equation 21.7, the simplified trade-off assessment of the perceived benefits (numerator) and perceived risk (denominator) associated with VRP product options in the market can be assessed.

Perceived benefit

Looking specifically at the numerator of Equation 21.7, value perceptions are significantly influenced by perceptions of quality (Wang & Hazen, 2016), and thus a perceived quality factor ($PQF^{i,j,k}$) is used as a proxy measure of the customer's perception of the value derived by acquiring the product (Dodds & Monroe, 1985). Transaction value ($TV^{i,j,k}$) is a framing device for the actual transaction price, in which any discount differential between price and acquisition value is assumed to create additional value for the consumer (Monroe & Chapman, 1987). This approach allows for the capture of the consumer's awareness of differential (e.g., their gain, achieved via price discount), such that a 30% price discount (relative to the acquisition value) creates equivalent transaction value of +30% (a factor multiplier of 1.3) for the consumer (Appendix Table 21.5). This equivalency was proposed by Jacoby et al. (1971), who contend that perceived value can be evaluated through price comparisons between a product and an appropriate substitute. This approach is common in the literature examining various aspects of the relationship between new and non-new (e.g., VRP) products, where the price-ratio for non-new products is typically assumed to be discounted from a new version (e.g., <1.0) (Abbey et al., 2015; Bittar, 2017; Dimoka et al., 2012; Guide & Li, 2010; Subramanian & Subramanyam, 2012; Wang & Hazen, 2016).

Perceived quality is typically represented in the literature as a simplified mechanism for common discounted quality perceptions that customers may have towards non-new or VRP products (Hazen et al., 2012; Lichtenstein & Burton, 1989). In many cases, the actual performance quality of the remanufactured product is equal to or better than the as-new version, and is typically supported by a warranty equal to that of a 'new' product (Lichtenstein & Burton, 1989). However, the market continues to perceive and assume a discounted quality associated with VRPs, and this model reflects this asymmetry (Appendix Table 21.6). Per Abbey et al. (2015), negative attribute perceptions have a significantly detrimental effect on remanufactured product attractiveness.

Perceived risk

Hamzaoui-Essoussi and Linton (2014) highlight that sensitivity to quality is often associated with the level of perceived risk associated with the product. In this model, it is assumed that the perceived quality factor captures, through normalised discounting, the perceived risk inherent in VRP products relative to the new product option. Given the discounting function of perceived risk, the denominator function in Equation 21.7 extracts the negative aspect of discounted perceived quality ($1 - PQF^{i,j,k}$). Risk aversion behavior and sensitivity to perceived potential for loss is known to vary across cultures and social groups (Hofstede, 1980, 2011). However, with a the loss function that is always steeper than the gains function, the effect is that people have greater sensitivity to the prospect of a loss than to the prospect of a gain, to a factor as much as 2.3 times greater (Kahneman & Tversky, 1979; Thaler & Sunstein, 1999).

The Sensitivity to Risk of Loss parameter ($\partial^{k,i}$) is introduced in the VRP diffusion model to account for the variation in sensitivity to risk observed across different cultures and social groups around the world (Appendix Table 21.7). There is a statistical basis for differentiating risk aversion/ sensitivity to perceived loss, for example, between the United States and China (Bao et al., 2003). The sensitivity to perceived loss parameter is culture-based and should be adjusted to account for the increased risk sensitivity associated with VRP products in different economies (k,i).

The VRP diffusion model

Bringing the insights from the proposed modified Equations 21.4, 21.5, and 21.7, together, the VRP diffusion model is presented collectively via Equation 21.8 and Equation 21.9. In Equation 21.8, the absolute product attractiveness (APA), specific to a product (j), process (i), and economy (k) is modeled.

$$Absolute\ Product\ Attractiveness(APA)_t^{i,j,k} = \left(e^{Sc^{k\left(\frac{IB_t^{i,j,k}}{IB\ Thresh}\right)}} \right) * \left(\frac{TV^{i,j,k} + PQF^{i,j,k}}{1+\left(\partial^k * \left(1 - PQF^{i,j,k}\right)\right)} \right) \forall\ i,\ j, k \tag{21.8}$$

In Equation 21.9, the final piece of the extended diffusion model, relative product attractiveness, is then assessed to estimate evolving market share of VRPs (as a proxy for demand) relative to each other and to new products, over time ($t = 7$) (Equation 21.9).

$$Relative\ Product\ Attractiveness_t^{i,j,k} = \frac{APA_t^{i,j,k}}{\sum_i (APA_t^{i,j,k})} \forall\ i,\ j,\ k \tag{21.9}$$

Sensitivity testing of extended diffusion model for VRP products

Structurally, the VRP diffusion model proposes that relative product attractiveness offers a proxy approach to estimating demand share of the market for VRPs in the absence of meaningful micro-data. Parameterised models can be particularly useful when seeking to simplify complex systems that are characterised by uncertainty, variability, or a lack of data. To demonstrate and test the model, two case studies of industrial digital printers (new and VRPs) are introduced to both the United States and China. Both Perceived Quality Factor (PQF) and Sensitivity to Perceived Loss (∂) parameters were tested at –20%, –10%, +10%, and +20% variance from the base VRP diffusion model values, using data provided by the International Resource Panel report (International Resource Panel, 2018)(see Appendix, Tables 21.1–21.7). Sensitivity analyses were conducted to observe the magnitude, directionality, and other descriptive influences of select parameters upon absolute product attractiveness (Equation 21.8) (Figure 21.3) and estimated product demand, a proxy based on relative product attractiveness (Equation 21.9) (Figure 21.4). These findings can help to clarify which interventions are likely to be most effective, when adapted to specific VRPs, product categories, and economies.

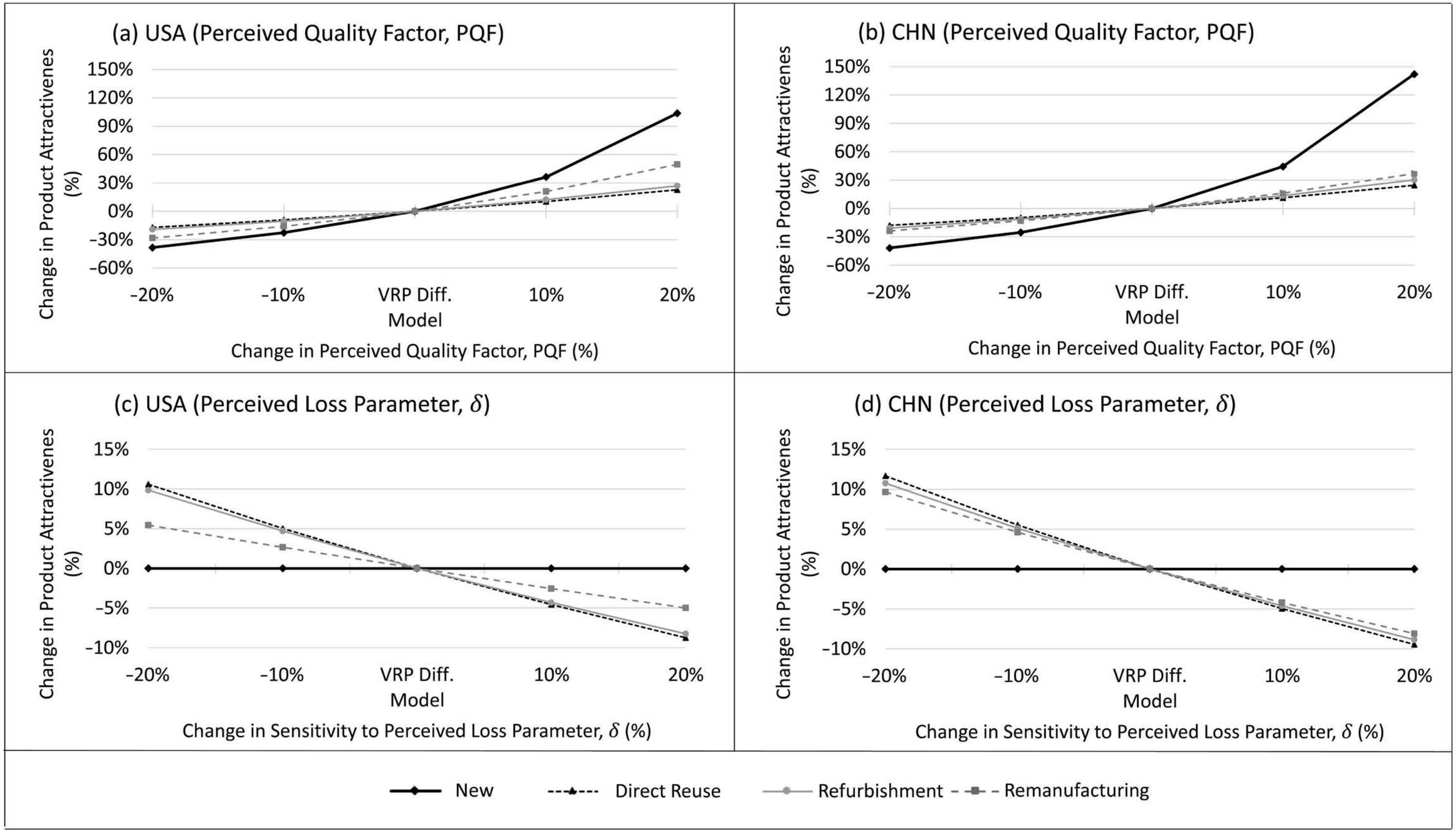

Figure 21.3 Sensitivity of absolute product attractiveness for case study VRP industrial digital printers to change in perceived quality (PQF) (panel (a), USA; panel (b), China), and to change in perceived loss (∂) (panel (c), USA; panel (d), China).

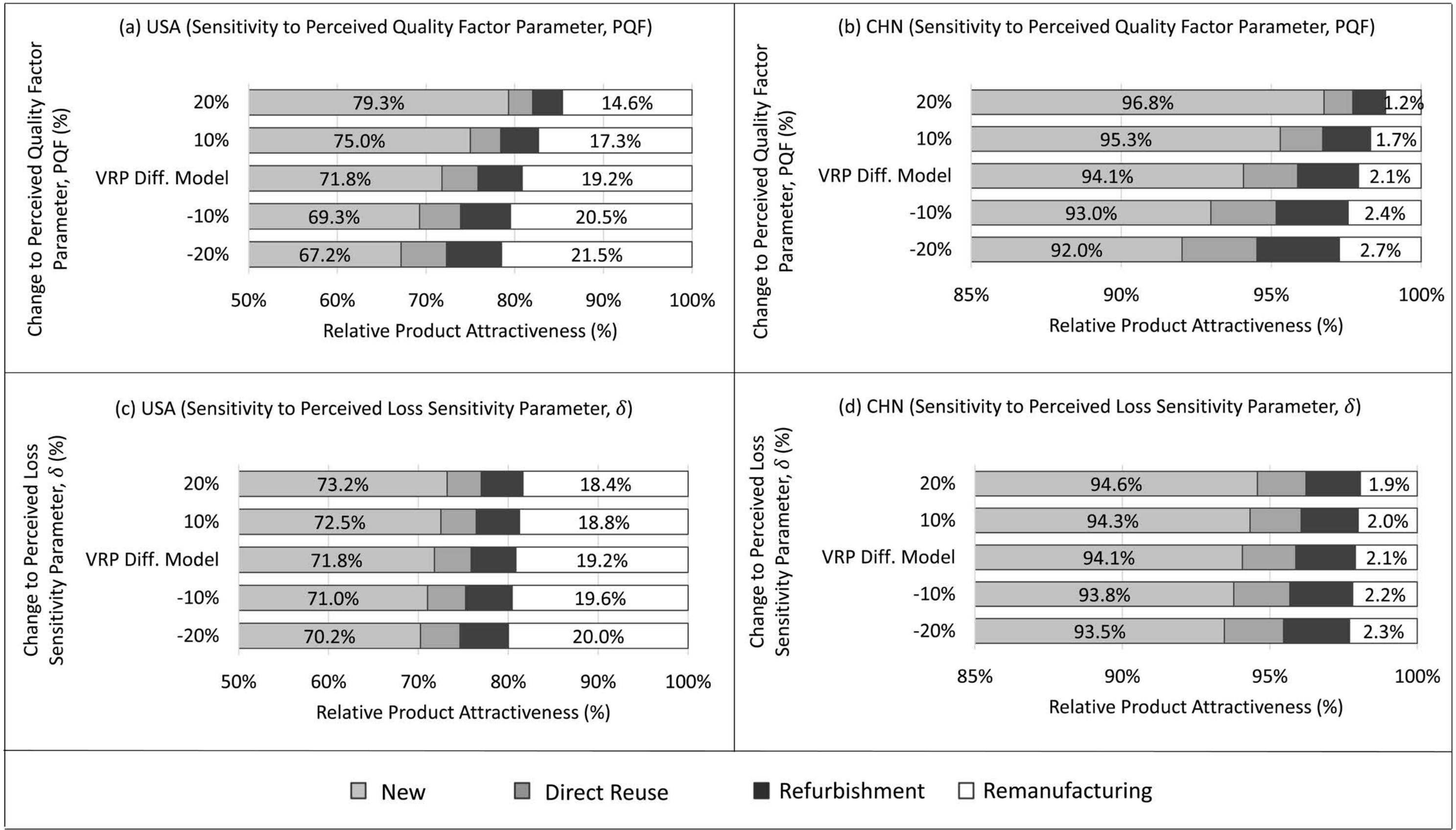

Figure 21.4 Sensitivity of relative product attractiveness for case study VRP industrial digital printers to change in perceived quality (*PQF*) (panel (a), USA; panel (b), China), and to change in perceived loss (∂) (panel (c), USA; panel (d), China).

Sensitivity of absolute product attractiveness

The sensitivity of new and VRP product attractiveness scores to variance in perceived quality (*PQF*) model parameters are described for the United States (Figure 21.3, panel (a)) and China (Figure 21.3, panel (b)); results for variance in sensitivity to perceived risk (∂) are described in Figure 21.3, panel (c) (USA), and Figure 21.3, panel (d) (China), respectively.

It is assumed that the market for new and VRP products is integrated, and as such, new products are also relevant to the VRP diffusion model. As shown in Figure 21.3, improving perceptions of product and process quality may have a significant impact (>100%) on the relative attractiveness of new products that are competing alongside VRP products in both markets. In the United States, a +20% change to perceived quality (increased perception of quality) results in a >100% increase in the relative attractiveness score for the new option (Figure 21.3, panel (a)). An even more pronounced effect (~150% increase) was observed when modeled for China (Figure 21.3, panel (b)). For VRP options in both markets, a +20% change to perceived quality results in an approximate 25% to 50% improvement in product attractiveness.

Sensitivity analyses were conducted for additional parameters to further inform understanding of the dynamic interactions of key factors upon product attractiveness. Results indicate a relatively strong inverse relationship between product attractiveness and the installed base threshold parameter (*IBThresh*); a relatively strong positive relationship between product attractiveness and the installed base sensitivity parameter (*Sc*); and a moderate positive relationship between product attractiveness and the transaction value parameter (*TV*). Further, the effect of variance to parameters of the network effect (*IBThresh* and *Sc)* were more pronounced for the attractiveness of new products than for the attractiveness of VRP products.

Sensitivity of relative product attractiveness (proxy for demand share of the market)

As a reminder, the model utilises product attractiveness as a proxy for demand share of the market. Despite the independent relationships between *absolute* product attractiveness and model parameters for new and VRP options (Equation 21.8), the interrelationships between parameters must also be considered in the context of *relative* product attractiveness for the purposes of estimating proxy demand share (Equation 21.9). This is because potential buyers will not be considering an option in isolation, but instead compared to all the other options that are available. The influence of variance in key model parameters upon the resulting demand share of the market are presented for the U.S. case study (Figure 21.4, panels (a) and (b)) and China (Figure 21.4, panels (c) and (d)). It is important to note that the analysis presented in Figure 21.4 reflects firm-level changes to perceived quality (*PQF*), for example, a brand-wide focus on perceived quality variance affects both new and VRP options; and firm-level changes in sensitivity to perceived loss (∂), for example, brand-wide responses to mitigate perceived risk via the provision of enhanced warranty coverage.

Figure 21.4 also reveals that, when applied uniformly across new and VRP options (e.g., brand-based), an increase in perceived quality will largely favor the resulting attractiveness of the new product. In the U.S. analysis (Figure 21.4, panel (c)), a +20% change to perceived quality leads to a 7.5% increase in the relative attractiveness of new products, and a resulting 4.6% decrease to the relative attractiveness of remanufactured products. The effect in China is similar, if less-pronounced: a +20% change to perceived quality at the firm level leads to a 2.7% increase in the relative attractiveness of new products, and a 0.9% decrease for the remanufactured version (Figure 21.4, panel (d)).

However, other firm-level interventions in pursuit of a desired outcome (e.g., increased relative attractiveness of VRPs) may be more effective for increasing the attractiveness of VRP products. For example, a –20% change in consumers' sensitivity to perceived loss (∂) (becoming less sensitive to perceived risk) can lead to a 0.8% increase to the relative attractiveness of remanufactured products in the United States (Figure 21.4, panel (c)); in China (Figure 21.4, panel (c)), the same change can lead to only 0.2% increase in relative attractiveness of the remanufactured option.

Discussion

Consumers do not view all VRPs as equal; consciously and subconsciously, VRP products are differentiated from one another and from new products on the basis of perceived risk and perceived benefits (Abbey et al., 2015; Dimoka et al., 2012; Rennings, 2000). Depending on the consumer's personal system of values, the valued attribute may be the discounted price, or it may be the relatively lower environmental footprint.

Not all parameters of the VRP diffusion model necessarily offer impactful or meaningful opportunities for system change; however, parameters that reflect the mindset and paradigm of the system and its actors may serve as potential points of intervention and leverage (Meadows, 2008). A key objective of developing the VRP diffusion model is to expand upon conventional notions about the factors that influence mindsets, paradigms, and perceptions regarding the attractiveness of VRP products. From these insights, potential strategic interventions to effectively communicate the appropriate value proposition to consumers can be developed and explored by different actors in the system to help accelerate the CE transition in the context of VRP products.

Balancing the perceived costs and benefits of VRP products and systems

The significant influence of perceived quality upon product attractiveness is a compounding opportunity. Perceived quality affects both the numerator and denominator of the perceived value formula (Equation 21.7), with an increase in perceived quality serving to increase value and decrease risk at the same time. Behavior economics, and prospect theory in particular, highlight the important influence of perceived risk in consumer decision-making. Intentionally introduced into the VRP diffusion model, this parameter also represents an important strategic opportunity that has not been fully utilised by many VRP producers. The simple presence of perceived risk may be enough to sway a consumer away from a VRP product for the perceived 'safety' of the new version. Accordingly, the simple insistence of VRP producers that, for instance, their remanufactured product possesses 'as new' quality, may be insufficient to reassure potential consumers of the integrity, quality, or expected performance of the product. Some common measures undertaken to alleviate perceived risk, such as a price discount, or provision of warranty, replacement and/or service guarantees, provide opportunities for VRP producers to engage with their customers in a manner that can address perceptions regarding quality and risk of loss at the same time.

Results shown in Figure 21.3 confirm the expected directionality of the model in the case of both sample economies, the United States and China, respectively: Per panels (a) and (b), there is a relatively strong positive relationship between product attractiveness and the perceived quality factor (*PQF*); and per panels (c) and (d), there is a moderate negative relationship between product attractiveness and the sensitivity to perceived loss parameter (∂). In Figure 21.3, panels (a) and (b), show that the positive relationship between product attractiveness and perceived quality is greater than 1:1 for both new and VRP options. However, as highlighted in Figure 21.4, panels (a) and (b), interventions to increase perceived quality must be applied at the VRP process level (e.g., efforts to shift perceived quality that are specific to remanufacturing), and not at the company level, such as brand-wide efforts to address perceived quality. Without effectively differentiating between the perceived quality of OEM new and VRPs in the approach, the status quo preference for new products will be reinforced, and long-term attractiveness of VRP options may be relatively diminished.

The negative relationship between product attractiveness and the sensitivity to perceived risk of loss (∂) affirms that, where a buyer is more sensitive to the risk of loss (e.g., concern about the potential for defect or failure), and in the presence of a perceived quality discount (e.g., for VRP options), the resulting decrease in product attractiveness will be more pronounced for VRP products. As shown in Figure 21.4, panels (c) and (d), efforts to mitigate or reduce perceived risk of loss (∂) can lead to increased relative product attractiveness (proxy for demand market share) in both the United States and China, respectively.

Increasing consumers' understanding and understanding of consumers

Given the interaction of key parameters, including transaction value, perceived quality, and the influence of the network, it is likely that interventions to promote VRPs will be more successful if all of these factors are addressed in a combined manner, for example: education campaigns targeting improved information and transparency about actual VRP quality for decision-makers, alongside price discounts, comprehensive warranties, and policy-based tools including subsidies and/or tax incentives.

Drawing directly from the model, initiatives to educate and provide greater consumer understanding can influence the denominators in both of the perceived value formulas (Equations 21.6 and 21.7). Consumers equipped with greater understanding of VRPs may be less disadvantaged by information asymmetry and better able to assess the appropriateness of VRP product options for their needs. This greater understanding and information ultimately lead to a reduction in product uncertainty, which drives improvements to both perceptions of the risk of loss and perceptions of VRP product quality. There are a range of interventions that can be undertaken, including the standardisation of VRP definitions and activities, such as in the Specifications for the Process of Remanufacturing, ANSI RIC001.2-2021 (American National Standards Institute, 2021). Further, increasing the transparency of VRP processes, and data-based demonstrations of the resulting product quality and performance are also crucial for reducing the information asymmetry that commonly undermines consumer understanding and perceptions of quality and risk.

Perceptions about the value of VRPs will vary by economy depending on social norms and cultural values, and therefore require considered and customised approaches by industry decision-makers and policy-makers. For example, customer-satisfaction guarantees, and price discounts may be more effective with U.S.-based customers who belong to more diverse (less homophilic) networks, and who have a lower sensitivity to perceived loss (Hofstede, 1991, 2011; Russell, 2018). In contrast, these approaches are less likely to be effective in the Chinese marketplace, where higher sensitivity to perceived loss, combined with strong hierarchical and homophilic network structures may make these types of interventions less effective (Hofstede, 1980, 2011; Russell, 2018). Interventions that may be more appropriate for the Chinese VPR market might instead target acceptance and adoption by key highly placed decision-makers, emphasising the overarching value of VRP options alongside their increasing prevalence and adoption (International Resource Panel, 2018; Russell & Nasr, 2022).

In the case of the parameters introduced in the VRP diffusion model, some are beyond the control of individual actors within the system. For example, the growth rate of a particular VRP product market cannot be directly influenced by a single VRP producer; and, the threshold at which a market could be considered ‘saturated’ by a particular VRP product is the culmination of many market actors and conditions. Understanding how these external or preexisting conditions might affect VRP product attractiveness and adoption can help to inform the decision-making of individual actors throughout the system. On the other hand, some of the modeled parameters can be directly influenced by single actors: The VRP producer can determine the transaction value/discount rate that is offered; similarly, consumer’s sensitivity to perceived risk may be lessened if they receive comprehensive warranty coverage on VRP products. Recognising that these parameters may vary across economies and cultures is also important: The optimal strategy for accelerating VRP diffusion in one economy may be very different from what would be most effective in another economy.

Conclusions and future work

The goal of the CE transformation is to shift the current state of the world’s economies towards more desirable ones; in the case of this study, we model this transformation via enhanced value retention that is possible through the adoption of VRPs – eco-innovations of process, technologies, and products – as part of CE. For market transformation to succeed, the thorough understanding and incorporation of decision-maker values, contexts, and perspectives into strategic system interventions is essential (York & Paulos, 1999). That means that all people must become engaged in CE practices and processes, including the purchase of circular-based eco-innovations such as remanufactured, refurbished, repaired, and reused products.

The VRP diffusion model was developed to explore the different factors that affect the perceived attractiveness, and thus the adoption of VRP products in the market. This parameterised approach focused on consumer perceptions brings additional value to the discussion, specifically the ability to identify and understand the influence of key underlying factors that may help to catalyse CE transition.

Consumers differentiate VRP products from one another, and from new products on the basis of perceived risks and perceived benefits (Abbey et al., 2015; Dimoka et al., 2012; Rennings, 2000). Relative VRP product attractiveness is influenced by the relationship between perceived benefit (value) and perceived sacrifice (risk of loss), and this model clarifies the factors that contribute to the formation of these consumer perceptions. Importantly, the VRP diffusion model demonstrates the need for strategic, thoughtful, and diverse approaches to scaling VRP adoption and catalysing CE, that account for both risk and reward.

Based on these findings, it is clear that catalyzing CE requires rethinking how VRPs, circular products, and other eco-innovations can be best presented and marketed to consumers to facilitate necessary adoption and scaling. Business developers and decision-makers engaged in VRPs as part of CE need to go beyond the basic price-discounting strategy in order to truly and strategically engage with potential customers. Rather than emphasising price discounts, VRP business developers and marketers need to focus on effective strategies to mitigate the perceived risks associated with non-new products, such as the potential for and cost of poor product performance or failure. Such mitigation strategies may include providing potential customers with transparent information about VRP product provenance and company operations, offering risk-free product trial periods, providing enhanced (as-new) product warranty coverage, and communicating a clear process that can be followed if failure occurs.

VRP producers must adopt more refined and strategic marketing and customer engagement practices. The simple insistence of VRP producers that, for example, their remanufactured product possesses 'as new' quality, may convey the potential benefits of the VRP product, but is likely insufficient to reassure potential consumers of the integrity, quality, or expected performance of the product. As demonstrated by the case studies, marketing and operational strategies that effectively mitigate or reduce the consumer's perceived risk of loss can lead to increased perceived VRP product attractiveness.

It is also critical that business developers and marketers recognise the importance of appropriately differentiating VRP products from new versions. A global, one-size-fits-all marketing strategy may backfire. Given the influence of cultural norms for social and professional networks, the promotion of VRP products in the United States, for example, should consider the relatively more heterophilic, and relatively less risk averse nature of the average American customer, and thus, should be considered as very different from the promotion strategy used in a different region of the world.

Finally, consumers who have greater knowledge of VRPs will be better able to assess the relative costs and benefits of the VRP products available to them, and accordingly, they will be less susceptible to the perceived risk that can arise from situations of information asymmetry. Hence, consumer education and industry transparency initiatives can contribute to improved perceptions of VRP product quality and reduced perceptions of risk and uncertainty. Consumer education can be initiated by individual VRP companies, or collectively through coordinated industry and/or policy efforts. For example, the Remanufacturing Industries Council (RIC), representing remanufacturing companies and associations from around the world, has launched Global Reman Day (April 13, annually) as a day to advance awareness of the remanufacturing industry through coordinated remanufacturer-hosted events, education and awareness campaigns, and workforce development initiatives.

There is significant need for future research to assess and better understand the unique factors and influences that facilitate the adoption of eco-innovations, including VRPs, in order to support a faster transition to CE models. The results and analysis of this proposed VRP diffusion model have revealed insights that affect the modeling approach undertaken for eco-innovation and non-traditional product offerings, as well as the implications of different strategic interventions in different economies, cultures, and for different products. Understanding the role of different social, communication, and influence norms as a part of the innovation diffusion process will help to inform and develop marketing and communication approaches (e.g., targeted audience) that are more effective at modifying the perspectives of key influencers.

As part of future research initiatives, this model must be tested with data across more diverse products, processes, economies, and cultures. Further, the collection of market data that can be used to validate the outcomes of the model, for example, the relative attractiveness of VRP products as a predictor of market share, are needed. In terms of further refinement of the model, a logical extension of this proposed VRP diffusion model is the incorporation of quantifiable environmental benefits associated with VRPs into the perceived value function.

Educational content

1. How can VRP producers improve the relative attractiveness of VRP products?
2. How can VRP producers manage the perceived risk associated with VRPs?
3. Why is it so important for VRP producers to initiate dialogue with customers?
4. Why is there is no 'one-size-fits-all' strategy for marketing and promoting VRP products?

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Appendix

SUPPORTING DATA SETS USED TO MODEL AND CONTRAST THE UNITED STATES AND CHINA VIA THE EXTENDED VRP DIFFUSION MODEL

The data presented in the following tables represents the inputs used to demonstrate the VRP diffusion model presented in this chapter. There are seven tables in this section. There is an additional reference list for the seven tables in this section.

Appendix Table 21.1 Summary of notation for VRP diffusion model

Notation	*Description*
t	Number of economy-level model simulation periods (*t*=7)
k	Sample economy, e.g., China and USA
j	Case study product (3 industrial digital printers)
i	Production process: new, direct reuse, repair, refurbishment, and remanufacturing
Sc	Sensitivity to Network Effect; a measure of degree of homophily/heterophily within culture and/or social group
IB	Estimated total installed base of product (*j*) via process (*i*) in economy (*k*) in period (*t*)
IBThresh	Inflection threshold within VRP diffusion model, established to meet inflection target for case study
TV	Transaction Value: Expressed as relative to new product price, framed to highlight discount as a value gain
PQF	Perceived Quality Factor: Expressed as relative to new product quality, framed to highlight discount as risk
∂	Sensitivity to Perceived Risk of Loss; a measure of degree of risk-aversion and sensitivity to loss within culture and/or social group

Appendix Table 21.2 Estimated market share/installed base ($IB_t^{i,j}$) for the United States (US) and China (CH) product (*i*) and process (*j*) utilised for model demonstration. Estimates of market size for China are based on international trade data from the Observatory of Economic Complexity, using 2014 data (Observatory of Economic Complexity, 2015). Production printers are based on HS92 Code 8443: Industrial Printers/Printing Machinery, and printing presses are based on HS92 Code 844313

Case	*Product*	*Total Est. Market Size (Qty)*	*New (%)*	*Reman (%)*	*Comp. Refurbished (%)*	*Direct Reuse (%)*
CH	Digital Production Printer	2,517	94.8%	0.0%	0.2%	5.0%
	Digital Printing Press #1	2,108	94.9%	0.0%	0.1%	5.0%
	Digital Printing Press #2	2,176	94.8%	0.0%	0.2%	5.0%
US	Digital Production Printer	20,537	66.3%	32.9%	0.5%	0.3%
	Digital Printing Press #1	1,838	66.3%	32.9%	0.5%	0.3%
	Digital Printing Press #2	1,838	66.3%	32.9%	0.5%	0.3%

Appendix Table 21.3 Market and inflection threshold (*IBThresh*) parameters for the United States (US) and China (CH) product (*i*) and process (*j*) utilised for model demonstration. Production mix estimates for China are based on adjusted U.S. market values (UNEP IRP Berlin Workshop, 2016)

Case	*Product*	*Product*	*New (Qty)*	*Reman (Qty)*	*Comp. Refurbished (Qty)*	*Direct Reuse (Qty)*
CH	Est. Installed Base	Production Printer	2,387	0	4	126
	Quantity (Year 1)	Printing Press #1	2,000	0	3	105
	($IB_{t=1}^{i,j,k}$)	Printing Press #2	2,064	0	3	109
	Est. Absolute Inflection	Production Printer	692	692	692	692
	Threshold	Printing Press #1	580	580	580	580
	(*IBThresh*; 27.5%)	Printing Press #2	598	598	598	598
US	Est. Installed Base	Production Printer	13,608	6,773	103	55
	Quantity (Year 1)	Printing Press #1	1,218	606	9	5
	($IB_{t=1}^{i,j,k}$)	Printing Press #2	1,218	606	9	5
	Est. Absolute Inflection	Production Printer	5,648	5,648	5,648	5,648
	Threshold	Printing Press #1	505	505	505	505
	(*IBThresh*; 27.5%)	Printing Press #2	505	505	505	505

Appendix Table 21.4 Sensitivity to network effect (*Sck*) parameters of case study process (*j*) and market (*k*) utilised for model demonstration

Sensitivity to Network Effect (Sc^k) for All Case Study Industrial Digital Printers	*New*	*Remanufactured*	*Comp. Refurbished*	*Direct Reuse*
China	1.00	1.30	1.30	0.30
USA	1.00	1.10	1.10	0.30

Appendix Table 21.5 Transaction value (*TVi,j,k*) parameters for product (*i*) and process (*j*) in the international marketplace utilised for model demonstration. The estimated average market price was based on average customer market prices taken from a sample of publicly available pricing for case study products in 2018. The transaction value factors reflect equivalent price discounts relative to the prices of the new product option. For the purposes of generalization, these values are held constant for both U.S. and China markets. Based on weighted results of price discount offered by imaging product remanufacturers, relative to new (per Nasr et al., 2017)

	Est. Avg. Market Price ($USD)	*Transaction Value Factors ($TV^{i,j,k}$)*			
		New	*Remanufactured*	*Comp. Refurbished*	*Direct Reuse*
Production Printer	$97,600	1.0	1.29	1.50	1.80
Printing Press #1	$494,000	1.0	1.29	1.44	1.80
Printing Press #2	$616,000	1.0	1.29	1.44	1.80

Appendix Table 21.6 Perceived quality factor (*PQF)* parameters for the United States (US) and China (CH) product (*i*) and process (*j*) utilised for model demonstration. The PQF for remanufactured products in China is reduced relative to the United States per Matsumoto, Chinen, and Endo (2017)

Case	*Product*	*Perceived Quality Factors ($PQF^{i,j,k}$)*			
		New	*Remanufactured*	*Comp. Refurbished*	*Direct Reuse*
CH	Production Printer	1.0	0.75	0.7	0.6
	Printing Press #1	1.0	0.75	0.7	0.6
	Printing Press #2	1.0	0.75	0.7	0.6
US	Production Printer	1.0	0.9	0.7	0.6
	Printing Press #1	1.0	0.9	0.7	0.6
	Printing Press #2	1.0	0.9	0.7	0.6

Appendix Table 21.7 Sensitivity to perceived loss (∂) parameters for case study economies (*k*) and processes (*i*). The sensitivity to perceived loss parameter for the VRP products are estimated by multiplying the mean risk aversion score (Bao et al., 2003) by the sensitivity to perceived risk of loss (Kahneman & Tversky, 1979)

	Sensitivity to Risk of Loss (Kahneman & Tversky, 1979)	*Mean Risk Aversion Score (Bao et al., 2003)*	*Adjusted Sensitivity to Risk of Loss (∂^k)*			
			New	*Remanufactured*	*Comp. Refurbished*	*Arr. Direct Reuse*
China	2.3	14.76/12.44 = 1.19	2.73	2.73	2.73	2.73
United States	2.3	12.44/12.44 = 1.00	2.3	2.3	2.3	2.3

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CO-CREATION ART TO CATALYSE COMPETENCIES FOR A SUSTAINABILITY TRANSITION

Juha Suonpää and Peter Sramek

Introduction

A growing number of academic researchers are eagerly looking to identify an essence of interconnecting competency needs that are required by the nature and implementation of sustainable development. As one example, *Issues and Trends in Education for Sustainable Development* (Leicht et al., 2018), published by UNESCO in 2018, posits a type of future citizenship: 'sustainability citizenship'. It outlines competency needs according to which individuals might better learn to understand the world's complex nature and adapt to the uncertainty and social changes that are occurring at an increasing pace (Wals, 2015; Wals & Lenglet, 2016). The most significant competency articulated here is expressly related to being able to operate within heterogenic groups, an ability that Rychen (2003) in *Key Competencies for a Successful Life and a Well-Functioning Society* also defines as essential for the global future.

Such ideologies concerning a sustainable future involve recognising and understanding relationships, the ability to understand and evaluate various future outlooks, the competency to understand the norms and values that underlie one's actions, and the collective ability to develop and implement innovations. Professor of Higher Education Pedagogy at the University of Vechta Germany Marco Rieckman also compiles key competencies that are particularly important for achieving the ideology and actions of sustainable development. According to Rieckman, the education competencies must:

> enable and empower individuals to reflect on their own actions by taking into account their current and future social, cultural, economic and environmental impacts from both a local and a global perspective. [This] requires individuals to act in complex situations in a sustainable manner – to explore new ideas and approaches and participate in socio-political processes, with the objective of moving their societies progressively towards sustainable development.
>
> (Rieckman, 2018, pp. 44–45)

Seen from this perspective, the need for innovative, transformative solutions is obvious. The research and debates concerning the development of circular economies address many key

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challenges related to the need for systemic change, the reexamining of linear growth thinking, consideration of the interconnectedness of materials, issues of energy and biodiversity, and an ongoing assessment of the overall impacts of climate change. Alongside these, the need has emerged for critical research into decision-making, cultural change, ethics and social justice, and for alternative and more creative visions of the circular economy (Frienant et al., 2020, p. 4.).

Unfortunately, the term 'circular economy' (CE) is often used to refer merely to a type of enhanced waste recycling (e.g., Ghisellini et al., 2016) and if CE is defined mainly as a technical problem, as measurements and indicators, it may not motivate civil society to build constructive ways to create a less biosphere-destroying future (Kovacic et al., 2019). It is a question of comprehensive change. According to a newly released IPCC report (IPCC 2022), the environmental catastrophe caused by climate change will threaten all of humanity in immediate decades, sooner than previously predicted. Despite knowing this, challenges are faced by science-based approaches in working to mobilise change at individual, societal, governmental, and global levels. The IPCC 2022 report attempts to present a compelling case in describing the consequences of climate change, but it seems that scientific reports alone are not capable of instigating the substantive change required to achieve a sustainable future (Maggs & Robinson, 2020, p. 13).

At the same time, the situation may not be as bleak as the IPCC 2022 report suggests. If we consider that the technical solutions are known for tackling the challenges of climate change and development of CEs, what we urgently need is a new way of thinking that breaks away from old, entrenched mindsets, which are at the core of our current problems. Put in other words, we must answer how one might turn the 3,675-page IPCC 2022 report into something that speaks to people's hearts rather than their intellects.

Transitions to CEs and sustainable development require humanity to let go of the rigid thinking of the past that has been primarily characterised by selfish interests. We must adopt a creative re-imagining process, which will generate a social perspective on a global scale. We must imagine the world in a different way (e.g., Lehtimäki & Pöyhönen, 2020). The traditional 'business as usual' mindset is not likely to yield radical or creative ways to move forward in ever-changing environmental circumstances. Here, we propose that creative activity in the arts, when used in collaborative forums, can provide effective models for such shifts in perspective (Figure 22.1).

The recent trend away from a policy-maker form of agency in the arts to a global changemaker agency can be seen in numerous art-driven projects worldwide. An example of this is UNESCO's global effort to support artists and ensure access to culture in ResiliArt and Art of Change 21, a collective project positively contributing to addressing climate change. The utilisation of arts-based collaboration concepts is also possible in academic contexts, such as the Finnish multidisciplinary research project CICAT2025. A critical part of this project has been the review of visual catalysts as an essential factor toward a sustainable CE (CICAT2025).

The catalytic potential of art

Art can be a catalyst. It can inspire reflection on the individual's role in local and global communities, often calling into question society's norms and practices. As described in the open call for participants in the Visual Catalysts workshop in Berlin (Figure 22.2), art can connect people so that new perspectives are learned from others. By strengthening strategic competencies that support sustainability thinking, art can play a significant role in creating change.

Artistic methods provide tools that are both intellectually and emotionally engaging. The development of collaborative interaction strategies within groups has the potential to address the challenges of animating change and support necessary shifts in thinking. Active participation in

Figure 22.1 Co-creation in process, Visual Catalysts workshop, University of Europe for Applied Sciences, Berlin 2019.

Source: The authors.

creative experiences may inspire individual motivation and reveal alternative approaches to issues. Working collaboratively creates spaces in which empathy and understanding of others can occur.

In business, art has traditionally been utilised as decoration and entertainment to create a pleasant environment. But in fact, during the past 20 years, different types of organisations have

> *… … Visual representations are a powerful global language and through a process of international co-creation, artists can be future change makers, creating new visual catalysts that can speak across cultures. Artistic methods can make us see things from a new angle. Our way as consumers needs to be seen from fresh perspectives in order to move towards sustainability.*
>
> *Creativity happens on the edges of different cultures. Every individual's choices have an effect. Personality and locality matters. In the global sphere, respecting local perspectives is the nucleus of change for a sustainable future. … …*

Figure 22.2 The open call for a Visual Catalysts workshop INTAC–VICAT in Berlin, 2019.

begun giving attention to the impact of art as a noteworthy enabler of change. Although it is difficult to measure the effects of art projects realised within organisations, educators Berthoin Antall and Strauß (2013, p. 3) have discussed research in order to identify a multitude of categories of art intervention impacts. Art has strategic importance. For example, artworks in the workspace impact the development of organisations, not only with the improved general work atmosphere, but also in an expansion of social relationships and networks that increase team behaviour and a sense of belonging. There is improved productivity and an increase in business operations when art is included in the environment.

More than this, in her well-known book *Artful Creation* (Darsø, 2004), educationalist Lotte Darsø points out the instrumental opportunities of art. Nonverbal communication, improvisation, and the production of co-created art may result in meaningful shared experiences in a work community, and in this way, creative exploration becomes a strategic method for empowering and including workers within change. Artistic methods of expression combine with art's ability to communicate on an emotional level.

Creative art experiences can reshape the thinking and perspectives of individuals – in their reflective capacity and in their ability to process positive and negative emotions. There is personal growth and the development of self-confidence, encouraging the learning of new skills and methods and, thus, the strengthening of courage and risk-taking abilities. In this manner, working methods drawn from art-based strategies can help to build more comprehensive or alternative perspectives and support innovative capacity even when change and uncertainty prevail. The ability to engage with a diversity of inputs or to work in collaboration can lead to qualitative changes in both process and outcomes.

Artistic methods change the internal dynamics of organisations, communities, and businesses by challenging previous ways of doing things and creating alternative ways of thinking. Such activities can break away from analytical and structural approaches to problem-solving, allowing for playful, imaginative, and open-ended visualisations through speculative exploration and emotional expression, which are based on images or gesture rather than facts and figures. Broader forms of thinking can result, rather than technical and goal-focused statements.

Crucially, according to Berthoin Antall and Strauß (2013), art's activating potential is enabled by a shifting of established operating models, creating interspaces between formal structures and informal relationships. In this, collaboration can be key. When singular projects develop into joint community-based operations, organisations accumulate added potential, strengthening their effectiveness. New perspectives and ways of operating energise the experience of both organisations and individuals, thus activating change. Art education benefits from a shift away from a perspective that concentrates on the production of works for a materialistic society to one that collaborates in envisioning change.

When applied to thinking about sustainability and CE, such shifts in methods of working with groups can support the achievement of significant competencies (Rieckman, 2018, pp. 44–45): collective and cross-cultural thinking; emotional and empathetic awareness; critical ability to explore new perspectives. Such a role for art as a catalyser can be harnessed for enabling strategic sustainability change and since the most important future sustainability competence is precisely related to working with heterogeneous groups (Rychen, 2003), it is of particular interest to examine how artistic collaboration has pedagogical potential to shift perspectives and build a sense of global solidarity, togetherness, and willingness to participate.

When working across communities, visual tools are useful where cross linguistic or literacy barriers occur, which is why image-based models of community action and education have developed in such contexts (Barndt, 2001). The use of photography to examine the world can provide groups with an open-ended format that thrives through individual agency and collaboration between facilitators and participants. Participatory methods like Creative Voice (Rivera et al., 2018) and PhotoVoice (Bennett & Dearden, 2013) have long used photography to give people a communal and democratic means of critical exploration of their worlds.

In the context of sustainability challenges, where the sharing of ideas that lead to options and solutions is so important, artists can model a circular and iterative process, inspired by others and visualising concepts into novel forms that contain elements of surprise. Surprise, in turn, makes us aware of our ignorance (Gross, 2010) and awakens curiosity for change. By sparking new perspectives and emotions, art and creative visions can lead to new thinking, changes in social behaviour, and real action. These are needed for catalysing our transition to a sustainable economy (e.g., Aarikka-Stenroos, 2020; Jokinen, 2020; Ladkin, 2020; Suonpää, 2020; Taylor, 2020).

Co-creating art and competencies through international collaboration

This article asks, What is a potential role of an international collaborative art process in catalyzing competencies for sustainable CE? There is great motivation within the arts and culture fields for participation in positive steps towards more sustainable futures, but how does one effectively harness the energies, inspiration, and deeply affective aspects of the cultural, visual, and aesthetic realms, in order to catalyse substantive transitions in global thinking?

Today, photography is no longer a specialist activity. Most people take and share photographs and videos, providing an accessible means of communicating ideas and experiences. In a rapidly changing world, it is apparent that traditional ways of imparting knowledge cannot be relied on as before and the use of visual tools can be productive in many more learning contexts than simply the training of artists. We do know that visual images communicate and that we connect with them on an emotional level. They provoke critical thinking and provide a common arena where diverse cultures can cross-fertilise (Bertaux & Skeirik, 2018). Today, emotionally charged images and videos can spread rapidly on social media, and thus are capable of sparking an unprecedented wave of change, particularly when they speak to our humanity. For these reasons, art and creative activities can be a space where hope is embodied, where artists and audiences can face questions while envisioning and proposing solutions. Art allows for inclusion of non-experts in considering and imagining the future.

Here, we review the operations of the International Art Collaborations (INTAC) network of international institutions of higher education and the resulting change-enabling potential that they exemplify. INTAC was developed in the 2010 by Professor Peter Sramek (OCADU, Canada) and Head of Fine Art, Dr. Juha Suonpää (TAMK, Finland) to provide art students with international creative competence using a newly available combination of online tools provided by the internet (INTACnet, 2018). Early beginnings evolved into a cyclical program with a history that spans over a decade (see Figure 22.3).

Our case study reviews the INTAC network's circular pedagogic collaboration process and outlines some of the outputs, taking an ethnographic starting point (cf. Gordon et al., 2001.). We approach the artistic impact of the collaborative process primarily from an aesthetic perspective, paying attention to how art can inspire and engage new ways of thinking (cf. Sköldberg et al., 2015). Our research material is mainly based on the participatory observations of this article's authors over a period of 12 years and review of a range of INTAC-produced works, through description and content analysis, particularly referring to photographic and video-based art projects. Alongside the conclusions drawn from the art projects themselves, it is important to review

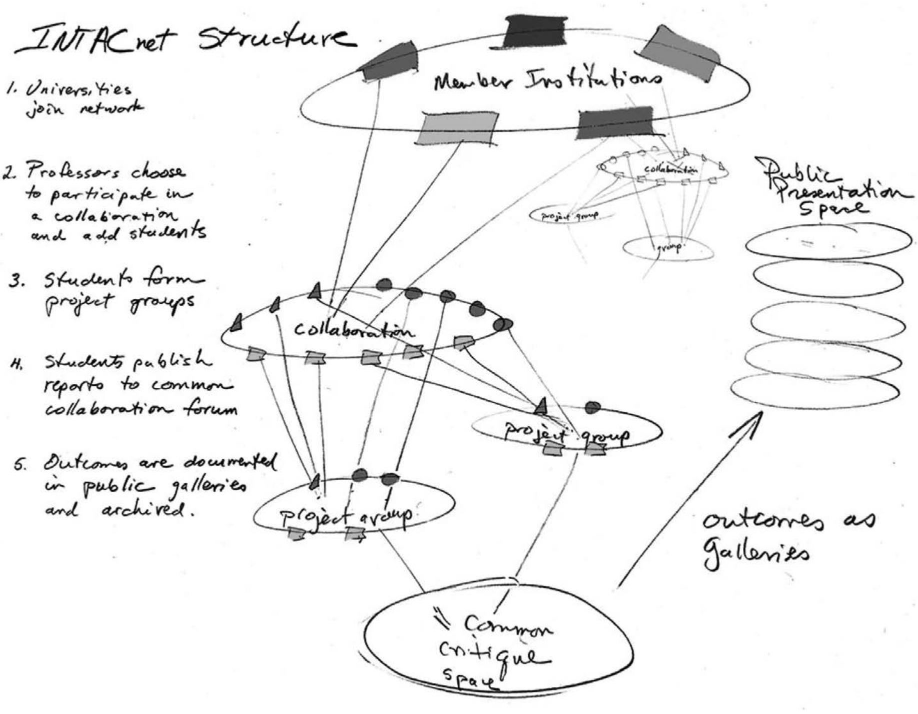

Figure 22.3 The INTAC network structure.

Source: The authors.

INTAC's ongoing experimental, and new ideology-enabling, collaboration model, which potentially catalyses and develops the formation of sustainability competencies.

Initially, INTAC's goal was to create interactions for many students without the need for international travel, realising that such travel was limited to only a few. Very quickly, it was discovered that structuring projects as collaborations between international partners greatly increased the level of communication and meaningful exchange. With over a decade of iterations, INTAC has honed its process, created annual exhibitions and publications, and adopted new virtual work environments as these have become available. The current use of a team workspace for online communication (Slack) and a whiteboard platform for the development process (Miro), as seen in Figure 22.4, is proving to be effective precisely because it is so visually based. Facilitation strategies are key, and these components are provided by a team of individual professors from up to seven universities each year, currently from four continents, including Europe, Asia, and North and South America.

Belief in global experiential learning, an open-ended operating objective, collaboration of international institutions and cross-cultural interaction have produced continuity for the INTAC network. As a result of this collaboration, various printed and virtual exhibition publications, documented co-creation art projects and works, websites, blog posts, printed-on-demand (POD) publications, and workshop materials have accumulated (Figure 22.5).

The INTAC model dissolves the traditional university canon of teaching individualistic creation of art and enables the formation of a mediating mechanism, which activates collaboration based on co-creation. The learning from others, seeking of new perspectives and understandings through art, critical questioning of prevailing standards and values, and seeking solutions

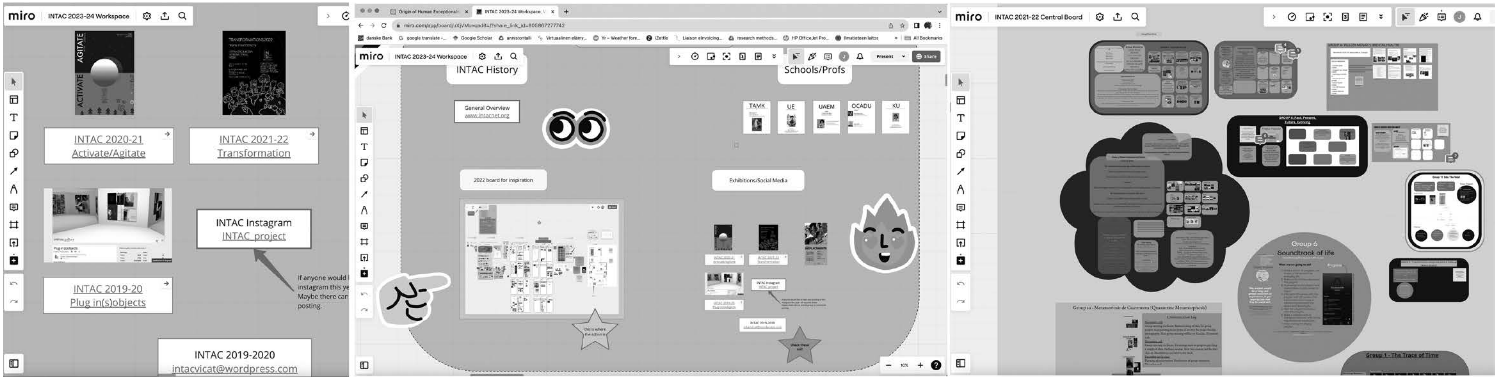

Figure 22.4 Screenshot from Miro whiteboard platform.

Source: The authors.

Figure 22.5 Examples of INTAC exhibition catalogues.
Source: The authors.

to problems have all been an integral part of the operational idea behind the learning process. Activities follow general principles of collaboration where the inherent respect for students, and their active participation, plays a crucial role in creating human-centred meanings, shared value, technical solutions, ideas, and art products and services (cf. Degnegaard, 2014; Jensen & Krogh, 2017; Roberts 2004, p. 205). The INTAC structure can be considered as a catalyst of change (ref. Cabell & Valsiner, 2011, p. 7) as the collaborative experience creates an alternative to the teaching of 'business as usual = art as usual' forms of art and limits the entrenchment of such blinkered thinking. Instead, it leads to a competency toolkit that includes critical thinking, self-awareness, and integrated problem-solving.

Over the years, the INTAC network's operations have evolved into a diverse, circular, online collaboration model with a learning platform that includes an annual program of co-creation between partner universities as well as workshops and seminars, jam events and conferences. Among these, the Visual Catalyst (VICAT) workshops concerning visual catalysts and the intensive online INTAC Sustainability Jam have been platforms for the creative development of sustainability catalysts.

The Visual Catalysts intensive co-creation workshops have been in person and short term, each taking place over one week (INTAC–VICAT, 2019). Groups of students have visited a host university and formed project teams to imagine and undertake responses to the challenge of how art can be harnessed to respond to climate change and sustainability issues. Each location presented its own particularities. With Finnish students visiting China (2019), Germany (2019), and Mexico (2021), the local participants were living in their own context of climate change. The recognition of differences, as well as similarities, between hosts and visitors helped to build knowledge, understanding, empathy, and a sense of global community.

The 2022 INTAC Sustainability Jam workshop (INTAC Jam, 2022), sponsored by OCADU's International Online Residency Experience initiative, took the VICAT program to a larger scale where the intensive workshop model was held online. This allowed for 65 students from 17 universities in 12 countries across five continents to spend nine days developing projects and presentations. The co-creation workshop asked students and teachers to imagine how art can play a role in moving the world towards more sustainable futures and to create projects on issues that concerned them. Due to the size of the group and the compressed timeframe, working groups were pre-organised by the facilitators, but the process maintained the core values of participant agency and team autonomy in coming to their choice of topic, research, creative mediums, and outcomes.

In their structure and methodologies, these various INTAC workshops provide insight into co-creative approaches that may be applied to diverse contexts and, especially, model their capacity for movement towards change.

Competencies for global collaboration and thinking

Here, we shall review three main areas of competence identified in the UNESCO in 2018 publication on education for sustainable development and which are potentially produced by the art-based co-creation process exemplified by INTAC's operating model. Various examples of projects undertaken by student collaborators, including ones mentioned here, may be accessed through the INTAC network web portal (INTACnet, 2023).

In the case of INTAC, students from diverse language groups communicate and collaborate typically through exchange of photographs, drawings, videos, and music. The multidisciplinary co-creation process forces students to pay particular attention to social interaction. The ground rule of INTAC's process is to operate in multinational groups. This means that progressing with art projects requires, in principle, considering others' opinions and cross-cultural thinking so that thoughts and ideas lead to a joint completed project. When English is used as INTAC's main language, a communications challenge arises in the student groups between native English speakers and speakers of other languages. When analysing the art projects created by the student groups, attention turns to the special opportunity that visual tools, such as videos, photographs, or drawings, provided as a cross-linguistic working method. In the *Diverse Iridescence* art project (INTAC, 2015) concerning the symbolic meanings of colours, the student group studied the associations produced by colours with the help of photographs they had taken. This enabled cultural characteristics to be brought out despite language barriers.

Seen from a more documentary angle, an image is an efficient tool when seeking a common understanding of various phenomena. An example is the *Useless Objects* co-creation project (INTAC, 2017) concerning consumption and materialism (Figure 22.6). Students took photographs of objects that were no longer useful to them and compiled the individual photographs into a large banner symbolising consumption. Such co-created photo compilations work as both a socially inclusive methodology and a tool for presenting the ideas and discussions the group may have about an issue.

Multinational co-creation artworks are most often surprising and there have been many approaches to co-creating works that students have adopted over the years. Combining diverse ideas

Figure 22.6 Co-creation project *Useless Objects* from the exhibition *Turmoil*, at the Off Festival, Bratislava, Slovakia, 2017.

Source: The authors.

in a visual format catalyses alternative meanings. On the one hand, surprisingness produces new types of creative combinations of meaning, and on the other hand, there arise intentional 'misunderstandings', which are constructively and consciously utilised in art projects. For example, in the *RE* video production (INTAC, 2013), a student was shown a video clip made by a partner on which basis they shot a continuation clip they found suitable for it. The working method, based on the 'exquisite corpse' method, produced a chain of video clips. The final video production was a surprise for all, including the members of the group. Similar structured expressive innovations have been implemented with photography. *Overlap* (INTAC, 2014) had students send an image file to the members of the group to be further edited as they pleased, while for the *Film Exchange* project (INTAC, 2017), each student took photographs and sent the roll of film to another, who, in turn, used multiple exposure to add their own photographs to the same roll.

In the INTAC workshops focused on sustainability, the participants' keen interest in issues of climate change, environmental and social justice, and other global challenges have meant that they embodied a constituency motivated to engage with ways to create change. By incorporating creative art methods in these programs, participants were prompted to harness the nonverbal impact and emotions that images can evoke along with critical thinking and reflection. Such exploration can shift the possible rigidity of logical discourse that can lock in attitudes and current ways of thinking. The visual process can empower and inspire, create hope, and expand the imagination.

Whereas most participants in the VICAT workshops were already using photography, video, and a broad range of other art media, the INTAC Sustainability Jam (INTAC Jam, 2022) included students from the performing arts, environmental studies, and media studies programs as a deliberate shift towards broadening into trans-disciplinary territory. The active participant response suggests these are effective methods for engaging constituencies beyond the arts, as well as blending groups of professionals from multiple fields or including non-experts in workshops. The benefits that could accrue from such creative exchanges appear to be exciting.

In crossing disciplines, an ability to view issues from a variety of perspectives can be enhanced, offering a blend that can be fact-based, inquisitive, flexible, intuitive, creative, and visionary. Connecting people using virtual platforms, both in real time and offline, allows for access to information across local, regional, and international spheres. In working together, the pieces of a complex global puzzle can be assembled, and this was seen in the projects undertaken, including those related to fast fashion, food production and deforestation, wildlife protection, and microplastics (INTAC Jam, 2022.). With such workshops, one understands that there can be an expanding circle of learning outcomes: the individual participant, the teams, the workshop group, and those who form an audience and experience the resulting presentations.

As an example, one group researched images of oil and mining sites in their countries, placing markers on a virtual world map. Through the process of comparing situations, the group analysed how mining companies everywhere were not only taking resources but also 'mining' human lives through exploitation and environmental destruction. It represented a collective 'aha' moment for this working group as they merged data into the visual format of an interactive website, which could be publicly accessed.

Creating emotions, empathy, and self-awareness

An ability to connect emotionally and to experience empathy are significant components of motivating action in response to global challenges, yet because individuals and communities may not be directly affected by any particular problem, many may have difficulty becoming emotionally engaged (Geels, 2011). When the INTAC structure sets participants the tasks of identifying an issue, gathering information, and formulating how to contribute to a greater public awareness, these activities can both inform and animate participants and also lead to outcomes that are meant to affect a broader audience. Objectives can be to increase awareness of issues and to expand empathy for the depth of the challenge.

Throughout the INTAC iterations, we, as facilitators, have found that if workshop participants are asked to actively select issues that mean something to them and then form into small groups to tackle the task, emotional engagement follows. They, the participants themselves, get to decide what to communicate and how to do so. By working in diverse groups, the process brings in multiple perspectives from which everyone can learn. Knowledge of other realities, experiences, and worldviews can lead to the openness to difference required for reaching complex solutions. Working with art and visual media to create experimental works provides a provisional space where diversity of views can be accommodated, unlike position papers where hard-edged statements and opinions may be staked out. Through these creative experiences, workshop participants learn skills necessary for individual and collective change.

In relation to common artistic practice, INTAC's co-creation model breaks away from the stereotype of an artist genius independently creating their work. Getting to know each other and working together is concretised in the art projects as a dialogue of emotions leading to the presentation of emotions. In various photo series made by annual INTAC participants, such as *Bedroom Portraits* (INTAC, 2018), *Childhood Aspirations* (INTAC, 2015), and *What's in My Fridge?* (INTAC, 2020), students have shared concrete views of their everyday lives and revealed intimate moments, based on a developing trust within their groups. In the *Long Distance Relationships* (INTAC, 2020) project, the group members documented their personal online remote meetings with their beloved friends. In the individual screenshots making up the photo compilation, humane moments of encounters are revealed, while overall, a common feeling of connection is shared visually. The exhibited presentation challenges the viewer to interpret the photo montage from a humane perspective and, in our experience, catalyses the personal feelings into an experience of collective empathy in those who view it.

The emotional nature of such creative solutions becomes a social glue that combines sharing of both information and emotions through the interaction of the partner participants. INTAC's art projects include examples of how the art-making activities of a co-creation group enable a sense of connection to be formed between the project members. For example, in the *You and I Are* (INTAC, 2012) project, students shared selfie-type images of their lunches, trips, transport, and belongings. On the surface, such images simply presented facts and personal choices, but through this, the participants learned about each other's lives. The *You Are Here* (INTAC, 2012) project shared details about the students' habitats and, through this, participants could feel a connection. In the interactive *Altogether* (INTAC, 2013) project, with the help of video montage software, a person sitting in front of a computer blends into the recording of another person who has previously sat in the same place, figuratively stepping into another person's shoes.

The goal of the Visual Catalyst (VICAT) workshops has specifically been to address sustainability challenges and when the stated objective is to affect an external audience on an emotional level, the visual arts provide a powerful vehicle. Within the imaginative space of the arts, creators are free to move beyond the simply informational to engage people in an experience in creative ways – using juxtaposition, humour, surprise, or other art strategies, including site-specific public interventions. In VICAT Berlin (INTAC–VICAT, 2019), several groups made posters that were aimed to create audience empathy. To create awareness of food waste, photographs were taken of imperfectly formed vegetables and fruit posed in public spaces (Figure 22.7). Laughter and

Figure 22.7 Poster project *Ugly Food*. VICAT Berlin workshop.

Source: The authors.

sympathy resulted from the final posters of anthropomorphised produce requesting to be taken home. In another project, images of common personal clothing were labelled with data of the materials, origin, and the environmental damages caused in their making. The concept was that the average westerner would connect with the familiarity of the clothes but then be confronted with a more distant problem. This connection between personal and remote realities aimed to raise conflicting emotions that required some resolution. Both projects came from research into statistics about food waste and fast fashion, but the art-making process resulted in outputs for evoking felt responses in viewers and the poster format created materials that could easily be duplicated and distributed into public spaces to reach a broad audience.

Catalysing critical thinking

From the participant perspective, the motivation in international co-creation centres on the participants' own social, cultural, and creative identities and their interest in communication and connection with each other. Observed activity is undertaken for social interaction, a gain in knowledge and experience, meaningful project activities, significant discussion and feedback, and tangible sharing of outcomes such as an exhibition or publication. This all suggests that co-creation will result in a level of self-recognition and ownership in the project outcomes and that participants will see themselves in relation to the problems they are investigating. New ways of thinking evolve through interactive experiences and hopefully the process is designed to address the challenges of working together in a globally distanced virtual arena.

Although digital virtual platforms are nowadays a natural part of students' everyday life and enable INTAC's cross-continental communications, many of INTAC's art projects bring out the boundaries between direct physical interaction and the virtual experience. The cultural, social, and economic challenges and power structures of the online environment quite naturally arise in this international co-creation process.

Critical attention to the means of communication emerges in multinational co-creation projects, where visual language instead of written language becomes an effective tool for exchange. When the use of English language was very limited among the Chinese students during an INTAC workshop in Wuhan, China, in 2018, the group switched to communicating with each other on mobile phones using the exchange of photographs and emoji symbols. The result was experimental art video based on visual symbols and the use of sound, building a new kind of link across the hegemonic languages of English and Mandarin. Such direct experiences develop alternative ways of thinking critically about the challenges of global cooperation.

In the *Here We Are* (INTAC, 2011) art project implemented by a student group, the almighty status of the internet was broken down by combining photographs taken with an analogue camera and computer screenshots in a collage. In *CellulART* (INTAC, 2015), students examined contemporary shifts in visual culture by seeing if popular photo-editing tools of camera phones could produce meaningful artistic expression. Then, in 2016–2017, Canadian, Korean, Chinese, Spanish, and Italian students of the *Lost in Google Translation* art project (INTAC, 2017) challenged algorithm-produced communication by entering an English saying into Google Translate. At the end of the translation chain, the English phrase had transformed into an absurd English saying, ironically questioning the perceived almightiness of companies producing online services.

The use of a digital operating platform also considers materialism from a new perspective. The transport or delivery of large art pieces to international exhibitions is not possible on a student's shoestring budget; instead, the work must fit into a suitcase. The re-scaling of art-exhibiting practices in the INTAC process has catalysed a change that, on the one hand, limits the traditional established and material form of presentation and, on the other hand, guides art-based activities towards a more community-based direction. In another approach, it is possible to implement impressive pieces of art using small elements if each student provides their own smaller work as part of a larger entity. This emphasises everyone's importance as part of the whole. Collages consisting of artistic postcards created by students (e.g., *Desire*), collages of drawings (e.g., *Scars*) or a tapestry compiled of small pieces created by students from different countries (*Quilt Project*) are examples of impressive artworks that have been created as results of co-creation and collaboration (INTAC, 2017).

Co-creation also catalyses a change in which, after identifying existing facts, art-based thinking enables alternative activities at a conceptual level. The VICAT workshop in Mexico (INTAC–VICAT, 2020) utilised a three-step approach: facing the facts, seeing the possibilities, and sharing the possibilities. This three-step approach sought not only to map out the challenging current state of the environment, but also to look for promising art interventions outside the university. The art performances that resulted related to social justice and gender equality. These performances were eye-opening, for example, from the perspective of the Finnish students who are accustomed to a sense of security prevailing within Scandinavian democracy. A need for physical integrity and personal security emerged during the workshop as a critical societal prerequisite for sustainable development and the CE.

As previously described, the VICAT workshop held in Berlin (INTAC–VICAT, 2019) saw participants question first-world consumer standards that contribute greatly to waste, land contamination, and social injustices. In gathering available data from the internet, the participants formulated messages using critical skills, as well as their creative imaginations in designing posters for potential audiences.

Overall, the INTAC experience has shown that visual art can act as a language through a use of symbols and metaphors, while also doing much more than simply conveying pictorial content. Art photographs can overcome the weight and burden of realism and carry theory elegantly and eloquently. They can encourage embodied knowledge. In many cases, the visual bypasses the purely intellectual, leading instead to expressing what a particular experience is like, how people feel and think. This suggests that images can be more accessible than many forms of academic discourse (Weber, 2008, pp. 44–48). The many student co-creation projects continue to exemplify ways of developing awareness and pointing to ways to explore and communicate complex ideas.

Co-created cluster of sustainability competencies

In this case study, we started by considering potential opportunities for art collaboration's catalysing competencies for a sustainable transition. In the various INTAC activities referenced here, we described how students were given responsibility for choosing an issue, making a proposal, and negotiating the group process; every step presented problems that needed solutions. In fact, throughout the annual eight-month INTAC projects, students faced multiple challenges, whether that of coming to a consensus on topics and methods, solving communication difficulties, or managing the shared art-making process. In the international context, with its language and cultural differences, these can all be daunting at times. In bringing together these diverse partners, the abilities necessary for working collectively towards a common global goal are developed. The bonus of the art-making context is that such workshops can be creative, fun, spontaneous, and community-building, with all these characteristics supporting visionary and hopeful perspectives when faced with difficult challenges.

The history of art practice, like most disciplines, is one of reference and inspiration. The cycle of seeing effective art works that lead one to consider a response builds a continuum of articulations. Collaborative co-creation adds another layer that brings people together to share perspectives, knowledge, action, and visions. This process does not require professional skills. Anyone can feel a part of such processes of inspiration and action. As participants actively work together, innovative experiences lead to new and surprising outcomes, often not predicted by facilitators. The shared identification of issues, choosing what to tackle, setting goals, and working towards creative outcomes can become self-sustaining and expandable through a continuing series of iterations.

From a collaborative problem-solving perspective, the brainstorming sessions and small breakout group methods used to animate students in the INTAC workshops prepare them for independent team activities. Taking on a creative task together requires collective thinking and cooperation, whatever the mix of participants is given, be it a diversity of disciplines, professions, or cultures. Collaborating on the task of an art project, as opposed to solving something as big as climate change, can move people past the feeling of, 'I can't do this, it's too big for me'. In an expandable circle of connections, co-creation can link individuals, diverse groups, and sectors by building communities of support and shared motivation.

The co-creation workshop process also catalyses change skills by shifting away from traditional academic methods of teaching. Individual-centredness is an important starting point for artistic thinking and production, but the co-creation model allows for personal starting points to be linked as part of a larger entity. The power of change found in a co-creation model, such as INTAC's, is based on filling the interspace of a traditional organisation model with creative, unprejudiced, open-ended collaborative methods. In this way, a cluster of competencies is formed with a potential to catalyse international thinking for change, such as:

- The use of art-based co-creation workshops encompassing collaborations between local and international groups in working to expand global thinking.
- Art-based collaboration with internationally, culturally, and socially diverse participants to engage their emotions and create empathy.
- Artistic exploration of global conditions, complex dynamics, and sustainability issues through images to develop competencies related to critical thinking through the questioning of norms, practices, and opinions.
- Collaboration that engages and empowers the individuals by bringing them into the process of understanding problems and imagining responses. Working from where one sits in relation to such problems promotes reflection on one's own role and builds self-awareness.
- Defining problems and seeking creative responses begins the process of addressing problems holistically, through novel as well as accessible and practical means for viable and inclusive artistic solutions.

The co-creative art methodologies provide some pathways that can be applied to a diversity of contexts. Key competencies and their applications offer a usable umbrella toolbox for co-developing different projects. Our efforts are not, by any means, individual or unique, but are used here to illustrate how collaboration through art-based co-creation events can animate new thinking and essential competencies.

Discussion

As many consider how to support global transitions, it is important to consider methods that catalyse changing attitudes, rather than reproduce traditional delivery of information. Group creativity and problem-solving go beyond simple knowledge accumulation. Change comes with learning, and learning is a social practice. Social skills, curiosity, and an appreciation for different perspectives are all enhanced through collaboration. Such attributes support an openness to innovation When participants define questions themselves in search of new knowledge, there is the possibility of mobilising concern towards action and hope, using people's range of existing knowledge, skills, and creative inspiration.

An international co-creation art process harnesses capacity building for our human potential. Global thinking, enabling empathy, critical thinking, self-awareness, and integrated problem-solving can be seen as catalysts for competencies in sustainability thinking. Even though co-creation art processes do not provide a quick fix for solving societal problems, it can form a necessary competence basis for future 'sustainable citizenship' (cf. Wals, 2015). Seeing art as decoration and as an amusement is important, but in addition to this, art is an instrument for the strategic processes of transformation involving personal development, leadership, and creative innovation (ref. Darsø, 2004).

If we are to develop sustainable changes, thinking globally is needed even while addressing local situations. Forms of artistic collaboration provide models for circular thinking and co-creative actions in ways that bring people and communities together to think in new ways. Collaborative models are key because they engage participants actively, breaking the distinction between self and other. This shift is needed if humanity is to understand how we coexist in a complex web and that our survival is dependent on restoring balance. Nature is not viewed as a pyramid with humanity at the top. Co-creative experiences help to move individuals away from limiting conceptions of the world towards shared meanings – like a dance in which we move harmoniously together (Gergen et al., 2001, p. 693).

Circles of co-creation, using a process of identifying issues, choosing what to tackle, setting goals, and working towards a creative outcome can lead to cyclical initiatives that become self-sustaining and expandable through a continuing series of iterations. In working together, diverse perspectives can be shared, and commonalities can be recognised. Such circles of action can then begin to intersect and form larger and larger networks. Barriers can also be broken. Each workshop, event or facilitated group can work with its own appropriate formats and methodologies. Common spaces for sharing outcomes can be established and links maintained. An international vision can expand to reflect the need for us to grow in our understanding of how we are travelling in this one world and need to find creative solutions together.

The model of art co-creation does not, in principle, aim to create artistic masterpieces, but instead uses artistic thinking to form essential sustainability skills required in the future. In this case, we can refer to a hybrid artistic process in which the model of linear learning and activities – business as usual – is reformed with the help of creative co-creation that takes place in an international context.

In INTAC's model, learning is enabled through co-creation between several universities, and partially takes place outside the curricula, producing an interspace that allows for new methods of viewing and experiencing. In other words, open-ended international co-creation constructively disturbs the prevailing methods of learning and thinking and catalyses a change towards UNESCO's critical competencies for sustainable development and CE.

Art co-creation has the potential to build bridges between linear and circular ways of thinking. To carry out an art project with international strangers in diverse groups, project group members must find new constructive ways to communicate and develop socially respectful and creative ways to execute shared art projects. This format radically changes the traditional art process, where a talented individual is expected to create artistic masterpieces on their own.

By creating international art together, diverse group members can achieve something meaningful as a unit, producing strategic sustainability skills. Personal development, self-direction, and encountering and respecting cultural identity differences create the prerequisites to face realities in complex situations where solutions must be creative and sustainable both socially and economically.

Although co-creation art projects are planned and implemented jointly by the relevant group, the result is a multi-voiced and multi-interpretable work that does not offer simple answers to complicated questions. INTAC's international co-creation skills development model does not produce physical paintings to be sold, nor is it a hammer that can be used to drive a nail to hang a painting on a wall. Instead, INTAC can be considered as the wall of a yet empty gallery, waiting for new ideas from an operator who must have artful competencies; they must have or learn the ability to solve a challenge at the level of ideas in a socially, economically, and environmentally sustainable manner.

In the co-creation process, personality is linked to the universal. When the starting points for co-creation art projects are the participant's personal observations, emotions, and experiences, a sense of social belonging is formed. These features operate as a strategic glue in the ideology of global sustainability. For example, art-based co-creation art projects related to food, housing, and mobility are linked together at an individual and international level.

Because art-based creation and learning differ from acquiring text-based knowledge, the international co-creation art process produces an alternative toolkit and necessary agency at both instrumental and strategic competency levels for finding alternative and sustainable solutions to the current global status.

Epilogue

COVID-19 shook the world in the winter of 2019, leading to a long-planned INTAC joint exhibition in Mexico being cancelled. This cancellation, however, did not discourage students. Instead, the completed artworks were converted into a virtual exhibition, and the opening ceremony was virtually held in Finland at Tampere University of Applied Sciences' international iWeek 2019 event. The exhibition, implemented under the lead of the Autonomous University of the State of Mexico students' digital skills, presented INTAC's agile functionality in practice. Instead of travelling, the opening ceremony of the joint exhibition could be attended from around the world. Later that summer, a second virtual exhibition, curated by the INTAC students at the University of Applied Sciences Europe in Berlin, carried in its name a core message inspiring hope and describing the problem-solving potential of co-creation: *Future Art: Stay Creative/Stay Alive*.

Educational content

What are some key competencies that will support individuals and organisations in moving towards implementing necessary changes and move humanity to sustainable futures? How can creative art-making experiences contribute to developing these?

Visual art can lead to new ways of thinking about the challenges of sustainability. How might art-making lead to motivation, new insights, emotional identification, or hope? How might creativity alleviate experiences of climate fatigue?

How can international collaborative activities expand thinking and build cross-cultural awareness and empathy? What are some advantages to programming creative art-making projects for these collaborations?

How could the collaborative formats discussed here be used with non-art groups? How could art-making be appropriate in these contexts or how could collaboration and creative problem-solving be applied?

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23

UTOPIAS AS CATALYSTS FOR A SUSTAINABLE CIRCULAR ECONOMY

Marileena Mäkelä and Maili Marjamaa

Introduction

We are living in a world of crises. Climate change and the loss of biodiversity are but two examples of current, urgent, and global problems. One proposed solution to these problems is the circular economy (CE). While there is an abundance of CE literature – Schöggl et al. (2020) analysed almost 4,000 CE articles in their review – circular futures have been recognised as an under-researched area (e.g., Bauwens et al., 2020; Marjamaa & Mäkelä, 2022). In particular, Gümüsay and Reinecke (2022) have called for more studies on this topic and for researchers to take stronger stances on preferable futures. They indicated that "if we don't imagine the future, others like technology companies will" (p. 241). The research gap we address in this chapter relates to preferable futures, which can also be called utopias. We aim to study how CE utopias can catalyse sustainable CE, which we define as "creating environmental quality, economic prosperity and social equity for current and future generations" (Marjamaa & Mäkelä, 2022, p. 5).

We study the topic from a futures research perspective. Futures research aims to make the future more predictable and more transparent (e.g., Rubin, 2013). The goal of futures research is not to predict the one future that will come (Kamppinen et al., 2003; Niiniluoto, 2003; Rubin, 2004), because scientific prediction of the future is not viewed as a realistic possibility. Instead, futures research strives to visualise many alternative futures (Kamppinen et al., 2003; Niiniluoto, 2003; Rubin, 2004) that could lie ahead of us. Alternative futures can be visualised by using, for example, futures images or scenarios; futures images are visualisations of the future held by either individuals or communities (Mäkelä et al., 2022) whereas a scenario features also the path between the present and a futures image. In this chapter, we focus on futures images because the path from the present to the future should generally be decided together with the people affected by the research topic. Futures images can address probable, possible, and preferable futures (Amara, 1981). They are essentially, as Rubin and Linturi (2001) note, mental models.

Mental models are "internal images of how the world works" (Senge, 2006, p. 163). They are created based on individuals' experiences, perceptions, and understanding of the world (Jones et al., 2011). Although they are incomplete representations of reality (Jones et al., 2011; Lynam & Brown, 2011), they still determine how we act (Senge, 2006). Dufva (2022b) nicely explains the action of mental models in futures research, stating, "Many of our current achievements used to

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be someone's dream in the past. The problems of the current days are the results of what we did not consider in our dreams in the past". As mental models guide our reasoning, decision-making, and behaviour (Lynam & Brown, 2011), we propose that it is vital to focus on preferable futures images (i.e., utopias). We cannot be overwhelmed and depressed by negative news and wait passively for our seemingly doomed, or at least bleak, future to arrive. The key premise of futures research is that we can influence the future with our own actions. As Rubin (2013) has argued, futures images are powerful tools to make the future more transparent and visible to take actions towards preferable futures today.

In this chapter, our aim is to study how CE utopias can be used to catalyse sustainable CE. We use Finland, a CE frontrunner, as our empirical context and create utopias for a sustainable CE in 2050. A utopia can be defined as a description of an ideal or even perfect society, where all current social, environmental, and economic problems have been solved. The research questions we answer are as follows: What kind of utopian elements do CE professionals identify in relation to 2050, and how do they help us in the sustainable CE transition?

This study contributes to CE research by presenting utopias and detailed descriptions of a sustainable CE. Simultaneously, we contribute to this book's theme of CE catalysts by offering a futures research perspective. Actively influencing the future is a key premise of futures research, as opposed to passively waiting for a future to happen. In this chapter, we aim to promote this idea in the CE field. We can decide that our CE future will be a bright one, and we can take measures to shape it.

This chapter is structured as follows: The next section focuses on its two main concepts: utopias and futures images. We then describe our materials and methods, which consist of 61 interviews with Finnish CE experts and a qualitative content analysis of those interviews. In the results section, we present the four utopias, each focusing on separate sustainability dimensions. We close the chapter by discussing our contribution. The Appendix provides a table summarising our research data.

Literature review

The need for utopias

Utopia is a multifold concept. The word originates from Greek, with *topos* meaning 'place' and *eu* meaning either 'good' or 'ideal' or *ou* meaning 'no' (Levitas, 2010; Manuel & Manuel, 1979). The word was first used in 1516, by Thomas More in *Utopia*, a book describing an ideal society far away (More, 1997). However, the idea of utopia has been around even longer and appears in many cultures and religions (Levitas, 2010). Some dictionary definitions of the concept are presented in Table 23.1, based on which a utopia is a perfect or ideal society in terms of laws, government, and social conditions. These definitions also highlight the imaginary or aspirational nature of the concept.

The definitions of 'utopia' often emphasise its imaginary and impractical nature. For example, Mikko Karhu (2022), who has studied utopias in the context of regional development, describes utopias as often associated with ambitious targets and plans whose success is doubted. Furthermore, Karhu and Ridanpää (2020) summarise the concept as follows: "Utopian literature commonly refers to a literary genre in which the narrative settings are apparently imaginary, places in fictional societies, typically in the future, reaching beyond the scope of our known world and known history" (p. 2). However, the imaginativeness built into the concept can also be viewed as a strength. For example, Lakkala (2020b) calls a utopia a counter-image of the present with

Table 23.1 Dictionary definitions of the word 'utopia'

Source	*Definition*
Merriam-Webster Dictionary (Merriam-Webster, 2022)	• A place of ideal perfection especially in laws, government, and social conditions. • An impractical scheme for social improvement. • An imaginary and indefinitely remote place.
Oxford English Dictionary (Oxford University Press, 2022)	• An imaginary island in Sir Thomas More's *Utopia* (1516), presented by the narrator as having a perfect social, legal, and political system. • Any imaginary or mythical place (without implication of perfection), imagined as existing in some remote location on earth. (*Obsolete*.) • An imagined or hypothetical place, system, or state of existence in which everything is perfect, esp. in respect of social structure, laws, and politics. • A real place which is perceived or imagined as perfect. • A written work (now esp. a fictional narrative) about an ideal society, place, or state of existence. • A plan for or vision of an ideal society, place, or state of existence, esp. one that is impossible to realise; a fantasy, a dream.
Cambridge Dictionary (Cambridge University Press, 2022)	• A perfect society in which people work well with each other and are happy.

the focus of improving today's society. Ruth Levitas (2010), a well-known utopia researcher, had made a similar point when defining utopias as "not just a dream to be enjoyed but a vision to be pursued" (p. 1).

Utopias have been studied in many disciplines; Levitas (2010) identifies history, literature, theology, cultural anthropology, sociology, political theory, and psychology as examples. The late futurist and sociology professor, Wendell Bell (2008), summarised utopian studies in the social sciences as having four aspects. First, utopias are preferable to existing society, based on values. Second, utopias criticise existing society (see Lakkala, 2020b). Third, the utopian societies that are described do not (yet) exist. Fourth, utopias call for human action. It is easy to dismiss the idea of utopia as depicting a perfect society and thus being impractical. However, we follow Dufva's (2022b) logic and wording: "It is by no means trivial what kind of futures we imagine". Positive futures, including utopias, inspire people to take action, while negative futures, including dystopias, can prevent action, as discussed next.

The opposite of utopia is dystopia, which means "a diseased, bad, faulty, or unfavourable place" (Clayes, 2017, p. 4). Literature, television series, and movies commonly feed on dystopias and, as Clayes (2017) points out, the word is often associated with the dystopian literature. Based on both literature and historical events, Clayes (2017) divides dystopias into three categories: political dystopias (different forms of totalitarianism), environmental dystopias (e.g., out-of-control climate change), and technological dystopias (when science and technology dominate humanity). Dystopias can also be used to cause action today to prevent humanity from ending up in a dystopian future. For example, Hjerpe and Linnér (2009) studied the rhetoric of climate science and policy documents. They found that dystopias are used to avoid "economic catastrophe by acting too fast or ecological catastrophe by not acting fast enough" (p. 234).

The obvious problems with focusing on dystopias and other negative events are the anxiety and short-sightedness that often result. Therefore, we need utopias to provide an image of a positive future. As Lakkala (2020a) puts it, "we need . . . collective, facilitating, future-oriented mass-utopia to tackle the global problems we are facing today. . . . This is where the need for utopian social imagination comes into play. In a situation where it is difficult to imagine alternatives for destructive, anthropocidal capitalism, we need to teach ourselves to dream and to imagine again" (p. 34). The same point was emphasised by Polak (1973), nearly half a century ago: societies preserve their vitality as long as they are able to imagine a positive future. Therefore, we need a positive and preferable futures image to motivate us and inspire action.

Futures images and the circular economy

What are futures images? They are visualisations of the future held by either individuals or communities (Mäkelä et al., 2022). In other words, they are still pictures or snapshots of the future (Gordillo Kontio & Tapio, 2017). However, as Beers et al. (2010, p. 725) note, the images are "a simple, metaphorical representation of a complex real-world phenomenon", as the real world is too complex to be described in detail. Although futures images are always simplifications of the real world, they still need to be, as Rubin (2013) notes, systemic in nature. Although Rubin (2013) indicates that imagination plays a part in creating futures images, their main structure comes from the data and knowledge of study participants. The data addresses their views on both past and present, including their values, needs, hopes, fears, and expectations. The key reason for creating futures images is to spark discussions about the preferable future. Jokinen et al. (2022) emphasise that the simplicity of futures images helps to communicate the future actions that are required. Slaughter (1991) and Rubin (2013) share this point of view and state that the role of futures images is to help make decisions today. Furthermore, Vinnari and Tapio (2009) see the role of futures images as guiding us towards the preferable future state.

CE futures have been studied to some extent, but there has been wide variation in approaches and methods (see Table 23.2 for details). We analyse previous studies from four perspectives: an overview of the research area, topics and context, methodological choices, and preferability of the futures images.

Overall, the study of CE futures remains a narrow field of research. We were only able to find eight studies focused on CE futures. In addition, we found three studies in which CE is mentioned in only one futures image (Heinonen & Karjalainen, 2019; Mont et al., 2014; Svenfelt et al., 2019). Furthermore, we can conclude that CE futures is a fairly new field; in our review, the first study was published in 2014, and almost half appeared in the 2020s.

There was great variation in study topics and contexts. Typically, the CE has been studied at the societal level, although there are two exceptions. Luoma et al. (2022) examined CE futures in the textile industry, and Kuzmina et al. (2019) studied the fast-moving consumer goods sector. Both studies adopt a global perspective, whereas societal studies often focus on European countries. Only two societal-level studies chose a global perspective. As to specific topics, previous research can be divided into two groups. The first consists of studies with broad topics, such as exploring, conceptualising, examining, or presenting (CE) futures images. The second focuses on much narrower topics, such as technology development or resource efficiency.

CE futures have generally been studied using qualitative methods, with two exceptions. Bibas et al. (2021) and Wijkman and Skånberg (2017) used quantitative approaches (i.e., modelling). Within qualitative approaches, there has been variation in data collection methods. Previous studies have often used some combination of the following methods: literature reviews, interviews, workshops, and Delphi method.

The preferability of the created futures images has been variously discussed in existing research. Kaskinen and Parkkinen (2018) created one preferable CE futures image. Bauwens et al.

Table 23.2 Summary of previous studies focusing on CE and futures

References	*Topic and context of the study*	*Methodology (specific research method)*	*Futures images created*	*Key content of preferable futures image*
Kaskinen and Parkkinen (2018)	Exploring CE potential in Finland	Qualitative (survey, workshops)	One preferable CE futures image	In their images, both consumers and businesses have a strong role in promoting and acting on the CE. Consumers adopt the sharing economy, and business produces innovative applications to support it. Furthermore, society supports the CE by bringing decision-making close to citizens.
Bauwens et al. (2020)	Conceptualising CE futures (no specific context)	Qualitative (literature review, focus group)	Four futures images: 1 Planned circularity 2 Bottom-up sufficiency 3 Circular modernism 4 Peer-to-peer circularity	None of the futures images is a preferable futures image as such; rather, a preferable image consists of a combination of the four.
Urashima et al. (2020)	Identifying emerging CE technologies in Japan and Finland	Qualitative (Delphi)	Four futures images for Japan (CE is not included): 1 Humanity 2 Inclusive 3 Sustainability 4 Curiosity Four CE futures images for Finland: 1 Transformation 2 Expansion 3 Stagnation 4 Agility	Transformation was viewed as the preferable futures image for Finland. The main driver of this image is strong technological development in business, supported by political decisions.

(*Continued*)

Table 23.2 (Continued)

References	*Topic and context of the study*	*Methodology (specific research method)*	*Futures images created*	*Key content of preferable futures image*
Bibas et al. (2021)	Analysing how CE policies can help decouple economic growth from material use in the world	Quantitative (modelling)	Two quantitative futures images: 1 Material fiscal reform 2 Combined material fiscal reform and energy transition	Two images offer a reduction in emissions and the use of resources.
Wijkman and Skånberg (2017)	Enhancing resource efficiency in five European countries	Quantitative (modelling)	Three quantitative futures images: 1 The renewable scenario 2 The energy efficiency scenario 3 The material efficiency scenario	Each image would result in CO_2 emission reductions and increases in employment and GDP.
Marjamaa and Mäkelä (2022)	Examining CE futures images in Finland	Qualitative (interviews)	Four futures images: 1 A circular success story 2 A circwcircles 3 Structural, regulated circularity	The circular success story is the preferable futures image. Global regulations support the CE, and the economic system is CE-based. Environmental problems have been addressed. Collaboration between multiple partners flourishes. Technological development supports the CE.
Svenfelt et al. (2019)	Presenting qualitative futures images on sustainability strategies in Sweden	Qualitative (literature review, workshops, interviews)	One image addressed CE: • CE in welfare state	None of the created images was considered preferable.
Mont et al. (2014)	Describing sustainable lifestyles in Europe	Qualitative (Delphi, workshops)	One image addressed CE: • Local loops	None of the images is preferable as such, but each is preferable for certain stakeholders.

(*Continued*)

Table 23.2 (Continued)

References	*Topic and context of the study*	*Methodology (specific research method)*	*Futures images created*	*Key content of preferable futures image*
Heinonen and Karjalainen (2019)	Describing four futures images of electrification of a peer-to-peer society from the global perspective	Qualitative (interviews)	One image addressed CE: • Green, do-it-yourself engineers	This image is almost a dystopian future, as the starting point is global ecological catastrophes and the failure of states to address them. The only solutions have been local engineering ones.
Kuzmina et al. (2019)	Envisioning futures of fast-moving consumer goods	Qualitative (workshops, interviews)	1 Five futures images: Rinse and reuse 2 The cycling of pure materials 3 The rise of the circular retailer 4 A world without supermarkets. 5 Connected living	None of the created images was considered preferable as such.
Luoma et al. (2022)	Creating three futures images of CE in the textile industry	Qualitative (literature review, Delphi)	Three futures images 1 Transparency 2 Conflicting interests 3 Sustainable textiles	Sustainable textiles were evaluated as the preferable futures image. In this image, CE practices are applied with the increased use of recycled and wood-based fibres. Businesses and consumers were identified as key drivers in this image.

(2020) stated that none of their images were preferable as such; rather, a preferable image would be comprised of parts of each image. In Urashima et al. (2020), Marjamaa and Mäkelä (2022), and Luoma et al. (2022), one image was explicitly nominated as preferable. In addition, the promoters of preferable futures varied between the studies. Kaskinen and Parkkinen (2018) and Luoma et al. (2022) identified business and customers, while Svenfelt et al. (2019) focused on customers as the main drivers, and Urashima et al. (2020) and Svenfelt et al. (2019) saw the government as the key actor.

Against the background of these few previous studies on CE futures, our study's unique contribution lies in its explicit focus on CE utopias. In our first article on CE futures images, we created four futures images of CE: a circular success story, a circle of disaster, local circles, and structural, regulated circularity (Marjamaa & Mäkelä, 2022.). A circular success story was considered to be a preferable futures image. The CE utopias created in this chapter are elaborations and extensions of that image but stand independently, as is explained in the following section, by focusing on our research context, interviews, and the creation of CE utopias.

Materials and methods

Research context

Our research context is Finland, a Nordic country. At the time of the study, Finland aimed to be a CE frontrunner; in 2019, the government established a target to become the world's first fossil-free welfare state (Finnish Government, 2019), and in 2021, it announced the goal of achieving a carbon-neutral CE by 2035 (Finnish Government, 2021). In addition to the official governmental targets, Sitra, a national fund accountable to the Finnish Parliament, had organised an open dialogue process with CE experts and stakeholders to create the world's first road map to a CE in 2016 (Sitra, 2016). Furthermore, due to this national-level support, several Finnish companies have actively pursued CE initiatives in their operations.

Naturally, the data we collected represented CE expertise in the Finnish context. However, most of our interviewees worked for organisations with active international relationships. For example, many of the interviewees' companies operated in multiple countries, generally in the Nordic region or elsewhere in Europe. Furthermore, the research, innovation, and support organisations whose representatives we interviewed sought to support the internationalisation of Finnish companies. Last, the other organisations whose representatives were interviewed cooperated with international partners.

CE expert interviews

We selected CE experts with different positions from a wide range of organisations, as we were interested in creating richly detailed and well-informed CE utopias. We first identified organisations that played a central role in promoting the CE concept in Finland. These organisations encouraged, for example, CE-based business, urban and regional development, legislation, technologies, and research. Therefore, they played an important part in influencing CE futures in Finland. At each organisation, we identified people with CE expertise, using one of three techniques. First, our research project, CICAT2025, had a list of key CE stakeholders. Second, we browsed the personnel sections of organisation webpages and searched for 'circular economy' in job titles or descriptions. Third, we contacted the heads of the organisations to suggest names for us. We used emails and telephone calls to set dates for the interviews.

Our empirical material consisted of 61 interviews with Finnish CE experts. Knowledge of the practical, organisational-level CE implementation was determined from those working at companies in both manufacturing and the service sector. Regional-level CE implementation was sought from the municipalities and other regional actors. The representatives of research, innovation, and support organisations and industry organisations provided valuable information on CE implementation either at a general level across Finland or within a specific sector. Last, the representatives of ministries and other political bodies enlightened us with aspects of political decisions and legal issues regarding CE implementation, which was supplemented with general national and international CE implementation. In addition to their expert role, the interviewees elaborated on their positions as consumers and private citizens. We interviewed both women and men with moderately high positions in their organisations, such as CEOs, directors, managers, and experts. The interview data are summarised in Table 23.4 in Appendix 1 of this chapter.

We adopted the semi-structured expert interview approach (Eriksson & Kovalainen, 2008). For our purposes, semi-structured meant that we had four themes that were covered in each interview. However, the precise questions asked in each case varied with participant expertise and the time available for the interview. The four themes were as follows: the relationships between CE and sustainability; current and future issues of CE implementation; CE collaboration; and CE futures in 2050. The interviews were conducted between May 2019 and June 2020, with 22 interviews held in person and 39 as online interviews. The length of the interviews varied from 31 to 110 minutes and totalled 71 hours of material. All interview data was tape-recorded and transcribed verbatim, with the transcribed data amounting to 723 pages.

Our approach had certain limitations. Although our interviews covered CE experts from multiple sectors, we limited data gathering to Finland. Therefore, for future studies, we welcome interviews in other geographical locations to widen perspectives on the futures of sustainable CE. We noted in our review of the CE futures literature that previous research has generally examined European contexts. Therefore, we encourage more studies outside Europe and from a global perspective. However, as we looked at this phenomenon in Finland, which is a Nordic country, we believe that our results are applicable at least in Nordic contexts and to a certain degree in European contexts.

Analysing interview transcripts and generating utopias

We used qualitative content analysis to examine the research data; because the data was both rich and large, we needed to reduce them to a manageable size. First, we focused on sections where the interviewees described future CE and global problems that had been solved. Second, we used the PESTEC framework to code these sections and obtain a systemic view of CE futures. The PESTEC framework was first described in Francis Aguilar's *Scanning the Business Environment*, which was published in 1967 (Dufva, 2022a). The framework is typically used in business for scanning the operating environment and understanding upcoming changes to that environment (Dufva, 2022a). PESTEC is also often used in futures studies to systematically analyse societal factors affecting the futures of a given topic (e.g., Mäkelä et al., 2020). The PESTEC framework consists of six dimensions: political, economic, social, technological, environmental, and cultural (e.g., Brennan & Sisk, 2014; Yüksel, 2012). The categorisation was carried out with the help of the ATLAS.ti software package, version 8, and an Excel spreadsheet. This coding gave us an understanding of what the interviewees said regarding the political, economic, social, technological, environmental, and cultural dimensions of the CE and its futures.

Our next step was to create the utopias. As we focus on a sustainable CE in this chapter, we selected sustainability as the framework for those utopias. The connection between CE and sustainability or sustainable development has been discussed, for example, by Geissdoerfer et al. (2017) and Korhonen et al. (2018). In these two articles, sustainability is divided into economic, environmental, and social sustainability. However, an examination of the concept of sustainable development reveals a fourth dimension of cultural sustainability (e.g., Meireis & Rippl, 2019). In this chapter, we sought to emphasise the role of culture in creating change because any CE implementation requires alterations in people's daily habits, which can be easier to adopt if their cultural backgrounds are respected. Furthermore, our four sustainable CE utopias followed along the lines of Kuhmonen (2017), who provided the original inspiration for this work. Kuhmonen created futures images on the Finnish food system, with each focusing on different sustainability dimensions: a short food chain for economic sustainability, a green food chain for environmental sustainability, a fair food chain for social sustainability, and a genuine food chain for cultural sustainability. Our PESTEC coding served as the basis for the utopias; codes in the economic dimension created the basis for economically sustainable CE, environmental codes for environmentally sustainable CE, social codes for socially sustainable CE, and cultural for culturally sustainable CE. The two remaining dimensions from the PESTEC framework (political and technological) provided inputs for all our utopias. Based on these codes, we wrote the narratives of the utopias presented in the next section.

Our utopias target the year 2050. It is typical in futures studies to set a time horizon that is rather far in the future. We also used this year during the interviews when we asked about informants' perceptions of CE futures. Using a specific year in the relatively distant future can help interviewees to imagine future possibilities without current constraints and probabilities while opening avenues for human creativity and imagination.

Sustainable circular economy utopias in Finland in 2050

Summary of the utopias

Our analysis of the interview data generated four utopias based on four dimensions of sustainability: economic, environmental, social, and cultural. These utopias are presented in the form of narratives of an economically sustainable CE, an environmentally sustainable CE, a socially sustainable CE, and a culturally sustainable CE, all set in 2050. The utopias focus on explaining what Finland looks like when the utopias become a reality. While each utopia depicts a particular sustainability dimension, they also partly overlap and intersect. To summarise, in an economically sustainable CE, the whole economy (consumers, companies, municipalities, and Finnish society in general) operates on CE principles. In the environmentally sustainable CE utopia, all current environmental problems have been solved, and the loss of biodiversity has been reversed. The core of socially sustainable CE is agile and multifaceted cooperation between different people, partners, and sectors. Finally, the culturally sustainable CE respects Finnish cultural heritage, and CE is applied in a country-specific style based on changes in values and behaviours. The images are summarised in Table 23.3. In the sections that follow, the narrative of each created utopia is detailed and supported with an artistic illustration.

Economically sustainable circular economy: Focus on firms and market orientation

In 2050, the linear economy is regarded as a stage in the history of humanity, as Finland's economy and society are now organised around circularity. CE thinking and CE activities are part

Table 23.3 Summary of the content and key features of each utopia

	Economically sustainable CE	*Environmentally sustainable CE*	*Socially sustainable CE*	*Culturally sustainable CE*
Key features	• Economic system within planetary boundaries. • Decreased production and consumption. • Statutory bookkeeping for a firm's economic, environmental, and social impacts. • CE-aligned business models and mutual value creation. • Strong support of corporate finance towards CE. • Finland is the leading CE country, which increases CE innovation tourism.	• Current environmental problems addressed. • Care for nature: rewilding and recovering natural ecosystems and biodiversity. • Careful renovation and brownfield construction. • Green cities and rural areas, carbon sequestration. • Technology-assisted food production and nutrition cycles. • Self-sufficiency and security of supply in food systems. • Self-sufficiency in renewable energy.	• Well-being with less use of natural resources. • Increase in employment. • Cooperation and partnerships. • Social innovations. • Strong emphasis on education. • Vitality and high quality of life. • Safety.	• CE integrated into Finnish culture and values. • Changed relationship with ownership. • Mending, lending, and sharing products. • Respect for old goods, services, and immateriality. • Food choices: plant-based and vegan. • Use of physical places (e.g., cellars) as 'libraries' for exchanging goods and materials. • Sustainable modes of mobility.

of everyday life and are conducted at the private, corporate, municipal, regional, and societal levels, as well as internationally. CE is market-based, cross-sectoral, and constantly evolving. The previous economic system has been successfully challenged in recent decades, and today's economy, overall, remains within planetary boundaries. The economy creates wealth, viability, and well-being differently due to changes in consumption and production, with the strong support of technology. Production does not lead to negative impacts on climate, biodiversity, and natural ecosystems. Under legislative directives, companies must measure the risks and impacts of their activities and commodities with environmental and social impact metrics in addition to the traditional economic metrics and report them all in their statements to the tax authorities, investors, financiers, other companies, and society. As a practical example, a harmonised and holistic calculation indicates which material in road construction in a particular place is truly sustainable when viewed from different sustainability perspectives. Figure 23.1 illustrates these aspects and summarises the economically sustainable CE.

All companies and their businesses are aligned with a CE and implement CE principles either fully or at least to some extent. Scarcity, material prices, and generally high material taxation are significant drivers of CE business models: much needs to be produced from little. 'As-a-service' business models are common, and sharing (whether through leasing, borrowing, or exchanging) and the platform and data economy are central, as are proactive service and maintenance, life cycle extension, reuse, repair, and modular design. For example, a firm may be able to profit from a product for the duration that it remains in circulation, perhaps through a usage fee when the product circulates from one customer to another. Partnership models and the value network's

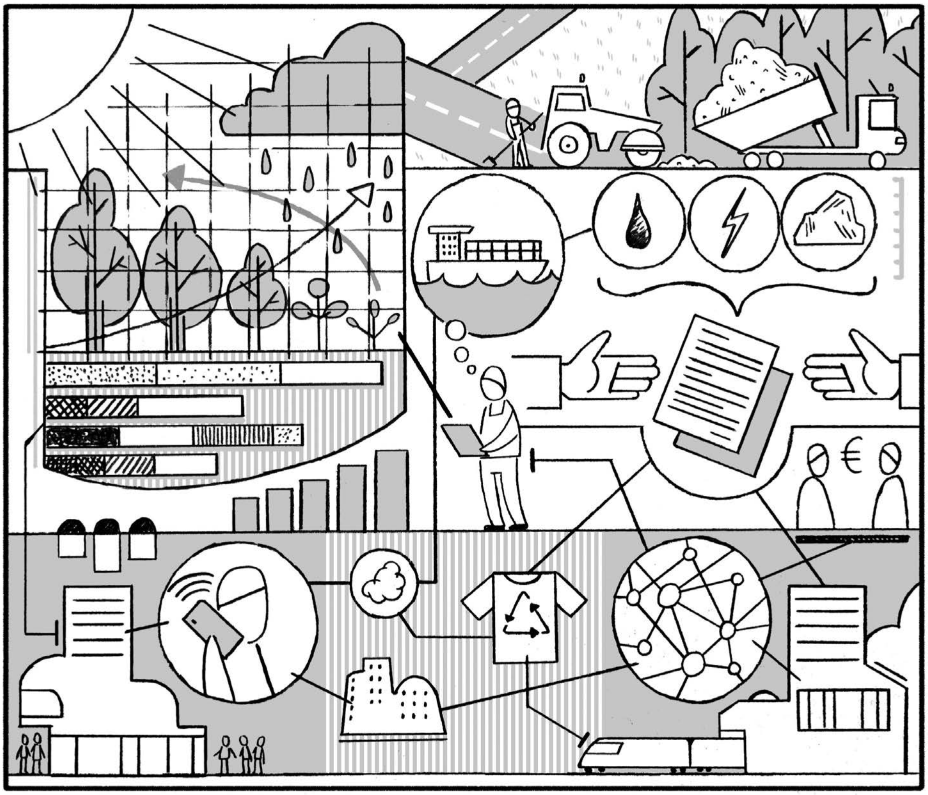

Figure 23.1 Economically sustainable circular economy.
Source: The authors.

well-being are important. For example, a mutual business model could combine a textile firm with the involvement of laundry and logistics companies, guaranteeing mutual value creation and business opportunities for all and benefits for other stakeholders. For a long time, and still in 2050, the CE has meant opportunities for efficiency and energy savings, improved productivity, and significant customer satisfaction. New innovations and business are constantly emerging, and ecosystems form the foundation for CE-based business. The CE has led to the emergence of numerous small companies that sell urban food and repair services. Factory-as-a-service concepts are popular. All in all, the CE has increased self-sufficiency in Finland, and Finns use products made by Finnish companies more than ever before.

Finland is now waste-free and is a global leader in that regard. EU taxonomy influences the background of the corporate finance market, which works efficiently; financiers and investors support sustainable funding. Finland is part of global value chains, and industrial operations are organised according to CE principles that benefit Finnish exports. Finnish CE expertise is in demand around the world. Municipalities and cities play a significant role in enabling several CE activities, such as CE parks where companies use one another's by-products. Public procurement and land use in municipalities and corporate governance in public companies are organised in accordance with sustainable CE. Finland a global leader in countries in successfully implementing CE and attracting CE innovation tourism.

Environmentally sustainable circular economy: Focus on land use, construction, and rewilding

Major global environmental problems have been addressed, including climate change, loss of biodiversity, and the challenges posed by chemicals and the circulation of plastics. Biodiversity, natural ecosystems, and natural richness have begun to recover due to stricter and smarter environmental regulation and protection, combined with forestation and restorative and regenerative actions both in cities and in the countryside. The Finns' already strong relationship with nature has deepened. Finland is self-sufficient in renewable energy, energy storage is quite highly developed, and across the board, decentralised energy production is emphasised. CO_2 emission targets are met – or more than met – in 2050, and the CO_2 generated as a by-product in industrial processes is gathered and recycled for use with next-generation technologies. Climate and biodiversity considerations, the sustainable and reduced use of natural resources, circularity, and the purity of nature are all taken into careful consideration in decision-making at all levels of society. Finland is no longer among the 'winners' in material consumption in Europe, as consumption has decreased dramatically.

Ecologically sustainable cities are built according to CE principles, with actively considered soil construction, occupancy rates, multi-use spaces, life cycle, energy use, and the space efficiency of estates and buildings. CE thinking is also at the core of infrastructure construction. The focus of construction is on renovation and brownfield construction, whereas new construction and greenfield construction are minimised. In 2050, there are no more empty spaces in buildings. New construction largely uses materials and structures that have been removed intact from existing building stock and retained their value, and the health and safety-related problems associated their use have been solved. In general, buildings and real estate are designed for reassembly. Real estate is far more efficiently used through digital services, for example, buildings that are in official public use during the daytime can be rented for evening use by individuals. In 2050, for water saving and nutrition cycle reasons, indoor composting toilets have replaced water toilets, even in multi-storey buildings.

City parks, woods, and green areas enjoy the finest of care, with trees, bushes, and plants planted to sequester CO_2 and enrich biodiversity. Bee hotels are common, and endangered flora and fauna are carefully moved to safety from places threatened by construction. Green roofs and walls flourish, along with a wide variety of trees and urban greenery. The role of driving has decreased in urban planning, while cities have good air quality and are cleaner and quieter due to sustainable modes of mobility. The key aspects of the green care in cities described previously are shown in Figure 23.2.

In rural areas, regenerative agriculture is practiced, as fields sequester and store carbon and do not release nutrients. Forests are valuable assets and are carefully tended. Land use is thoughtfully designed, and wetlands, pollination fields, and food production have their own specific areas. As the CE aims at a better use of resources like farmland, animal production has decreased, and the cultivation of plant-based protein has increased. Self-sufficiency and security of supply are highlighted in food production. Technology enables new ways of making food, even in containers, with the help of microbes or through vertical farming. Nutrient cycles work efficiently, and food waste and traceability are managed using novel technology. Several new kinds of jobs and other innovations exist in the countryside.

Socially sustainable circular economy: Focus on well-being, collaboration, and education

In 2050, compared to decades earlier, a fraction of the use of natural resources achieves the same level of well-being and results in Finland. Politically, there is a joint commitment to developing

Figure 23.2 Environmentally sustainable circular economy.
Source: The authors.

the CE over a longer time horizon than four-year government programmes. The CE, as such, has increased general employment in the private and public sectors as new needs and demands generate new solutions and supply. As part of CE implementation in organisations, social sustainability issues like wages, working conditions, and the value chain are carefully monitored nationally and globally, especially in the international manufacturing industry.

On an international level, engagement and interaction with the EU and major international bodies and companies are reciprocal and continuous. National promotion of CE is multidisciplinary and multisectoral, and there is a diverse selection of cooperation and partnerships. For example, public–private–people partnerships and alliance models are robust. CE issues are actively discussed, co-created, and co-developed between ministries, cities, communities, regional actors, research and development actors, lobbyists, the third sector, and businesses. Collaboration in particular is further illustrated in Figure 23.3. The fourth sector also promotes the CE. Powerful cooperation increases community spirit and encourages commitment. A variety of digital platforms support polyphony and inclusion. Debates vary from innovating and co-creating new commodities to sharing best practices for preventing occupational accidents. Beyond economic and technological innovations, social innovations also emerge. Specifically, old factories are now used as lively CE parks or city villages where rehabilitative work activities can be organised, and the employment of young people, immigrants, and the disabled are supported.

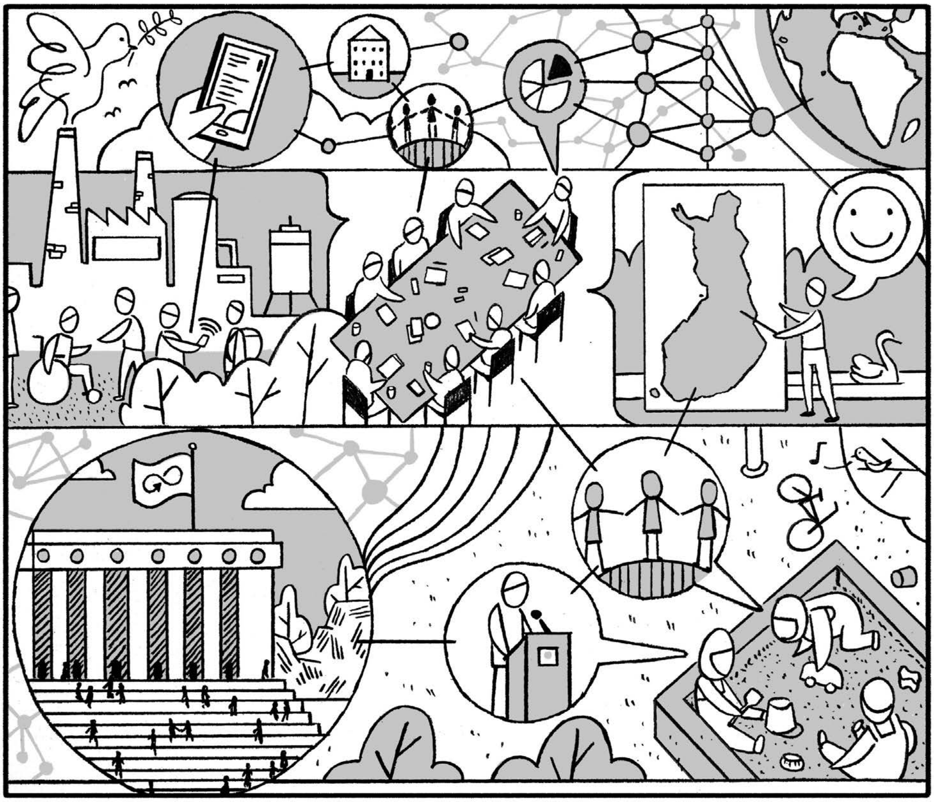

Figure 23.3 Socially sustainable circular economy.

Source: The authors.

CE thinking is also part of basic education starting in day care, and there are numerous study units and modules around the CE at various school levels. Educational paths are also flexible in working life. Finland's age structure is steady, and the new generation of decision-makers was born and educated to view the world through sustainable CE lenses. In 2050, Finland has properly fulfilled its international role in the CE and is a good and safe country in which to live. The CE has brought vitality even to the smallest of villages, while common CE solutions make people's everyday lives easier. Thanks to real-time communication and a networked society, information about the latest best examples of CE from around the world quickly reach Finland.

Culturally sustainable circular economy: Focus on change in culture

In 2050, a CE is well integrated into both the Finnish state and Finnish national values. Due to a strong and unified culture, Finland and the other Nordic countries had served as a kind of CE test laboratory. Due to early experimental successes, the CE has gained a strong position and is highly valued and widely implemented, with a local Finnish flair of equality, trust, honesty, perseverance, and respect for one's own space and nature. Recycling culture is high among both individuals and enterprises. The tradition and culture of ownership have evolved into usership, and people's relationship with goods has altered. The general atmosphere supports mending, exchanging, renting, and sharing all products from clothes to cars, as depicted in Figure 23.4. People are heavily oriented to using a wide range of services, especially digital services. In general, sustainable, old, and nonmaterial things are valued. From the perspective of a young adult, the consumption patterns of previous generations appear sadly old-fashioned. Today, everybody takes seriously the responsibility to consume sustainably. Timeless clothes and clothes-as-a-service concepts replace fast fashion, and the origin of clothing in general interests people. Fashionistas combine new findings in interesting ways. Quality and intangibility are appreciated over quantity. Fewer new goods are bought, and more are repaired and maintained. People choose to live in smaller flats and houses for sustainability reasons and because they do not need as much space to store material goods. Digital platforms and social media support current consumption trends. In addition to libraries, many other physical spaces are used to circulate everything from small commodities (e.g., toys, clothes, and sport equipment) to bigger ones (e.g., grills, lawn mowers, and 3D printers). In particular, many multi-storey houses have a room in the basement meant to house shareable items ranging from drills and bicycle pumps. Sustainable and healthy food choices are a crucial part of consumption behaviour; therefore, vegetarian, and vegan diets flourish.

Mobility is based on sustainable solutions, including cycling and walking, mobility-as-a-service, public transportation, and fossil-fuel-free vehicles. Mobility services are so affordable

Figure 23.4 Culturally sustainable circular economy.

Source: The authors.

that there is no need to own a car. The raw materials for electric car batteries circulate successfully. The use of cars outside urban areas and public transportation coverage are based on car-sharing systems. Logistics are also based on sustainable transport methods. The corporate culture has changed profoundly; even the smallest things, such as choosing different snack options for a meeting, are evaluated against a sustainability scale. Value-based companies attract like-minded employees. The culture of learning and developing oneself is strong; instead of staying in one profession, people develop themselves throughout their careers.

Discussion and conclusions

The aim of this chapter was to study how CE utopias can be used to catalyse sustainable CE. Theoretically, we have built on futures research and especially the concept of utopias as imaginary descriptions of a better society. We created sustainable CE utopias for Finland in 2050 by interviewing 61 CE experts in Finland. The utopias are based on the four dimensions of sustainability: economically sustainable CE, environmentally sustainable CE, socially sustainable CE, and culturally sustainable CE. Although in the previous section these were presented as separate images, their practices overlap and influence one another. Economic issues influence the background of almost all operations. Environmental issues, especially global environmental problems, affect all people. Social aspects are important, as it is people who are responsible for making CE happen. The cultural dimension enables the application of CE with a unique twist that can be modified, tailored, and approved while respecting the traditions of different locations.

We make two contributions. To this book's theme of CE catalysts, we contribute by offering a futures research perspective. To the broader CE literature, we contribute by focusing on the emerging field of CE futures (e.g., Bauwens et al., 2020; Marjamaa & Mäkelä, 2022; Weigend Rodríguez et al., 2020). Our contribution focuses on preferable futures images; that is, utopias and detailed descriptions of sustainable CE. Actively influencing the future is a key premise of futures research, as opposed to passively waiting for a future to happen. In this chapter, we aim to promote this idea in the CE field. We can decide that our CE future will be a bright one, but that means we need to immediately roll up our sleeves and be proactive about achieving our goals.

How do our results act as catalysts for CE transition? The answer is simple: very practically. Sustainable CE utopias describe action targets. We can all compare our actions with the utopias and evaluate what we would need to change in terms of everyday actions. In most cases, we are not talking about mere tweaks, such as recycling waste more diligently or reducing the amount of food waste generated. Rather, we are referring to significant changes in how we consume (and especially not consume), choose diets, commute from one place to another, and influence employers regarding the CE transition. We now highlight the core of the CE transition to ensure that CE utopias become reality, which is massive change at all operational levels. That change affects us in the different roles that we have and the decisions we make at home and in the workplace, as consumers and citizens. The changes that are needed rather nicely follow the dimensions of sustainability.

First, our economic system should become CE-based. This means altering the underlying dominant economic theory. For example, Velenturf and Purnell (2021) argue that a sustainable CE requires a new economic theory, since it is incompatible with all the current approaches. However, they find common ground for a sustainable CE from doughnut economics (Raworth, 2017), which is based on respecting planetary boundaries. From a business perspective, the change means that companies will need to focus on prolonging the life span of their products at every step. Currently, companies focus largely on selling as many products as possible and hoping that customers will buy new products as soon as possible. In the future, products should be used as long as possible by multiple consumers through repair and upgrade practices; in the end, the materials and components can serve as raw materials for new products.

From an environmental perspective, the future requires massive transformation. We need to make the environment central to everything we do. For example, production and consumption must respect planetary boundaries. The long life spans of various products are also key in this regard. This is especially true in the construction industry. Currently, many structures are built for one purpose only, and many remain used only during office or school hours. We would also need to have nature closer to us through practices like green roofs and walls and urban farming instead of restricting it to reserves.

Socially, we need stronger collaboration than we currently enjoy. Collaboration needs to happen at all levels: international, national, regional, and local collaboration are all equally important. Politics, business, technology, nongovernmental organisations (NGOs), academia, and ordinary people need to join forces. Cultural changes relate to social change. We need to move from an individualistic culture to a more collective one. There should be greater emphasis on doing things together. One example is sharing things like tools, appliances, and cars among neighbours in both apartment buildings and detached homes. This is also our key message to international audiences. Although we have used Finland as an example, the key point of our chapter is the urgent need for change everywhere. The CE is not yet a reality anywhere in the world. According to the Circle Economy Reporting Initiative (2022), an NGO focused on CE issues, the world now is only 8.6% circular, with the leading country, the Netherlands, currently at 24.5%.

The distinctive approach of our study is its focus on CE utopias. Previous research has often failed to connect CE futures images with preferability or only connected CE with local circles. We wanted to show that CE can exist in a preferable society and aimed at verbalising how a preferable future could look. The definitions of utopia make clear that it is an imaginary, perfect, and even impractical and hypothetical place where all people are happy. In comparison to our current situation, the utopias we have sketched out more than meet this definition. While no country is currently a fully CE society, many societies have already applied various elements of CE utopias.

The utopias have the potential to change one's insights into and understanding of the future and to illuminate and make visible what is possible and preferable. Utopias can change people's mental models of which directions the world could take. Utopias are normative and dynamic; they change over time. In general, utopias stretch the limits of our conventional thinking and worldviews. Utopias can also change mental models in relation to agency; it is possible to genuinely influence the future in an inspirational way, and everyone can have a role in shaping the future. To build a preferable future with concrete steps, there first has to be an insight, a vision, or a utopia of what is desired. To conclude, we hope that our futures images created from the ideas of current CE experts can serve as new mental models to inspire all of us to discuss, make decisions, and act to help create a future of sustainable CE.

Educational content

- Utopias can be viewed as powerful mental models to empower people with positive ideas about the future.
- CE enables a sustainable transition by considering the economic, environmental, social, and cultural aspects of CE.
- The actions and decisions we make today shape the future. If we act now, we can achieve a sustainable CE future.

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Appendix 1
INTERVIEW DATA

Table 23.4 Interview data

No	*Organisation category*	*Interviewee(s)*	*Duration (min)*	*Length (pages)*
1	Company 1 (Waste management)	CEO	62	11
2	Company 2 (Information and communication technologies)	Enterprise growth programme leader	49	7
3	Company 3 (Construction, engineering, design, and consultancy)	Senior specialist	39	7
4	Company 4 (Silviculture and forestry)	Business unit manager	55	17
5	Company 5 (Waste management)	CEO	62	9
6	Company 6 (Architecture and engineering)	Director	31	5
7	Company 6 (Architecture and engineering)	Country director	62	8
8	Company 7 (Investment)	Investment director	54	7
9	Company 8 (Urban farming)	CEO	92	27
10	Company 9 (Clothing)	Project manager	55	7
11	Company 10 (Management consultancy)	Deputy CEO, partner	80	10
12	Company 11 (Waste management)	CE specialist	79	9
13	Company 12 (Real estate)	Adviser and adviser	96	12
14	Company 13 (Clothing)	Communications specialist	93	9
15	Company 14 (Construction)	Quality and sustainability manager	68	8
16	Municipality 1	Environmental specialist	72	13
17	Municipality 1	Environmental specialist	52	7
18	Municipality 2	Research and development manager	74	12
19	Municipality 2	Liaison manager	88	11
20	Municipality 3	Environmental director	65	10
21	Municipality 3	Environmental director	83	10
22	Municipality 4	Director of sustainable development	54	8

(*Continued*)

Table 23.4 (Continued)

No	*Organisation category*	*Interviewee(s)*	*Duration (min)*	*Length (pages)*
23	Municipality 4	Director of sustainable development	56	8
24	Regional actor 1	Project manager	49	16
25	Regional actor 1	Director of development	72	15
26	Regional actor 1	CEO	69	8
27	Regional actor 1	Head of sustainability and innovation	87	10
28	Regional actor 2	Director, innovation and foresight	58	16
29	Regional actor 2	Director, innovation and foresight	68	10
30	Regional actor 3	Project manager and Development manager	78	14
31	Regional actor 3	Development manager	84	10
32	Regional actor 4	Executive director	110	13
33	Regional actor 5	CEO	85	11
34	Research, innovation, and support organisation 1	Programme director	65	16
35	Research, innovation, and support organisation 1	Programme director	57	10
36	Research, innovation, and support organisation 2	Senior expert	81	22
37	Research, innovation, and support organisation 2	Senior expert	73	9
38	Research, innovation, and support organisation 3	Senior lead	74	20
39	Research, innovation, and support organisation 3	Leading specialist	64	9
40	Research, innovation, and support organisation 4	Specialist researcher	79	10
41	Research, innovation, and support organisation 5	Professor (entrepreneurship)	80	9
42	Research, innovation, and support organisation 6	Head of bio and circular program	84	10
43	Industry organisation 1 (Construction)	Environmental manager	61	21
44	Industry organisation 1 (Construction)	Director, environment and energy	90	12
45	Industry organisation 1 (Construction)	Director, business policy	83	10
46	Industry organisation 2 (Chemicals)	Chief advisor, bioeconomy and CE	81	26
47	Industry organisation 2 (Chemicals)	Chief advisor, bioeconomy and CE	48	8
48	Industry organisation 3 (Technology)	Executive director	57	15
49	Industry organisation 3 (Technology)	Executive director, sustainable development	69	9
50	Industry organisation 4 (Textile)	Chief advisor, sustainability and CE	59	7
51	Industry organisation 5 (Municipalities)	Manager for environmental affairs	70	10
52	Ministry 1 (Environment)	Senior specialist (CE)	77	23
53	Ministry 1 (Environment)	Head of unit	52	15
54	Ministry 1 (Environment)	Senior specialist (CE)	101	13

(*Continued*)

Table 23.4 (Continued)

No	*Organisation category*	*Interviewee(s)*	*Duration (min)*	*Length (pages)*
55	Ministry 1 (Environment)	Senior specialist (CE)	110	14
56	Ministry 2 (Agriculture and forestry)	Senior adviser and ministerial adviser	54	20
57	Ministry 2 (Agriculture and forestry)	Ministerial adviser	45	8
58	Ministry 2 (Agriculture and forestry)	Ministerial adviser	46	6
59	Ministry 3 (Economic affairs and employment)	Program director	73	16
60	Ministry 3 (Economic affairs and employment)	Senior adviser	81	10
61	Other 1 (European Parliament)	Member of the European Parliament	79	10
	TOTAL		71 hours 14 minutes	723

PART IV

Conceptual understanding of catalysing

24

TOWARD A TYPOLOGY OF CIRCULAR ECONOMY AGENCY

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Introduction

Faced with climate and biodiversity collapse (IPBES, 2021; IPCC, 2021), the ecologically sustainable future of humankind is increasingly questioned (Rockström et al., 2009; Steffen et al., 2015). The shift from a linear to circular economy (CE) has emerged as a systemic means via which the economic system can steer toward carbon neutrality and reduce the usage of natural resources (Schöggl et al., 2020). CE represents fundamental changes in business, causing paradigm changes in regard to how humans interact with nature, requiring implementation at the micro-, meso-, and macro-levels (Prieto-Sandoval et al., 2018). Taking a critical stance, however, CE tends to be viewed from a techno-operational and economic lens, which ignores its sociocultural dimensions (Mäkelä et al., 2022). The need for speed in mobilising the agency of societal change agents to accelerate CE transitions is recognised (Blomsma et al., 2022). Nevertheless, the nature and role of CE agency remains poorly considered (Jokinen et al., 2021; Koistinen et al., 2022; Sarja et al., 2021).

To start addressing this gap in understanding, this chapter explores actors and their agency in catalysing the CE transition. To guide our inquiry, we ask: 'How do individual and organisational actors exercise their agency in accelerating CE transitions?' Our research approach is abductive, building upon our interdisciplinary research team's theoretical and empirical insights in the study of CE agency in 2015–2022. The main contribution of the chapter is introducing the concept of CE agency, while developing a typology of CE actors and their agency at the individual, organisational, and inter-organisational levels of analysis.

The chapter proceeds as follows: The next section reviews theorising on agency and sustainability agency. Section three introduces our methodological approach and research settings. In section four, building on empirical findings, we present our typology of CE agency, consisting of individual, organisational, and inter-organisational actors exercising their active and relational agency in catalysing CE transitions. The final section highlights the contributions of our work alongside limitations, future research directions, and educational implications.

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Prior theorising on agency and sustainability agency

The question and study of agency cuts across the history of the humanities and social sciences, with roots in early philosophical inquiry. In this section, we offer a review of agency and sustainability agency to position the chapter in prior theorising.

To begin with, agency appears in many forms. Theorising on agency across the social sciences implicitly equates this concept with living beings; this is particularly exemplified via human agency (Ritzer, 2000). Also, non-human agency is recognised (Latour, 1987; Law, 1992). Multispecies sustainability acknowledges the agency in all forms of life in nature, be it in animals, viruses, bacteria, plants, etc. (van Dooren et al., 2016; Rupprecht et al., 2020). Further, there is also material agency (Knappett & Malafouris, 2008), whose connection with human agency becomes critical in the CE context (Jokinen et al., 2021). While acknowledging other forms of agency, in this chapter, our focus is on human agency.

Agency can further operate at different levels of analysis. The bulk of theorising in the social sciences has equated human agency with individual-level agency (Bandura, 2003; Emirbayer & Mische, 1998). For example, in management research, the notion of change agency represents active change-makers involved in organisational change (Caldwell, 2003). Beyond individuals, agency can also refer to collectives that act (Crozier & Friedberg, 1980; Ritzer, 2000), such as social classes (Touraine, 1977). What is more, agency can materialise in relationships with others, then termed as relational agency (Burkitt, 2015).

We build upon definitions of agency as an individual's or a collective's capacity to act (Dietz & Burns, 1992; Giddens, 1984). The focus on one's 'capacity to act' explains why questions of agency can be considered to define what it means to be human (Bandura, 2003), as well as why questions of agency can be considered to characterise the history and evolution of humankind.

The relationship between agency and structure marks a classic divide within the social sciences, as stances toward one or the other represent alternative paradigms (Caldwell, 2003; Emirbayer & Mische, 1998). In this realm, Giddens's (1984) theory of structuration, addressing the relationship between agency and structure, is influential. He considers agency and structure as operating in a dialectical interplay, given that all social action involves structure and vice versa. In contrast, other scholars have provided primacy toward either agency – as in phenomenology – or to structure – as in structuralist or institutional theories (Ritzer, 2000).

There is an increasing interest in the role of actors and their agency in building sustainable futures. Yet, this knowledge is scattered both within and across disciplines (Koistinen & Teerikangas, 2021; Onkila et al., 2019; Teerikangas et al., 2018). Furthermore, the terminology used is multifaceted and spans multiple levels of analysis, with numerous forms of agency in building sustainable futures having been identified. Thus, management theorists study firms' non-market strategies (Doh et al., 2012), social entrepreneurship (Waldron et al., 2016), shareholder activism (Goranova & Ryan, 2014), and employee volunteering (Rodell et al., 2016). Together with sociologists, they possess an interest in social movements (de Bakker et al., 2013; Heaney & Rojas, 2014) and institutional entrepreneurship (Pacheco et al., 2010). This parallels the psychologists' interest in environmental activists (Gousse-Lessard et al., 2013). Environmental management scholars study firms' engagement in external collaborative partnerships (Wassmer et al., 2012) and within-firm sustainability change processes (Haugh & Talwar, 2010). In sustainability science, the role of niche, regime-shaping, and incumbent actors is recognised (Smith & Raven, 2012). In sum, numerous terms are used to denote sustainability actors and their agency. Taking a critical look, integrative views of actor types, roles, and their means of influencing sustainability transitions remain amiss (Garud & Gehman, 2012; Geels & Schot, 2007; Markard et al., 2012; Pesch, 2015).

To this end, based on an interdisciplinary review of different forms of agency in the pursuit of sustainable futures, the concept of sustainability agency was introduced by Teerikangas et al. (2021), referring to intentional, proactive individual or collective-level action geared toward sustainable futures – also involving interaction with material forms of agency. The concept of sustainability agency was introduced as an umbrella concept in consideration of the variety of actor types exercising their agency in the pursuit of sustainable futures. It deserves mention that scholars of sustainability agency tend to study active change-makers. In order to capture the multiplicity of actor types, Teerikangas et al. (2021) present sustainability agency via four lenses. The first lens to sustainability agency illustrates individuals, be it managers, professionals, employees, or consumers. The second lens to sustainability agency refers to active actors, as in the example of institutional workers, sustainability activists, social and environmental entrepreneurs, citizen collectives, or social movements. The third lens to sustainability agency is relational, representing sustainability agency occurring in interaction, negotiation, and collaboration with a broad spectrum of stakeholders – be it via projects, partnerships, networks, or ecosystems. The fourth lens to sustainability agency builds on governance – be it (in)formal economies, legislation, governments', regions', cities', public organisations', or companies' agency. In sum, these four lenses portray sustainability agency occurring within and across different levels of analysis. In this chapter, we build on the concepts of agency and sustainability agency to guide our effort to appreciate CE agency.

Methodology

This chapter builds on methodological innovation and integration, as we bring together an interdisciplinary research team's insights garnered while exploring CE agency. In light of the lack of prior research on the subject matter, we adopted a two-way, abductive research approach.

To begin, our research was guided by an interdisciplinary, conceptual, and integrative enquiry into the nature of sustainability agency. While working across the disciplines of management and sustainability science, we observed the lack of a mutually agreed upon view as to what sustainability agency is. Subsequently, our research team edited an international research handbook on the subject matter, inviting leading authors to review a particular element of sustainability agency (Teerikangas et al., 2021). The previous section offered a succinct overview of this enquiry.

In parallel, we adopted a grounded theory-building research approach (Glaser & Strauss, 1967) to study CE agency in empirical contexts, which offered insight into CE transitions that are actively in the making. Grounded theory-building is welcomed in the study of novel phenomena and ongoing social processes, in which little available theoretical insight is available (Glaser & Strauss, 1967). All the while, we extensively read across the literature on corporate responsibility, CE, sustainability transitions, and ecosystems, seeking to appreciate each field of research while also aiming to identify the role of active sustainability actors therein. Extensive reading across the literature is suggested in grounded theory building as a means of enhancing the researchers' theoretical sensitivity (Glaser, 1998). Our empirical focus was on Finland, a revelatory case study, the first country in the world to develop a national-level roadmap for CE implementation. Moreover, CE is featured on the government's agenda, which aims for Finland to be a CE-based country by 2030 and carbon neutral by 2035. Our interest was in appreciating the agency of front-runner individuals and organisations via three parallel studies, conducted in 2018–2021 as part of the Finnish Academy Strategic Research Council–funded Circular Economy Catalysts

Table 24.1 Overview of the three studies and findings presented in this chapter

	Study 1	*Study 2*	*Study 3*
Focus of study	Managers and change agents in front-runner CE firms	Eco-influencers and activists	CE innovation ecosystems
Level of analysis	• Individual • Organisational • Industrial • Societal	• Individual • Societal	• Individual • Organisational • Ecosystem
Timing of interviews	2019–2020	2021	2019–2020
Data (number)	51 interviews	20 interviews	21 interviews 24 meeting recordings
Interview themes	• CE strategies • CE practices, challenges, success stories, • Change agency and stakeholders	• Motivation, triggers for lifestyle transformation • Challenges and coping strategies	Innovation ecosystems: • Emergence and development • Management, organising • Social interaction
Theoretical framing	• Top managers' power and agency • Professional change agents' agency • Strategy	• Sustainable consumption • Behavioural change	• Ecosystems • Ethnomethodology • Conversation analysis
Analysis approach	Inductive, grounded theory-building during analysis, turning toward abductive when building contributions per study and for this chapter		
Findings on CE agency	• Top managers' agency • Change agents' agency • Companies' agency • Inter-organisational collaborative agency	• Citizen-consumers' agency	• Relational agency

research project (studies 1 and 3) and the Kone Foundation–funded Circular Citizens research project (study 2) (see Table 24.1):

1 The first study consisted of interviews conducted with 51 managers and professionals in Finnish companies considered to be CE spearheads.
2 The second study consisted of 20 interviews of consumer-citizens acting as eco-activists.
3 The third study was an in-depth longitudinal case study of an emerging city-based CE ecosystem in the city of Espoo, based on interviews with managers and professionals representing public and private-sector organisations, as well as online meeting recordings from project and working group meetings.

Our analysis proceeded in three phases. First, using inductive analysis, we identified the types of individual and organisational actors as well as their agency in shaping the circular transition. This led us to define the empirically derived categories of:

1 Individuals exercising their CE agency as 1) citizen-consumers (study 2), 2) professional change agents and 3) top managers (study 1), and 4) professionals working in circular ecosystems (study 3);

Table 24.2 Typology of CE agency

	Active agency exercised via an actor's role		*Relational agency exercised via interaction*
Individuals driving the circular transition	Prosumer's agency of citizen-consumer Citizen-consumer's eco-influencer agency	Professional's change agency Top manager's agency	Professionals' orchestrative agency
Organisations driving the circular transition	Companies' agency *Cities and regions' agency* *(Inter-)national institutions' agency*		Collaborative inter-firm agency Collaborative public-private agency
Inter-organisational collaboration driving the circular transition	Agency via *partnerships, supply chains, networks,* ecosystems		

Note
Actor types marked in *italics* are not covered in this chapter.

2 Companies exercising their CE agency (study 1);
3 Inter-organisational collaboration as a driver of CE transitions (study 1).

Second, we reflected these inductively derived categories onto prior literature. This led us to connect citizen-consumer roles to the concepts of prosumers and eco-influencers in the CE and sustainable consumption literatures, while the concept of change agency connected with management theory (Caldwell, 2003). Returning to the concept of sustainability agency (Teerikangas et al., 2021) enabled us to find theoretically derived labels to categorise the types of agency identified via our empirical analysis. This led us to use the concept of active agency to categorise our individual, organisational, and inter-organisational actors, given that they actively drive the circular transition. Moreover, this led us to utilise the concept of relational agency to refer to professionals collaborating in ecosystems and organisations involved in inter-organisational collaboration. In summary, this abductive approach led us to develop a two-dimensional typology (see Table 24.2), where one axis represents levels of analysis, while the other axis represents forms of CE agency as active and/or relational agency. In the next section, we present our findings.

Findings on CE actors and their agency

In this section, we present our abductively derived findings on CE agency, while embedding our findings onto relevant literature. First, we discuss how active individuals drive circular transitions as citizen-consumers (based on study 2) as well as in the work roles of professional change agents and top managers (based on study 1). Second, we detail the relational agency exercised by professionals and managers involved in the making of a CE ecosystem (based on Study 3). Third, we study active companies engaged in catalysing CE transitions (based on study 1). Fourth, we analyse the relational agency of organisations as they engage in inter-organisational collaboration to steer the CE transition (based on study 1).

Active individuals driving the circular transition

Citizen-consumers' agency

Both a hesitant company culture and consumers' lack of interest or awareness toward CE choices have been recognised as explaining the slow diffusion of CE models (De Jesus & Mendonça, 2018; Kirchherr et al., 2018). It is therefore important to explore examples of proactive change-making among active citizen-consumers. At the individual level, circularity is not only about correct recycling, but importantly about precycling – the systematic prevention of waste and sustainable handling of resources (Greyson, 2007; Klug & Niemand, 2021). In everyday life, this translates into curbing personal consumption, the careful planning of purchases in favour of durable and repairable items, the reuse and repurposing of goods, the renting/borrowing of infrequently needed items, minimizing waste by purchasing in bulk with minimum packaging, and eliminating unnecessary plastic waste. In other words, circularity in everyday life implies profound lifestyle changes. Therefore, both educational and policy support are needed to enable such widespread societal change (Edbring et al., 2016; Korsunova et al., 2021).

At the same time, much of the progress towards circular transitions is claimed to be happening from the bottom up, initiated by civil society and NGOs with the aim of changing legislation and encouraging the involvement of private actors to support circularity (Ghisellini et al., 2016). Understanding the dynamics, dependencies, and tensions between the different actors in circular transitions can shed light on the levers for accelerating the transition process. Although CE-minded actors are emerging among producers and civil society, the misalignment with traditional market players may lead to reconfigurations of actor roles across the systems of production and consumption (Laakso et al., 2021). In interviewing active citizen-consumers (study 2), we found them to engage in prosumer and eco-influencer agency, as detailed next.

Prosumer agency. Initial insights from the interviews with followers of a zero-waste lifestyle in Finland illustrate the dependencies and tensions arising between change-making consumers and conventional ones in implementing everyday circularity. While some local niche manufacturers, such as small businesses offering alternative products, have started to produce alternative personal care products, such as shampoo soap bars with minimal cardboard packaging, these are mainly available in specialised eco-shops and online stores. Meanwhile, mainstream retailers continue to offer personal care products packaged in plastic. As online purchasing requires anticipating a need and placing an order in advance, this practice is more cumbersome than visiting a convenience store on the corner. Frustrated with higher pricing and limited availability, some zero-waste followers have started making their own products at home, such as deodorants, to ensure their own supply and minimise packaging waste:

> When I got interested in Zero Waste and really got into it, I found all those instructions and decided to try out making stuff myself. . . Maybe it was exactly about avoiding all the plastic and at the same time, finding affordable options. And also, the fact that you know everything that you put inside the self-made deodorant. Maybe I'm that kind of person who always wants to try out whether something works, and I tend to question what is being marketed to us.
>
> (26-year-old eco-influencer)

While they may still purchase the ingredients for their products from conventional stores and, in that way, fulfil the traditional consumer role, these pioneering citizens also turn into producers, thereby bypassing their dependency on traditional suppliers. Hence the 'prosumer' term, which has been earlier used, for instance in the energy context, refers to citizens producing their own energy from renewable sources (Ruostetsaari, 2020).

Eco-influencer agency. In addition, followers of the zero-waste lifestyle often blog about their experiences, recipes, successes, and failures in an accessible manner, engaging with different audiences, and thereby facilitating circular transitions. This kind of informal education through blogging is an example of media use for civic and democratic purposes, practising responsibility and citizenship, described as 'citizen-consumers' (Wallis & Buckingham, 2013). Other citizens may find it fashionable and interesting to try out the practices and lifestyles of influencers/bloggers, while market actors, including producers, can learn from such influencers' experiences for product/service development. Fischer and Newig (2016) argue that interactivity, relationality, and embeddedness in society facilitate the flexible reconfigurations of roles, extending the agency of the actors.

As circular transitions are progressing, traditional market arrangements will experience increasing pressure from change-seeking actors (Loorbach, 2017). The ongoing reconfigurations of roles require that all the market actors reconsider their activities and value propositions, adjusting to the needs of circularity-driven lifestyles. It is already evident that CE implies that individuals be active in the trading, reselling, reusing, and remaking of goods – foregoing the one-dimensional consumer role. In the context of CE, we illustrated how proactive citizen-consumers become prosumers, thus practicing citizenship by engaging in the making of products for personal consumption, while engaging as eco-influencers in sharing their recipes and experiences via personal blogs in a charismatic manner.

Professionals' change agency

In this section, our focus shifts to individuals in professional roles (i.e., not teams), as change agents who initiate, lead, or take responsibility of making change happen (Caldwell, 2003). As change agents, professionals in private and public organisations take on a powerful role in initiating, managing, and leading such changes by motivating and inspiring others to act (Carroll et al., 2008). Professionals' change agency refers to one's ability to pursue goals via value-driven action (Sen, 1985; de Haan & Rothmans, 2018) that goes beyond self-interest (Crocker & Robeyns, 2012). While such change agency essentially involves leadership, it is not necessarily tied to a managerial position. Instead, change agency is also possessed by individuals in non-managerial positions who enable and initiate bottom-up changes towards CE.

A tensional experience. Our interviews (study 1) reveal the duality of the change agency experienced by professionals who act to initiate and lead changes towards CE in front-runner companies. This duality is created between their willingness and passion for change set amid often unsupportive environments. On the one hand, they have a strong commitment to and motivation for CE, perceiving themselves as missionaries for this change. On the other hand, they struggle in their change agency, especially when handling problematic instances, such as resistance to change, lack of support from societal structures or ignorance of CE. The following quotes exemplify the duality in change agency experiences amid interviewees:

> I do this [CE work] wholeheartedly and I believe in this. It is like a religious cult. And if I see that when I speak about this [CE] and if I'm able to get others to think differently and wake them up to this different kind of thinking, it is very satisfying. It brings strength to my own work and I'm very grateful for it.
>
> (Manager, textile firm)

> Sometimes you encounter parties that are very resistant to change and very eager to be upfront about it. If someone does not believe in something [CE], I still don't find it appropriate to push others down.
>
> (Manager, construction firm)

As exemplified in the previous quotes, problematic situations arise, for example, from resistance to change and societal structures hindering CE-related change, but also from a tension between non-spoken idealistic expectations and the reality of change agents' practice on the ground. At a personal level, this means that the change agents must navigate between their identity as active and enthusiastic actors while being victims of surrounding circumstances limiting their potential to act. Such realities of agency also result in rather negative emotions among these actors, such as frustration and exhaustion.

Top managers' agency

Top managers bear a central role in shaping their companies' sustainability strategy and performance (Koistinen et al., 2022; Salaiz et al., 2021). In this section, we appreciate how top managers in front-runner CE companies, via their active agency, engage in furthering the circular transition. Given their institutional role, top managers' agency is closely connected with their access to and use of power (Koistinen et al., 2022). To this end, top managers' career development and character traits explain how they gain access to formal power. As they have secured their managerial positions, they exert power through their institutional position. Finally, we find that despite their formal power position, top managers' practiced power is set amid a bi-directional movement between their agency and the surrounding structure (e.g., organisation, sector, or society).

Career paths with meaning. Our findings imply that top managers' career paths explain why they become involved with CE. The interviewed top managers of front-running CE companies had adopted career transitions to develop CE in their companies (study 1). Yet, top managers do not necessarily make these career changes out of a pure interest towards CE. Occasionally, top managers either drift to CE-related professions or they make career turns to further their professional or financial career development.

Career changes thus acted as individual-level drivers in the transition toward circularity. It is via career choices that top managers gain access to positions vested with formal power. Thus, top managers' career paths capture the interplay between their agency and prevailing structures amidst a circular transition. Taking a closer look, top managers' interest in CE and the experienced meaningfulness increases while working with circularity. Executives' career choices and growing meaningfulness embody their role as active CE agents, as illustrated next:

> On my behalf, I want to contribute to the state of the globe and future. The meaning of this work is that large. On daily basis, I believe I am doing good deeds.
>
> (Top manager, environmental service company)

Character traits. Top managers' personality traits offer micro-level insights as to why they engage in CE. In our analysis, the interviewed top managers were characterised as pioneering, problem-solving, and resilient. These traits enable them to access and thrive in demanding positions. Such personality traits underlie their active agency in the structuration towards circularity. As an example, one top manager discussed how his pioneering attitude has resulted in their company becoming a CE trailblazer in Europe:

> We are pioneers in Finland. Actually, I would argue that in Europe too. . . and I have led this pioneering work.
>
> (Top manager, services company)

Power position. Top managers enable circularity by leveraging the power vested in their managerial position. They steer their companies towards circularity despite the possible risks. The top managers use their roles to enable circularity by communicating about CE while balancing between cooperation and competition with stakeholders. Doing so, they engage in an active interplay between their agency and societal structures. This is illustrated in the following excerpt of a board chairman, who emphasises how long-term cooperation can outweigh short-term monetary profits. Therefore, despite the financial threats, he exerts his executive power in the company by engaging the organisation toward long-term cooperation to drive CE:

> Euros are not our only motivation. Rather, we see that we are building a brand and we are being transparent. We are building a relationship grounded on trust and cooperation. In the upcoming years, this will create a market and will translate into profit.
>
> (Top manager, construction company)

In summary, top managers are perceived as the most powerful members of a company, and they play a key role in implementing sustainability strategies. Despite this position of formal power, their agency is dependent on structural constraints within their companies, in the industry, and society at large. For example, their power in shaping the circular transition in companies depends on their ability to secure business profitability.

Professionals' relational agency via orchestration

In this section, the focus shifts toward relational agency (Burkitt, 2015; Emirbayer & Mische, 1998), whereby agency is conceptualised as an interactive process rather than an individual capability. In this view, CE agency occurs as mutual responsiveness of agents in interaction, negotiation, and collaboration with a broad spectrum of stakeholders. Agency is being viewed through the activity of orchestration: mobilising multiple, diverse stakeholders across organisational boundaries in innovation networks (Reypens et al., 2021; Ritala et al., 2009). This section offers micro-analytical insights on an orchestrator catalysing the CE transition.

Orchestration is being viewed by using the lens of ethnomethodology and conversation analysis (Sacks, 1992) for studying the micro-level processes of social interaction. Through this lens, agency occurs in social encounters, as individuals enact their agency with others in their talk and embodied interaction. The question in this view becomes, When and how does an orchestrator act in relation to other participants, and how do the other participants in turn orient themselves to the orchestrators' actions and make them relevant? An empirical example is used to demonstrate orchestration in interaction. The data has been recorded from a meeting for developing a circular urban area in Finland. In the meeting, the employees of a circular ecosystem representing a city and companies aim at co-creating energy solutions (study 3). The relational properties of orchestration are presented in the following sequence of six minutes of recorded online talk (transcript simplified).

Prompting for orchestration

Towards the ending of the meeting, energy firm employee (EN) and landowner company representative (LA) are discussing the contracting of future energy solutions. The context of a multilateral partnership poses challenges for contracting, thus the employees express explicitly their hesitation to proceed in the situation (Energy solutions, 1:17:15–1:17:55):

01 EN: But hmh we are now kind of waiting for that how it now seems to be forming [...]
02 LA: Maybe the content of the {firm's} letter of intent was maybe in any case sort
03 of more binding for the {firm} than us so I don't believe that it like is on
04 our behalf obligatory

The extract shows how orchestration is being prompted for responding to the problematic state of affairs. The orchestrator's resulting actions are illustrated next.

Enacting orchestration

After being prompted by previous speakers, a city employee, assuming the role of an orchestrator intervenes in such a way that is specifically designed to mobilise the other participants over organisational boundaries. The orchestrator uses a specific form of talk, storytelling (Mandelbaum, 2013), to enact orchestration in interaction. The orchestrator's turn is three minutes long, consisting of several components (Energy solutions, 1:19:09–1:22:25):

1 The orchestrator (OR) launches storytelling by referring to her personal history and stance on the subject matter:

01 OR: Yes, back in the day when we started talking, I've also been calling for
02 the tripartite contract model [...]

2 The orchestrator makes the current situation problematic by reiterating the problems that a public organisation like the city has in regard to contracting:

03 OR: Although the city has committed itself to the circular economy in many different ways
04 the double decision-making by the public administration makes it difficult to
05 commit [.. .]

3 The orchestrator proposes her own solution for how to solve the problem:

06 OR: The old contract model, which was [...] so if it could be done bilaterally by the {firms}
07 then I would see it as a good thing [...]

Here, the storytelling structure serves as a means for "offering something that does something now, i.e., describes, explains, accounts for, our current circumstances" (Sacks, 1992: II: 465). The orchestrator's actions illustrate purposeful action to influence on hesitant ecosystem partner representatives.

Recipient responses

The last excerpt shows the consequences of the orchestrator's action in the responses of the other participants. The excerpt shows how the energy firm and landowner representatives respond with a changed understanding of the situation and move to finding ways forward in contracting (Energy solutions, 1:22:54–1:23:21):

EN: So I would see that it still isn't necessary to bury maybe the letter of intent matter.
LA: It can be [...] could it even then like be updated in a sense even closer to concreteness when you have designed further [...]

Moreover, there is an important change in the way the participants express their belonging to a collaborative group. In this excerpt, the speakers enact the so-called 'division of labor pattern', complementing each other in interaction (Couper-Kuhlen & Etelämäki, 2014). The activity of the orchestrator has thus important consequences for membership categorisation (Pomerantz & Mandelbaum, 2004), which is an important catalyst for collaborative and emergent organising.

To conclude, relational agency and the interactive view bring to the fore the tacit dimensions of the social catalysts for change. The orchestrator's influence on the thinking and group formation processes in emergent partnerships and ecosystems provides an important domain for further exploration of the catalysts for collaboration in CE transitions.

Active companies driving circular transitions

Our analysis of front-runner CE companies (study 1) led us to inductively categorise their agency in catalysing CE transitions as strategic, organisational, innovative, communicative, market-shaping, financial, and location-based agency, as presented next.

Strategic agency. At the core of companies' sustainability agency was a clear vision of how CE manifests in the future, this steering the company's long-term activities and promoting business longevity, if the vision was also shared by the industry and regulators. Strategic agency coupled with research into CE indicators offers tools to monitor performance (Elia et al., 2017).

Organisational agency. Taking part in the circular transition requires alignment between the company's strategic goals and its operations. While top managers develop strategy, including CE, the entire organisation then needs to adopt this strategy:

> The need for it [CE] yes was identified at the top management level. It is maybe a necessity that a company makes changes as well. At the moment, it goes through everything, from material selection, application, and processes.
>
> (Business director, consumer goods)

It is recognised that ensuring new innovations within organisations and implementing CE strategies is tied to employee engagement (Veleva et al., 2017).

Market-shaping agency. Companies combined different means to make an impact, varying from achieving a leading position in the market, initiating or participating in pilot projects, investing in their own or others' CE ventures, and affecting demand by offering new CE solutions or requiring them from suppliers. At the core of a market-shaping agency was an interest in different stakeholders' CE needs:

> We have learnt that people are different; they think differently, and, for different types of people, there need to be different types of models to enable that CE. They won't do it the way we want, but we need to offer them the possibility to take part in CE in their own way.
>
> (CEO, online flea market)

Innovative agency. Innovation was recognised as the most common denominator in the numerous ways new solutions and technologies were developed for advancing the CE transition, including product development, research, the re-planning of operations and processes, applying novel technologies in existing practices and products, and ideating and offering new venues to utilise one's own or others' reusable or recyclable material flows. Yet while innovations play a key role in CE transition, they need to be tied to strategic alignment and employee engagement (Veleva et al., 2017).

Communicative agency. Corporate communication, in particular two-way communication, helps to raise awareness and shape the attitudes of internal and external stakeholders regarding CE. Improving internal knowledge on CE and sharing this knowledge with external commercial or public actors is also a means to further the CE transition. Persuasive communication strategies in promoting CE have been recognised as key elements in overcoming attitude-related barriers (Muranko et al., 2019). Furthermore, multinational companies recognised that they can positively affect their external political environment by lobbying and acting as facilitators.

Financial agency. A healthy financial balance sheet reflects a company's ability to catalyse a CE change through the markets. Thus, companies need a sufficient bottom line and resources before they can undertake a more active role in supporting other actors in the CE transition. To achieve this, measurement tools are needed that appreciate the CE. The literature often discusses CE together with traditional linear economy measurement tools, such as cost leadership, differentiation, operational performance, and efficiency (Mura et al., 2020). In addition, some have proven the benefits of adopting CE strategies via modelling, thus providing quantitative data as evidence (Alizadeh-Basban & Taleizadeh, 2020). While some of the linear measurement tools and proof may help to support the initial steps of the circular transition, they do not consider the vast changes required nor the long-term nature of the transition. As such, there is a need for CE-based measurement tools supporting the promotion of CE among internal and external stakeholders:

> For me, the biggest disappointment and challenge has been finding funding [for their technology-driven company] … It requires a mentality change within the financing field that there comes this impact point of view that means that they need to accept that the profits will come in a longer time frame.
>
> (Founder, a machinery manufacturer)

Location-based agency. Some organisations found it easier to practice circular business in geographical areas where distances between actors were not too great and population densities were higher. This offers urban areas and growth centres an edge in terms of circular business initiatives.

Companies' relational agency via collaborative inter-firm agency

Beyond individuals exhibiting relational agency when working with others, we observed companies to also do so. Due to the systemic nature of the circular transition, companies need to engage in collaboration with other companies to deliver CE solutions (Bressanelli et al., 2018; Ghisellini et al., 2016; Ormazabal et al., 2018; Ruggieri et al., 2016). Based on our interviews with frontrunner companies (study 1), companies collaborated to foster CE 1) with their existing partners, competitors, and networks and 2) by forming new networks.

Collaboration in existing networks. To begin, companies exercise their CE agency in their existing networks via knowledge and information sharing (Sudusinghe & Seuring, 2022), innovations, and collective action (Fischer & Pascucci, 2017). Companies need to share information, as CE connects organisations with different needs and expectations across the value chain. By sharing relevant information along the value chain – be it changes in regulation or design – different actors become aware of and can prepare for such potential changes:

> The regulation and legislation at this specific area is unclear. This affects how we can develop our products, and how we can instruct our clients. [to overcome this difficulty] we have been building collaborative networks along the value chain, to reach our customers and customers' customers, [for the relevant] information to flow up and down the chain. [This exchange of information concerning] the current and potential future needs is needed, for furthering CE.
>
> (Plastics sector representative)

Collaboration between competing firms has also been a spark for new innovations, while sharing information openly is considered as a key component of the circular transition:

> We want to believe that we do not hide information but rather give it directly to our competitors. . . there was this company that you could see as our competitor but on the contrary, we gave them information and they gave us information and that healthy competition increases innovation, and you avoid doing the same things and gives the work substance.
>
> (Founder, construction company)

Companies can also join forces and act collectively. Such collaboration aims to bring about consensus regarding the best practices within the industry (e.g., via federations). As the CE is an emerging paradigm, new ways to organise business as well as general rules and guidelines are lacking. Finding common ground helps companies make sense of how they could implement, realise, and benefit from a CE.

Collaboration via new networks. Companies also realise a CE-supportive agency via new networks (Brown et al., 2020) by creating new connections, building CE-supporting infrastructure, and creating a modus operandi enabling CE to be within their sector or outside of it. Inter-company connections provide companies with new opportunities to deliver CE via complementary competences. Value-chain collaboration enables developing infrastructure that accommodates functioning CE operations for multiple actors. For example, material flow supporting infrastructure can be used for other purposes than waste, while companies can seek means to utilise the side streams of waste. Last, by collectively creating a modus operandi (e.g., via councils), companies can act toward the formation of common norms and guidelines for CE operations benefitting the business landscape at large:

> In order to move forward, we need the references, which require investments, which require financing. So now we have this CE plant with (company x and company y) in the making, which is going to be used to show that the closed-loop solutions work.
>
> (Recycling management company representative)

In summary, inter-firm collaboration in existing value chains aims to adjust the industry to meet the changes created by CE, whereas emerging collaboration in new networks aims to introduce new norms for conducting business through CE. Put differently, in existing inter-firm collaboration, CE is introduced as a novelty in the existing value chain, while new modes of inter-firm collaboration tend to become framed around emerging CE solutions and infrastructure. In the latter, CE binds the companies together around a shared purpose. Interestingly, the mode of collaboration is different with existing partners (via value chains) versus new partners via networks and new value chains. Based on the findings, it seems that inter-firm collaboration is a way to bridge the gap created by different types of inadequacies, mostly due to the novelty of the CE business model.

Discussion

In this chapter, we have explored the roles and agency of individuals and organisations engaged in catalysing circular transitions. The main contribution of this chapter is in extending the concept of sustainability agency (Teerikangas et al., 2021) into the CE context, and to this end, developing a typology of CE agency (see Table 24.2). Beyond explicitly recognising the role of actors in shaping the circular transition, we hope that the typology of CE agency supports scholars and practitioners in appreciating how actors can catalyse the CE transition.

Comparing with and building on the generic concept of sustainability agency conceptualised as the interplay of individuals', active actors', relational agency, and governance (Teerikangas et al., 2021), CE agency bears these four elements, though building particularly on active and relational agency, as detailed in the next section. Similar to sustainability agency, CE agency is also a multi-level phenomenon, occurring at and across multiple levels of analysis. While sustainability agency relates to any type of sustainability work, CE agency focuses on actors and their agency in furthering the circular transition. Theoretically, the role of agency in the transition towards a CE reflects onto structuration theory (Giddens, 1984). CE agency is set amid a negotiation between the agency of individual, organisational, and inter-organisational actors as they seek to change the prevailing regime and structures. The latter's resistance and path dependency create frustration for those seeking to make a difference. This leads to a view of CE transitions as structuration processes, wherein the agency of individual, organisational, and inter-organisational actors is shifting the balance from a linear economy towards CE. This transfer appears to be an ongoing, cumbersome, and fragile process.

Our typology of CE agency conceptualises active actors and their agency in shaping CE transitions via two dimensions. First, the typology builds on individual, organisational, and inter-organisational levels of analysis. Second, two types of agency are at play: active agency (Teerikangas et al., 2021) as exercised via an actor's role (Emirbayer & Mische, 1998) and relational agency exercised in interaction with others (Aylett, 2015; Burkitt, 2015). While active agency refers to individuals and organisations actively taking a stance on and steering CE transitions, regardless of whether they hold a formal position of power or not, relational agency refers to the fact that, in CE, as in sustainability transitions, change occurs in collaboration with other individuals and organisations – be they existing or new partners. We do point out that though our two-dimensional typology conceptually distinguishes between CE agency as it regards level of analysis (y-axis) and form of agency (x-axis), these are in practice intertwined (Archer, 1988).

Zooming into our typology, the distinguishing features of CE agency per level of analysis are as follows. One characteristic of CE agency is the multiplicity of roles that individuals adopt when they actively engage in the making of circular futures. At the individual level of analysis, we distinguish between actors engaging in circular transitions in private consumer-citizen and work roles, such as professionals or managers. This distinction deserves recognition, as prior research in marketing, management, and CSR has studied these roles separately. Yet, in CE settings, these roles become at best enmeshed, as citizen-consumers' prosumer agency is needed, as the prevailing societal regime and structure do not enable living in a CE-based lifestyle. Citizen-consumers can be active in the trading, reselling, reusing, and remaking of goods, thus foregoing the one-dimensional consumer role. In addition, citizen-consumers can actively engage in shape-prevailing structures as eco-activists. Second, professionals shaping the circular transition as change agents experience a paradoxical agency, as their commitment and engagement contrasts with the resilience needed to maintain one's change agency in the face of resistance and setbacks. Third, managerial agency relates to those in formal, power-vested roles. Top managers exercise their agency via career choices, personality traits, and their formal position of power. Through their role, they actively engage in structuration toward a CE. Fourth, professionals and managers support circular transitions by engaging in the development of circular ecosystems that can combine public and private sector organisations (Aarikka-Stenroos et al., 2022; Hirvensalo et al., 2021). In interactional settings, agency takes the form of relational agency, as ecosystem participants become orchestrators of emerging circular ecosystems. Summing up, these findings recognise individual-level circular agency as occurring in numerous roles, and importantly, beyond those formally in manager and decision-maker positions. In so doing, CE agency reflects the characteristic of shared (Sweeney et al. 2019) and responsible leadership (Miska & Mendenhall, 2018) in that leadership can be enacted by anyone, regardless of one's formal power position.

At the organisational level of analysis, we observe companies to exercise circular agency via action within and beyond the company's remit. As active actors, firms exercise CE agency through strategic, organisational, market-shaping, innovative and communicative, financial, and location-based agency. In inter-organisational settings, companies connect with public or private sector organisations via existing value-chain partnerships and by actively forming new partnerships, networks, and ecosystems to adjust to and steer the CE transition.

In terms of limitations, this chapter focuses on active actors in a CE-pioneering country, Finland. Therefore, our typology of CE agency can be further developed in countries with different levels of CE maturity. Similarly, research on the CE agency of public-sector organisations, such as cities, institutions, and governments, is needed, as is an appreciation of CE agency in partnerships, supply chains, and ecosystems. While we focused on agency as human action, future research is also warranted combining the agency of humans and materials (Jokinen et al., 2021) alongside the agency of other species (van Dooren et al., 2016; Rupprecht et al., 2020) and nature (Soper, 1995), while recognising their interconnections (Plumwood, 1993). Finally, CE needs to be discussed against the broader systemic landscapes within which sustainability transitions and grand challenges, including climate change and biodiversity crises, occur.

Conclusion

In this chapter, we have explored how individual and organisational actors act as catalysts of the circular transition. The typology of CE agency we develop shows that when they do so, they exercise active and/or relational agency. The concept of agency set amid ongoing structuration processes highlights that while a circular transition is ongoing, everyone's agency shapes its direction and speed. While we have focused on proactive individuals, the circular transition is being slowed down by passive and/or ignorant actors maintaining the prevailing linear economy. Thus, the agency of all individuals and organisations acts either as a catalyser, maintainer, or suppresser of CE transitions. Until there is sufficient agentic push toward circularity, this paradigmatic shift will not materialise. This leads us to call for all actors to recognise and consider their CE agency as exercised via everyday acts. Our chapter is a call for action. The time to act is now, for everyone.

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Educational content

The CE transition calls for agency. Our chapter bears the following educational implications:

1 Our findings are a call for educational institutions, at all levels, to radically consider their role as enablers (versus disablers) of CE agency and CE transitions.
2 There is a dire need for education to catalyse an awakening of CE agency, as many actors still do not recognise the importance of CE transitions nor their role therein.
3 As regards active CE actors, many operate in isolation or might feel succumbed by the prevailing linear regime. There is a need for CE actor support, be it via networking, joining forces, or establishing support for emotional resilience and well-being.

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ROLES OF VIRTUAL INTERMEDIARIES IN THE TRANSITION TO A CIRCULAR ECONOMY

Magnus Moglia, Christian A. Nygaard, Olamide Shittu, Tmnit H. Halefom, and Sean Trewick

Introduction

Transitioning a business ecology to a circular economy (CE) is a complex process as business start-ups, new technologies, or business models can be a part of challenging the dominance of existing businesses that predominantly remain anchored in non-circular practices. Business startups do this by carving out market niches. For existing businesses, a key consideration is whether one or more such market niches present a shorter or longer-term threat to their market dominance or position. Depending on this assessment, existing businesses may choose to absorb new businesses (hostile or non-hostile takeovers), adjust their business models to compete with startups, or utilise their current market as well as political economy position to undermine the viability of challengers.

For many existing businesses seeking to adjust their business model to align with CE principles, the transition requires reimagined business models built upon technically and organisationally, yet unfamiliar solutions. Key challenges in transitioning entire economies to CE principles is the product and business-practice innovations providing proof-of-concept (market, financial, and organisational viability) and is challenging in the absence of economies of scale; moreover, the scaling up and diffusion of product and business-practice innovations across economic sectors or regimes is complex. The latter is the case due to a multitude of factors and contexts reflecting socioeconomic-political dynamics, institutional inertia, and power imbalances.

Business is not undertaking this transition towards a CE in isolation, and there is increasing awareness and urgency across policy, regulatory, and societal arenas that current business and consumer practices are incompatible with in terms of both sustainability outcomes and climate change challenges (Cohen & Dong, 2021). Existing institutional frameworks, policy regimes, or societal practices or perceptions have not evolved to enable or deliver CEs and practices; this is a new challenge.

Victoria is the second most populous state in Australia, with the capital Melbourne having a population of about five million. Victoria has a highly diversified economy, with a high reliance on the service sector. The CE transition in Victoria has been mostly driven by new businesses and NGOs through niche innovations in technology, business models, product and service offerings, and organisational processes. The policy and regulatory environment for CE in the state is still

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emerging. For instance, Recycling Victoria was recently established to oversee the execution of the state's CE short- and long-term goals including minimising waste, maximising recovery, and reusing resources (DEECA, 2020). This chapter draws on ongoing research into enabling a CE transition in the state of Victoria, Australia. The research involves prototyping a digital platform for data and knowledge collection and dissemination that can function as an intermediary for technical and organisational re-imagining of business models.

CE has taken on political salience in Australia as a whole following China's 2021 ban on waste imports (Melles, 2021). This external shock accelerated an emerging policy focus on recycling and waste management (Commonwealth of Australia, 2018). However, much of the policy and regulatory emphasis focuses on the management of 'end of pipe' material flows (Melles, 2021; Shittu et al., 2022) that, we argue in this chapter, broadly focuses on only one aspect of the technical challenge associated with CE business models. While CE intermediaries already exist that also focus on linking and re-linking for the purpose of advanced understanding of CE principles, there is insufficient intermediation emanating from business itself.

From the current vantage point, transitioning to a CE is a systemic realignment of business, regulatory, and societal practices, and this transition is characterised by uncertainty. In the sustainability transition literature, intermediaries frequently play a critical role in linking and re-linking actors for the purpose of sustainability outcomes (Kanda et al., 2020; Kivimaa et al., 2019). To enable a CE transition, business, regulatory, and societal actors across and along particular waste streams, supply chains, different sectors, and at different government levels require linking and re-linking. This chapter explores the functions that a virtual intermediary (VI) can play in supporting this transition.

The chapter consists of three key sections. The first section provides a general introduction to the roles and functions that VIs can play. The following section draws on a series of conceptual frameworks to establish key opportunities for transitioning a business ecology to CE principles. The last section describes four roles that a VI can take on to support the transition.

Introducing intermediaries

Intermediaries have been identified as critical to enable collective institutional learning and practice development. Intermediaries are sometimes specific actors or entities, but they may also be platforms for cooperation (Hyysalo et al., 2018; Mignon & Kanda, 2018). They may connect, coordinate, and align multiple actors for sustainability purposes (Bush et al., 2017; Frantzeskaki & Bush, 2021; Kivimaa et al., 2019).

Notwithstanding differences in which an actor conducts intermediation, there is a shared understanding in the literature that "intermediaries bridge between actors and their related activities, skills and resources in situations where direct interaction is difficult due to high transaction costs, information asymmetry or communication problems" (Kanda et al., 2020, p. 451). Intermediation can take place and can operate at multiple levels (Kanda et al., 2020), for example, between:

- entities in a network (e.g., supply chains),
- networks of entities, and
- actors, networks, and institutions.

Intermediaries have received growing attention from researchers because intermediaries can catalyse sustainability transitions (Kivimaa et al., 2019). The possible functions of intermediaries in sustainability transitions include knowledge aggregation and learning, networking, interest and financial brokering, innovation and diffusion of both knowledge and technology, visioning and joint vision articulation, and institutional advocacy, implementation, and legitimisation (Sovacool et al., 2020).

In sustainability transitions, intermediation is a fundamental governance activity (Frantzeskaki & Bush, 2021). Other authors have noted that intermediation can occur at different scales (Kanda et al., 2020); in between actors, for example, in supply chains between networks of actors; and across all actors, networks, and institutions. They can be specific actors but can equally be platforms for cooperation (Hyysalo et al., 2018; Mignon & Kanda, 2018).

Primarily, transition intermediaries act as "agents who connect diverse groups of actors involved in transition processes and their skills, resources and expectations" (Sovacool et al., 2020). It is also noted that much of the literature on intermediaries in the sustainability realm focuses on their role as catalysts for market or systems disruption (Sovacool et al., 2020). New technologies, business models or practices, or institutions can in this respect enable 'creative destruction' and socio-technical adjustments.

The VI is an intermediary actor enabled by both virtual and digital platform-based technologies that have particular strengths in knowledge transfer functions (Albats et al., 2022). While intermediaries have been discussed and explored in terms of their role in sustainability transitions (Kivimaa et al., 2019; Kutter et al., 2023; Pedersen et al., 2023), the term 'VI' is new, and refers to a sub-class of intermediaries that operate via online platforms. While VIs operate in a virtual context, they must, however, also acknowledge and address issues related to the proximity of actors (cognitive, social, institutional, and geographical) as a key contextual factor that enables effective knowledge transfer (Albats et al., 2022; Alpaydın & Fitjar, 2021).

For simplicity, we categorise intermediaries based on whether they operate primarily in a virtual context or not, with the non-VI referring to all type of intermediaries that are not primarily online. One important characteristic of intermediation (whether virtual or not) is that it is a social process (Ren et al., 2020) and, therefore, dependent on existing social networks, trust between actors, and power dynamics. In terms of similarities, we note that both VI and non-VI intermediation shapes social interactions. Importantly, as argued by Ren et al. (2020, p. 848) and drawing on Zhang and Ng (2013), reciprocity is "the precondition for the establishment of good social relations", where reciprocity is the strong social norm of rewarding good behaviour (positive actions), meaning if an actor provides something for another actor or intermediary, they will expect some type of award in return.

VIs can help catalyse the transition to a CE as special cases of intermediaries that can support sustainability transitions (Kivimaa et al., 2019; Kutter et al., 2023; Pedersen et al., 2023), however, literature is nascent on how this can be done. Therefore, we must first go back to understanding how a transition to CE may occur (a Theory of Change). In this chapter, we first describe the research method where we introduce the concept of a Theory of Change, and this is followed up by our findings that describe the conceptualisation of the transition to a CE across three transformation arenas. These conceptualisations are then used to develop a taxonomy of CE business actors, as well as outline four types of roles that a VI could play in the transition.

Study context

This research was undertaken in the State of Victoria, which has a population of 6.6 million and is in the southeastern part of Australia. It is a highly urbanised jurisdiction, with much of the population in the capital Melbourne (4.9 million). It has government targets for a transition to a CE by 2030 (DEECA, 2020), including to:

- Divert 80% of waste from landfill by 2030, with an interim target of 72% by 2025.
- Cut total waste generation by 15% per capita by 2030.
- Halve the volume of organic material landfills between 2020 and 2030, with an interim target of a 20% reduction by 2025.
- Ensure every Victorian household has access to food and garden organic waste recycling services or local composting by 2030.

Research method

This research was undertaken to understand the roles by which a VI can support the transition towards a CE in the State of Victoria, Australia. To map out the roles and activities by which this can happen, we used a qualitative, interpretive research approach. This was done to explore key actors' thoughts and actions within the social context of the economy during shifts to a CE. Our approach consisted of three stages:

1 Identify a broad set of relevant theoretical frames describing systemic transformation, based on a review of the literature. This step, which is further reported on in the first project report (Moglia et al., 2022), and was undertaken by several members of the research team, and the choices of theoretical frames cross-checked and agreed on collectively. The review of literature is described further in project reports (Moglia et al., 2022; Shittu et al., 2022).
2 Develop a boundary object, a Theory of Change, that diagrammatically describes the individual transformation arenas within which business, regulatory, and societal practice change is required to effectuate systemic realignment towards a CE. Each team member developed their own boundary object, and then this was synthesised iteratively into one more coherent representation by removing redundancy, ensuring conceptual coherence, aiming for simplicity, but maintaining as much of the complex dynamics as feasible.
3 Utilise the boundary object to ground the conceptual understanding of the business, regulatory, and societal change processes based on a series of key actor interviews with industry, governmental, and community actors for subsequent refinement of the conceptual process.

Development of a theory of change

To conceptualise how a VI might operate to facilitate CE business models, a working backwards approach was taken. This approach focuses on identifying actions and transformational arenas where actions can be agreed on by stakeholders to achieve specific goals. Working backwards, methods, such as a Theory of Change methodology (Breuer et al., 2016; Cash-Gibson et al., 2023; Colloff et al., 2021; Sellberg et al., 2021; Werners et al., 2021), conceptually identifies the contextually relevant causes and actions, acknowledging complex interactions across systems and actors, which can be used in strategic planning (back-casting).

In sustainability science, the result of a set of sequenced actions to achieve a desired outcome, is often referred to as adaptation pathways, meaning pathways within which "decisions and measures are sequenced in time to achieve future goals" (Werners et al., 2021, p. 268). Our working backwards approach, developing theories of change, focuses on a systemic realignment, and our thinking draws on the pathways approach. In fact, "theories of change and adaptation pathways are complementary [and] adaptation pathways provide context for a theory of change and the desired change process." (Colloff et al., 2021, p. 166).

Theories of change operate at a lower level, however, within contexts that stakeholders have agency over, and for the sake of this chapter, we refer to this level as transformation arenas. Within each of these transformation arenas, we outline a Theory of Change. Drawing on a Theory of Change, actors can sequence their actions adaptively, and thereby achieve the desired change. As such, in practice, these arenas for change may encompass multiple adaptation pathways for specific businesses or actors.

Interviews

For this study, we drew on data from 18 semi-structured interviews of purposively selected business representatives, as well as key government staff and planners in Victoria, Australia. We also attempted to achieve interviews from a mix of established business with a level of inertia to adoption of CE products and services, as well as recent startups that have wholeheartedly embraced CE principles. The interview was also subject to field testing and amendments, and the survey was approved by the Swinburne Human Ethics Sub-Committee (application 20216144-8820).

To support the interviews, we used diagrams that represented our Theory of Change as boundary objects. Star and Griesemer (1989) described a boundary object as a conceptual representation, for example, a diagram or a piece of art that describes different disciplinary, social, or professional perspectives in one object. This helps translation across social worlds and promotes cross-disciplinary and holistic conversation. Artefacts, or boundary objects, such as diagrams are often used in interviews (Tracy, 2020). To guide the interviews, researchers were guided by experiences in using similar methods (Bravington & King, 2019; Crilly et al., 2006; Pierre Johnson et al., 2017).

The interview design focused on generating information that provides systems understanding of the transition of businesses to CE practices. The interviews also serve as use cases for a VI while also providing data on how such VI may be useful for businesses. The interviews further provide information on the CE business strategies, opportunities, enablers, and barriers. Interview data enabled the classification of participating businesses based on a beta taxonomy of organisational CE transition.

Findings

The main finding that we report on is the conceptual understanding of how Victoria's economy can shift towards a CE, described in terms of three identified transformation arenas. In the following sections, this is then used to develop a business actor typology as well as to identify four roles of a VI within the transition dynamics.

Theoretical frames

Specifically, using this data, and as outlined in project reports (Moglia et al., 2022; Shittu et al., 2022), we identified relevant theoretical frames to draw on when describing systemic sustainability transformation:

a Pathways approach to climate adaptation (Colloff et al., 2021).
b Theories about systems (Retamal, 2019).
c Evolutionary economics (Nelson & Winter, 1982; Spaargaren et al., 2006).

d Institutional and transaction costs economics (Coase, 1937; Williamson, 1985).
e (Social) Learning theory (Alexander, 2008).
f (Socio-technical) Transitions theory (Loorbach et al., 2017).
g (Individual level) Decision theories (Ajzen, 1991).
h Organisational behaviour theory (Pojani & Stead, 2014).

As a result of these multiple theoretical perspectives, we describe the systems as consisting of multiple entities in networks, networks of entities, and actors and institutions that jointly and individually represent arenas for intermediation.

These frames were combined and synthesised iteratively, as described in Shittu et al. (2022), with inputs from interviews as a way to refine and improve a shared conceptualisation of the transformation towards a CE in the State of Victoria. We extracted factors and inter-relationships between factors from all these theoretical frames and developed a kind of meta-theory. Many, if not most, of the identified factors coexist across multiple theoretical frames, as can be expected, but often with slightly different names and meaning. Through extensive deliberation within the research team and with experts, we developed a combined conceptualisation of relevance for the local context, which was then iteratively improved through interview feedback.

In other words, this process was initiated based on a literature review, followed by a series of brainstorming sessions to develop a draft representation of a Theory of Change, and associated transformation arenas. Based on a set of interviews, we then refined the Theory of Change, and the associated descriptions of transformation arenas. Figure 25.1 presents a higher-level representation of the boundary object, with further details about the Theory of Change in project reports (Moglia et al., 2022; Shittu et al., 2022).

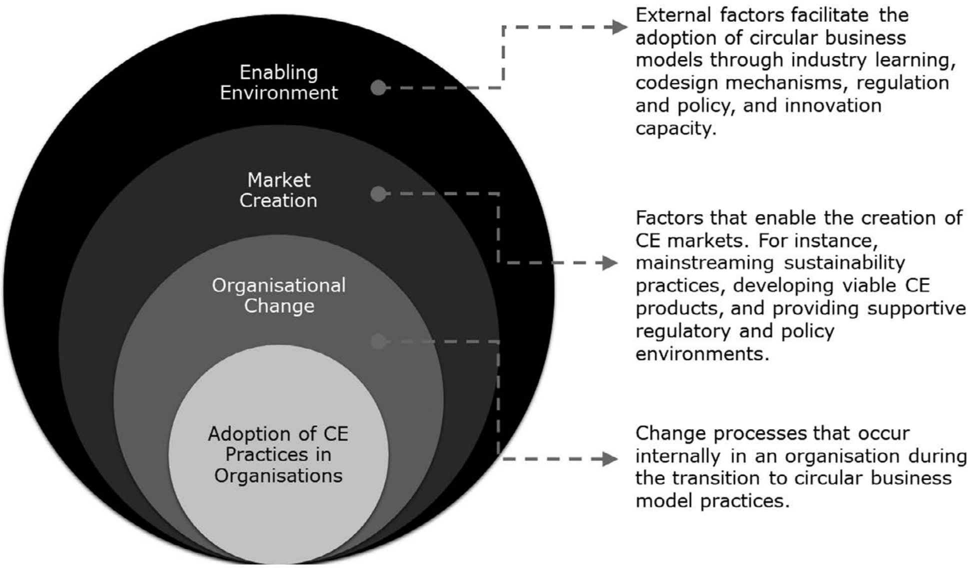

Figure 25.1 High-level conceptualisation of the necessary CE transformation.

Source: The authors.

Conceptualisation of the economic transformation towards a CE

The Theory of Change that we developed consists of three transformation arenas. Here we describe the key transformation arenas that we identified as needing change to support a transition to a CE. According to this model, the transformation towards a functioning CE will depend on the purposeful alignment of the following transformation arenas:

- Market creation for products and services that is aligned with CE principles. This represents that a business can only operate if commercially viable, but also indicates that this is a two-way relationship. Businesses need to innovate to develop new CE products and services, but the community also needs to be receptive to CE products and services.
- Organisational change among businesses, government departments, etc. This represents that every decision that a business/organisation makes needs to be aligned with a CE, and that skills and mindsets in the organisation need to support a CE. Otherwise, simply adopting a CE business model is insufficient in the long term, and the organisation would revert to non-CE practices unless external drivers to adopt CE are present.
- Enabling environment across multiple domains of society. This represents that CE business models need supportive functions and capabilities, as well as a society that values sustainability. As such enabling environment consists of supportive regulations and policies, effective industry learning, including innovation of new products and services, as well as the development and sharing of a systemic understanding of how to overcome hurdles and barriers on the transformation pathways to a CE, as well as collectively agreed visions across society (especially among community, financial institutions, and government).

We argue that failure to consider all the three transformation arenas is likely to lead to reduced opportunities for change. Each of the transformation arenas is characterised by change processes specific to the transformation arena as well as in direct interaction with the other transformation arenas. For instance, staff upskilling and CE standard reporting are change processes in the organisational change transformation arena. Staff upskilling largely depends on the context of each organisation such as workforce profile and composition. However, while CE standard reporting aids the transformation of a business, it is directly related to other change processes in the enabling environment such as standardisation and CE assessment policies.

Transformation arena 1: Market creation

This section synthesises what we have learnt about the market creation transformational arena, both from interviews as well as from the literature.

Conventional economic theory frequently treats behaviours, preferences, and institutions as something exogenous to peoples' experiences or interactions of and with each other (Hodgson, 2000). Adopting a narrow focus on the laws of supply and demand often neglects that laws and institutions of governance also are socially and culturally constructed (Hodgson, 2000). Market creation involves the technological innovation behind new product development, but it also involves the coordination of partners and input producers, distribution channels, and consumer behaviour, preferences, acceptance, and practices (O'Connor & Rice, 2013).

One argument in institutional economics is that an individual's preferences and behaviours cannot be taken as given, or exogenous, to institutional and cultural situations (Hodgson, 2000). While behaviour and preferences shape and create the norms and institutions within which markets operate, behaviours and preferences are, in turn, fundamentally shaped by institutions and norms. As a CE transformation takes place within and across three transformation arenas, the role of a 'downwards reconstitutive causation' (Hodgson, 2000) is explicitly recognised. Sarasvathy and Dew (2005, p. 558) argue that new market development can follow an effectual logic, that is, new networks of stakeholders, with commitments to particular transformations, determine what the new markets look like.

Our Theory of Change framework identifies CE market creation as dependent on developing viable products and services that not only embody CE principles, but that ensure the profitability of businesses. Furthermore, market creation is achieved through CE business model innovation, technological readjustment and development, and by enabling supply chain capacity (De Mattos & De Albuquerque, 2018). CE business model innovation refers to the process and strategies that aid organisations in creating value propositions through product and service offerings that reinforce CE outcomes such as designing out waste, designing for reuse, restoring material life cycle and regenerating natural systems (Ellen MacArthur Foundation, 2022). Meanwhile, technological development has been defined as "the systematic use of scientific, technical, economic and commercial knowledge to meet specific business objectives or requirements" (Solleiro et al., 2016). Last, supply chain capacity is the ability of a business to generate a certain volume across the supply chain over a specified period that could be related to the business' input, or output of materials, funds, and/or other resources, or a mixture of both (Radhakrishnan et al., 2018). Presenting a viable CE product or service to the market requires measuring and improving the capacity of supply chains, production, transportation, and distribution networks (De Mattos & De Albuquerque, 2018).

In relation to market creation, our current findings based on interviews with businesses in Victoria, Australia, also emphasised the importance of developing a risk profile when creating viable CE products and services, defined as "an assessment of the threats existing in the market with the capacity of the organisation to tolerate or take risks to achieve set goals" (Shittu et al., 2022, p. 19). Interview participants highlighted the inability to attract customers for new CE products and services as one of the risks associated with entering the CE market in Victoria. Findings also show that risk profiling can enable businesses to anticipate both CE market and supply chain volatility. Notably, while risk profiling is key to business due diligence, from an institutional and evolutionary perspective, a systemic transformation process also creates a strategic space for business, in conjunction with other stakeholders, to shape future risk parameters.

Regarding market creation, government support, and associated regulation and policies act as a nexus between mainstreaming sustainability and developing viable CE products to create a CE market. In this sense, government supports are guidelines, regulations, finance, and other resources that transform markets towards CE or aid in the adoption of CE practices among businesses and consumers.

Mainstreaming sustainability practices and mindsets is the process of embedding sustainability concepts and principles into the routine and practices of a society (Maru et al., 2018). In evolutionary theories, such processes exhibit both upwards and downwards reconstitutive logics, that is institutional and cultural settings can shape preferences and behaviours (Granovetter, 1985; Nygaard, 2022). From a market creation perspective, the implication is that demand and preferences for CE products and services can be shaped through regulatory and institutional processes, creating downwards reconstituting impulses to accompany societal, or upwards, reconstituting impulses, such as through sustainable lifestyles, for CE market creation. A vehicle for embedding sustainable lifestyles as a social norm, and preferences for CE products and services, is societal awareness of CE principles, education, and advocacy (Maru et al., 2018), but also learning in local (smaller) networks that particularly promote trust and reciprocity in the exchange of ideas and practices (Lazaric et al., 2020).

Transformation arena 2: Organisational change

This section synthesises what we have learnt about the organisational change transformational arena, both from interviews as well as from literature. Insights are therefore based on a mix of theory and empirical findings.

Transitioning to a CE business model includes change processes internal to the organisation. Organisational (managerial and governance) practices may require adaptation to what, for many existing businesses, will be unfamiliar values, objectives, and business cultures. The main factors that create the necessary change in organisations for CE transformations include setting CE goals, improving competencies internally, and reframing organisational decision contexts. Nonetheless, these three factors are intertwined with other change elements, some of which are external to the organisation, for instance, regulation, the operation of financial markets, and shared visions for a future.

Goal setting implies the steps and decisions an organisation takes or is planning to take at different stages to adopt CE principles, embedding circularity-related goals into key performance indicators or in other methods, making sure circularity is a vital part of the organisation's goals. This involves the description of a sequence of events that lead to sustainability outcomes. Depending on context, an organisation's CE goal setting should be relevant across all temporal timescales, that is from the current to the short-term aspects (e.g., retrieval of product packaging after consumption) or future and long-term aspirations (e.g., redesigning products as services) of the business.

As with the market creation arena, organisational change takes place in response to internal and external impulses. For instance, regulation relating to both the governance and the monitoring and evaluation (M&E) of the CE systems influence the type of CE goals that an organisation sets (Ranta et al., 2018). Considerations for regulations are also important when reframing the decision contexts of the organisation by forming CE values and updating business rules. CE value formation involves the transformation of the organisational culture to reflect CE norms, principles, and strategies. Reassessing the decision contexts of an organisation largely depends on implementing the social learning process of incorporating a learning culture into business practices and constantly engaging in a reflective process of analysing the methods and goals of CE transitions (Stein & Valters, 2012).

Another aspect of organisational change towards embracing sustainability is the improvement of internal sustainability competencies, by enhancing the skills, knowledge, and behaviours of all levels of its workforce. This not only helps to sustainably transform business practices but also increases the competitiveness of the organisation in the CE market (Pavel, 2018). While competencies aid the organisation in reframing its decision contexts, they, in turn, are a result of complex interactions between social learning, external knowledge development, and internal technological change. In this regard, we identified from our interview data that organisational leadership and internal champions are critical factors that enable sustainability competencies by "triggering and galvanising the momentum needed for change within organisations" (Shittu et al., 2022, p. 20). Interview findings (from Shittu et al., 2022) also note that an organisation's stakeholders will react differently to the sometimes unanticipated ramifications of organisational change. There is, therefore, the need to coordinate stakeholder responses through people management.

Organisations are an integral part of the production of sustainability knowledge by research institutions, which then informs technological developments (Wooltorton et al., 2015). The VI referred to in this chapter is an example of a technology that is produced in partnership between research institutions, (non)governmental organisations, and businesses.

Transformation arena 3: Developing the enabling environment

This section synthesises what we have learnt about the enabling environment transformational arena, both from interviews as well as from the literature.

The ‘enabling environment’ is created by the intersection of industry learning, co-design mechanisms, regulation and policy, and innovation capacity to facilitate the adoption of circular business models. Enabling a transformation to a CE thus also involves creating new networks of stakeholders that concurrently expand the resources available to support market creation and organisational change, and provide convergence of constraints within which industries or economic sub-sectors operate (e.g., convergence of regulations, laws, and policy) creating incentives for scaling up and coordinating CE practices (Lazaric et al., 2020; Sarasvathy & Dew, 2005). In institutional and evolutionary theories, markets can be co-created and scaled up through coordination and strategic shaping of regulations, institutions, and societal norms in the enabling environment.

Industry learning involves the creation and exchange of sustainability knowledge, skills, and training among organisations to achieve CE transitions. However, industry learning is realised through the combination of three factors: accumulation of financial resources through various funding mechanisms (e.g., subsidies, loans, grants, and donations), utilisation of intermediary tools, and consistent M&E assessments. Industry-based M&E apply sustainability assessment tools to systematically monitor flows and progress of circular business practice adoption among organisations against organisational, local, and international sustainable development objectives (Avdiushchenko & Zając, 2019). A VI could aid this process by empowering businesses to review their CE growth and learn from both internal and external experiences. Overall, industry learning connects organisations to external CE innovation systems such as the development of new technologies and higher learning collaboration to overcome barriers to circularity.

The effectiveness of an enabling environment for CE business practices can be supported by implementing co-design mechanisms that utilise creative methods to engage sustainability stakeholders (e.g., communities, government agencies, organisations) in designing solutions and practices that achieve societal transformations. Such co-design process is more effective when it is participatory, gender-sensitive, addresses unbalanced power relations and identifies key partnerships that are required to achieve impact (Maru et al., 2018). This process can be supported through funding mechanisms that are external to the business.

External funding mechanisms at national and international levels are critical to ensure the flexibility, value, and feasibility of circular business model transitions. Accounting frameworks and financial market reporting practices similarly require re-alignment in a manner that enables, rather than penalises, CE business model innovations. The institutionalisation and harmonisation of environmental, social, and governance frameworks across national and supra-national jurisdictions provides a guide for the sorts of realignments that are required to enhance the competitiveness of CE business models, while also utilising the inherent strengths of markets to generate economies of scale in behaviour and practices. To achieve this, however, there must be an alignment of power dynamics and agreed visions of change among sustainability stakeholders.

Policy instruments such as legal frameworks, reporting frameworks, fiscal policies, and tax implications are external factors that can encourage the adoption of circular models by businesses.

Furthermore, local and international laws are mechanisms that could promote cleaner production, end-of-life material management, and sustainability strategies among businesses (Wastling et al., 2018). The synergy between these factors strengthens the CE innovation systems, that is, "the capabilities and resources of firms for discovering opportunities to engage in new product development" (Tajvidi & Karami, 2015, p. 125). Circular innovations could be in terms of designing new products and services, transforming production and delivery processes, or the methods of performing business practices (OECD, 2005).

Furthermore, interview findings emphasise the role of consumer and communities as important stakeholders in creating and shaping the enabling environment (Shittu et al., 2022). Aside from their role in mainstreaming sustainability, communities are vital in co-designing and experimenting circular innovations that address local needs. Findings show that communities are also an integral part of developing a collectively agreed-upon vision of CE transformation within the enabling environment.

Synthesis: A taxonomy of CE actors

In this section, we provide a taxonomy of actors based on what we now understand to be the conceptualisation of the transition towards a CE. This draws on our findings and has been cross-checked and considered in the context of existing theories for sustainability transitions.

The adoption of CE principles across transformation arenas implies tackling both familiar and unfamiliar technical and organisational challenges. Furthermore, there is a diversity of actor types that at any one time are actively working to effectuate transformation, maintain a status quo, or deliver a partial technological or organisational adjustment. Sustainability literature (Smith & Raven, 2012; Sovacool et al., 2020) provides a taxonomy of archetypal actors that links "empowerment to the dual challenge of sustainability transitions (across both technical and institutional dimensions)" (Sovacool et al., 2020, p. 4). Applied to businesses, for instance, ideal-typical representations of whether businesses are operating in a familiar or challenging space, "based on combinations of the degree to which they depart from mainstream technical and institutional dimensions" can be identified (Sovacool et al., 2020, p. 4). With respect to a CE business ecology, these archetypes can be described as:

- *Pioneers* (CE is a technical and institutional fit) have aligned (either transformed or commenced with) their business's values, competencies, and decision contexts to a CE and have CE products to sell to an accessible, adapted, and/or niche market (e.g., by product differentiation).
    - This category will include innovators and market disruptors that may be challengers to dominant business actors, but also early transformers.
    - Pioneers have stronger incentives to transform existing market environments as part of challenging the domination/market share of traditionalists.
- *Reformist* (CE is a technical fit but requires institutional transformation); they have products/production processes for which CE substitutes readily exist, but have not yet adopted business values, competencies, and decision contexts that align with CE. Managerial knowledge and organisational capability gap exists.
- *Opportunist* (CE is a technical stretch but conforms institutionally); they have business values, competencies, and decision-making contexts aligned with CE but do not yet have products/production processes for which CE substitutes readily exist. Supply chains and material/technological knowledge gaps or innovations are required.

- *Traditionalists* (non-CE is a technical fit and conforms to the institutional foundation) are businesses that have neither reformed to embrace a CE, nor do they have CE products to sell on an accessible, adapted, or niche market. This category will include most of the currently existing and dominant businesses in the Victorian business ecology. Traditionalists have stronger incentives to preserve the current market environment as part of staving off challenges from Pioneers.

Discussion: Four roles for VIs

A VI may seek to promote and facilitate the emergence of a CE, for example, by the reconfiguration of resources (human and technological) within and between firms in a business ecology (regime), and/or economic ecology (landscape). Specifically, a VI may target the three transformational arenas or operate at a systemic level, to:

- Facilitate reduced transaction costs: supporting market creation for businesses.
- Overcome inertia: prompting organisational change and/or fast-tracking growth of networks, especially by connecting and empowering actors.
- Streamline: providing and/or strengthening accreditation and standardisation, and thereby supporting the enabling environment, by providing processes and benchmarking of performance, thus helping in scaling up and building capacities.
- Facilitate systemic learning: allowing ongoing learning that supports sharing of knowledge and insights and therefore speeds up the transition, for example, by creating an M&E framework.

When developing a VI, it is important to consider that its strengths are in the area of knowledge capture and transfer, and that proximity, reciprocity, and trust are critical attributes that enable its successful function.

Type 1: Reduce transaction costs

Market creation involves coordination of partners and input producers, distribution channels, and consumer behaviour and practices (O'Connor & Rice, 2013). In transitioning away from current market practice to circular practices, or in scaling up circular practices, businesses are faced with additional risks and knowledge gaps, including access to qualitatively and quantitatively appropriate supply chains, access to finance, lower economies of scale, and consumer responses. In practice, these risk and knowledge gaps constitute a high transaction cost environment. Moreover, new relations or connections are, to begin with, often unique and non-standardised, and therefore commonly characterised by a high degree of asset-specificity, potential information asymmetry, and, a priori, low volume/potentially one-offs. By comparison, existing business practices are characterised by well-established relationships and partnerships that reduce risk and information asymmetry.

While intermediaries are key to generating new connections and networks, a particular challenge for the VI will consist of facilitating the trust and reciprocity that encourages repeat interactions, knowledge and information sharing, and joint learning. In a relational view, intermediation performs three key brokering functions (Spiro et al., 2013, referenced in Kanda et al., 2020), each of which can generate transaction cost-saving outcomes. Next, we discuss what role a VI can play in facilitating market creation, with the three brokering functions identified by Spiro et al. (2013, referenced in Kanda et al., 2020).

First, businesses transitioning to CE principles invariably share several common challenges that are unrelated to being connected via a supply chain or operate in the same economic sub-sector. These relate to how CE businesses coordinate for a supportive regulatory and policy environment, but also the mainstreaming of sustainability practices and mindsets within the wider CE community. Through its knowledge capture and share role, the VI can enable the mainstreaming of shared understandings around what policy, regulatory, or community of practice action and innovation may be required to facilitate a larger-scale transition to CE to take place. Our research suggests that coordination of shared CE practices and expectations across businesses is considered a key barrier to adopting circular business models in Victoria, Australia (Iyer-Raniga et al., 2022). In this respect, the VI may enable a convergence of CE interests, requirements, and metrics across disparate economic sub-sectors that begins to coordinate advocacy and engagement with the enabling environment across also businesses without direct bi- or multi-lateral ties.

Second, additional uncertainty, risk, and costs are associated with the transfer of material resources from one party to another. Here, information asymmetry contributes to transaction cost. Initiating and implementing an ongoing monitoring of new intermediate products and commercial relationships are, to begin with, characterised by uncertainty. New products or business models are faced with the added challenge of not benefitting from the pre-existing market selection. That is, markets provide important information-sharing functions that new products and business models have not yet benefitted or learnt from. Enabling environment initiatives, such as the certification of minimum standards, can reduce risk, but firms are still faced with ongoing risk around the quality of intermediate inputs. Research conducted in Australia suggests that quality-related knowledge concerning circular products is a key concern for businesses and a barrier to input innovation or scaling up (Iyer-Raniga et al., 2022). As the commercial relationship evolves, risks are reduced through repeat transactions and the acquisition of transaction-specific knowledge. However, in a transition phase, where scaling up commercial relationships is required to generate systemic transformation, CE businesses will likely face ongoing uncertainty related to scale and product quality as the production of intermediate inputs is scaled up.

By acting as an information and resource repository and distributor, the VI will enable users at different stages in the individual business's transition to circular principles, to benefit from experiences of businesses at a related stage in the transition to CE, or within the same industry. A key design principle for a VI is, thus, the ability to capture information salient to businesses navigating knowledge and resource bottlenecks at different stages in the transition to CE. The principle of 'by users and for users' is key to enhancing trust and reciprocity in the adoption and diffusion of organisational and market-creating experiences and resources. This may be of relevance to firms whose business model currently is not circular. That is, beyond an embedded remit to enable a transition to CE, the intermediary is not associated with technical solutions, industry, or civil society groups.

Third, there is a need for matchmaking or otherwise enabling the creation of direct ties between two or more previously unconnected entities. As an information and resource repository, the VI will also facilitate new connections being formed across supply chains, and within and across economic sub-sectors. The ability to connect previously unconnected businesses reduces search costs and reduces transaction cost risk associated with establishing commercial (or otherwise) connections within the community of users. The VI can achieve the former through its knowledge capturing and brokering facility. Moreover, coupled with the potential to classify businesses into a business taxonomy, additional qualitative information is generated, for users, about the skills and competencies of potential partners. The VI can achieve the latter by generating a form of social control. There is a potential cost to business 'misbehaviour' within the VI network of users. In both cases, the risk associated with establishing new connections is reduced and ongoing, repeat relationships or transactions is incentivised.

Type 2: Overcome inertia

Inertias in system adjustment and markets are frequently the result of some actors' reluctance to change (i.e., the traditionalists, see previously) or having a vested interest in maintaining an existing socio-technical configuration.

Therefore, a challenge when activating a CE is how to transition such dominant and inert market leaders to a new economic paradigm. Incumbent firms and actors have a reason (e.g., market or thought leadership) to maintain the status quo, and incumbent firms and these same actors also have the material and policy resources to maintain a given socio-technical configuration. This is sometimes referred to as the "dual challenge of sustainability transitions" (Kemp & van Lente, 2011; Sovacool et al., 2020). Incumbents, therefore, tend to resist transitions or innovations in business practices, but may also have a good reason to initiate or facilitate alternative transition pathways that more closely advantages their incumbency.

In terms of mainstreaming a CE shift, the socio-technical transitions literature (e.g., Smith & Raven, 2012) stresses the need for innovations, such as CE practices, either to become competitive within the existing selection environment or for changes in the selection environment that favours CE innovation. Incumbent actors are then faced with a situation where current business models are anchored in well-known and established technological solutions and consumer preferences, that is their business models 'fit and conform' (Smith & Raven, 2012; Sovacool et al., 2020) to the existing technical/institutional selection environment.

In practice, a shift to CE practices would mean that incumbent firms and actors need to 'stretch and transform' (Smith & Raven, 2012; Sovacool et al., 2020) their business models, potentially giving up competitive advantages and adopting business practices that, with other factors being equal, no longer conform to the existing technical and institutional selection environment. For such actors to shift, they may also overcome conservatism that arises out of the perception of risk associated with adopting practices that are thought to be 'unproven' or associated with low community acceptance (Marlow et al., 2013). Critically, one of the most important drivers for change within organisations, in the adoption of sustainable business models, is the personal values of the staff, especially managers (Williams & Schaefer, 2013). It can be expected that the greater the disjoint between an organisation's activities, and the staff's values, the less attractive the organisation becomes, making staff retention and recruitment increasingly challenging. Ultimately, this shows that even Traditionalist organisations, over time, need to build the competencies and capabilities for the transition. They may even be better off by moving early to maintain a dominant position in the new market.

For transformation to a CE, the role of a VI to overcome the inertia of incumbents can be to:

- Support staff engagement with CE and create conversations and discussions about what a shift to new business models would involve for the organisation.
- Reward a culture of innovation and challenging the status quo, in recognition that double- or triple-loop learning is often required for the organisation to change (Mitchell, 2013; Mitchell et al., 2012).

- Identify gaps in capability and bottlenecks in supply chains or other key factors such as land use patterns (Gedam et al., 2021; Yang et al., 2015), that the organisation must address if new business models are to be adopted.
- To facilitate a change of culture and decision-making contexts (Kiefer et al., 2019), to align it with the transition to a CE.

We also note that the emerging literature suggests that when shifting incumbents towards sustainable practice, the role played by intermediaries largely resembles that of transition intermediaries in general, albeit with some additional emphasis on institutional innovation (Sovacool et al., 2020). In addition, a VI can help overcome inertia among other actors, for example (Shittu et al., 2022), as follows:

- "Better connecting customers with CE businesses" (p. 11),
- "Organizing workshops and seminars building knowledge of CE practices and business models" (p. 11),
- "Deepening the relationship and trust between customers and CE brands", as well as "promoting community acceptance of CE practices" (p. 12), and
- "Promote constructive collaboration to drive the consolidation of the CE market" (p. 15).

Type 3: Streamline and standardise

The enabling environment transformation arena is critical for creating and maintaining incentives for scaling up and coordinating CE-aligned practices. The VI is, in the first instance, directed at influencing the market creation and organisational change transformation arenas. However, in developing a network of actors across material streams, supply chains, and economic sub-sectors and in the coordination of CE businesses' needs and requirements, advocacy coalitions can form that also engage with the enabling environment to effectuate a convergence of business constraints. Several advocacy agendas can be identified in the literature and policy emerging practice globally. Here we consider two: taxation and regulatory standards.

Taxation: these settings determine the cost of operating in different businesses, including the relative prices that govern resource allocation and procurement of different inputs. Differential taxes – such as higher tax rates for the things we want less of and lower taxes or subsidies for things we want more of – are one way through which the enabling environment shaped business models. In many cases, these tax changes may be temporary. As CE practices are scaled-up economies of scale, it will in many cases remove the need for differential taxation. A good example is the equivalised cost of electricity production from renewable energy sources, which, over the past 20 years, has converged on – and now in many cases are lower than – the equivalised cost of electricity production from carbon-based fuels. Some have argued that, based on European research collaboration, to facilitate systemic change towards a CE in Finland, the taxation systems require change from a tax on labour to a tax on a resource use and pollution basis (Yrjö-Koskinen et al., 2019).

Regulatory standards: these are instrumental in scaling up the adoption of circular practices and initiating economies of scale convergence. The inclusion of renewable obligations in the energy mix of some countries is one way of achieving this. The EU is in many regards a frontrunner in developing a supportive legislative environment for transitioning to a CE. The EU's 2015 CE Action Plan set out several short-term actions for developing the EU's enabling environment. Specifically referring to CE, under the heading 'Making Sustainable Products the Norm', the European Commission's CE Package (2022) expanded its existing Ecodesign Directive for energy-using products. Ecodesign elements include the potential to set minimum entry requirements for almost any product on the EU market. Minimum standards will cover regulatory standards on durability, reusability, reparability, fibre-to-fibre recyclability, mandatory recycled fibre content, the presence of substances of concern, and micro-plastic shedding. The CE Package also introduced regulations to influence consumer choice. For instance, measures to counter greenwashing practices or the premature obsolescence of products. The EU's Ecolabel certification is a further example of creating an enabling environment by altering the constraints that all businesses operate under, providing additional scope for business and consumer practices to converge into CE practices.

In relation to these areas, for the transition to a CE, the role of a VI in the enabling environment transformational arena could be to:

- Streamline processes of CE accreditation, including providing the access to skills, training, and competencies, as well as providing an easy-to-use interface with accreditation providers.
- Allow businesses to benchmark performance across several impact metrics.
- Facilitate a more standardised approach to government implementation and enforcement of policy settings, such as tax credits or minimum standards.

Further examples of this type of VI function were identified from our research interviews (Shittu et al., 2022), such as:

- Including more CE-related specifications in procurement policies and tenders.
- Providing local governments with innovative but more standardised approaches to addressing waste management issues.
- Promoting and facilitating more ambitious, higher-order strategies to be embedded within regulations and policies, such as the 'R principles' (refusing, rethinking, reducing, reusing, repairing, refurbishing, remanufacturing, and repurposing).

Type 4: Facilitate learning

A VI can be designed to facilitate systemic change through learning about the complex dynamics across the ecology as well as about strategies that support the transition. This would draw on the strengths of a VI around knowledge capture and transfer and can be based on the conceptualisation of an M&E framework. This can be based on a Theory of Change (Moglia et al., 2022; Shittu et al., 2022); as has previously been done for a university to navigate an organisation's change process (Levy & Cox, 2016); by both advocates for social justice (Klugman, 2011) and international health organisation for evidence-informed priority setting (O'Brien et al., 2020). This type of function would act as a sensor and controller for the economy as a dynamic system, helping to navigate a complex process of change.

An M&E framework can support this using quantifiable measures (Impact Metrics) that help to evaluate the level of progress. This can also support computational systems that help identify causal mechanisms, and likely efficacy of interventions, as described by Moglia et al. (2012). Drawing on an M&E framework, a VI could support the transition by the dual functions of:

1 Capturing information that helps to estimate progress against Impact Metrics, presumably by engaging with the users of the VI and getting them to contribute their data, insights, and

judgments. This, in turn, provides a holistic assessment, over time and for different sectors, a current and complex picture of the progress towards a CE. This, in turn, will help to identify the bottleneck, such as opportunities for improvements where further action is necessary to promote a more rapid transition.

2 Identifying and supporting actors to address such bottlenecks, either individually or collectively. To support this, a VI could connect actors with similar concerns, allowing them to develop action partnerships, and perhaps even to support the co-design of solutions that will address dilemmas.

Other opportunities for a VI to facilitate systemic learning were identified in interviews (Shittu et al., 2022, pp. 11–12):

- "Establishing CE hubs for knowledge sharing, networking, and collaboration".
- "Disseminating information to local stakeholders on CE processes, guidelines, and opportunities".
- "Driving and demonstrating the viability of technological and business model innovation and development".
- "Driving ongoing collaboration, intersectoral partnership, and industry learning among organisations".

Conclusions

In this chapter, we have described the role that VIs can play in catalysing a shift to a CE. This can play out across three transformation arenas: market creation, organisational change, and the enabling environment, or at the system level by acting as a learning and navigation device.

From a system's transformation perspective, alignment of innovation and change in each of the three transformation arenas is required. In institutional and evolutionary approaches, this creates a strategic space for co-designing and co-evolving internal and external change drives. A VI can assist in this process, particularly concerning market creation and organisational change, but also in how the activity and advocacy of CE stakeholders are coordinated concerning the enabling environment. In a context where the dynamics of creative description may be sought to introduce competition, rather than disruption or replacement, a VI may also benefit from being a user-driven entity.

However, unlike more conventional forms of intermediation, the VI's ability to exert agency on stakeholders, not within its network, its potential remains more circumspect. A VI should be designed based on three design principles.

First, it needs to act within and across transformation arenas. By being an algorithm-based entity, a VI has the advantage of avoiding capture by a business or societal interest groups for particular purposes. This does not, however, imply that a VI is a neutral broker. Acting within and across the transformation arenas to facilitate a CE is, in itself, a value-driven parameter.

Second, a VI needs to deal with issues of reciprocity, trust, and proximity, to ensure broad engagement with the platform, and to acknowledge that ultimately people are people who will only engage if the VI makes sense at a human level. The VI can achieve this through open-source software available for widespread use, but with sensitive or private data well protected through secure IT systems. It can also achieve this through its 'by users and for users' principle – capturing information salient to businesses navigating knowledge and resource bottlenecks at different stages in the transition to CE.

Third, it would be remiss to ignore the fact that a VI has strengths in knowledge capture and transfer, which a non-VI would struggle to achieve. In this chapter, we have also outlined four use cases for how a VI could act to catalyse a transition to a CE, showing in our mind very considerable promise.

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Educational content

1 What are the design principles of a VI to support the transformation towards a circular economy?
2 Transformation towards a CE requires coordination across many actors.
3 Actors are necessarily located in three transformation arenas: markets creation, organisational change, and the enabling environment.
4 VIs can play a key role in supporting CE transformation by reducing transaction costs, overcoming perception inertia, streamlining and standardising regulatory standards and benchmarks, and facilitating learning through knowledge capture and transfer.

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26

THE ASSEMBLING OF CIRCULAR CONSUMPTION

A sociomaterial practice approach

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Introduction

Consumption plays a pivotal role in the transition to a circular economy (CE). The ways in which we, as consumers, buy and use products and services, how we take care of these through maintenance and repair, and how we get rid of and circulate things no longer needed or wanted are crucial for such a change towards a CE (Hobson et al., 2021; Sijtsema et al., 2020).

Many of the currently promoted CE policies and practices rely on consumers' post-consumption practices (Hobson et al., 2021). Often, policy-makers address different market actors, such as legislators, manufacturers, and retailers, in the transition to a CE (Mesiranta et al., 2022), but ultimately, the success of these policies relies on consumers. Consumers are expected to take on the responsibility of recycling products, redesigning their garments, or finding new homes for their discarded products by gifting them or reselling them. Despite this, relatively little research has been conducted on understanding the work that goes into making this possible. In general, consumption has only recently become a prominent topic in CE research (Camacho-Otero et al., 2018, 2020; Hobson & Lynch, 2016; Hobson et al., 2021; Mylan et al., 2016).

Moreover, previous consumer research in the CE field often takes an individualistic approach, focusing on attitudinal and behavioural changes at the individual level. This research has offered insights into the drivers related to the acceptance and adoption of CE solutions among consumers (for a review, see Camacho-Otero et al., 2018), showing that consumers' personalities, attitudes, and amount of knowledge, as well as the features of the CE solutions all impact consumers' willingness to adopt circular consumption practices. However, while not without value, this research is limited because it tends to reduce the consumer to a choice maker who, influenced by several factors (e.g., personality and available information), can merely choose to reject or adopt CE solutions (Hobson & Lynch, 2016; Hobson et al., 2021).

This individualistic approach overlooks the important aspects highlighted by sociological studies of consumption. First, more research is needed to explore and understand the actual practices and related consumer work involved in shifting to circular modes of consumption (see Hobson et al., 2021). Recycling and redesigning products, participating in sharing schemes, and reducing waste all require considerable consumer work to be accomplished. Some previous

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studies have already started to explore the embodied, symbolic, and ethical work required from consumers so that they can do their part in a CE (Hobson et al., 2021; Lehtokunnas et al., 2022).

In addition, the individualistic approach to circular consumption tends to overlook or de-emphasise the social and material patterning of consumption. As research has decisively shown, consumption is intertwined and embedded in the everyday practices performed by consumers (Warde, 2005). In the CE context, Mylan et al. (2016) suggested that research should pay more attention to consumers' everyday practices, including their skills and competencies, shared cultural meanings, and social norms, as well as material infrastructures. Although CE and circular consumption are largely about the reduction, reuse, and recycling of material resources, theories on sociomateriality are only beginning to enter the discussion (Lehtokunnas & Pyyhtinen, 2022; van der Velden, 2021).

In this chapter, we conceptualise and empirically illustrate the formation of circular consumption. We approach circular consumption not as a ready-made pattern that end users simply adopt when they make choices about products and services, but as a continuous process and performance. Drawing upon the sociomaterial perspective, we argue that the performance of circular consumption is both enabled and shaped by broader sociomaterial processes. To understand the role that consumers play as catalysts of circular consumption, we must first understand how and under what conditions circular consumption is made possible.

To illustrate our theoretical arguments, we use empirical insights from a research project in which two of the authors generated data on circular fashion. Our method is inspired by narrative research (Polkinghorne, 1988; Riessman, 1993) and 'creative analytical processes (CAP) ethnography' (Richardson & St. Pierre, 2005, p. 962). We narrate three different stories, each following the biography of a singular consumption object as it becomes entangled in three circular consumption scenarios inspired by the three commonly used Rs of the CE: reducing, reusing, and recycling. While we acknowledge that various interpretations of the partly overlapping Rs exist and that researchers have detailed more nuanced CE processes (Kirchherr et al., 2017), we believe that the three Rs fit our purpose of illustration. By offering a reading of the sociomaterial assembling (DeLanda, 2006) of circular consumption through these narratives, our chapter contributes to the field of sociological studies of circular consumption (Camacho-Otero et al., 2020; Hobson et al., 2021; Lehtokunnas et al., 2022; Mylan et al., 2016).

A sociomaterial practice approach to circular consumption

In this section, we briefly present our sociomaterial practice approach to circular consumption. After a brief introduction to practice theory and a description of how it has been applied and developed in consumption studies, we discuss our approach to the sociomaterial assembling of circular consumption.

An introduction to practice theory

Practice theory is a school of thought developed and broadly used in the social sciences and philosophy that focuses on practices (rather than discourse, interactions, understandings, attitudes, or values) and makes these the central units of analysis. Practice theory scholars argue that diverse social phenomena, such as ethics, sustainability, consumption, and organisations could and should be understood by examining social practices (Reckwitz, 2002; Schatzki et al., 2001). Therefore, practice theory offers a theoretical framework, a lens, if you will, for seeing and approaching social phenomena. It is what could be called a perspective theory; rather than explaining why phenomena exist, it conceptualises how they are constituted and how the constituent entities relate to one another.

Since its formulation as a coherent approach in the early 2000s, practice theory has become a well-used resource across the social sciences in general. It has made an impact in the fields of management and organisation studies (Corradi et al., 2010; Orlikowski, 2007) and marketing studies (Kjellberg & Helgesson, 2007), and it is particularly relevant to our argument on consumption (Halkier, 2009; Warde, 2005).

But what exactly is a practice? According to Reckwitz (2002), a practice is

> a routinized type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge.
>
> (p. 249)

Practices can be carried out individually (e.g., reading a book or running) or can be collective and involve some sort of interaction (e.g., eating a family dinner, going to a concert, or playing soccer). However, whether done individually or in a group, practices are social because they are "a type of behaving and understanding that appears at different locales and at different points of time and is carried out by different body/minds" (Reckwitz, 2002, p. 250).

Practice theory in the field of consumption

Practice theory is widely used in consumption studies and has been employed to analyse a wide array of topics, including food consumption (Halkier, 2009), everyday household practices (Hand et al., 2005), and recreational practices (Shove & Pantzar, 2005). However, its main area of application has been sustainable consumption (Evans, 2019). In this area, practice theory has been used to understand the diffusion of sustainable product-service systems (Mylan, 2015), explore and assess the role of smart technologies in reducing energy consumption (Hargreaves et al., 2010), investigate the difficulties of promoting package-free shopping (Fuentes et al., 2019), analyse how food practices can be made more sustainable through design interventions (Devaney & Davies, 2017; Sirola et al., 2019) and speculative experimentation (Kaljonen et al., 2019), and, for our analysis, to conceptualise circular consumption (Hobson & Lynch, 2016; Hobson et al., 2021; Mylan et al., 2016).

This research stream has taken an interest in both how sustainable consumption is performed and what is involved in practices such as the shopping of fair trade products (Wheeler, 2012), and package-free shopping (Fuentes et al., 2019). Practice theory studies have also taken an interest in efforts to bring about sustainable consumption transitions, examining efforts to green household consumption through green technology (Hobson, 2006), or efforts to reduce food waste (Lehtokunnas et al., 2022; Mattila et al., 2019; Sirola et al., 2019). Finally, and importantly, theories of practice have been central to our understanding of escalating consumption. They have illustrated how combinations of materialities, conventions, and temporal rhythms of everyday life that support increasingly resource-intensive modes of household consumption, such as showering, laundering, and heating, become locked in (Hand et al., 2005).

Central to the practice theory approach to consumption is the assertion that "consumption is not itself a practice but is, rather, a moment in almost every practice" (Warde, 2005, p. 137). Warde defined consumption as "a process whereby agents engage in appropriation and appreciation, whether for utilitarian, expressive or contemplative purposes, of goods, services, performances, information or ambience, whether purchased or not, over which the agent has some degree of discretion" (Warde, 2005, p. 137). This is a broad definition that moves beyond the act of purchase and includes use. Moreover, expanding on the idea that consumption is a process rather than a practice, Warde, and later Evans, conceptualised consumption as a process consisting of various phases, what they called the three As of acquisition, appropriation, and appreciation and the three Ds of devaluation, divestment, and disposal (Evans, 2019).

Acquisition entails processes of exchange, such as purchasing, but it can also include other ways in which people gain access to goods, such as gifting, trading, or borrowing. Appropriation involves the process of giving meaning to the things acquired and making them fit into one's everyday life. Appreciation refers to various forms of pleasure and satisfaction from the use of goods. Devaluation is understood as the counterpart of appreciation, which entails the loss of value, either materially through wear and tear, or the loss of cultural meanings, for example, by something going out of style. Divestment is the counterpart of appropriation and refers to instances in which goods no longer fit consumers and their everyday practices and are therefore divested from use. Finally, the counterpart of acquisition, disposal, involves the various ways in which goods are disposed of, such as gifting, recycling, or binning (Evans, 2019). Thus, a single good – a service or a product – can go through multiple phases of consumption from being acquired, appropriated, and appreciated to being devalued, divested, and disposed.

Theories of practice and the assembling of circular consumption

The previously discussed broad definition of consumption is important to the issue of circular consumption, as it includes not only the purchase and use of goods but also the processes and activities connected with the goods' (de)valuation and disposal or recirculation. Circular consumption is, in large, about recirculating goods through the phases of consumption. A consumption object, such as a piece of clothing, ideally moves in a CE through several rounds of acquisition, appropriation, and appreciation in several sets of different consumers' practices before it is finally used up.

However, accomplishing this typically involves the (re)assembling of the elements of practices. As is made clear from the definition presented previously, practices involve and interconnect several heterogeneous elements. For the sake of analytical clarity, this wide arrangement of possible elements is often summarised as meanings, competencies, and materialities (Shove & Pantzar, 2005; Shove et al., 2012).

Practices such as the shopping for clothes can involve competencies, such as an overarching understanding of the retail landscape and how the materials or sizes of clothes are evaluated. They also involve a set of meanings, an understanding of what shopping for clothes entails, what counts as proper shopping, and why it is meaningful to perform. Finally, shopping for clothes is also made possible and shaped by materialities, such as shops, the mobility infrastructure that allows consumers to travel to and from stores, packaging/wrapping, signs, apps, and other elements involved in shopping practices.

To practice a more circular mode of shopping, such as buying secondhand clothes, will then require a different set of competencies (e.g., determining where one can buy secondhand clothes and evaluating the quality of used clothes), meanings (e.g., secondhand as nostalgic, retro, sustainable, or a necessity), and materialities (e.g., stores and their organisations, the material of clothes, and apps and digital platforms that enable the exchange of secondhand items). In other words, for a more circular mode of consumption to be performed, several specific elements need to be assembled, put in place, arranged, and interconnected. While this is not solely the responsibility of consumers, many actors are involved in developing and interconnecting the elements required for circular consumption to be performed. The CE model typically expects considerable work from consumers to make circular consumption possible.

Moreover, taking here a sociomaterial approach means not only considering devices, infrastructures, and materialities but also acknowledging that these have agency in the sense that they can come to change practices (Fuentes & Sörum, 2019). From this perspective, things are not merely used in practices; they also play a role in actively reproducing and reconfiguring practices (Preda, 1999). The materiality of things, such as how textiles behave when they are washed or how tools and devices direct us to use them in certain ways, shapes the way practices are performed, making certain actions more possible than others. This suggests that one needs to consider the active role of devices, infrastructures, and other materialities when trying to understand the assembling of a specific practice arrangement, such as the arrangements that make various forms of circular consumption possible.

Drawing on the theoretical framework outlined previously, we set out to examine various efforts to assemble circular consumption – efforts to assemble a specific type of sociomaterial arrangement that makes the performance of circular consumption possible. We discuss the arrangement and adjustment of the necessary elements to temporarily stabilise circular consumption arrangements. By examining the processes of assembling the necessary configurations of meanings, competencies, and materialities that make circular consumption possible, we can say something about the mechanisms and difficulties involved in enabling and thus catalysing circular consumption.

Narratives of circular consumption: Assembling, reducing, reusing, and recycling arrangements

We exemplify alternative scenarios of assembling circular consumption arrangements in the context of clothing for several reasons. First, the textile industry is one of the most polluting industries globally, and the circularity of the industry remains low (Berg et al., 2020; Ellen MacArthur Foundation, 2021). To reduce the fashion industry's emissions and meet the 1.5-degree pathway addressed in the Paris Agreement, one out of five garments would need to be traded through circular business models by 2030 (Berg et al., 2020). In a circular fashion system, fashion items are used more, made to be made again, and made from safe and recycled or renewable inputs (Ellen MacArthur Foundation, 2020). Second, for consumers, clothes are culturally meaningful and relate to the construction of (social) identity (Matthews et al., 2021). However, clothes are not only 'containers of meaning' but also material objects that have biographies of their own (Cwerner, 2001, p. 88).

The data we draw from were generated in a research project conducted from 2020 to 2022 in Finland. It is an insightful country context to study the circular consumption of textiles. Increasing the circularity of the textile industry is part of Finland's pursuit of CE. For instance, Finland is aiming to start a separate collection of textiles by 2023 (Finnish Textile & Fashion, n.d.). This will highly depend on consumers who will need to sort and recycle their textiles. Our data include interviews with sustainable social media fashion influencers, as well as the social media postings they made. We also use secondary data and our own experiences as sustainable fashion consumers. Inspired by the tradition of narrative research (Polkinghorne, 1988; Riessman, 1993) and CAP ethnography (Richardson & St. Pierre, 2005), we use narrative knowing to synthesise knowledge (Heikkinen, 2000). To keep with our sociomaterial approach, we structure the fictional narratives by adopting a follow-the-thing approach (Evans, 2020), in which we follow the biography of a single garment. We follow this garment first in the linear economy and then through three alternative narratives that are based on the 3Rs of the CE: reduce, reuse, and recycle. We start the narratives from the point in the biography of a garment in which it meets the consumer, whom we refer to as Ann. However, we acknowledge that many other phases earlier in the supply chain are relevant to CE. Both Ann and the sweater are fictional characters created from a combination of the interviewees' and the authors' experiences and reflections. The fate of the garment is different in each narrative: in the first narrative, the garment is redesigned (Reduce), in the second it changes owners (Reuse) in the third, it becomes energy (Recycle). In the narratives, Ann is a 30-year-old high school teacher who lives in an urban area in Finland.

The biography of Ann's green sweater

The story begins with a green sweater lying at the back of Ann's closet. The sweater used to be displayed at a retail store as part of a new fashion collection, positioned at the front of the store on a mannequin. The sweater, as an object, emphasised the meanings of novelty, fashionability, and style for potential customers. As part of the window display, it drew customers to the store, serving as part of the display space. However, it did not stay there for long. In line with the logic and business model of fast fashion, products are quickly replaced as new fashion items arrive in the store. This means that the displays and the store are in a continuous state of being rearranged (Anguelov, 2016) to not only cater to but also to enact a desire for novel products (Ingram et al., 2007). As a result, after a certain period, the sweater was moved from the window display to the on-sale section of the store. The price of the sweater was reduced, with an added red price tag attached to it. Thus, when combined with this price tag, the sweater became part of the practice of discount shopping, thus highlighting, among other things, the meaning of monetary savings and the creation of a moral justification for purchasing inexpensive items.

When Ann visited the store, she was drawn to the sweater, attracted by its colour and design; she then decided to purchase it on an impulse (Petersson McIntyre, 2021). This exemplifies the process of acquisition. Ann started to use the sweater in her yoga class, as she had seen others use the same brand, and she wanted to fit in with the group and express her belongingness to this collective (Matthews et al., 2021). This phase entails the processes of appropriation of the sweater into everyday use and appreciation of the value it had for Ann, as it became a key part of performing social identity in this specific context. Its value went beyond the mere warmth and protection that the sweater offered; it even went beyond its aesthetic qualities. To Ann, it was also valuable for its symbolic qualities. However, Ann soon learned that she was pregnant, and as her body changed, the sweater no longer fit her. As her body changed, the sweater went from being uncomfortable to impossible to wear. This entails the process of divestment, as the sweater no longer fit Ann's everyday practices (Evans, 2019). The sweater's material capacities did not accommodate wearing it, so it ended up in her wardrobe as an unworn item (Bye & McKinney, 2007).

Up to this point, Ann's sweater had been participating in practices related to the linear economy of fashion. However, close to her baby's due date, Ann became more aware of the unsustainability of her fashion consumption habits (Schäfer et al., 2012). She realised that most of the baby clothes she had were secondhand, gifted to her by her relatives, friends, and colleagues (Ritch, 2019). These used baby clothes were part of practices of care, so they were laden with affect and cultural meaning. In addition, she understood that using clothes by circulating them from one child to another, rather than throwing them away when they no longer fit, is much more reasonable and sustainable. She also started to think about her own wardrobe and all the unworn clothes hanging in her closet. Ann had not disposed of these clothes, and they were not completely devalued, but they were also not signs of a sustainable way of living. The unworn clothes represented less optimal use of resources from the point of view of a CE. What would happen to the yoga sweater when it was now of no use to her?

Reducing – The story of the upcycled sweater

One day, Ann was browsing her Instagram account when the algorithm displayed a post that was potentially interesting to her. This post was by a social media influencer who promoted the upcycling of clothes by repairing and customising them (Bhatt et al., 2019). Ann was inspired by the different ideas presented in the post, including using different materials, such as flannel, lace, and denim, to creatively design a completely new style for a sweater. The aesthetic images of clothes that were upcycled inspired Ann to start her own upcycling project for her sweater. To accomplish this, however, Ann needed a sewing machine, so she loaned one from her friend. In addition, to avoid buying new materials, she visited the nearest charity shop to look for lace. Ann also watched several YouTube sewing tutorials to refresh her sewing skills. As a result, the sewing machine and the lace enabled her to transform her yoga sweater into a new style that she could wear in her everyday life. This upcycling project also sparked Ann's interest in shopping her own closet, as she realised that she already owned clothes that could be combined or upcycled to create a unique style. She also started to look for inspiration for these projects by following the hashtag #shopyourcloset on Instagram. Because of browsing online for upcycling ideas, the algorithms displayed more interesting and relevant content to her. Although some of the targeted content was also related to the marketing of new items, Ann found it easier to resist the temptation to buy new things, as she had already successfully performed the practice of reducing consumption. Ann also started to take more care of her clothes to stretch their life cycles, for example, by washing them at the appropriate temperature (Mylan, 2015) or learning how to use a lint remover.

In this case, Ann's disposition, such as her personal interest in making her own clothing consumption more sustainable, made her pay attention to a social media post, which, in turn, was suggested to her based on her previous use of social media, the Google search engine, and other specific fashion and sustainability websites. This sparked a process of practice (re)formation, as Ann set out to learn how to first redesign her clothes and approach her closet and previously devalued items in a new way. She began the re-appropriation and re-appreciation process for her sweater to make it fit her life again and for her to gain value from using it.

Therefore, the assembling of these new, more circular practices required the reskilling of the consumer, as new competencies and practical know-how were needed to transform clothing items. However, as this story illustrates, this matter is also thoroughly material. To learn to redesign, Ann relied on social media platforms; to accomplish the redesigning, she had to borrow a sewing machine and acquire additional material. Access to infrastructures, tools, and materials was crucial in the performance of this form of circular consumption. Finally, while sparked by a specific consumer disposition (personal attitudes, values, and goals), the meanings of circular consumption also changed as Ann became a skilled re-designer. Ideas of sustainability are complemented by the enjoyment of engaging in craft consumption (Campbell, 2005), making it possible to express one's creativity through consumption. The result is the (re)assembling of practice, as new elements are developed and interconnected to make the practice of redesign possible.

Reusing – The story of how the sweater changed owners

One afternoon, Ann met her friend at a café, and they started sharing their experiences of cleaning their closets. Both women were frustrated about the amount of clothes they had but did not use anymore. Ann's friend had read about clothing swap parties in a magazine; during these parties people could bring clothes they no longer wanted and swap them with other people's clothing (Camacho-Otero et al., 2020; Henninger et al., 2019). Inspired by this, the women decided to organise a clothing swap party event in their neighbourhood. They reached out to their friends and relatives and invited them to join the event, turning it into a social gathering as well. Ann took her sweater with her to the event, swapped it, and found a nice scarf for herself. During the event, the participants also discussed their opinions and experiences on sustainability and fashion consumption, including trying monthly garment rental services. They described the benefits of these kinds of services but also complained about the effort needed for returning the clothes and also expressed concerns regarding the condition of the clothes, such as signs of wear (Clube & Tennant, 2020).

However, although many people tried on Ann's sweater at the swapping event, it did not find a new owner as it did not fit anyone. After the event was over, Ann still wanted to get rid of the sweater, so she engaged in a process of divestment by washing it and putting it into a cardboard box, together with some of her children's used clothes. Ann disposed of the box by mailing it to an online secondhand store, and thus eliminated the need to put any effort into selling the sweater herself. The online store had a business model in which they used secondhand experts – consumers who have much experience and competency in pricing, photographing, and sorting secondhand fashion items – to facilitate the selling. One such expert went through Ann's items, photographed, and priced them, engaging in a process of re-appreciation. Ann was notified through email that her sweater was acquired by a customer at the online store. As the buyer appropriated the sweater for new use, both Ann and the expert shared the profit from the resale.

What we see here is the assembling of a different type of circular consumption, one configured to promote the reuse of clothing. As in the previous example, the formation of circular consumption is a complex activity involving the development of competencies, the interconnection of materialities, and the fostering of new meanings and goals. To begin with, regardless of whether the exchange of material resources (i.e., the sweater) from one user to another takes place offline or online, there is a need to have a platform for it (e.g., a physical gathering or an online platform). Assessing the appearance and fit of clothes is difficult to do, especially online, which makes the work done by secondhand experts crucial. The digital platform provides free training for expert consumers on issues such as how to price items, provide garment measurements, and take attractive photos. Therefore, material objects, such as measurements and photos, facilitate the practice of reuse. In addition, organising clothing swap events requires competencies, such as planning, marketing, and logistics (Camacho-Otero et al., 2020). The organisation of consumer-to-consumer markets involves considerable consumer work. More specifically, reselling goods also requires work from consumers to turn their devalued goods into valuable secondhand products by, for example, washing, sorting, pricing, packaging, and sending fashion items to be resold. Connected with this, consumers involved in reselling need to learn to reconfigure the meanings of secondhand consumption, counteracting its stigmatisation, which has often been seen as a low-status form of consumption. These consumers need to learn to re-appreciate both secondhand consumption in general and their used products. Thus, the formation of circular consumption, in this case, also involves cultivating new norms around secondhand consumption, as well as developing the ability to express and promote these shifting norms to others. That is, as part of the reselling of goods in consumer-to-consumer markets, the new marketer–consumer also needs to learn how to sell and ascribe value to their used goods.

These efforts to assemble circular consumption in the form of reuse practices can be thwarted not only by the stigmatisation of secondhand products but also by the materialities involved. The body of the one wearing the clothing is a significant material agent in clothing practices (i.e., clothes may need to be washed because of sweat and other bodily traces, bodies change the appearance of clothes through stretch and wear, and also determine whether they fit), which may prevent the re-appropriation of a garment in practical terms. In addition, the materiality of the clothing items may also act as a barrier, preventing its resale. Certain materials and designs are more difficult to resell than others; the physical wear and tear of products makes them, in certain cases, less adaptable to reselling; however, the opposite can also be true in, for example, the selling of items with patina, in which the wear and tear adds value rather than reduces it. In other words, assembling the reuse arrangement is by no means an easy or straightforward task.

Recycling – The story of how the sweater became energy

As Ann really liked her sweater, she stored it in a box where she kept clothes that she would like to be able to wear again one day. Thus, Ann divested the product from her everyday life. After a few years, during a spring clean-up, Ann found the sweater and tried it on again. The sweater now fit her quite well, and she started to wear it again, re-appropriating it to her use. However, during lunch the next day, Ann accidentally spilled some tomato soup on her sweater, and it was stained. After using a variety of stain removal methods, as well as the washing machine for washing the sweater, Ann noticed that the sweater still had some visible stains. Although she felt that throwing the sweater away would be unsustainable, she considered the sweater too stained to be used by anyone. Ann heard that there was a waste policy measure in her municipality that instructs citizens not to throw textiles into the mixed waste bin (Rotimi et al., 2021) and wondered what she should do with the sweater. Luckily, she was following a social media influencer who shared a flowchart to help consumers recycle their clothes. This flowchart detailed different pathways for the clothes, including donation to charity, taking it to a clothing bank or a retailer's take-back container, or putting it into the mixed waste bin. This flowchart was made into an easily shareable image on social media. It became a go-to resource for sustainable fashion influencers to communicate recycling efforts. The flowchart assisted Ann in finding the best recycling option, which was a textile recycling centre in her hometown.

Ann travelled by bus to the recycling centre and disposed of the sweater by donating it to the centre. The decorative buttons from the sweater were removed and sold for craft projects at the recycling unit. The fabric itself was partly cotton and partly elastane, which meant that it could not be industrially reprocessed (Rotimi et al., 2021). While elastane facilitates the wearability of the garment on one's body by stretching and enabling movement, a large amount of it prevents material circulation in later stages of the garment's life cycle. Thus, the recycling centre delivered it to a power plant for use during energy production. From her social media feed, Ann saw a post by a sustainable fashion influencer discussing the impact of a fabric's material on its cyclability. She realised that to impact the recycling of fashion and contribute to the sustainability of the textile industry, she should pay attention already to the materials of clothes when shopping. Next time she would acquire new things, she would adopt the practice of always checking the clothes' tags for their materials before purchase. Ann also became more interested in purchasing fashion made from recycled materials and was happy that there were already many companies in her home country that offered circular fashion products (Vehmas et al., 2018).

This example illustrates once again the complex and not always easily predictable process of the assembling of circular consumption. The original idea to simply start reusing the sweater was impeded by an accident; the stain on it made it impossible for this clothing item to work properly in this context. Therefore, Ann's efforts to engage in the practice of maintaining the sweater in its original use failed. The stain gained material agency and prevented Ann from wearing the sweater, given existing norms regarding cleanliness. Once this was clear, Ann found inspiration and help in an influencer using their social media account to assist consumers in recycling their goods properly. Here, the competency needed to recycle was made available via social media, which guided her through the recycling landscape. The recycling centre was, of course, a key infrastructure without which this mode of circular consumption would have not been possible. The centre enabled and shaped circular consumption. Moreover, by performing this circular practice, Ann's understanding of recycling changed, and so did the manner in which she framed her consumption as being meaningful. As a result of becoming involved in this recycling assemblage, Ann also changed her way of acquiring goods, now considering the recyclability of clothing materials; a new sociomaterial arrangement around recycling emerged.

Discussion and conclusions

We exemplified three modes of circular consumption by following Ann's green sweater in three very different circular consumption scenarios. The accompanying theoretical readings of these examples showed that for each type of circular consumption mode to be possible, the garment had to go through several processes of acquisition, appropriation, and appreciation, as well as divestment and devaluation (Evans, 2019). A specific set of elements also had to be assembled for these to happen. This sociomaterial reading illustrated that the assembling of circular consumption arrangements was a complex accomplishment involving the cultivation of new meanings, the development of competencies, and the use of and access to materials, devices, and infrastructures. Figure 26.1 presents a summary of the insights from the three narratives.

Our reading makes several things evident. First, it stresses the importance of materiality for the assembling of circular consumption. To be clear, our reading of circular consumption does not deny the importance of consumer dispositions, which consist of, for example, personal attitudes, values, and goals. Ann was driven by her ambition to be more sustainable in her consumption. This shift in meaning came because of a new life situation and was reinforced by the information she had acquired. However, taking a sociomaterial approach to circular consumption shows that, while consumer dispositions can at times be necessary starting points for the formation of circular consumption, they also require access to several devices and infrastructures, as well as the development of competencies. It is only when all the elements are in place and appropriately interconnected that a new, more circular mode of consumption becomes possible.

Second, our reading illustrates that while materiality is key, performing circular consumption in all three versions involves considerable work from consumers. Time and effort must be spent to reduce, reuse, or recycle clothing; in other words, the re-appropriation and re-appreciation of consumer objects occur in a continuous manner. Considerable effort is also necessary to develop the competencies needed. Therefore, while the assembling of circular consumption is not solely done by consumers, as they are expected to perform much of the work of cultivating and interconnecting the necessary elements that make reducing, reusing, and recycling possible.

Third, our reading of circular consumption also suggests that understanding materiality is key to understanding not only how circular consumption is made possible but also what stands in its way. In the examples mentioned previously, it was clear that the materiality involved (e.g., the

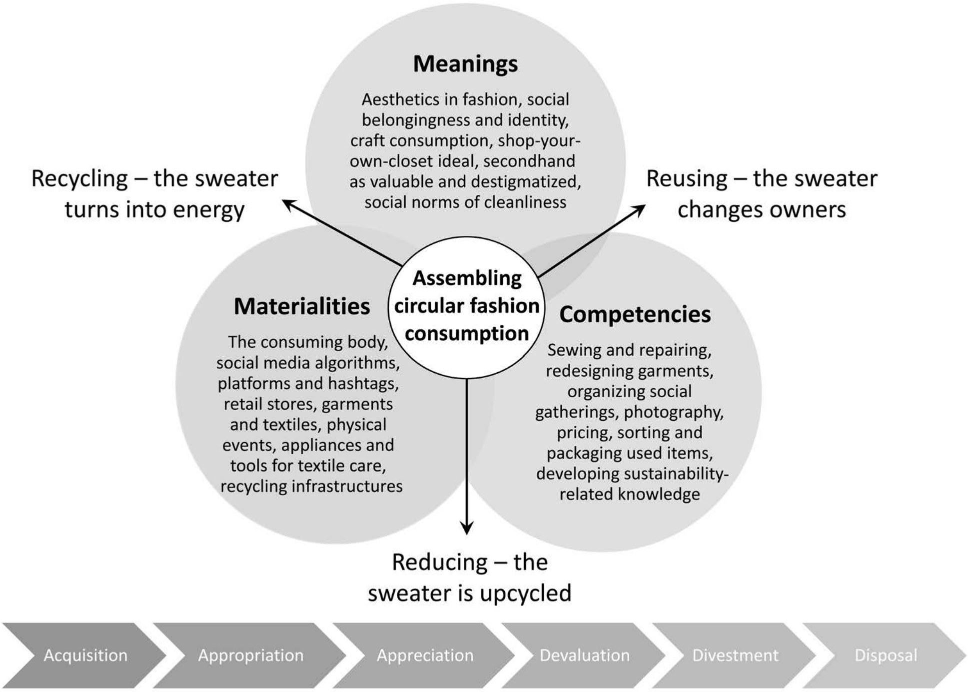

Figure 26.1 The assembling of circular fashion consumption.

fabric of clothes) or the lack thereof (e.g., access to social media or recycling stations) is a common problem for the assembling of circular consumption.

Our chapter contributes to research on CE in the following ways. First, we offer an alternative way of approaching and explaining circular consumption – one that goes beyond the consumer acceptance model. Mainstream research on CE has attempted to identify the reasons why consumers fail to accept or adopt new circular business models and solutions. For instance, failure to meet consumer needs and a mismatch between consumer values and the solutions provided to them have been identified, together with consumers' cognitive biases (Singh & Giacosa, 2019). By contrast, our work illustrates that the transition to circular consumption is not about simple adoption or acceptance. It entails assembling the necessary elements – meanings, competencies, and materialities – for the practice to be performed and reproduced. The work involved in accomplishing this is often at least partly performed by consumers. The motivation to be circular is not enough to bring about change. This indicates that we cannot, or at least should not, rely solely on consumers to bring about the transition to circular consumption. Assembling the necessary elements to perform circular consumption is time-consuming and resource intensive, and it requires contributions from several actors and the removal of structural constraints (Ertekin & Atik, 2020; Pekkanen, 2021).

Second, we contribute to studies that have addressed circular consumption from sociological perspectives (Hobson et al., 2021; Lehtokunnas et al., 2022; Mylan et al., 2016) by introducing the three narratives of assembling circular consumption arrangements in the context of fashion: reducing – the upcycled sweater; reusing – the sweater changed owners; and recycling – the sweater became energy. These narratives are illustrations of circular practices that are inherently sociomaterial in nature (see van der Velden, 2021), bringing forth the agency of devices, infrastructures, and materials and the work involved in assembling the necessary conditions for circular consumption. There are still limited studies taking a sociomaterial approach to circular consumption, so we hope that our study can inspire other researchers to continue this fruitful path.

Third, our study contributes methodologically by using narrative research and CAP ethnography to follow the journey of a garment in circulation. This kind of approach is unconventional, as we do not include any direct quotations from the empirical data in our analysis. However, at the same time, it allows us to take advantage of creativity and knowledge synthesis, as well as to keep to our sociomaterial perspective. Qualitative and interpretive empirical approaches, such as in this chapter, have so far been in the minority in circular consumption literature (Camacho-Otero et al., 2018).

Finally, our chapter provides insights for practitioners in the CE context, be they business managers, policy-makers, societal organisations, or technology developers. Based on our findings, providing consumers with education and information about the CE is not enough to make them catalysts of change. More effort should be placed on increasing the availability of infrastructures (including places and spaces) for circular consumption and on developing people's competencies for enacting circular practices.

In addition, if we accept that circular consumption requires consumer work, facilitating this work when possible becomes important, for example, not only by equipping consumers to be more circular, providing devices that are easy to use, and making circular consumption more convenient but also by making their efforts and work more meaningful through, for instance, providing rewards for the work that they do in the transition towards more circular modes of consumption. For example, deposit systems for returning food packaging are already in place in many countries; the same could be applied to other types of consumption objects and materials. We also invite actors to collaborate and plan journeys for material objects (e.g., clothes, food, electronics, and plastics) that fit and support people's everyday lives and practices. In this work, our chapter can be a useful starting point. Beyond this, approaches such as service design can also offer practical tools. It is important to underscore that by the term 'infrastructure', we mean not only facilities for recycling different materials but also digital platforms and social media communities where people can interact with one another. In our narratives and the empirical data, social media was often used to obtain inspiration, ideas, and concrete advice for performing circular practices. Obviously, these digitally shared ideas can be spread in offline gatherings, too. Therefore, different actors should not underestimate the power of social networks in spreading circular practices among consumers.

Educational content

Think about a consumption object you own. What was its biography like before you received it? How did you appropriate and appreciate it in your own consumption practices? What kind of work will be required from you as a consumer to circulate this object?

In what ways can consumer work for a CE be facilitated by other stakeholders?

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27

CATALYSING A CIRCULAR TRANSITION IN BRIXTON

Joanna Williams and Josefine Hintz

Introduction

Circular experiments are emerging in cities across Europe. In Brixton (London, UK), there is evidence of a circular transition process. Brixton provides a good example of circular experimentation, driven by the local community and supported by the local authority. Over a 15-year period, the communities of Brixton have experimented with a range of circular activities including: food reuse cafés, urban farming, repair workshops, and renewable energy production on rooftops. Over this period, the involvement of Brixton's community in these experiments has generated local knowledge and built capacity for a circular transition.

Tactical urbanism has enabled the reuse of sites and vacant properties in Brixton, avoiding wastage of land or materials and enabling the recirculation of space. It has also provided opportunities for low-value, circular activities to exist in an otherwise space-scarce environment. Circular tactical urbanism, has helped to produce a nascent circular food system, linking food production, food waste reuse, and composting in the locality. Thus, Brixton provides an opportunity to study the circular transition process, as well as the catalysts and barriers to the scaling up of circular activities.

In the sustainable transitions literature, the theorisation of the circular transition in urban systems is nascent or lacking. Limited empirical evidence of the circular urban transition process has been collected. This detailed case study is designed to address this gap. The key contributions of the chapter are as follows: (1) theorising the circular urban transition process, (2) identifying the catalysts and barriers to scaling up, and (3) providing empirical evidence to support both.

Using a historical event analysis of secondary data over a 15-year period, we observe the transition process in Brixton. We supplement this analysis with a series of key stakeholder interviews, designed to identify the catalysts and barriers to the scaling up of circular activities in the urban district.

Circular urban transitions – A theoretical framework

In this section, we attempt to theorise the circular urban transition, drawing from the existing sustainable transition literature, and have tried to develop our own conceptualisation. First, we must define a circular urban transition. Taking a more regenerative view of circularity, a circular

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urban transition can be defined as a radical, structural change of an urban system producing circular processes, infrastructure, and practices. These are diverse and cover a range of activities linked with resource looping (reuse, recycling, and recovery), the ecological regeneration of urban systems, and the adaptation of infrastructure and communities to new circumstances (Williams, 2021). Circular practices emerge as a result of the radical transformation of the incumbent economic, cultural, technological, ecological, and institutional arrangements that underpin the urban development regime (Williams, 2021).

The urban development regime is instrumental in the way in which cities are produced, governed, managed, and maintained (Williams, 2016). A circular transition would require the destabilisation and (partial) reconfiguration of the incumbent regime. Regime destabilisation results from three mutually reinforcing processes: landscape pressures, performance problems in the regime, and loss of commitment by regime actors (Turnheim & Geels, 2012, 2013). These could be viewed as catalysts for the transition process.

The build-up of economic and socio-political pressures in the landscape (for example: resource insecurity, climate change, economic recession, and food poverty) may provide the catalyst for the destabilisation of the development regime, enabling circular innovations to emerge and flourish. Performance problems within the regime may catalyse a circular transition, for example, the interruption of supply chains may undermine the legitimacy of the regime resulting in the closure of resource loops locally. Finally, a loss of actor commitment to elements of the regime may increase pressure for transition by exacerbating performance problems. For example, a change in political leadership could alter the commitment to existing linear systems resulting in the emergence of circular systems. In these circumstances, circular experiments in the niche regime may begin to scale up.

We theorise that circular transitions may be managed through the creation of a transition arena, in which key actors collectively develop a clear vision for a circular future (Bosman et al., 2018; Loorbach & Rotmans, 2010). A circular vision will focus on resource looping, ecological regeneration, and adaptation. Experiments will be used to test new, circular systems to determine how new structures, cultures, and practices emerge, operate, and impact urban systems. Those engaged in the experiments will learn, through implementation, what the benefits and disadvantages are in the adoption of such an approach, as well as the barriers to implementation (a deepening process). Through the creation of transition networks, these experiments can begin to multiply and diversify (broaden), eventually disrupting the development regime (scale up).

There are three stages that are critical to the circular transition process: deepening, broadening, and scaling up (van den Bosch & Rotmans, 2008). A process of deep learning amongst actors engaged in experiments helps to embed new circular practices within the community (deepening). Experiments also provide valuable experience of alternative lifestyles, which could eventually lead to an alternative organisation of socioeconomic life (Feola & Nunes, 2014). Circular experimentation may occur across various contexts and linked functions (e.g., production, reuse, and recycling of food). This broadening process helps the actors involved to test a variety of models and to develop context appropriate solutions. In this way, niche regimes may develop. We theorise that it is particularly helpful with circular systems in which linked activities are critical to success (e.g., the circular food system). Circular experiments will scale up when the dominant ways of thinking and doing within the development regime are altered to encompass the lessons learnt from experimentation (van den Bosch & Rotmans, 2008).

The catalysts for (and barriers to) scaling up circular urban experiments are likely to be comparable to those already identified in the transition literature for sustainable experiments. Landscape pressures and problems within the regime can provide catalysts for experiments to scale up

(Turnheim & Geels, 2012, 2013). However, more deliberate actions may also be taken to speed up the process. Societal support offered through the provision of resources, institutional backing, and financial investments could be used to create a favourable context that catalyses the scaling process (Frantzeskaki & De Haan, 2009). The standardisation of practices through regulation could also assist in the scaling up processes (Frantzeskaki & De Haan, 2009; Geels & Raven, 2006; Magnani & Osti, 2016).

The standardisation can be further leveraged by government support for circular experiments. First, creating both regulatory and financial instruments can increase the number of actors that favour new socio-technical systems (Frantzeskaki & De Haan, 2009; Smith, 2007). Second, linking to national/international networks could provide greater opportunities to connect, communicate, and access additional resources (Frantzeskaki et al., 2012; Seyfang & Longhurst, 2016). These connections and additional resources are essential for scaling up. Third, building networks with diverse partners, which provide support and improve information sharing, can aid the scaling process (Seyfang & Longhurst, 2013; Prendeville & Bocken, 2016). Last, the provision of circular, socio-technical systems is likely to create demand that will support scaling up (Nevens et al., 2013).

The limited economic viability of circular experiments creates a major barrier to scaling up. The lack of resources (finance, human, time) reduces the ability for experiments to sustain and, for those involved, to build the capacity needed to scale up (Nevens et al., 2013; Prendeville & Bocken, 2016). Local, community-led experiments often lack resources and face struggles to just survive, because they are not viable within the current economic paradigm (Seyfang & Longhurst, 2016; Seyfang et al., 2014). This lack of resources may also limit supply, causing a mismatch between supply and demand. This mismatch limits market trust in the new products and services offered, and this, in turn, also prevents scaling up. The problem of poor economic viability is reinforced by the higher transaction costs associated with innovation and risk averseness amongst investors, policy-makers, and consumers.

The socio-technical lock-in to existing systems of provision creates a barrier to scaling up (Geels & Raven, 2006; Seyfang & Haxeltine, 2012). The existing lock-in to infrastructure, social practices, and lifestyles creates one set of problems, whilst the lock-in to the existing culture, structures, and practices of institutions create another set (Williams, 2019). Circular experiments test new sociotechnical systems, which require the public and service providers to change their practices, daily lifestyles, and systems of provision. This requires wholesale cultural, social, institutional, and technological shifts, which, in turn, demand significant resources. Thus, it is likely the transaction costs associated with overcoming the lock-in will create a barrier to circular experiments scaling up.

In this section, we have theorised the circular urban transition process, the catalysts, and barriers to scaling up based on the existing transition literature. We will now test the theory using a single case study.

Brixton – A neighbourhood in transition

Brixton was chosen as the case study context because it offered a variety of community initiatives pioneering circular practices. There were two dimensions to the research. First, a historical event analysis was completed to determine the key events and catalysts for the emergence and scaling up of circular experiments in Brixton. The research examined a 15-year period. Second, stakeholder interviews were conducted to determine the factors that had catalysed or barred the scaling up of these circular experiments. Stakeholders engaged in implementing circular experiments were mapped (Figure 27.1). The findings were triangulated using secondary data (technical

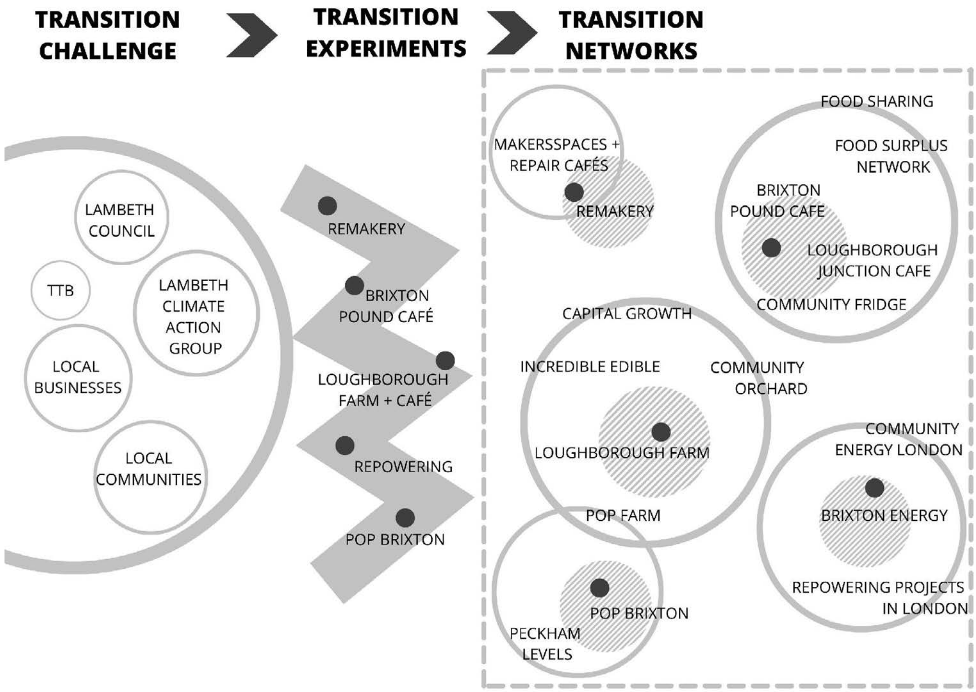

Figure 27.1 Transition process in Brixton.

Source: The authors.

and media reports). Both datasets were analysed using deductive content analysis. The coding framework was based on the theoretical framing derived from the transition literature and presented in the previous section. The analysis of data was then completed using NVivo Software v11. A summary of these findings is provided in this chapter.

Brixton is a neighbourhood in the London borough of Lambeth. It is filled with community-driven initiatives and projects, deeply rooted in a culture of community activism. In 2007, Lambeth Climate Action Group suggested Brixton should become a Transition Town. There was an increasing local public interest in combating climate change and moving to a new development trajectory after peak oil. Brixton became a Transition Town in 2010. It created a transition arena in which a diversity of community actors (social enterprises, government bodies, private businesses, and community) could experiment (Figure 27.1). Transition Town Brixton produced an alternative vision for future development of the area, through a highly collaborative and bottom-up process.

The vision of Transition Town Brixton sought to tackle climate change, resource consumption, increase local self-sufficiency, and address local social issues. Although Transition Town Brixton was not focused on the creation of circular systems per se, the work of the group did lead to the emergence of several circular experiments on vacant sites and in vacant buildings.

Tactical urbanism was certainly a catalyst for the emergence of circular experiments in Brixton. Tactical urbanism uses spaces in communities temporarily for a variety of activities (e.g., generating renewable energy, urban agriculture, etc.); it can be supported by temporary planning permissions and leases. It enables the reuse of vacant sites and properties, avoiding wastage of land and materials. So, it is a circular process in itself. Tactical urbanism has been encouraged by various London boroughs, through the allocation of sites, temporary leases, and planning permissions. By 2020, this activity was formalised by the London Spatial Plan (Mayor of London, 2021b). Thus, a fragmented process that had appeared only on ad hoc sites across London was standardised and the practice became embedded in the development regime.

In Brixton, this process became circular tactical urbanism. It enabled circular, community-led experiments to emerge and compete with higher value land-use activities. The historical event analysis explored the transition trajectory of experiments in Brixton, enabled by circular tactical urbanism (Table 27.1).

Repowering London – Renewable energy on empty roofs

This first circular experiment, which reused empty roofs for solar arrays on social housing, demonstrated a degree of scaling up. The experiment was set up by Repowering London (RL), a not-for profit organisation. The focus of the project was on providing affordable, green energy in social housing by retrofitting renewable and efficient technologies, to address greenhouse gas emissions and fuel poverty. The experiment was enabled by RL, Transition Town Brixton, and Lambeth Council, a collaboration that gave rise to Brixton Energy. Four additional solar projects have been completed in Brixton since 2012, suggesting scaling up. The initial catalysts for the experiment appeared to be a local desire to tackle fuel poverty and global warming.

The experiment was installed in 2012. The capital investment in the project came from RL. However, the feed-in tariff provided the operational subsidy, introduced in the UK in 2010. The feed-in tariff provided a catalyst for many community renewables schemes, as it guaranteed the price of the energy produced. Residents generating renewable energy were paid partially in Brixton pounds (a local currency introduced in 2012, which enables locals to pay with a currency other than the pound sterling), to encourage spending within the local area, enabling the local circulation of resources. Energy could also be bought using Brixton pounds. This was the first significant use of the local currency. It was intended to have a broadening effect in terms of supporting additional circular experiments, as well as producing a market for locally produced renewable energy, with the intention of scaling up.

By 2013, RL had set up two more renewable energy projects in Brixton, and by 2015 it had established projects in Hackney and Vauxhall. This was also supported by the feed-in tariff. In 2016, RL co-developed Community Energy London, which brought people together to engage in energy-related activities and to share experience in running community energy projects across London. This capacity-building exercise was designed to increase public interest, which would help scale up community-led renewables further. However, in 2019, the feed-in tariff ceased. Fortunately, the price of solar technologies was declining, and energy prices were rising. Thus, there was still an economic case for installing solar energy and other energy-efficient technologies. RL established Lambeth Community Solar in 2019, with the intention to install solar panels on schools and public buildings (broadening). By 2020, two school projects had been completed in the borough and subsidies were given by the Greater London Authority for further expansion (scaling up).

RL has now established five energy co-operatives across the capital city. There are eight different solar arrays generating 670 kWp, avoiding 114 tonnes of greenhouse gas emissions each year. These projects have also raised £155,000 for communities to spend. RL has introduced an educational programme, to foster local fluency related to renewable energy and community-driven business. This could provide a catalyst for broadening and scaling up the activity. In 2018–2019, climate protests in London re-emphasised the need to address climate change in the public domain. In 2022, rising energy prices and increasing fuel poverty are likely to support

Table 27.1 The timeline of circular transition in Brixton

Year	*Key events*
2007	• Members of Lambeth Climate Action Group become inspired by the growing Transition movement and establish one of the UK's first city-based Transition groups: Transition Town Brixton (TTB).
2008	• TTB receives its first funding and officially launches TTB at Lambeth Town Hall. • TTB establishes working groups in Transport, Buildings and Energy, Economy and Business, Food and Growing, and Waste (Remade in Brixton, now the *Remakery*).
2009	• Launch of the *Brixton pound*.
2010	• TTB becomes a community interest company. • Council-owned site of disused garages is identified as suitable to create a reuse centre for Remade in Brixton with support by Architecture for Humanity London. • Introduction of the feed-in tariff.
2011	• *Repowering London* was founded with support from TTB. • Remade in Brixton/Brixton Reuse Centre receives funding from Lambeth Council and becomes 'the *Remakery*'.
2012	• Brixton Pound Café opened in 2012. • *Repowering* launches Brixton Energy Solar 1 and 2 on the Loughborough Estate. • Work on creating the *Remakery* spaces commences. • Incredible Edible Lambeth was established as a community interest company. • Capital growth supported the creation of 2,012 new community food growing spaces across London.
2013	• Initiation of *Loughborough Farm* on a derelict site that had been unused for over 25 years. • *Repowering* launches Brixton Energy Solar 3 at Roupell Park Estate. • A Zero Hunger City Tackling food poverty in London report released highlighting issues of food poverty. • Brixton Soup Kitchen opened; reuses food waste from supermarkets, cafés, and restaurants to feed the homeless. • The Restart Project opened: the repair of electronic goods (London-wide).
2014	• Lambeth Council ran a competition in search for a meanwhile use of a derelict piece of land. Carl Turner Architects proposed *Pop Brixton*, and this was chosen. • Lambeth Council begins to collect food waste for composting.
2015	• *Repowering* starts an energy project in the Borough of Hackney (Banister House) and a second project in Vauxhall. • *Pop Brixton* opens, providing spaces for local small businesses and community activities. • *Bag It or Bin It?* started; managing London's domestic food waste, February 2015. • The Courtauld Commitment 2025 to redistribute food waste was signed. • 'Growing Underground' started: hydroponic farming opens to provide a zero-carbon food supply.

(*Continued*)

Table 27.1 (Continued)

Year	*Key events*
2016	• Construction work of the *Remakery* concludes and the space officially opens.
	• *Loughborough Farm* co-develops a Community Café.
	• *Repowering* co-develops Community Energy London.
	• The Felix Project sets up: a London-based food redistribution charity.
	• *Pop Brixton* builds Pop Farm, and the People's Fridge opens.
2017	• The main site of *Loughborough Farm* is developed into LJ Works, which includes a 20-year permission to continue the farming practice.
	• *Pop Brixton's* lease gets extended to 2018.
	• The company operating *Pop Brixton* called 'Make Shift' opens up another meanwhile space, reusing a car park as Peckham Levels.
	• Brixton Orchard is planted on vacant land – project by Urban Growth.
2018	• *Loughborough Farm* together with the London Orchard Project plants a community orchard in Wyck Gardens.
	• Extinction Rebellion; first protests in London brought the need to address climate change and the extinction of flora and fauna into the public eye.
	• New London Food Strategy published.
2019	• Lambeth Council declares a climate emergency and pledges to be net-zero by 2030.
	• End of the feed-in tariff.
	• Lambeth Community Solar (LCS) was started through *Repowering*, as a borough-wide initiative to install community-owned solar panels on schools and community buildings.
2020	• London Spatial Plan 2020 supports the temporary reuse of spaces and food growing.
	• Lambeth Council expands food waste collection to flats.
	• Start of COVID-19 pandemic.
	• Brixton's first Zero Waste shop opens.
	• The Community Repair Network emerged from conversations at Fixfest UK 2020.
	• First two schools in Lambeth fitted with solar panels and given a grant by the London mayor for expansion.
2021	• Lambeth Citizen Assembly on Climate formed.
	• UK Right to Repair regulations introduced.
	• COP 26 in Glasgow – further rise in public awareness of climate change and drivers.
	• COVID-19 pandemic continues.
	• *Pop Brixton*'s lease extended until 2022.
	• Salon restaurant opens – a circular food restaurant.
2022	• Global energy /fuel price rises.
	• *Pop Brixton*, the *Remakery*, *Loughborough Farm,* and the *Repowering* projects are all still in existence and thriving.

Source: The authors.

growing interest in community-owned, greener energy alternatives. No doubt this commercial viability will further catalyse the scaling up process.

The Remakery – A repair café in a disused car park

Repair cafés are also recognised as key contributors to the circular economy (CE). The second circular experiment, the Remakery, is a repair café in Brixton, based in an abandoned underground car park. This project was instigated by Transition Town Brixton in 2011, emerging alongside other repair projects across the capital, (e.g., the Restart Project in 2013). Repair cafés provided co-working spaces for small businesses, startups, and artists. Members could access the materials, skills workshops, and tools needed to repair and refurbish products. It offered training for the local community, enabling the reuse and recycling of a range of goods. There were also biweekly markets for the community to buy and sell reclaimed, reused, and secondhand items. The project was awarded capital funding from Lambeth Council in 2011, and a temporary lease of the property for 15 years. Construction was completed in 2016. It is now reliant on the support of volunteers, shareholders, pro bono advisors, and material suppliers.

The Remakery is part of a London-wide broadening process, which appears to have created a niche regime. It is part of the Open Workshop Network (39+ Makerspaces, Hackspaces, Fab Labs, and open workshops), which spans across London, enabling remanufacturing and repair. It is also a member of the Community Repair Network that emerged from the Fixfest UK in 2020. There are now seven repair cafés in London. The transition process so far has been slow, however, the introduction of the 'Right to Repair' regulation in the UK in 2021 may help to scale up the practice across the capital. Currently, the lack of commercial viability hinders the process. Presently, there is no evidence for the practice of repair scaling up in Brixton.

Pop Brixton – Recycled shipping containers, land, and closing the food loop

Pop Brixton provides temporary leisure and workspace for the local community, built on a disused car park owned by the municipality; it was completed in 2015. The buildings were designed for easy disassembly and reassembly and fabricated from recycled shipping containers. Pop Brixton accommodates Pop Farm (a community garden) and the People's Fridge opened in 2016. Both help to locally close the food loop. The businesses operating from Pop Brixton adopted circular practices: buying local food, growing food, and reusing food waste. Thus, Pop Brixton offered another example of circular tactical urbanism.

Lambeth Council has been a key actor in the establishment of Pop Brixton. It provided the site, chairs, the project steering group, and in return it receives 50% of any profit made. This profit is reinvested in the local community. Pop Brixton has also received capital funding from the Greater London Authority. It has had its lease extended several times and is now a commercially viable entity. In 2017, 'Make Shift', the company originally operating Pop Brixton, opened a similar project called Peckham Levels, in an adjoining district. Like Pop Brixton, it is a multifunctional space in a disused car park. Although commercially viable, there is no evidence to suggest that Pop Brixton has scaled up.

Circular food experiments – Growing, reusing and composting

Transition Town Brixton wanted to develop a local food system. Initially, the focus was on localising food production; this was driven by the desire to reduce the distance travelled by food and to address fresh food scarcity amongst the urban poor. It was a reaction to growing public concern (landscape pressures) precipitated by climate change and food poverty and was highlighted by the Zero Hunger City Report (2013).

Loughborough Junction Farm was an early farming experiment in Brixton. One community group squatted at a contaminated brownfield site in 2013; this site had remained derelict for 25 years. The project aimed to be self-sufficient; however, the surplus food produced was sold in Brixton market and used in a community café. Organic waste produced by the café and local growers was used as compost onsite (closing-the-loop). In 2017, the site was redeveloped for commercial and residential uses. However, the farm was retained at the centre of the development and was given a 20-year lease. Those engaged in establishing and running the farm developed relevant expertise and new practices, which they have applied to other projects in the area. These sites are also on vacant, publicly owned land. For example, the project members planted a community orchard in Wyck Gardens (2018) and helped to establish the Southwell Community Garden (2018), which was funded by the London Wildlife Trust. Recently, the group also began to support residents of the Moorlands Estate to regenerate a neglected allotment space for growing food. Thus, this experiment demonstrates evidence of both deepening and broadening processes.

Since 2013, a variety of mostly unrelated, urban growing projects composed of gardens, community farms, and orchards have appeared across the borough. Increasingly, local cafés are sourcing their food supply from other projects (e.g., Pop Brixton sources some of its food from Loughborough Junction Farm). More actors have been involved, most notably Incredible Edible Lambeth (founded in 2012), which is an alliance of over 140 community growing projects in Lambeth, part of a national food growing network called Incredible Edible. Over the years, the experiment connected with wider food networks (e.g., Urban Growth, a London-wide organisation and creator of the Brixton Orchard in 2017) and a diverse range of actors (e.g., Zero Carbon Farms founder of Farming Underground an underground hydroponic farm in Clapham, 2015). Arguably, there is a process of scaling up of community food production in progress, enabled by vacant, publicly owned land and networks for capacity building.

Food growing capacity in Brixton has developed alongside an increase in public interest in food growing across London. This has been supported by Capital Growth (2012) and more recently by both the London Food Strategy 2018 and London Spatial Plan 2020. There is now a requirement that empty spaces are used for food growing in London, and that consideration of space for food growing is included in new developments (Greater London Authority, 2021a). Here, the spatial plan is being used to standardise food growing practices. Thus, changes in the development regime are also beginning to support the increase in urban farming projects and the scaling up of food growing practices.

The Brixton Pound Café was opened in 2012. It experimented in food waste reuse to create affordable meals. The café hosted classes that taught residents how to utilise their food waste in cooking. These classes deepened local understanding of the possibilities for food waste use and encouraged a change in local practices, at least to a limited extent. The practice of food waste use was further reinforced by the opening of the People's Fridge in Brixton in 2016 (broadening). This enabled residents and businesses to donate unwanted food for those in food poverty. This followed on from charitable projects operating in the borough, whose aim was to feed the homeless and urban poor. One example, the Brixton Soup Kitchen, opened in 2013 and used food waste from local cafés, bakeries, supermarkets, and restaurants to create nutritional meals for its patrons.

During this period, food poverty was a growing problem nationally as was food waste (drivers for change in the landscape). The *Bag It or Bin It?* report (2015) sought to manage London's domestic food waste. The Courtauld Commitment 2015 encouraged the redistribution of food waste. Thus, the London food regime began to support locally run food reuse schemes operating in Brixton. These were joined by London-based (the Felix Project) and national schemes (e.g., Food Surplus Network), also operating in Lambeth. Thus, the linking of efforts to sub-national and national networks, and engaging new actors, helped to increase resources available locally, enabling more experiments to emerge. Food reuse projects increased and diversified across the borough, which helped to close the food loop locally. However, the original experiment of the Brixton Pound Café closed. Nevertheless, the practice of food waste use was scaling up. By 2021, new players were emerging in Brixton. For example, the Salon restaurant combined local food production, food reuse, and recycling as composting to close food loops locally, and in 2020, the first zero waste shop appeared in Brixton.

Finally, the local authority (a regime actor) began to collect and compost food waste in 2014, which it used in parks and gardens. The scheme was designed to close the food loop in Brixton. It was extended to those living in flats in 2020. Thus, the practice of recycling food waste began to scale up. This experiment had the advantage of being implemented by the municipality, and it may serve to reinforce food circularity in Brixton. However, an unintended consequence may be to undermine the practice of food reuse.

Separate activities that combine to create a circular food system have emerged in Brixton. Few experiments have combined food growing, reusing, and recycling. A variety of catalysts have led to scaling up. For food production, the key catalyst was land availability. The key catalyst for food reuse appears to have been the need for food, either on behalf of the urban poor or the local authority wanting to reduce waste going to landfill. For food growing and reuse schemes have also catalysed scaling up, engaging with a larger network, enables the capacity to be built for learning, funding, and distribution.

Catalysts for a circular transition in Brixton

In this section, we will explore some of the catalysts for scaling up. Most of the catalysts for a circular transition identified in the literature have been observed in Brixton (Table 27.2).

Landscape pressures and performance problems in the regime

Events in the landscape, socioeconomic, ecological, and cultural concerns have begun to change the discourse, needs, and policy priorities within the neighbourhood, so that conditions are more supportive and favourable for a circular transition. Increasing fuel and food poverty and public awareness of the urgent need to address climate change have increased interest amongst the public, charities, and local businesses to support local projects addressing food and energy needs. Rising energy prices and increasing waste production have also led service providers (local authority, housing associations, schools, waste companies) to reevaluate their models of provision. Both phenomena have encouraged scaling up of community renewable energy, food reuse, and composting projects in Brixton.

Government support at a sub-regional level

The use of capital and operational subsidies and land allocation through the planning process (spatial plan and temporary permissions) has also helped to catalyse scaling up. This is demonstrated in the case of food growing and community energy projects. Land release and the feed-in

Table 27.2 Overview of catalysts in Brixton

Catalysts	*Identified in transition literature*	*Brixton catalysts*
Landscape pressures	Landscape pressures	Local concerns around climate change, waste, energy security, food poverty, food waste, food security, and social inequality.
Government support leveraging and protection	Institutional backing	Policy and plans; capital funding for projects from GLA and Lambeth; feed-in tariff – operational subsidy for community renewable energy; use of local currency to encourage circular projects.
Standardisation of practices, laws, routines	Standardisation of practices through regulation.	Repair legislation; spatial plan promoting the temporary reuse of spaces and food growing.
Large, diverse networks providing opportunities to connect and communicate and provide additional resources	Networks – connecting, communicating, and providing additional resources.	Evidence of linking up with sub-national and national networks enabling the exchange of resources (knowledge, finance, experts) and sharing of resources (food, energy).
Availability of vacant land and properties	-	Available space for temporary circular activities.
Culture of activism	-	Culture of activism and community engagement in Brixton; the emergence of TTB; strong local social capital; clustering of innovators and early adopters in community; inclusion and involvement of multiple actors.
Symbiotic relationships	-	Foster mutually beneficial relationships between local actors enabling the circulation of resources locally.
Positive narrative	-	Creation of a community narrative around resilience, social equity, addressing climate change and resource security, local community and businesses, all of which increases the demand and supply of circular goods and services.

Source: The authors.

tariff have proved critical for scaling up community renewable energy and local food production. However, the long-term economic viability of some of the circular experiments is precarious and the dependence on government support, volunteers, publicly owned land, and temporary planning permissions is apparent (e.g., Brixton Pound Café, Remakery, Loughborough Farm). Once any support mechanism is removed, the projects tend to fail.

Standardisation of practices

The regulatory framework is also assisting in scaling up some circular experiments. The London spatial plan has standardised the practices of tactical urbanism and food growing, both critical to scaling up circular food systems across the capital. The Courtauld Commitment has encouraged the creation of more imaginative methods for redistributing food waste, food reuse, and recycling to emerge. Currently this is reinforced by the Landfill Directive. It is expected that the UK Right to Repair legislation will also assist in scaling up repair cafés across the capital.

Networks connecting, communicating, and providing additional resources

Over time, the actors involved in the circular experiments have either established or joined networks of similar experiments with sub-national (Capital Growth, Felix Project, Open Workshop Network, Community Energy London) and national coverage (Incredible Edible, Food Surplus Network). These networks form niche-regimes fostering knowledge exchange and building a collective voice to lobby policy-makers and potential funders for support. These networks can also increase access to circular resources, which is necessary when local demand outstrips supply (e.g., through the national food reuse networks). This has been instrumental in the scaling up of local food growing and food waste reuse. Some catalysts that key stakeholders suggested would eventually lead to the scaling up of circular activities in Brixton had not been identified by the literature.

Availability of vacant land and empty properties

The availability of vacant land and empty properties has provided a catalyst for the scaling up of circular experiments in Brixton, whether acquired through local authority allocation or commandeered by the community. Certainly, this has been a critical resource for scaling up the practice of food growing and generation of renewable energy on empty roofs. However, it has not been so successful in encouraging other circular activities like food reuse and repair cafés to scale up. These activities are incentivised and constrained by factors other than space.

Culture of activism

Brixton has a culture of activism. It is home to many innovators and community leaders (early adopters) willing to try new practices and encourage others (early majority) to engage in the transition process. Thus, circular experiments emerge. Social networks are strong and well-developed. There is a range of actors, with different skills and capacities who are willing to engage in the process. The experiments provide opportunities for citizens to directly invest in circular products (*Repowering*), get training in circular practices (Repowering, Remakery, Loughborough Farm), or link their own business to the wider Transition Town Brixton project (Pop Brixton, Remakery), which reinforces local connections and support for the circular experiments, resulting in scaling up.

Symbiotic relationships

The creation of local symbiotic relationships between projects is also key for scaling up. These symbiotic relationships enable the sharing of resources (people, space, materials, finance), the exchange of experience and knowledge between experiments. For example, the urban farming experiments share personnel, enabling the exchange of technical expertise and the sharing of administrative tasks. Waste from one activity is used by another; for example, the waste hop and wheat from a local brewery is turned into fertilizer used in Loughborough Farm. Finance from some of the commercially successful experiments is being used to support others. For example, businesses in Pop Brixton pay part of their profit into a community fund, which supports schemes like the Remakery. These local symbiotic relationships enable scaling up, they are essential for closing resource loops.

Creating a positive narrative

Social media and local media in all formats have also helped to build the narrative around the circular and sustainable transition that is underway in Brixton. The identity of the community has become entwined with this vision. It also draws people together in the community, advertises the circular activities that engage existing residents, and encourages like-minded “others” (pioneers and early adopters) to move into the community and get involved. This increases supply and demand for circular products and services, which eventually will lead to scaling up.

Barriers to a circular transition in Brixton

The barriers to circular experiments scaling up in Brixton reflected those identified in the literature. Broadly the barriers grouped around two problems: economic viability of circular activities and local socio-technical lock-in to existing systems.

Key barrier: The lack of economic viability

The key barrier to the circular transition in Brixton was the lack of commercially viable circular experiments (Table 27.3). Low economic returns and dependence on conditional funding created a significant problem scaling up circular experiments (highlighted by those interviewed in the Remakery). Often circular experiments struggled to attract funders because the market value for circular service/products was low. Low returns in the Brixton Pound Café eventually led to its closure. Thus, operational subsidies (e.g., the feed-in tariff), at least in the medium-term, are essential for scaling up to be possible. High transaction costs are also a major barrier. Scaling up is

Table 27.3 Barriers to experiments scaling up in Brixton

Barriers – themes	*Barriers identified by the literature and Brixton case*	*Transition management literature*	*Brixton case study*
Economic viability	Lack (human, time, money) resource	✔	✔
	Risk aversion of policy-makers, producers and consumers, investors	✔	
	Transaction costs	✔	✔
	Socio-ecological ambitions		✔
	Land value and competition for space		✔
Socio-technical lock-in	Socio-technical lock-in to existing systems of provision	✔	✔
	Institutional lock-in	✔	
	Technological lock-in	✔	
	Lack of expertise amongst service providers and policy-makers	✔	
	Existing cognitive rules and linear consumption habits		✔

Source: The authors.

particularly difficult for projects that operate a non-commercial, volunteer dependent model with a high personnel turnover, such as was seen in the Brixton Pound Café, Remakery, and Loughborough Farm. In all of these cases, a lack of financial and human capital resources hampered outreach actions and replication efforts.

Economic viability versus socio-ecological ambition

For all circular experiments in Brixton, commercial viability was not the main objective. They had socio-ecological goals: to improve community well-being, enable access to affordable food and energy, reduce greenhouse gas emissions, and increase local resource sufficiency. For example, Loughborough Farm's goals focused on community well-being and benefit rather than to establish the most productive and efficient local food system. However, such a model struggled to attract sufficient funding or to make an adequate return. The renewable energy schemes are a notable exception; they were initially commercially viable because of the feed-in tariff. More recently, as the market value of energy has increased, there has been growing public interest in securing cheap, clean energy; thus, the need for the operational subsidy has receded.

Land value and competition for space

The economic viability of circular experiments was further undermined by the high value of land and competition for space in Brixton. Less economically competitive circular activities (e.g., repair spaces, food growing) find it difficult to compete with commercial and residential development (e.g., Loughborough Farm). The experiments generally have short leases, although some have been extended (e.g., Pop Brixton) and others extended in a much reduced form (e.g., Loughborough Farm). The ephemeral nature of these activities undermines their potential for scaling up. This is particularly true for activities involving ecological regeneration, which is a much longer process. This might suggest that tactical urbanism is not a process that supports scaling up. However, it can enable the emergence of niche regimes, for example, creating circular local food systems, as long as there are steady supplies of new sites. We can see this across the capital region.

Socio-technical lock-in to existing systems of provision

There is a socio-technical lock-in to existing systems of production in Brixton that challenge circular practices. There is limited space for primary production of resources (manufacturing, farming, energy generation), which means it is difficult to establish local supply chains and to close loops locally. Incumbent socio-technical systems for generating and supplying energy dealing with waste, producing, storing, and transporting food also undermine the establishment of local circular systems of provision. For example, Repowering highlighted that the fossil fuel-dependent energy grid and a lack of roof spaces, posed a significant barrier to community renewable energy production.

Existing cognitive rules and linear consumption habits

Existing cognitive rules and linear consumption habits limit the transition to a Circular Economy. Ultimately, the circular experiments must add value to local communities, leveraging long-term membership and use. Overriding, existing, and dominant habits combined with cognitive rules around consumption creates difficulties for scaling a new model of production and consumption (e.g., Loughborough Farm, Pop Brixton, Repowering, and Remakery). Single experiments cannot bring about these changes, but they can enable individuals to experience the benefits of adopting circular practices and to find ways to integrate circular practices into their lifestyles.

Discussion and conclusions

In this chapter, we have theorised on the circular urban transition process and tested it using the Brixton case study. We have identified the catalysts and barriers to scaling up circular experiments and provided evidence to support both. Overall, the case supports our theorisation of circular urban transitions. The Brixton case study demonstrates that the catalysts and barriers to scaling up circular experiments are much the same as for any community-led sustainable transition experiments. The community-led, circular transition process we described has produced niche regimes and resulted in the emergence of circular practices in Brixton and across London. This has largely been assisted by a process we have called circular tactical urbanism. We realise that Brixton is one case study; more case studies will be needed to verify the catalysts for scaling up circular experiments we identified here.

Changes in the landscape are currently supportive of some circular experiments scaling up in London (Figure 27.2). Food and fuel poverty, induced by energy and food price rises, are likely to threaten the existing linear systems of food and energy provision. This produces failures in both regimes. In London, food poverty has become more prevalent, reinforced by rising food prices.

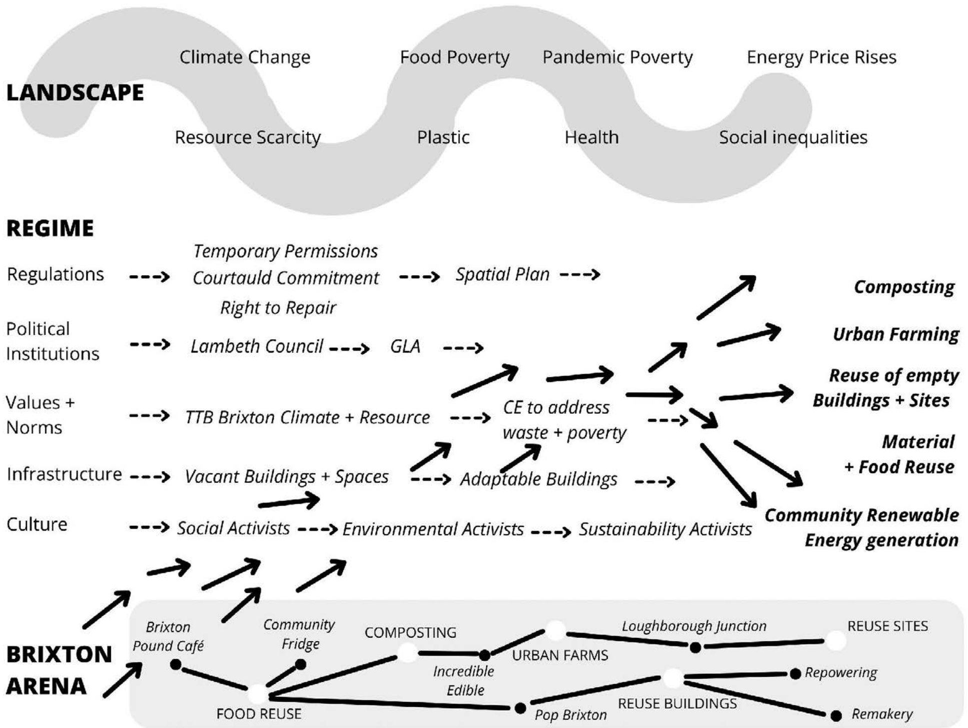

Figure 27.2 Circular transition process in Brixton.

Source: The authors, based on Geels & Schot, 2007.

Thus, food reuse and local food production are becoming increasingly popular amongst both policy-makers and the public. Strategies, plans, and networks have emerged within the regime that will enable the scaling up of these projects. Failures in the energy system have led to rising fossil fuel prices, which, in turn, increases the feasibility of scaling up via local renewable experiments such as composting and solar power. Recently, the COVID-19 pandemic has altered consumer and working habits (Howe et al., 2021), which has led to an increase in vacant properties such as retail and office spaces in London, thus providing a potential opportunity for accelerating circular tactical urbanism. These failures in the current regime, produce potential for scaling up circular experiments.

Within the current regime, the regulatory framework is shifting towards supporting circular tactical urbanism and urban farming (London Plan), food reuse (London Food Waste Strategy, Courtauld Commitment), and repair activities (Right to Repair regulations). New institutions and networks have emerged to support the expansion of food reuse, food growing, repair, and energy recovery activities in London. Some of the actors involved in Brixton are engaged in projects elsewhere in London, for example: Repower, Community Energy London, Capital Growth, Incredible Edible, Makeshift, Open Workshop Network, and the Repair Café Network. Thus, Brixton does appear to have followed a transition pathway, but has moved from the creation of a transition arena set up by the community, to a set of transition experiments that have linked up with other experiments through both London-wide and national networks. The emergence of these experiments during a period when the existing regime is performing poorly due to changes in the landscape and thus is altering itself to support new systems of provision, appears to be fortuitous and may offer future opportunities for scaling up. An ongoing longitudinal study in Brixton and London could help to determine this.

The catalysts that have led to experiments scaling up in Brixton are similar to those already identified by the literature. However, previously unremarked in the literature, is the importance of local symbiotic relationships in the process of closing loops and scaling up. For example, food growing, reuse, and composting activities could be clustered together, to enable a degree of symbiosis that would in turn accelerate scaling up. This finding may be particularly pertinent to scaling up circular experiments. The evidence is limited in this case but it deserves further attention. The availability of space for low-value circular activities also appears to offer a critical catalyst for scaling up, less reported in the literature. Given the need to create these local symbiotic linkages, the appropriate allocation of spaces, will require a degree of strategic thinking by urban planners. The role of local activism and the creation of positive narratives in the scaling-up process also deserves more attention in future research.

Educational content

1. Brixton does appear to have followed a transition pathway but has moved from the creation of a transition arena set up by the community to a set of transition experiments that have linked up with other experiments through both London-wide and national networks.
2. We identified a previously unremarked catalyst for scaling up: local, symbiotic relationships.
3. We find that availability of space for low-value circular activities is a key catalyst. And appropriate allocation of such spaces, will require a degree of strategic thinking by urban planners.

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We thank all the interviewees across Brixton for their time, support, and trust.

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28

'REGIME-NICHE' ACTORS AS CATALYSTS IN THE TRANSITION TO A CIRCULAR ECONOMY

Rachel Greer

Introduction

Circular economy and sustainability transitions

For decades, there has been a growing understanding of the unsustainability of a linear economy– that is, a 'take-make-waste' approach to economic growth on a finite planet – and for the need to bring our demand for and use of resources back within ecological boundaries (Brundtland et al., 1987; Meadows et al., 1972; Steffen et al., 2015). One increasingly popular concept to address these systemic waste inefficiencies is by envisioning a circular economy (CE). CE is defined by its aim to gradually decouple economic activity from the extraction and consumption of finite resources and to design waste out of the systems, and it has become central in academia, policy, and industry (Kirchherr et al., 2017; Korhonen et al., 2018).

To change from the current linear economic paradigm to a CE, a transition must occur. 'Transition' refers to a shift in the dominant cultures, structures, and practices of a society (Geels, 2011; Smith & Raven, 2012). These dominant cultures, structures, and practices are what we refer to in transition literature as the 'regime' (Avelino & Wittmayer, 2016; Kemp et al., 1998). 'Catalysts' are forces that often play an important role in the acceleration of a transition. When studying transitions, we refer primarily to desired sustainability transitions (Avelino, 2011; Köhler et al., 2019). Sustainability transitions are connected to a shift from an unsustainable dominant regime to an alternative desired regime, so there is much to be gained from understanding how actors within a regime context engage with emerging alternatives and what role they (could) play in scaling and institutionalising alternatives. 'Regime actors' are used in this chapter to refer to people and organisations that operate at a regime level. For example, governmental bodies and ministries would be considered regime-level organisations, because they embody – as well as determine in large part – much of what the dominant structures and practices in a society are.

Actors operating at a regime level that have alternative, innovative, so-called niche thoughts and actions have been referred to in the literature as the 'regime-niche (R-N)' (Greer et al., 2020). This unique type of actor relates to other similar terminology, such as the proactive incumbent, among others (Hengelaar, 2017; Strøm-Andersen, 2019). This chapter provides an outlook on the topical issue of actors as catalysts in the CE transition, and more specifically, innovative actors in

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the R-N context. It explores R-N actors that start incorporating new knowledge, assimilating, and adapting to transformative pressures they begin to face.

Transition theory and catalysts

Through this chapter, I aim to contribute to transition theory by addressing complexities within the regime dynamic that have gone understudied in transition literature. Thorough immersion in relevant literature and practice went into understanding the niche concept within transitions research (e.g., Kemp et al., 1998; Schot & Geels, 2008; Stiles, 2020) and the role of agency in driving their development and diffusion (e.g., Fischer & Newig, 2016; Grin et al., 2011). In the literature, much emphasis is placed upon front-running counter-regime actors that pursue radical, transformative changes. Yet, there is less attention given to the spectrum of types of actors and their related patterns of thinking within transition dynamics, including innovative thoughts and behaviour of actors embedded within an incumbent regime (organisation).

Relatedly, this chapter aims to deepen the concept of the R-N and describe some of these actors' functions within a transition context. Through the R-N's favourable positioning in an organisation with a traditionally high ability to create change – paired with the actor within the organisation's innovative inclinations – the R-N shows promising signs of potential for change-making and catalysing the transition to CE; yet it remains understudied to date. While the concept of the R-N has been coined and addressed in the literature, there is still a lack of depth in the understanding of its characteristics as a catalyst for CE and its role and functioning with other catalysts within a system.

Furthermore, this chapter sets out to fill an existing gap by expanding and developing further the concept of 'catalysts', which is defined in transition research as mechanisms of change in sustainability transitions (Contesse et al., 2021; Geels & Schot, 2007; Köhler et al., 2019). Catalysts are primarily spoken about in the literature referring to events or economic drivers (Fouquet, 2010; Kent et al., 2017); actors as catalysts are often overlooked. Yet, it is worth dwelling on why it makes sense to also see actors as catalysts, rather than, for example, only examining external events. 'Agency' is an important concept in this chapter, and it will henceforth be defined according to Ahearn (2001): "the socioculturally mediated capacity to act" (p. 112). Scholars are increasingly taking an agency perspective, claiming the role of human agency in catalysing change (Budowle et al., 2021; Koistinen et al., 2018; Slater, 2021). It would be reasonable then to take a similar scholarly approach when considering catalysts in transitions, particularly in the transition to CE as discussed in this chapter.

Finally, I take a closer look on how the transition to a CE can be catalysed through R-N actors. This is because a discussion about the potential for innovative actors operating in regime-level organisations to accelerate a transition, related to their role as catalysts, remains under-addressed. Based on the preceding literature and the gaps within, I frame this chapter with the following argument: to transition to a CE, we can look to the catalysts from within the regime. The catalysts discussed in this chapter are actors that make up the R-N, part of a nuanced understanding of the varying dynamics within the regime level. The R-N actors can take on various functions in their roles, which catalyse the transition to CE through several functions.

Empirical setting

There is a national agenda in the Netherlands to become fully circular by the year 2050, which is the reason this country was selected as the geographical scope from which to link empirical examples of catalysts in the CE transition. To reach this goal, the policy agenda focuses on transforming different pilot sectors. One of these sectors includes transitioning to a circular form of catering. The Ministry's vision of circular catering has been defined to encompass procurement, production, business operations, assortment choice, and the use of residual flows (Heijink, 2019). Another pilot sector includes a nationwide transition to circular furniture within the Ministry. This pilot sector transition refers to extending the life of current furniture by reducing the times in which new furniture is bought to replace the old, repairing and refurbishing current furniture, and allowing for more working from home to reduce the need for new office furniture (Appleton & Oberhuber, 2016). Studying these pilot sector transitions empirically offered insight into the role and complexity of regime actors, which is expounded upon in this chapter.

Research aims

There are three main purposes of this chapter:

1 To make a conceptual contribution to transition theory: by deepening our understanding of the R-N and by discussing the role of R-N actors in transitions;
2 To widen our perspective on catalysts in transitions: by establishing actors as catalysts and by proposing three catalysing functions of actors as studied in a Dutch case of the transition to CE; and
3 To create a contribution with potential application for practice: by examining factors related to R-N actors' catalytic impact potential, based on concrete examples from the Dutch context.

Accordingly, this chapter is structured around the following research question: *How are regime-niche actors catalyzing the transition to a circular economy?*

Theoretical framework

Transition research lens

The field of transition research emerged to "investigate the dynamics of complex societal problems and to guide the development of system solutions to address them" (Loorbach et al., 2017, p. 603). Because transition research investigates how it could be possible to make a structural qualitative shift from persistent unsustainability toward a more sustainable state, this is the research lens and entry point in this chapter to study how R-N actors act as catalysts in the transition to CE. Research on transitions in sustainability refers to the fundamental societal shifts in cultures, structures, and practices that take place in a complex, non-linear fashion over decades or generations related to sustainability (Grin et al., 2010; Markard et al., 2012; Rotmans & Loorbach, 2010). See Figure 28.1 for an illustration of transition dynamics taken from foundational transition literature, including a visual representation of the niche and regime levels (Geels, 2012). In this chapter, I examine the interactions between, and dynamics of, two of the core concepts from transitions theory – the regime and niche, as described in Geels (2002) and Grin et al. (2010). For the sake of clarity, when referring to regime actors, I refer to incumbents of the current societal system. When speaking about niche actors, I refer to people or organisations deviating in thought or practice from the mainstream manner.

When niche actors come together, building critical mass with similar values, they start to form a niche-regime (N-R): a dynamic wherein the whole is more than the sum of the parts, in terms of

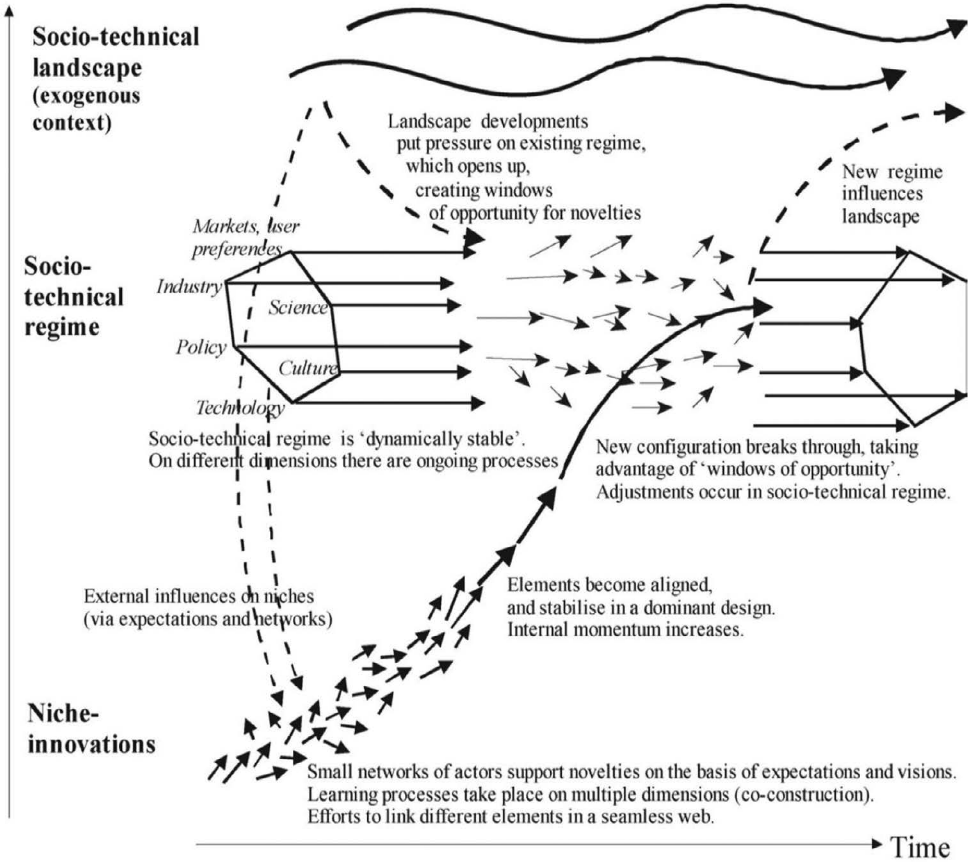

Figure 28.1 Transition dynamics (multi-level perspective).
Source: From Geels (2012).

political leverage, educational outreach, event-making as an exchange mechanism, and collective visioning and voicing (de Haan & Rotmans, 2011; Greer et al., 2020). A collection of niche actors and businesses with like-minded thoughts, values, and objectives that start to form their own N-R (de Haan & Rogers, 2019) are more recognisable to regime actors, in that these niche-level actors and startups are no longer isolated initiatives, but rather a part of a collective with a common goal. One example of an N-R related to this chapter includes the growing strength and numbers of circular catering initiatives and innovators in the Netherlands.

Reciprocally, there are alternative-thinking actors that operate within a regime context, i.e., the R-N. Building upon existing concepts such as niches and regimes and their dialectics over the course of a transition, increasing pressures for transition cause niches to start to develop within the regime or regime-level organisations. Under external pressures, proactive regime actors seek to engage with emerging alternatives from the niche to transform themselves and thereby contribute to accelerating and diffusing transformative innovations. One example of an R-N related to this chapter includes the innovation committee of a multi-national catering company working to transform the organisation's business model from the inside out. At the same time that niches begin to form within incumbent organisations (including governmental bodies), they often start to connect to emerging practices from the niche level, which may be facilitated by the visibility of the N-R.

Actors as catalysts in transitions

Based on these concepts and understandings, I posit that actors in the R-N are a prime example of a catalyst in sustainability transitions. This line of argumentation is similar to that of Erlinghagen and Markard (2012), who argue that actors can also be catalysts for transformation, that actors differ in their potential to bring about sectoral change, and that under certain conditions some actors may play a very crucial and transformative role. Thus, I refer here specifically to actors as catalysts and choose to focus on the actor aspect in this chapter. This builds on initial work focusing on the different types of actors in transition studies and their plural roles (e.g., Avelino & Wittmayer, 2016; Brown et al., 2013; Farla et al., 2012). Based on these works, the concept of actors will henceforth include individuals, divisions of organisations, or whole organisations as actors – organised around their ways of doing, thinking, and organising, defined by their cultures, structures, and practices.

Increasing tensions and emerging competition create the context for systemic transformation; these phenomena may be indicators for an emerging pattern of structural societal change. This is supported by the work of Ely et al. (2013), who addressed hybrid pathways in global and local innovation politics, and by Bosman et al. (2014), whose work analysed regime destabilisation and discursive regime dynamics in the Dutch energy transition. 'Regime destabilisation' is a multi-dimensional process whereby the existing regime begins to weaken, as a result of an increase of external pressures and a weakening of actor commitment to the incumbent regime. Studies describe regime destabilisation rooted in external forces, but there is little work describing how or why regime destabilisation may be sparked from within (Turnheim & Geels, 2012). "A concluding lesson therefore is that destabilisation is a relevant focus for advocates of sustainability transitions. Weakening the cultural, political, economic and technological dimensions of fossil-fuel related industries is just as important as stimulating green options. The bi-directional causality that we identified, suggests that both processes are two sides of the same coin" (Turnheim & Geels, 2012, p. 49). Although there has been increasing literature surrounding regime destabilisation in recent years, it remains a valuable subject of study in transition theory, receiving less analytical attention than emerging niches.

Methodological framework

To address the main research question of how R-N actors (can) catalyse the transition to a CE, I took a qualitative research approach to develop this conceptual chapter, with a transition science perspective as the theoretical framing. Principally, I conducted a literature review on CE, transitions, catalysts, and R-N actors while also including similar subjects such as innovative incumbents. This formed the foundation of my conceptual understanding and the theoretical basis for this chapter.

To ground this theoretical knowledge in empirics, the second core source of data included empirical evidence gathered during a descriptive case study of the phenomenon of a circular service being upscaled from a niche to a national level in the Netherlands. During the interviews conducted in 2018–2019 for the study, I investigated the conditions surrounding how and why the niche service of circular catering scaled to a national level – particularly as related to interactions between niche and regime actors. This empirical work included participant observation, co-working, and conducting interviews with actors and organisations from various sectors and pillars of society. The primary source of empirical data for this study drew on the results of 12 semi-structured face-to-face interviews from the descriptive case study research, which had a duration of 1–2 hours and were conducted on site at the interviewee's workplace. The interviewees included primarily Ministry civil servants, entrepreneurs, and innovation managers of a multi-national catering company. The case study described circular catering in particular, so the interviews relating to circular furniture and circular procurement more generally were not directly relevant to the previous study as originally intended. However, data from these interviews contributes directly to the results of this chapter as concrete examples, so novel, unpublished data from these interviews were applied in this chapter.

In the present study, I combined the described theoretical and empirical support into the conceptual research outlined in this chapter. First, I considered which interviewed stakeholders might be considered R-N actors. I delineated these actors to be the circular furniture section head, circular catering section head, and circular procurement officer for the Dutch Ministry of Infrastructure and Water Management (Rijkswaterstaat – RWS), as well as the innovation managers from Sodexo (international catering company). All these stakeholders were actors working on ways of thinking and doing that are alternative to the mainstream, incumbent ways of operating (i.e., niche) – yet, within a large, incumbent organisation with infrastructural or economic power (i.e., regime) – therefore, a part of the R-N. Then, I examined what their role was in catalysing some part of the transition to a CE. One example of this included connecting with and empowering a niche innovation, service, or actor, with the end goal to upscale this to the regime level. Another example included creating deviations within their regime operating context, among other roles and actions. These actions fit within three categorical functions, which I proposed, described, and exemplified. After defining these propositions in the following section, I discuss the main contributions of the chapter in relation to transition theory, to the concept of catalysts in transitions, and factors related to the catalytic impact potential in the empirical example described, which insight that may also be relevant to practice. Finally, I conclude by synthesising the discussion and reflecting on overall implications of the chapter's main contributions.

Propositions and exemplifications of R-N functions

In this section, three catalysing functions of the R-N are proposed, each of which are supported by two empirical examples from the context of the transition to a CE in the Netherlands. Table 28.1 summarises the proposed functions, which are defined, exemplified, and described in deeper detail in the text that follows.

(1) Enable connections between the niche and regime levels by connecting with N-R actors

One important way the R-N can catalyse the transition to a CE is by enabling otherwise unrealised connections between niche and regime parties, by connecting with their complementary counterpart, N-R actors. To make this proposition more tangible, I describe this in the context of two concrete examples from practice:

Empirical example 1: Sodexo innovation manager seeking out clusters of entrepreneurs.

Sodexo Benelux is a regime-level multi-national catering company. The thought patterns and actions typical in a regime-level organisation are present, but an innovation team also exists within.

Table 28.1 Catalysing functions of the regime-niche: Definitions and exemplifications

Catalysing function	*Actor position*	*Actor actions / characteristics*	*Function description*
1. Enable connections between the niche and regime levels by connecting with N-R actors.	Example 1: Sodexo innovation manager	Acted as a bridging mechanism between the two normally discrete dynamics of the niche and regime, connecting to actors in the N-R.	One important way the R-N can catalyse the transition to a CE is by enabling otherwise unrealised connections between niche and regime parties, by connecting with their complementary counterpart, N-R actors.
	Example 2: 'Circular catering' category group within RWS	Put out an attractive tender that catalysed connections with and scaling up of actors in the circular catering N-R that had been developing these alternative, circular business models.	
2. Engage the regime while empowering/growing the niche.	Example 1: Circular catering category manager at RWS	Empowered existing circular catering companies and financially incentivised previously linear catering companies to shift to circular practices – catalysing the growth of this circular N-R in size and critical mass.	The R-N is often in a favourable power or financial position to create settings for empowered niches to grow, while also having an inherent connection within the regime with access to engage these actors.
	Example 2: 'Circular furniture' category group at RWS	Offered circular job training encouraging learning how to rather reupholster cushions and fabrics and to repair the more skeletal structures of the furniture to hedge against job loss of previously linear workers, and involved many stakeholders who may never have considered or been involved in the transition to CE in any way previously.	
3. Accelerate diffusion of a circular niche through top-down influential mechanisms.	Example 1: Circular thinkers at the Rijksoverheid	Applied top-down power to catalyse the accelerated diffusion of circular concepts and movements to other Ministries in the Netherlands.	There is influence and power different forces can exert over connected elements to (at least in part) mandate the diffusion of circular practices and products within their respective spheres of influence.
	Example 2: Circular catering category group at RWS	Pushed companies to rise to a higher standard and pressure their second-order suppliers to do the same, to work progressively towards full circularity through the value chain.	

An interview with their innovation manager indicated that within this regime-level organisation, there is a group of thought leaders with interest and appetite for niche ways of thinking and doing: looking for circular, more sustainable alternatives to the current business model of the company i.e., an R-N.

The lead innovation manager informed that he regularly seeks out clusters of circular entrepreneurs to take up at a larger level and support in scaling up. These clusters of circular entrepreneurs, which are generally more accessible and visible than single niche actors, could be considered an N-R. In this case, the R-N actor within Sodexo acts as a bridging mechanism between the two normally discrete dynamics of the niche and regime by reaching out and connecting to actors in an N-R. Forming these connections allowed for upscaling of circular catering innovations from a niche to a regime level, catalysing their acceleration within this transition.

Empirical example 2: RWS catering tender and connecting with N-R actors.

Within the context of the 'Netherlands Circular in 2050' ambition, the RWS put forth a circular catering tender. Catering companies competed to win this tender, the evaluation criteria based upon circular metrics and benchmarks. The winner of this tender would receive a fixed contract for the catering services of business meetings and cafés inside 16 Ministry buildings in various cities, as was described in the interview conducted with the sector head of catering at RWS.

While a national governing body operates principally at the regime level, the civil servants comprising the 'Circular catering' category group within the organisation constitute an R-N: embracing alternative structures and practices for providing food and beverages to the rest of the organisation. Similar yet reciprocal to Sodexo's R-N strategy for connecting with N-R actors, putting out this tender offered the possibility for connecting and upscaling to actors in the N-R of circular catering who had been developing these alternative, circular business models. Because circular catering companies were applying for the competition to win the tender, the R-N of the RWS applied the power of the regime organisation from its prominence and notability in society to connect with niche organisations with circular catering business models and catalyse a mutually beneficial circular symbiosis.

(2) Engage the regime while empowering/growing the niche

The R-N is often in either a favourable power or financial position to create settings for empowered niches to grow, while also having an inherent connection within the regime with access to engage these actors. This proposition is exemplified with the following empirical examples:

Empirical example 1: RWS catering upscaling

The same circular catering tender from the RWS caused a visible shift in attention for and increased work towards circular catering in the Netherlands. The interview with the Circular Catering Category Manager at the RWS indicated that a significant number of catering companies that were previously fully or primarily linear changed their business models in major ways, so that they could conform to the circularity eligibility criteria to compete for the lucrative tender. This means, the transition was catalysed by this R-N by empowering existing circular catering companies through a substantial opportunity for growth – and furthermore, simply the creation of the tender catalysed the growth of this circular N-R in size and critical mass.

Empirical example 2: RWS furniture catalysing shifts to circular skills

The interview with a manager of Circular Procurement at the RWS offered insight about the Ministry's strategy to transition to a circular furniture model within the organisation. This Circular Furniture group could be considered another R-N within this regime-level national ministry. By transitioning to circular furniture, the RWS aimed to drastically reduce the amount of (new) furniture procured around all the national offices, and to rather repair or refurbish existing furniture to keep it in use and in circulation.

From the interview, it was learned that the group was aware that transitioning to circular furniture could have a negative impact on actors whose job and training until now was specifically to build furniture. For this reason, training was offered and encouraged for learning how to reupholster cushions and fabrics and to repair the more skeletal structures of the furniture. Again, because of the sheer size and volume of furniture across the country at the RWS offices, this involved a significant group of workers who could be retrained to have the skills for a more circular profession. In this way, this R-N empowered and grew this circular furniture niche by involving many stakeholders who may never have considered or been involved in the transition to CE in any way previously and may have otherwise continued indefinitely with the linear form of this trade.

(3) Accelerate diffusion of a circular niche through top-down influential mechanisms

There is influence and power that different forces can exert over connected elements to mandate, at least in part, the diffusion of circular practices and products within their respective spheres of influence. The following two examples serve to make this proposition more transparent:

Empirical example 1: Rijksoverheid circular furniture assignment.

The circular furniture assignment to RWS came from the Rijksoverheid, the highest governing body of the Netherlands. It was because of this R-N within the Rijksoverheid, an even higher governmental organisation than RWS, that an R-N within RWS came to be formed. An interview with the Circular Furniture Category Manager at RWS indicated that, before this assignment from the higher Ministry, even she had not heard of the concept of circular furniture. Yet, the R-N in the Rijksoverheid created a new R-N in RWS through their assignment to transition to circular furniture. This is an example of how top-down power held by the R-N, when applied appropriately, can catalyse the accelerated diffusion of circular concepts and movements.

Empirical example 2: Circular commitment by an R-N in the RWS catalyses a ripple effect throughout the value chain.

Connections via the value chain allow key players to nudge or influence certain other actors in the chain. Any company applying to win the RWS's tender must meet the minimum circularity guidelines for eligibility, forcing companies to rise to a higher circular standard and pressure their second-order suppliers to do the same. In the case of a multi-national catering company, incentives around sustainability were integrated into contracts to make the progression towards circularity more economically viable. Their position as an internationally operating organisation allowed for more room for negotiating power in contracts, and afforded them more reach to startups, both facilitating – and thereby catalysing – the diffusion of circular catering practices.

Discussion

The three key purposes of this chapter were:

1 to add to existing transition theory by deepening the concept of R-N actors and discussing their role in transitions.
2 to establish actors as catalysts by observing three of their catalysing functions, as studied in a Dutch case of the transition to CE, and
3 to offer potentially useful insights for practice by proposing factors related to R-N actors' catalytic impact potential (based on the empirical examples of the three functions proposed). Building on the theoretical framework and novel R-N actor functions described, this discussion section offers contributions to the gaps and puzzles identified in the introduction.

(1) R-N concept deepening and role in transitions

Because of the complexity and levels of depth to both niche and regime elements, it is important to view the regime incumbent not simply as a stock character of their function, but rather as a dynamic actor with flexible roles, influences, and opinions that change and adapt over time. This position develops concepts from transition theory by addressing complexities within the regime dynamic that have gone understudied. By taking a closer, nuanced look at intra-regime dynamics, we can observe potential for transformation and destabilisation of the regime from within.

The transition to a CE would mean completely changed economic and legal institutions within which production and consumption take place. If this successfully occurs on a societal scale, it is likely that regime destabilisation, a weakening of the previously dominant regime, has also occurred. This destabilisation could be the result of external opposing forces growing stronger against the regime, or of internal structures beginning to weaken within the current regime. With this in mind, the transition to CE is not possible without regime parties, actors, and organisations changing to a more default state of circularity or moving out entirely. In this way, 'catalysing' the transition might also be understood as supporting the reconfiguration of the regime. This idea expands the catalyst concept by bridging it with and integrating it in foundational transition theory to offer a new understanding of what catalysing could mean more explicitly in this field of literature.

The R-N's unique positioning may allow it access to various types of power and agency to catalyse destabilisation of the current linear economy regime from the inside out. At the same time, R-N actors can help accelerate the emergence of circular business models and practices by acting as the regime's liaison to the niche (expounded upon in the following subsection). It can thus be seen that R-N actors can play a unique and important role as catalysts in the acceleration of the transition to a CE supporting one of the key ideas of this chapter about actors as catalysts in the transition to a CE in relation to the present handbook. Through this perspective, we can better study and gain insight on how radical change towards a CE has been catalysed and speculate on how this can be further supported.

(2) Actors as catalysts in the transition to CE, in relation to their catalysing functions

(2.1) Enable connections between the niche and regime levels by connecting with N-R actors

One important way the R-N can catalyse the transition to a CE is by enabling otherwise unrealised connections between niche and regime parties, by connecting with their complementary counterpart: N-R actors. Through the same potential of the R-N to contribute to the destabilisation of the current

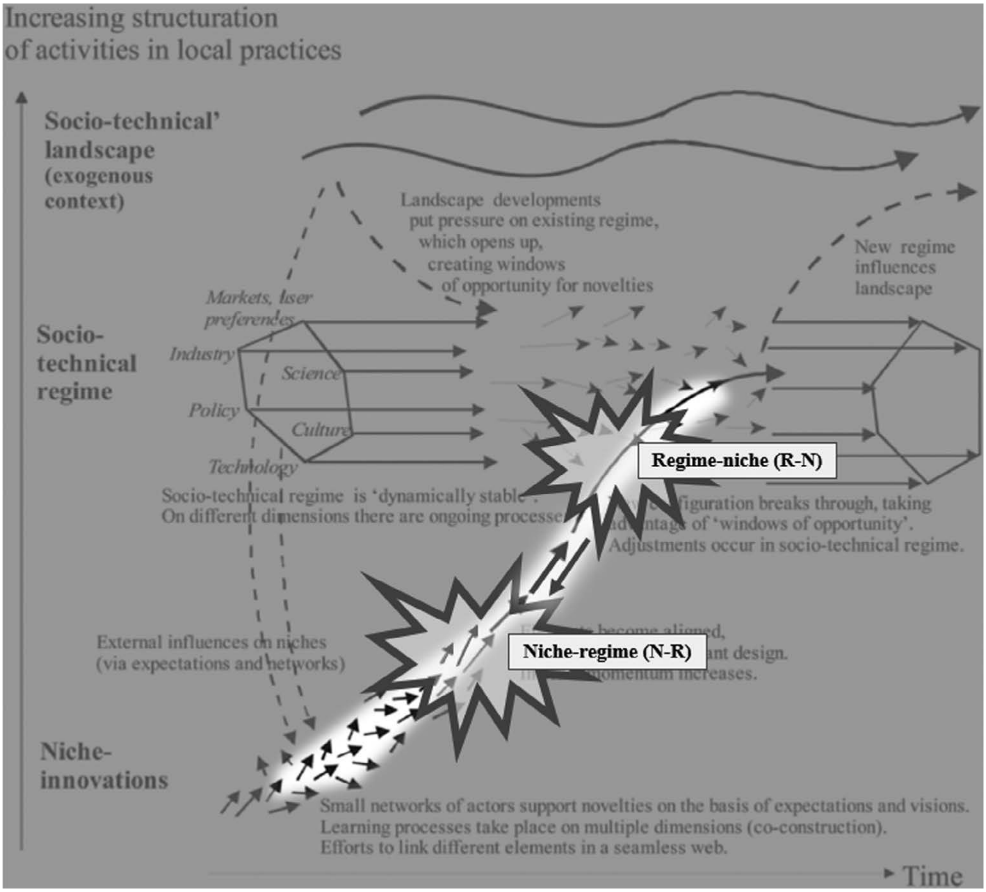

Figure 28.2 The niche-regime and regime-niche: Transition dynamics and bilateral connections.

regime from within, R-N actors can help lead to institutionalisation of new business models and sustainable innovations, techniques, and models by supporting an empowered niche to scale up to a regime level. This conceptualisation may offer insights into existing transition literature on the topics of destabilisation, institutionalisation, niche diffusion and upscaling, and actor agency.

These observations about the N-R and R-N connections may also help further develop the existing transition concept of the 'proto-regime', a sliding abstract concept, which describes when a radical alternative to the incumbent practice begins to emerge and flickers of regime destabilisation can begin to be seen (Geels & Raven, 2006). The N-R is a key part of the proto-regime, so it could be proposed that the R-N is the key counterpart with each of the two dynamics making up one half of the whole the proto-regime. Both dynamics may be operating and existing in parallel, but may find less success in scaling up circular innovations impacting the transition without the R-N catalysing a connection with the N-R. Thus, it could be reasonably asserted that connecting value-aligned R-Ns and N-Rs could be a promising methodological approach (connecting an empowered niche with an engaged regime) to support the co-creation of new knowledge and practices and to increase the future potential of the progression towards a CE. See Figure 28.2 for a visualisation of the R-N and N-R transition dynamics and connection, transposed onto Figure 28.1.

(2.2) Engage the regime while empowering/growing the niche

Circular elements often need to be incubated to develop and grow, but paradoxically they need to be out of incubation to grow to a systemic level of impact (Greer, 2022). Based on the literature on regime destabilisation and the empirical examples described here, it could be reasonably inferred that R-N actors may have a uniquely suitable position to catalyse these movements. Because of the R-N actors' alternative styles of thought that align with the cultures, structures, and practices of niches, they are particularly predisposed to connecting with and supporting niche elements. Reciprocally, these actors are also operating in a regime context and/or regime-level organisation, which offers them the visibility, power, and influence that is characteristic of regime organisations. For these reasons, the R-N is often positioned with the ability to create settings for empowered niches to grow, while also having an inherent connection within the regime, with the ability to engage these actors. This could be a key insight for the research topic of how sustainability transitions can be accelerated, and it would further support the idea of actors as important catalysts in transitions.

(2.3) Accelerate diffusion of a circular niche through top-down influential mechanisms

The practices observed of R-N actors catalysing the diffusion of a circular service and business models illustrate the influence and power different forces can exert over connected elements to mandate the diffusion of circular practices and products within their respective spheres of influence. This can occur in a top-down exertion of influence, like a governmental body mandating that other organisations or ministries adopt a specified circular service.

Alternatively, regime-level organisations also generally have economic power to set circular standards through value chain requirements for partners, producers, and manufacturers to be able to engage in business with them. Fully circular products and services mean that all parties involved in the product's production or service's execution must also be circular. This means, if the R-N can influence their respective organisation from the inside out to set these standards, it continues in a ripple effect throughout the value chain and can have direct and indirect impact on further catalysts. This may be a useful insight for practice and further supports the idea of actors as catalysts in the transition to CE.

(3) Factors related to R-N actors' catalytic impact potential

While there are certainly many factors that may relate to R-N actors' catalytic impact potential, three in particular became evident in the case studied here: the role of narratives, a top-down approach, and economic leverage/power. These observed influencing factors may be relevant to a practical application, for example in supporting the strength or impact potential of a circular R-N. This should not be considered an exhaustive list, but rather several factors observed in this case: acting as a starting point for future research and contributing to extant research on drivers and barriers of sustainability transitions.

Narratives: The role of narratives was important in both the RWS catering and furniture empirical examples becoming successes. The adoption of circular practices was pitched to them from the top down as an embodiment of values and a transformation towards societal sustainability from the inside out, rather than an arbitrary threshold to meet. This resulted in all interviews with RWS ministers explaining the transition in a way that made apparent their backing of the move with personal and structural support.

Top-down approaches: The top-down pressure from the Rijksoverheid had a strong impact – particularly visible in the effects of the RWS tender posed. This circular catering tender could be seen as a critical turning point: it was the first instance in the Netherlands of this niche of circular catering being taken up on such a large scale, overturning the current incumbent linear catering model in many branches of a prominent and widespread regime-level governmental body. One takeaway from these empirical examples is the value of top-down forces the transition to CE will be many times more difficult and time-intensive without parties from regime institutions incentivising or assigning implementation of circular practices, supporting the contribution of the chapter arguing for actors as catalysts.

Economic power: The RWS tender caused a shift and increased work towards circular catering many companies shifted their linear catering model to a circular one in an effort to compete for such a large tender. It is then not only governmental bodies that have this power as seen in this case, but any large organisation whose business is worth so much that other companies and organisations aim to comply. It is worth noting that these organisations can also have the opposite, hindering effect; large companies that prioritise linearity can be an impediment to the transition to CE because of their inertia for and path dependencies on linear practices. From these empirical examples and literature on regime destabilisation, it can be reasonably ascertained that the formation of an R-N within these regime organisations could catalyse a shift away from these practices and towards a circular transition by destabilising the regime from within.

Conclusions

By taking a transition research lens in this chapter, I set out to offer an alternative perspective for viewing the regime and the R-N in a nuanced way, to expand our conceptualisation of – and, therefore, create new space for – actors as catalysts, and to elucidate functions of critical actors in transitions in practice. More generally, through this chapter, I aimed to offer both a conceptual contribution to transition theory and insights applicable to CE in practice, through a novel understanding of actors as catalysts and their functions in accelerating the transition to a CE.

This chapter has addressed complexities within the regime dynamic. By positioning the concept of catalysis within existing principles of transition theory, it was newly discussed that ‘catalysing’ a transition might also be understood as supporting the reconfiguration of the regime. In exploring the R-N’s role in sustainability transitions, three functions of R-N actors as catalysts for transition were observed: to enable connections between the niche and regime levels by connecting with N-R actors, to engage the regime while growing the niche, and to accelerate the diffusion of a circular niche through top-down influential mechanisms. Narratives, top-down approaches, and economic (among other) power may be factors that relate to R-N actors’ catalytic impact potential. Studying factors relating to catalytic impact potential may also be a relevant topic for further catalysts research, particularly when taking the widened perspective of actors as catalysts.

Building on this work, certain questions remain unanswered. A driver/barrier analysis related to the emergence of an R-N could offer valuable insight into how an R-N might be created, supported, or the type of setting in which it emerges independently. Additionally, this study contained certain limitations; for example, the empirical examples studied here were limited to the Dutch context. This was a descriptive study of only one case of a circular transition; there must be further research replicating the present analysis in various other sectors, countries, and contexts to test for translatability before these R-N functions could begin to be considered generalisable.

Still, this chapter offers new insights that may be relevant for practice, transition theory, CE literature, and the catalyst discussions in this CE handbook. As contribution to the handbook on

CE catalysts, this chapter has clarified the conceptualisation of actors as catalysts, expanding our perspective on what constitutes a catalyst in transition. It has explored and deepened the concept of the R-N, adding to the continued development of transition theory by further nuancing the regime concept, and by positioning the R-N against existing concepts like the N-R and the proto-regime. Further, this chapter has substantiated conceptual discussions about the R-N and actors as catalysts through concrete empirical support. For example, it has illustrated the added value of interactions between niche and regime actors, which is related to both the professionalisation of transformative alternatives as well as their possible institutionalisation. Such connections could provide clues for transitions in general on how to overcome the divide between the niche and regime, particularly with respect to the future outlook on catalysts in the CE transition. Thus, it can be reasoned that the chapter satisfies its key intended contributions, and that the R-N is a potentially useful vehicle for catalysing the transition to a CE that merits further examination and support.

Educational content

1 Building on the idea of actors as catalysts in the transition to a CE established in this chapter, what other (types of) actors can be identified as catalysts in transitions? How have they impacted other transitions in practice, and how could they impact future transitions? How might their functions differ from the three proposed functions in this chapter in another transition or geographical context?
2 How do cultural differences impact the type of actors that can be catalysts? In the Dutch context, it is common to have a more horizontal governance structure within organisations and in society. Can a regime-niche exist in a more oppressive or authoritarian environment? In sharply different socio-political contexts, which actors can act as catalysts in transitions? Would the amount be reduced to only a select few actors in top power?
3 What other factors relate to an R-N's catalytic impact potential?

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CATALYSTS IN A SUSTAINABLE CIRCULAR ECONOMY

Directions for future research

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Circular economy as an established area of research

At the time of writing this book, the interest in the circular economy (CE) and initiatives based on its principles are rapidly increasing around the world. This is also illustrated by the geographic distribution of this book's close to 100 contributors from five continents and 16 countries. For example, after formally adopting the concept of CE in 2002, China has been establishing policies for 20 years towards a CE, including in its most recent five-year plan. The drivers for the Chinese CE, pressing domestic environmental challenges and strong resource import dependence, are likely to remain significant as China strives to move towards its vision of an 'ecological civilisation' (Bleischwitz et al., 2022). Similarly, in Europe, the CE approach is only picking up speed as is demonstrated by the new CE action plan and numerous other documents, which have been adopted recently by the EU (Mazur-Wierzbicka, 2021). North America has also recently taken its first circular steps in certain domains (Ryen & Babbitt, 2022), and states like California in the United States and the province of British Columbia in Canada have been working on zero waste initiatives, accompanied by initiatives by individual companies and organisations. CE has also sparked some interest in both Africa and South America, but its adaptation is clearly at more nascent stages, and it remains to be seen if the allure of CE leads to similar momentum in the Global South less economically developed areas of the world. The chapters in this book that provide insights from India and countries in Africa indicate that the CE framework will have a great potential in addressing the social and cultural issues in connection to technological and economic aspects of CE.

The CE transition is in an early, evolving phase of change. CE has become an established area of research and it is gaining interest and momentum in organisation studies, environmental policy, and social sciences at large. Recent academic work has brought up CE as a major presence in transition processes (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Morseletto, 2020; Reikea et al., 2018). The key literature shows that as a multi-disciplinary and multi-level approach to sustainability ambitions, a CE has a strong potential to advance structural changes in society (e.g., Prieto-Sandoval et al., 2018). Researchers are starting to view CE as a phenomenon that is not only about materials engineering, energy, or waste management, but also as including societal structures and individual consumer and citizen behaviour. Currently, CE appears to

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be dominated by thoughts of recycling rather than reusing, perhaps because the former is less disruptive to prevalent practices and operations, whereas the latter disrupts existing operational modes (see e.g., Ranta et al., 2018). Similarly, waste management is another domain that seems to amass almost excess attention. Nevertheless, there are more and more studies that address complex human and societal factors, such as consumers' (un)willingness to adopt circular practices or knowledge deficits.

Criticism and novel pathways

The broadening of the scope of research from environmental sciences and engineering studies to social sciences strengthens the impact of research on CE transition. Over decades, CE research has developed in a variety of paths and has become a legitimate area of research and is now attracting new researchers from many different disciplinary backgrounds with new research questions. All new approaches and research questions strengthen the CE phenomenon and give it the momentum of change. However, as is true for most concepts that are introduced with high expectations and rapid adaptation, time typically gives rise to more nuanced criticism that needs to be addressed. CE research has not been an exception.

A strengthening strand of CE criticism is asking how social and cultural dimensions could be better integrated in a CE (Corvellec et al., 2020; Geissdoerfer et al., 2017). This is because studies have shown that economic and technological perspectives tend to dominate CE thinking. In consequence, the applications of CE may lack a proper understanding of the social dimension of sustainability (e.g., Kębłowski et al., 2020; Hobson & Lynch, 2016). Similar observations have been made in the CE urban contexts, where social sustainability seems to be overshadowed by economic and environmental sustainability (Williams, 2019). As the social dimension is the key factor for a successful overarching CE – covering all societal domains in the long term – a suggestion for future research is to focus on integrating the social aspect into the circularity framework and developing CE towards a circular society.

One of the key themes of the CE is its relationship with economic growth. As noted in the Introduction, the ideal policy goal of CE is to reconcile economic, environmental, and social goals. For instance, Kirchherr (2022) argues that research should not be focused on whether an economy grows or does not grow, but rather on policies to balance environmental, economic, and social goals, and thus increase sustainability. This further means that circularity is understood as a path towards sustainability instead of a march towards post-growth or degrowth. On the other hand, the concept of CE has especially been critiqued by the degrowth lens, which demands more fundamental changes in the use of energy and materials. A major argument from the degrowth perspective is that it is impossible to decouple the link between energy and material consumption from economic activity, especially while striving for closed loop and economic growth simultaneously (Corvellec et al., 2022). Furthermore, advancements in resource efficiency may lead to increased overall consumption (Bauwens, 2021). Also, any potential savings gained from circularity could be spent elsewhere, which may result in more harmful consequences for the environment (Hofmann, 2019). These critics also note that when the focus is on promoting growth, CE cannot work unless more stringent legislation and regulation is introduced, because otherwise linear business models will continue to prevail over circular innovations (Bauwens, 2021).

Hobson and Lynch (2016) have critically identified the inherent idea of growth within CE and argued, therefore, that CE studies must also address the notions of diverse economies and post-capitalism to avoid the inevitable rise of resource consumption among the 'shallow' version of CE. The deeper ideas of sustainable CE or circular society identify also the active role of individual actors as consumers and citizens. This would also require informed choices from CE-conscious consumers; for this to happen, it may require the addressing of wider issues such as ownership, advertising, and power (Corvellec et al., 2022; Hobson, 2020; Korhonen et al., 2018). Thus, CE research should not only focus on business opportunities but also on a socio-cultural framing of CE, which means looking at the "how, why, and what of consumption practices" (Ortega Alvarado et al., 2022).

New research agenda on catalyzing circular economy

As this is the first book on catalysts in CE, this book sets a new research agenda in sustainability transition research. In developing the theoretical understanding of CE catalysts, we define the development of a CE as a concurrently crosscutting socio-technical transition affecting technology, business, and societal and cultural layers. Such a transition requires a simultaneous and co-directional change in preferred technologies, value chains, company and city business practices, regulations and policy-making, and consumption patterns. The transition also disrupts the dominant linear logics of economic development and, therefore, disturbs the existing status quo as well as the collaboration and competition among actors, thus awakening resistance to the change.

The chapters in this book correspond to the general idea of catalysis as a metaphor taken from chemistry in the following ways. First, we argue that a catalyst is a trigger that puts the CE transition into motion. The chapters of this book have identified different sharp, single, change-maker catalysts such as regulatory methods, actions by individuals, experiments, design thinking tools, digital tools, and scenario methods. There is also discussion about wider entities such as digital technologies, artificial intelligence and machine learning, art, envisioning, and various technologies as catalysts in CE transition.

Second, a catalyst is a tool for the intentional experimentation of system properties. In sustainability transitions, the routes to make progress may seem both promising and insurmountable at the same time. It is, therefore, important that the CE transition requires catalysts for experimenting, trialing, imagining, and identifying where and when the first steps can be taken or how the ongoing momentum can be strengthened. In this book, value-retention processes, financial services, and gamification are elaborated as examples of ways in which rigid system properties and tendencies maintaining status quo are challenged for CE change. Third, catalysts help transition management in evaluating the probabilities of what will happen next in the system and in assessing which components of the system are reactive in relation to one another, to stakeholder acceptance, and among CE consumers.

Fourth, catalysts start off change either at the initial state of CE transition or later when the momentum or directionality of CE transition should be strengthened. The chapters of this book elaborate on the interplay of catalysts by, for instance, including competences and resources as change-makers, as examples of catalysts that maintain the momentum of change during the different phases of CE transition. Fifth, a catalyst gives an impulse for a systemic change to the extent that this impulse leads to changes that move in the right direction to make the transition to proceed. It can be said that the catalyst creates favorable conditions for complex systemic change, or even maintains the transitional process. In all stages, the core characteristics of the catalyst is to serve as a trigger. The transitional processes of CE are examined here, for instance, in chapters that examine urban regeneration and regime destabilisation.

Overall, the elaborations on catalysts and catalysing mechanisms in this book highlight the importance of addressing a catalyst as a context-dependent phenomenon. Catalysts require suitable circumstances to become active. It is also important to pay attention to the mechanisms that give the catalytic force for technologies, policies, business models, or individuals, to mention a few. To our understanding, the concept of catalyst is particularly useful in studying a systemic change, such as transitions towards sustainable CE, in that it is a complex and long-term change where causalities are difficult to predict. With attention paid to CE catalysts, researchers can identify triggers for change while also taking into account the dynamic nature of change and related complexities that weaken predictability.

Finally, as the broad goal of the concept of catalysts is to accelerate CE transitions, it may be also useful for CE researchers to reflect on the societal impact of their own research. This includes questions such as, how do we ensure that the future research on catalysts has high usability for the real-world actors, who are supposed to implement these results in practice? While universities and research institutions may create innovations and produce useful research results, the general lack of resources and time to communicate and transfer these results into practical forms can be an issue, for example, the limited timeframe of research projects can hinder longer collaboration. A practice-oriented transdisciplinary approach may be especially beneficial in CE research, in which challenges are addressed and solutions developed in collaboration with businesses, public authorities, and NGOs. Compared to the traditional research models that disseminate results only after the research is complete, engaging CE actors and utilising an iterative and practice-oriented approach can allow for the immediate transfer of knowledge between the collaborators.

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GLOSSARY

Absolute contraction One-size-fits-all decarbonisation method for buildings in line with global pathways.

Acceleration of sustainability transition A phase in a transition process in which change accumulates through positive feedback loops and the speed of change increases.

Affordances (Gamification elements) Broadly defined, in the human-computer interaction field, affordances are what an environment offers to an actor to induce behaviours associated with the achievement of a concrete outcome. They are often considered as the relation between an actor with a goal in mind and the features of an environment to meet this objective. In other words, affordances are relations between actors' abilities and the social, emotional, cognitive, or physical action possibilities of an environment. In gamification, affordances are engineered by designers of gamification solutions in order to enrich an existing environment (e.g., an information system or service) with elements and mechanics that structure games (i.e., competitive features like leaderboards and scores) and aid in inducing gameful experiences.

Agency An individual's or collective's will and capacity to act and, in so doing, shape their surroundings.

Analogy model A research tool to generate knowledge of complicated research objects. The idea is to identify relevant dynamic similarities between a well-known source area and the target area and then create analogies that help to examine the target.

Artificial intelligence (AI) A technology or field of science that studies how to program machines to do tasks intelligently like humans do.

Assembling The sociomaterial process in which heterogeneous elements (meanings, materialities, and competencies) constantly form relations with and shape one another.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0) A project that aims to provide 100% coverage of the water supply to all households in and around 4,700 urban local bodies in India.

Augmented reality Modification or enhancement of the perceived physical environment via technologically superimposed sensory stimuli and (e.g., visual, auditory, olfactory, etc.) information.

Bio-CNG "A purified form of bio-gas whose composition and potential energy is similar to that of fossil-based natural gas and is produced from agricultural residues, animal dung, food waste, municipal solid waste, and sewage water".

Blue bioeconomy Water-related bioeconomy and the related businesses and technologies, connecting, for example, to nutrient recycling, agriculture, and aquaculture, and (bio-)energy production.

Business decision-making A process allowing professionals to solve problems and to determine the best option or course of action to meet the needs of the organisation.

CAGR Compound annual growth rate of carbon emissions to reach the 2DC global target.

Catalysis A chemical process in which catalysts accelerate reaction rates. Catalysts are not consumed in the reactions, and often even a small amount of catalyst is enough to enhance rates of chemical reactions.

CBL Circular building label compliance tag, also satisfying safety, health, and environmental protection requirements.

Change agent An individual who proactively and consciously seeks to steer matters toward a set purpose in organisations or societies.

Circular (sustainable) asset class An ideal pool of securities constituted by securities issued by companies that have been actively transitioning towards two features of sustainability: a circular business model and higher company-level metrics of circularity).

Circular business model innovation Innovating the value proposition (what value is offered), how value is created and delivered (how value is offered), and how value is captured (cost and revenue streams) towards a circular economy where products are made to last, products and materials are reused, and the natural environment is regenerated.

Circular business model Describes how an organisation generates, captures, and shares value in a circular economy context.

Circular consumption arrangement The outcome of assembling. A temporarily stabilised configuration of elements (meanings, materialities, and competencies) that makes circular consumption possible.

Circular economy agency actors Actors exercising their agency to steer society toward a circular economy.

Circular entrepreneurship The processes of formation and exploitation of opportunities using both commercial and ecological logics to address environmental challenges with the aim of closing, slowing, and narrowing the loop of resources and regenerating/reconstituting natural capital.

Circular fashion Circular economy of fashion, in which fashion products are either used more (e.g., through renting, secondhand purchasing, or repairing), made to be made again (e.g., materials can be recycled), or made from safe and recycled or renewable inputs.

Circular innovation The technology, product, value chain, business model, and ecosystem changes to break away from a linear economy paradigm where products are disposed of after a limited number of uses, to a system where products and materials are reused, and the natural environment is regenerated.

Circular managerial practices A set of actions that company management adopts to allow for the transition from a linear to a circular business model.

Circular resource strategy The resource-specific processes firms implement to enable their circular business model. These are often referred to as the circular economy principles (e.g., the Rs: reduce, reuse, or recycle) or the circular resource flows (e.g., narrow, slow, or close).

Circular startups Newly established firms that have been founded in recent years and follow circularity principles.

Circular tactical urbanism The temporary reuse of vacant or derelict spaces in communities for a variety of activities.

Circular urban transition A radical, structural change of an urban system producing circular processes, infrastructure, and practices.

Co-creation art The practice of multiple artists working together to conceptualise, produce, and disseminate artworks together, usually without attribution of distinct individual outputs. Not all contributors are necessarily professional artists or from the same discipline.

Co-creation Collaboration among key stakeholders within the whole ecosystem and the integration of various resources and unique capacities for overcoming challenges as participants with different roles align and offer diverse insights, gather new ideas, and break from their own status quo to develop better solutions.

Command-and-control instruments Regulation that states what is permitted and what is illegal. They include, for example, emission limits and rules on specific pollution-control technologies.

Compliance The abidance by laws and regulations targeted at the financial sector. Given the volume of sustainability-related rules that have been entering into force over the last years, this is a fundamental issue in respect to the environmental, social, and governance (ESG) paradigm or the transition to a circular economy.

Consumer textiles Include garments and household textile products utilised by both private and public consumers.

Consumption work The labour integral to the purchase, use, reuse, and disposal of goods and services.

Core competences Organisational processes, company attributes, information, knowledge, etc. controlled in a unique way by a company that enables that company to conceive of and implement strategies that create a competitive advantage.

Core resources A special type of asset, specifically an organisationally embedded nontransferable company-specific resource, whose purpose is to improve the productivity of the other resources possessed by the company.

Creditworthiness The financial soundness of a company; that is, the intrinsic ability to fulfil the company's financial obligations. The lower a company's creditworthiness, the higher the risk an investor faces in underwriting that company's securities (including equity), and the higher the return it should expect from that investment.

Decarbonisation target The amount of CO_2 emitted in the real estate sector in a local context.

Decay constant The process of reducing emissions at a consistent rate over a set period.

Deconstruction/disassembly Dismantling a building in such a delicate way that its constituent components are not annihilated but retain (most of) their shape, form, and performance.

De-risking strategy The process whereby an investor makes investment decisions aimed at reducing the various risks to which the investment is exposed, assessing a counterparty based on the soundness of its financial record or the volatility of the securities it issued.

Design The word 'design' relates to the Latin word *designare*, which means 'to mark out' and has been used since early history to define how humans create, maintain, and transform the artificial, man-made environment. Today it is a discipline, partly art and partly science, focusing on the acceleration of industrial, technological, and economic development.

Design thinking An iterative and experimental approach to develop innovations that are desirable for people, financially viable and technically feasible for organisations.

Diffusion (model) A mathematical model used to describe the process by which innovations are adopted by a population. Whether diffusion occurs and the rate at which it occurs is dependent on several factors, including the nature and quality of the innovation, how much information about the innovation is communicated, and the characteristics of the population into which it is introduced.

Digital affordance The interaction possibilities intuitively implying the functionalities and use of digital objects. Digital affordances enable firms to embed rules, algorithms, and mechanisms for self-governance into digital marketplaces (i.e., platforms).

Dystopia The imaginary description of an extremely unfair society; dystopia is the opposite of utopia.

Eco-design A concept that includes the development of dedicated methodologies, such as eco-design and life cycle assessment.

Eco-design principles The principles under this umbrella include increased focus on material and resource efficiency aspects in the transition towards a more circular economy by making consumer goods more durable, resource-efficient, and recyclable.

Eco-effective designs These designs strive to create material flows that create a workable relationship between the ecological systems and economic growth (aka 'closing the loop').

Eco-efficiency designs These designs take the linear approach to making the cradle-to-grave or take-make-dispose models more efficient by seeking methods to minimise the energy, volume, velocity, and toxicity of the material flow system.

Eco-influencer Individuals who use personal narratives and images to promote sustainability on social media platforms.

Eco-innovations The development of products and processes that contribute to sustainable development, applying the commercial application of knowledge to elicit direct or indirect ecological improvements. This includes a range of related ideas, from environmentally friendly technological advances to socially acceptable innovative paths towards sustainability.

Economic instruments Fiscal and other economic incentives and disincentives to guide towards certain objectives. They include taxes and other charges.

EDGE Excellence in Design for Greater Efficiency, an open source app for designing green buildings.

End-of-life textile A consumer textile product that the consumer has donated or discarded. Depending on their quality and condition, end-of-life textiles can either be reusable or become textile waste. Reusable textiles can still be resold as products, while textile waste can be either recycled into raw material or utilised for energy recovery.

Energy transition The overall transition from fossil fuel–based energy systems towards renewable sources, connecting to several technical developments. This transition is driven by, and impacts to, climate change and the overall resource use.

Enterprise development The process of allocating financial and scheduled resources to aid in the launch, growth, or improvement of a company or business. Long-term economic growth for individuals, their families, and their communities is achieved through enterprise development, which also helps people earn a living or escape poverty.

Extended producer responsibility (EPR) Producers, importers and sometimes sellers of the products are responsible for organising and collection, recycling, recovery, and final disposal of the end-of life products that are under the EPR legislation; they are also responsible for the associated costs.

Financial materiality The feature of an issue or topic that is reasonably likely to impact the financial condition or operating performance of a company (SASB definition), thereby having an effect at higher levels (e.g., that given industry, the economic system as an entirety, etc.). It is usually explained through sustainability-related items, and the handling of this information may or may not be reflected in company financials.

Futures images Can be regarded as still images or snapshots of the future. They are simple, metaphorical representations of possible future states.

Gamification Technological, economic, cultural, and societal developments in which reality is becoming more gameful, leading to the development of skills and other aspects perceived as positive benefits of play and playing games. Gamification can be an intentional process of transforming activities and processes, usually with the purpose of facilitating behavioural changes. Societal transformations resulting from increasing engagements with games and gameful interactions are known as emergent gamification; these practices resemble those of players, game communities, and games.

Greenwashing To deceptively persuade the public that products (e.g., buildings) are eco-friendly.

I=PAT equation This formula presents the impact of human activity on the environment (I) as the result of changes in population (P), affluence (A) and technology (T). The Earth's natural carrying capacity, also defined as the endurable impact due to the environment's self-regeneration processes, plays a crucial role in balancing the impact that humans (P) have on global hectares per capita (A). Technology (T) is a variable of efficiency that can both lead to improving the use of existing resources in a way that the Earth can regenerate itself; or lead to overshoot, this is, accelerate environmental degradation, hampering the Earth's ability to regenerate.

Idiosyncratic risk From an investor's standpoint, looking at a security, the risk associated with that security's issuer (i.e., the investor's counterparty) due to the latter's intrinsic features and conduct, rather than market-wide factors. This can be reduced via portfolio diversification.

Information Inferred from the data, which covers the values and observations from selected variables: Information means that the data is transformed into a meaningful and useful form.

Information-based instruments Instruments to distribute knowledge or information seeking to shift the audience's behaviour in a certain direction.

Information circulation A process of creating wisdom in business decision-making, placing emphasis on the aspects related to data, information, knowledge, and wisdom (DIKW).

Institutional theory Theoretical framework for analysing social and organisational phenomena, which considers the social world as significantly influenced by institutions, including rules, practices, and cognitive elements that impact the phenomena.

Intermediary "Agents who connect diverse groups of actors involved in transition processes and their skills, resources, and expectations".

International collaboration Shared engagements between partners from different countries and cultures in which the sharing of perspectives and cooperative processes leading towards a common goal form the main activity.

IoT (Internet of Things) A terminology used to describe the integration of technology with different sensing, connectivity, storage, computational, and other capabilities. There is no universal definition; IoT is also often called IoE (Internet of Everything), WoT (Web of Things), CoT (Cloud of Things), or M2M (Machine to Machine)

Kaya identity Projecting future carbon emissions based on population, GDP, energy, and carbon intensity.

Knowledge Know-how and the ability to interpret trends and put information into productive use. For example, the professional skill of understanding information that has developed over time.

Labelled data A data set that has been tagged with label(s) identifying certain classifications or characteristics.

Landscape Overall socio-technical setting, includes political contexts and social values.

Life cycle assessment A method that assesses environmental impacts associated with products, processes, or services all through their life cycle.

Machine learning (ML) A technology or field of science that studies how to train machines to learn experiences intelligently like humans do.

Market creation The mechanisms that enable the creation of circular economy (CE) markets. For instance, mainstreaming sustainability practices, developing viable CE products, and providing supportive regulatory and policy environments.

Mental models Internal images of how the world (or part of it) is constructed. They are created based on individuals' experiences, perceptions, and understanding of the world.

Micro actors The startup firms, programmes, and initiatives geared towards CE development.

Mid-range transition arena A streamlined and structured transition arena process that puts emphasis on participants' direct involvement in the pathway design work and the identification of the necessary actions and responsibilities.

Mid-range transition pathway design toolset (MTPT) A toolset utilised in the mid-range TA process, based on a metallic working canvas on which pathways are collaboratively designed in structured phases of work.

Mission A strategic goal that requires technological and non-technological solutions to grand societal challenges.

Mission-oriented policies Systemic public policies that draw on cutting-edge knowledge to attain specific objectives. Historically, mission-oriented policies are associated with defence, nuclear, and aerospace technological solutions. Currently, such named policies are designed to solve grand societal challenges.

National Policy on Biofuels, India A policy to utilise, develop, and promote domestic feedstock and its utilisation for the production of biofuels thereby increasing substitute fossil fuels while contributing to national energy security, climate change mitigation, apart from creating new employment opportunities in a sustainable way.

Network effect The situation where the value of membership/participation in something is positively enhanced when additional users join. This, in turn, encourages more users to join, increasing its value further. The term is often associated with the market value of a product, platform, or service.

Niche 'Space' for radical innovation and experimentation.

Niche-regime (N-R) A dynamic wherein niche actors and organisations with like-minded thoughts, values, and objectives come together and start to form their own collection of shared cultures, structures, and practices – their own regime within the niche level.

Non-biodegradable plastic These are conventional forms of plastics that are made from fossil fuels employing the polymerisation process, which cannot be degraded by natural or biological process, and remain for quite a long period in the environment.

Non-financial information disclosure The act of releasing information – and the documents in which it appears – whereby a company presents the policies it engaged in, as well as the results it achieved, in respect of items different from those featured in financial statements. In practice, the content mainly revolves around sustainability reporting, based on various paradigms like corporate social responsibility (CSR); environmental, social, and governance (ESG); or the circular economy (CE).

Perceived value Inherent in or linked through the use of some product, service, or object, perceived value is something perceived by consumers rather than objectively determined. Reflects the tradeoff between the quality or benefits perceived by consumers in the product, relative to the sacrifice that is perceived by paying the price, assuming the risk, etc.

Policy coherence Understood as a clear relationship between documents over time and at different hierarchical levels. Coherence implies that various documents go together because they share a set of ideas or objectives.

Policy integrity How the document flows logically, including how the goals set for the circular economy, their decentralisation across key actors, and tangible indicators to measure progress are included in the analysed documents. Integrity implies that various documents complement and clarify, rather than contradict, each other.

Practice theory A school of thought developed and broadly used in the social sciences and philosophy that focuses on practices (rather than discourse, interactions, understandings, attitudes, or values) and makes these the central units of analysis.

Prefabricated/precast concrete Building components manufactured out of concrete in a factory, which are then brought onto the construction site, where they are assembled together into a structure.

Probability of default The likelihood that a company may default on its debt, thus proving unable to fulfil its financial obligations over a given time horizon, either short-term (e.g., one year) or long-term (e.g., five years). It is expressed by a figure comprised between 0 (default is impossible) and 1 (default is certain).

Product-service system A business model based on offering a combination of products with services, which does not necessarily include transferring of ownership. This can mean, for example, providing lighting services instead of selling light bulbs.

Prospect theory A theory of behavioural economics and behavioural finance, where the observation is that people conclude their utility from "gains" and "losses" relative to a certain reference point. This "reference point" is different for each person and relative to their individual situation, and thus, rather than making decisions like a rational agent, decisions are made in relativity, not absolutes.

Prosumer Consumers who act as producers in parallel, either for self-consumption or for the consumption by others.

Public–private partnership (PPP or 3P) model Arrangement between a government or statutory entity that provides public services through private investment and/or management of assets for a limited period of time.

Recycling Waste Framework Directive 2008/98/EC defines recycling as any recovery operation by which waste materials are reprocessed into products, materials, or substances whether for the original or other purposes.

Regime Dominant practices, rules, and technologies that provide stability and reinforcement to the prevailing socio-technical systems.

Regime destabilisation A multi-dimensional process whereby the existing regime begins to weaken, as a result of an increase of pressures and a decrease of actor commitment to the dominant cultures, structures, and practices.

Regime-niche (R-N) A dynamic wherein actors operating at a regime level have alternative, innovative thoughts and actions – their own niche within the regime level.

Repair Refers to the fixing of a specified fault in an object that is waste or a product and/or replacing defective components, to make the waste or product a fully functional product to be used for its originally intended purpose.

Resource-based view A managerial framework to determine the strategic competences and resources a company can exploit to achieve a sustainable competitive advantage.
Reuse As opposed to recycling, where an existing material is physically or chemically disintegrated and reprocessed into a new material, reuse stands for using a deconstructed component in a whole, (more or less) intact form, in its original purpose or function or in a new one.
Rhetoric The process of national discussions about moving into a circular economy. It includes outcomes of consultative meetings and discourses that set the tone for CE enterprise development.
Roadmap A strategic plan or strategic planning technique that defines an overarching goal or desired outcome. This strategic tool includes the major steps or milestones, such as the vision, direction, priorities, and progress, which are needed to achieve the desired goal. A roadmap enables the clarification of the strategy and ensures its communication.
Scenario method (2DC) Forecast to achieve the 2015 Paris Agreement to limit global warming to 1.5–2°C before the year 2050.
Service design An approach intended for the creation of solutions for people and organisations in different sectors (e.g., transport, banking, etc.), delivered through the combination of intangible and tangible (i.e., touchpoints) mediums.
Sharing economy Economic model where users grant each other temporary access to underutilised assets.
Sociomateriality A perspective that sees the material and the social as intrinsically linked. Studies of social entities are always sociomaterial and consist of associations between heterogeneous elements.
Socio-technical landscape The overall societal context prevailing at any time, formed by a society's culture, values, and political and economic systems.
Socio-technical lock-in A technology, infrastructure or habit that has become standard for a society. Requires high transaction costs to change it.
Socio-technical regime The way things are done 'business-as-usual' in any given sector – an established intertwinement of rules, practices, education, organisations, etc. Regimes nest within the more general socio-technical landscape.
Socio-technical systems theory A theory that considers the interrelationship between the human and technology in a working system. It can be used to study the systems in a specific designed context, for example, digital, and circular business models.
Substance of concern Chemical substances that can be harmful for human health and environment. Usually, their use is managed through regulation.
Sustainability agency Actors exercising their agency to steer society towards sustainable futures.
Sustainability citizenship competency Knowledge or skills that enable individuals to participate in sustainability developments and changes that lead to more sustainable social, environmental, or material practices.
Swachh Bharat Mission-Urban 2.0 The project Clean India Mission, which aims to create 'garbage-free cities', launched in October 2022 by the prime minister of India.
Systematic risk From an investor's standpoint, looking at a security and the risk associated with market-wide factors rather than the intrinsic features or conduct of the issuing counterparty. Since the latter play no role in respect to such risk, there is no way to reduce it via portfolio diversification.
Technological niche Incubation environments for radical innovations, where technological development, learning, and coalition building is sufficiently protected from normal market mechanisms.

Technological transition Process through which a new technology eventually takes over markets from a prevailing older technology.

Textile circulation A combination of circular economy-based processes in which textiles are used by their owner as long as possible, maintained, reused as products, and recycled into raw material, for instance, as textile fibre, maximising each utilisation phase before the final disposal.

Textile recycling The process during which textile waste is processed into fibrous raw material that can be utilised either in the manufacturing process of new textile products or for other purposes. Textile recycling includes, for instance, mechanical, chemical, or thermal recycling processes, which are selected depending on the fibre composition of recyclable textiles and the intended use of recycled fibres.

Textile reuse A situation in which a used textile product or part thereof is used for its original purpose by a new user, with or without minor modifications or repairs. Textile reuse also can mean utilisation of a used textile product for a different purpose to its intended use.

Theory of Change A type of theory describing the logic for why and how a system can and should be changed, either as a diagram or as a set of logic statements. This can be used as a boundary object, providing a working hypothesis for how various interventions "trigger changes and continuously refines it through cycles of action and reflection".

Tool In the context of this chapter, the authors of Chapter 18 refer to tools as conceptual frameworks encompassing theoretical knowledge on innovation, condensed and translated into actionable (often normative) versions in order to support innovation practice.

Transaction costs Costs associated with writing, monitoring, and enforcing contractual relationships, including behavioural hazards, incomplete contracting, and conflict resolution costs within organisations and across markets. These vary with the specific characteristics of goods and services. Transaction costs determine the total cost of production and are relevant before and after transacting. Different governance arrangements (e.g., markets, hierarchies, and commons) manage transaction costs in different ways. Governance choice is, therefore, integral to managing transaction costs.

Transition A shift in the dominant cultures, structures, and practices of a society that takes place in a complex, nonlinear fashion over decades or generations; this typically refers to 'desired' sustainability transitions.

Transition arena (TA) A collaborative knowledge-creation process conducted through a series of workshops, in which a small group of carefully selected forerunner actors identify drivers and barriers, create a future vision, and develop transition pathways towards it.

Transitioning The process or a period of changing from one state or condition to another.

Transition management (TM) A transformative governance approach to identify change dynamics and align interests towards long-term implementation of policies and actions of various agendas.

Transition Management Cycle (TMC) Framework developed by Dutch transition researcher Derk Loorbach with the purpose of illustrating transition management practices. Originally created to distinguish between four different types of governance activities and their roles in societal transitions, this framework has been applied across various disciplines to study transitions, such as business development and organisational change.

Transition state Takes place just before the activated reactants in a chemical process convert into products. In chapter 2, transition state is used in analogous ways to describe the theoretical culmination point towards which an activated sustainability transition is moving.

Transition town Place-based, grassroot community projects that aim to increase self-sufficiency to reduce the potential effects of peak oil, climate destruction, and economic instability (e.g., Transition Town Brixton [TTB]).

Two-dimensional model of circular economy The CE literature distinguishes between biological and technical cycles. Biological cycles consist of renewable biomaterials and technical cycles include the flows of various product assemblies and the flows of nonrenewable resources.

Ultra-thin plastic shopping bags The thickness of plastic, made for bags, is less than 0.025 mm.

Urban circular economy This economy is under strong development in cities, and we do not know how the real 'circular cities' are going to look. Urban regeneration is an important research object to analyse the co-development of the urban circular economy and urban sustainability.

Urban nutrient cycle Unsustainable when the nutrients from food are discharged either through human excreta in the municipal wastewater or as food leftovers in biowaste. From these waste streams nutrients can be recovered through different technologies and potentially utilised again in food production.

Urban regeneration Public policy vision and action that seeks to resolve urban problems and create opportunities to improve urban areas. Previously it focused on the problems of economic and social decline in industrial cities, now it particularly focuses on broad sustainability targets and the stimulation of economic growth.

Utopia An imaginary description of a better society and can be described as a preferable futures image.

Value retention processes (VRPs) Production-type activities that enable the completion of, and/or potentially extend a product's service life beyond traditional expected service life. These processes include arranging direct reuse, repair, refurbishment, and remanufacturing.

Virtual intermediary An intermediary that is enabled by virtual and/or digital platform–based technologies, which have specific strengths in knowledge transfer functions.

Virtual reality Artificial environment that digitally substitutes or duplicates the perceived physical environment via technology.

Visual catalyst A visual form/object/product, often in the field of contemporary visual or performing arts, that proposes to lead viewers to altered awareness, thinking, or actions.

Waste recovery Waste Framework Directive 2008/98/EC defines waste recovery as "any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy."

Wedges Carbon mitigation initiatives, for example, resource efficiency of residents' housing materials from cradle to grave.

Wisdom The ability to understand relevant alternative actions within the context and time, to compare them, consider the effects on stakeholders, and to make an optimal business decision by utilising the appropriate decision-support tools.

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