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## 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 strategic 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.

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., Schöggel 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 re-use of by-products, and stimulating economic activities (e.g., Morsetto, 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 (Predeville 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 non-linearity 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 Ogbegie, 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 policy-making 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 Stähle, 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 Joonas 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, Tmmit 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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## Introduction

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