17. Circular economy ecosystems: a typology, definitions, and implications

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INTRODUCTION

The circular economy (CE) has recently emerged as a major paradigm in environmental sustainability, with the goal of creating economic and industrial structures that help reduce the use of natural resources and the generation of waste (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Ghisellini, Cialani, & Ulgiati, 2016). The CE challenges the dominant linear model of “take, make, and dispose” that creates excessive waste and is resource use inefficient. A transition to a CE is disruptive by nature: a shift to new circular models disturbs the status quo and changes the nature of the collaboration and competition among technology, innovation, business and governmental actors. CE transitions are socio-technical (Geels & Kemp, 2007) in that they concern multiple actors across economic and other domains. To enable circularity, resource efficiency, and environmental sustainability in markets and society, flows of material, energy, and value must change at the system level. This systemic change requires multiple different actors, such as diverse organizations, cities and municipalities, and consumer–citizens, to interact in a complex multi-actor setting.

To address this setting, the notion of the “ecosystem” has become important in understanding how linear models can be transformed into circular ones, representing resource efficiencies and material flows typified by feedback loops and interdependencies among different actors. A good example of multiple actors and interactions enabling circularity is the well-known industrial symbiosis-based Kalundborg¹ ecosystem, which focuses on the cycling of resources amongst diverse manufacturers and other industrial actors in Denmark. Another example are the tens of companies, universities and research institutes, labeled the “Telaketju ecosystem,” that collaborate to generate knowledge and build businesses for a CE of textiles. Yet another example is the platform ecosystem of the start-up company Netlet, which is focused on reducing waste and carbon emissions in the construction industry by linking large companies that have surplus materials and small players that need those materials. As these examples illustrate, ecosystems serve well as both metaphor and concept in CE settings, similar to its broader usage in the scholarly literature (Aarikka-Stenroos & Ritala, 2017; Thomas & Autio, 2020).

The ecosystem approach allows a consideration of complex constellations of actors, technologies, and institutions that are bound together via loosely coupled interdependencies and co-evolutionary patterns (see e.g. Aarikka-Stenroos & Ritala, 2017; Phillips & Ritala, 2019; Thomas & Autio, 2020). Interdependency between the ecosystem actors can originate from shared institutional logics, shared purpose or intentions, joint value propositions, affiliations, or a technological platform enabling actors to interconnect (Adner, 2017; Autio & Thomas, 2014; Jacobides, Cennamo, & Gawer, 2018; Thomas & Autio, 2020; Vargo, Wieland, & Akaka, 2015). Ecosystems also have a system-level outcome, in the sense that the ecosystem

produces an outcome that is greater than any single participant could deliver alone (Thomas & Autio, 2020).

As the examples above show, ecosystems have been adopted in CE settings, portraying distinct types of multi-actor networks with different system-level goals, differing levels of analysis, differing actor constellations and structures, and different conceptualizations of agency. These CE ecosystem examples and conceptualizations echo the development of the broader ecosystem literature into specific sub-types, such as innovation, entrepreneurial, and knowledge ecosystems, each with distinctly different views of agency (for reviews, see Aarikka-Stenroos & Ritala, 2017; Autio & Thomas, 2014; Hakala, O'Shea, Farny, & Luoto, 2020; Thomas & Autio, 2020; Tsujimoto, Kajikawa, Tomita, & Matsumoto, 2018). Thus, although the notion of the ecosystem resonates well with the systemic nature of sustainability and the CE transition, we have limited – perhaps even nonexistent – theoretical clarity regarding *CE ecosystems*. The coherent use of the CE ecosystem concept is important for communication among practitioners and scholars, and to enhance scholars' ability to empirically explore the phenomenon (Suddaby, 2010). Furthermore, to develop a theoretical foundation for ecosystems in CE settings, it is important to be aware of the full diversity of these conceptualizations.

In this chapter, we review and propose how ecosystems can be conceptualized in CE. We provide theoretical insights for academics and pragmatic guidance for practitioners who aim to initiate, support, and facilitate or be involved in such ecosystems. We make three contributions. First, we conceptualize three distinct categories of CE ecosystems, identify five distinct CE ecosystem types, and illustrate these through practical examples. Our goal is to provide an encompassing yet parsimonious typology that places existing CE ecosystem scholarship in context, and to develop a typology that can help stimulate cumulative future CE ecosystem research. Second, derived from this typology, we propose definitions and a heuristic for CE ecosystems. We define CE ecosystems generally as *communities of hierarchically independent, yet interdependent heterogeneous set of actors who collectively generate a sustainable ecosystem outcome*. We suggest that an important aspect of any CE ecosystem is its sustainable ecosystem outcome, defined as *a system-level outcome typified by circular processes of recycling, reuse, and reduction*. We believe that together these definitions can act as a “compass” to drive future coherent and cumulative research. Third, we discuss the implications of the typology and definitions for future research and practitioner efforts in improving environmental sustainability in society. Knowledge of CE ecosystems and their diversity has pragmatic relevance, as it can advise practitioners, companies and public actors (such as municipalities), and other organizations on (re)organizing their activities and making their ecosystems more sustainable.

THE CIRCULAR ECONOMY: GOALS AND CHARACTERISTICS

The CE has emerged as a major sustainability paradigm (Geissdoerfer et al., 2017) focusing on improving the sustainability of the economy by reducing the use of natural resources and the generation of waste (Ghisellini et al., 2016). Reflecting the systemic nature of the CE phenomenon, one of the most quoted definitions defines CE as “an industrial economy that is restorative by intention and design” (Macarthur, 2013). The shift and systemic transition toward a CE require the introduction of new technologies and innovations (Despeisse et al.,

2016; Prieto-Sandoval, Jaca, & Ormazabal, 2018), changes in firms' business models and management (Esposito, Tse, & Soufani, 2018; Hofmann, 2019), and a sustainability orientation (Geissdoerfer et al., 2017; Murray, Skene, & Haynes, 2017). Consequently, the CE is placed at a crossroads between multiple academic disciplines.

The CE considers the improvement of systemic resource efficiency through actions that extend the value of materials and resources, thus reducing the need for the extraction of further natural resources. The improvement of systemic resource efficiency and sustainability has been considered through the principles of "3R": reduce, reuse, and recycle (Ghisellini et al., 2016; Ranta, Aarikka-Stenroos, Ritala, & Mäkinen, 2018). *Reducing* products and materials refers to providing the same amount of value and well-being with fewer resources through, for example, the digitization, sharing, or creation of more lightweight products. *Reusing* refers to returning end-of-life products to use through, for example, second-hand markets or refurbishment. *Recycling* refers to returning materials to be used again through the process of material recycling. These CE actions have also been considered as the processes of narrowing, slowing, and closing resource loops (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Bocken & Ritala, 2021).

For a successful transition toward the CE, CE actions take place at the micro-level (i.e. individual) and firm level, meso-level (i.e. regional level), and macro-level (i.e. national and government level) (Ghisellini et al., 2016; Kirchherr, Reike, & Hekkert, 2017). Although the literature emphasizes a systemic perspective on the CE transition, the literature also acknowledges that the implementation of the CE typically happens with individual actors, and especially firms (Hofmann, 2019), thereby highlighting the issue of agency. Local and regional institutional settings and social institutions, however, shape how these individual actors, varying from customer–citizens to businesses and governments, can act and take initiatives for the CE, as a recent comparative study of three institutional contexts (China, Europe, and the United States) has shown (see Ranta et al., 2018).

On the company level, implementing a CE often requires firms to expand their perspective of value from the traditional economic value-centric view to a view that includes ecological and social value (Patala et al., 2016), to develop more sustainable technology and business strategies (Kaipainen, Aarikka-Stenroos, & Ranta, 2020), and to adopt new logics of value creation (Ranta, Keränen, & Aarikka-Stenroos, 2020). In particular, the CE seems to (re)shape the logic of value creation, not only for individual firms but also for value chains and networks, as the firm needs to acknowledge more and diverse actors and stakeholders for which the firm creates value (Kaipainen et al., 2020; Keränen, 2017; Ranta et al., 2018). Consequently, to ensure transparent and sustainable value chains, organizations must make decisions about their business partners based on sustainability criteria (Kapitan, Kennedy, & Berth, 2019; Lacoste, 2016).

The CE also shapes the business model landscape, as this approach often requires firms to include resource returning loops in the supply chain, use more renewable resources, and include more service elements in their business models (Bocken & Ritala, 2021; Kaipainen et al., 2020; Ranta et al., 2018). Service elements such as renting or maintenance provide opportunities for firms to create value and fulfill customer needs, and to close material loops. Therefore, these elements have become the core to the business models of sustainable and CE firms (Tukker, 2015). The CE also changes how the labels "consumer" and "customer" are perceived: due to loops and circular value creation, the "end-users" or "consumers" are given new "prosumer" roles (Zhong & Pearce, 2018), as they start creating value as a part of the

circular system, for example, when recirculating consumer waste back as resources (see, e.g. Peronard & Ballantyne, 2019).

The CE also requires a rethinking of the processes of innovation, technology, and knowledge development. Technology-driven innovations are often relevant in the implementation of resource efficiency and a CE. Thus, the firms implementing a CE often need to innovate and introduce novelties in their business: new materials that enable reduced use of natural resources or that allow better recyclability and process technologies that improve and optimize reuse and recycling of products and materials are important (Prieto-Sandoval et al., 2018). Most of the innovation literature on sustainability overall has focused on these types of product, material, and process innovations that improve sustainability.

ECOSYSTEMS AND AGENCY

In biology, an ecosystem is “a biotic community or assemblage and its related physical environment in a particular place” (Tansley, 1935), which can be any size given the existence of living organisms, physical environment, and interactions within them (Pickett & Cadenasso, 2002). From this initial biological conceptualization, ecosystems have been adopted in various contexts. For instance, the notion of the “ecosystem” has been adopted in industrial engineering (Frosch & Gallopoulos, 1989), urban planning (Decker, Elliott, Smith, Blake, & Rowland, 2000), economics (Seppelt, Dormann, Eppink, Lautenbach, & Schmidt, 2011), entrepreneurship (Autio, Nambisan, Thomas, & Wright, 2018), innovation management (Järvi, Almpantopoulou, & Ritala, 2018), and strategy (Adner, 2017).

Biological ecosystems, as nonequilibrium thermodynamic systems, focus on the processing, partitioning, and dissipation of energy between ecosystem actors (Golley, 1993; Pickett & Cadenasso, 2002). The extensions to engineering and the social sciences have focused on similar flows between actors. For instance, also focusing on flows of energy and materials within specific geographic regions, industrial ecosystems consider the interdependencies between industrial organizations (Korhonen, 2001), and urban ecosystems consider the interdependencies between actors in urban environments (Bai, 2016; Decker et al., 2000).

Relatedly, economics has developed the notion of ecosystem services as the benefits that humans obtain from urban and biological ecosystems (Lovell & Taylor, 2013; Pickett & Cadenasso, 2002). Management scholars, aligned with their interest in economic communities, have considered the flow of knowledge and the flow of value. For instance, innovation ecosystems are considered multi-stakeholder venues for value co-production (Adner, 2017; Jacobides et al., 2018), entrepreneurial ecosystems are considered the locations where ecosystem actors cultivate a shared knowledge base regarding “what works” in harnessing advances in digital technologies and infrastructures (Autio et al., 2018; Isenberg, 2010; Spigel, 2017), and knowledge ecosystems feature the creation of research-based knowledge and associated applications, reflecting the increasingly open processes of research and development (R&D) and innovation (Bogers et al., 2017; Järvi et al., 2018; Von Hippel, 2007).

Although the theoretical focuses of these ecosystems vary, some commonalities can be derived. First, each ecosystem is conceptualized as a network that has a *system-level outcome*, in the sense that the ecosystem produces an outcome that is greater than any single actor can deliver alone (Decker et al., 2000; Korhonen, 2001; Thomas & Autio, 2020). Second, these ecosystems are composed of a *heterogenous community of actors* that are hierarchically

independent but have *varying roles* within the ecosystem (Korhonen, 2001; Thomas & Autio, 2020). Third, the heterogeneous actors within such ecosystems are *linked through interdependencies*, such as physical interconnection, spatial proximity, technological complementarities, economic links, and shared cognitive perspectives (Adner, 2017; Autio et al., 2018; Decker et al., 2000; Järvi et al., 2018; Korhonen, 2001). Fourth, these ecosystems have distinctive *coordination mechanisms* that rely primarily on role definitions, complementarity, and technological, economic, and cognitive alignment structures that strike a balance between change and stability in the ecosystem outcomes (Autio & Thomas, 2018; Gulati, Puranam, & Tushman, 2012; Jacobides et al., 2018; Wareham, Fox, & Cano Giner, 2014).

As a consequence of these distinctive coordination mechanisms, actor *agency* within ecosystem contexts is nuanced. This is because the actions of an ecosystem actor are not contingent on an actor-level outcome only. Instead, in ecosystem contexts, the actions of an ecosystem actor are defined by their particular *role* within the ecosystem. In ecosystems that focus on energy and material flow, roles can vary significantly. For instance, in biological ecosystems, predators have a particular role quite distinct from that of prey, a role that is determined by their physical characteristics. Similarly, in industrial ecosystems, power stations have a different role than farms (Chertow, 2000), and transportation has a different role within an urban ecosystem than a utility (Li et al., 2017). Where the focus of an ecosystem is the flow of knowledge or value, role definition plays a fundamental part in ecosystem governance (Autio et al., 2018; Jacobides et al., 2018; Järvi et al., 2018; Thomas & Autio, 2020; Wareham et al., 2014). Put differently, the agency of an ecosystem actor is shaped by their role, which, in turn, determines their actual material, knowledge, or value contribution to the ecosystem.

The level of agency that any particular actor has, then, varies with their role. And the fact that roles are interdependent suggests that some roles may have high levels of agency, and others less so. Interdependency between ecosystem actors stems from propinquity, physical interconnections, asset specificity, shared institutional logic, joint value proposition, shared purpose, cognitive affiliation, or technological complementarity (Adner, 2017; Autio et al., 2018; Bai, 2016; Jacobides et al., 2018; Järvi et al., 2018; Korhonen, 2001; Teece, 1986). It is these physical, spatial, technological, economic, and cognitive interdependencies that enable and constrain the agency of a particular actor. For instance, some actors have specific physical interdependencies, such as infrastructure connections, while others have spatial interdependencies, such as proximity to other actors, that can enable or hinder agency. Similarly, some actors are cospecialized leading to technological complementarities (Jacobides et al., 2018), and economies of scale and scope result in other ecosystem actors having economic interdependencies (Thomas, Autio, & Gann, 2014). Yet other actors have cognitive interdependencies, such as socially constructed, historical patterns of material practices, assumptions, values, identities, beliefs, and rules (Thomas & Ritala, 2021; Thornton & Ocasio, 1999).

Agency in an ecosystem may vary. In some circumstances, the interdependencies that shape an ecosystem give particular role(s) significant agency. These roles are often called “keystones” or “orchestrators,” where a central actor acts as a “hub” to manage the ecosystem (Adner, 2017; Iansiti & Levien, 2004). In other circumstances, the nature of the interdependencies leads to agency being distributed across actors in the ecosystem (Autio et al., 2018; Järvi et al., 2018). These differing agencies link to the debates of to what extent the agency of individual actors is distributed and embedded within a specific context, or to what extent agency can be used to change the context (Garud, Hardy, & Maguire, 2007; Garud & Karnoe, 2003).

ECOSYSTEMS AND THE CIRCULAR ECONOMY

Given the broad range of ecosystem conceptualizations, we suggest that CE ecosystems can be grouped into three distinct categories based on their system interactions and flows as well as their system-level goals, with five distinct types of ecosystems, namely: material flow-based industrial and urban ecosystems, knowledge flow-based entrepreneurial and knowledge ecosystems, and economic value flow-based innovation ecosystems that include platform and business ecosystems. We developed this typology by integrating theoretical knowledge of the diverse ecosystem types discussed in this chapter with empirical insights that were gained through analysis and comparison of diverse multi-actor collaborations within the CE. Each category and ecosystem type have distinct characteristics, including ecosystem outcomes, location specificity, ecosystem actors, implications for agency, applicability to CE studies, and CE impact. We also detail key theoretical literature and provide empirical examples for each. The typology with five distinct types of CE ecosystems is presented in Table 17.1, and the implications for research on the CE for each type are shown in Table 17.2.

Flow of Materials: Industrial and Urban Ecosystems

Given the analytic focus on resource flows, CE phenomena often occur within the physical environment, enabling local resource flow through industrial or public–private collaboration (Ingstrup, Aarikka-Stenroos, & Adlin, 2021). One type of ecosystem that focuses on material and energy flows are *industrial ecosystems* which, in CE terms, are physically located industrial systems within which circular resource flows occur and have sustainable industrial production through resource recycling and reuse as their ecosystem-level outcome (Frosch & Gallopoulos, 1989). A second type of ecosystem that focuses on material and energy flows are *urban ecosystems*, which refer to the built environments that include administrative actors and the physical infrastructure.

In both industrial and urban ecosystems, the roles of ecosystem actors are determined by the specificity of their assets and resources (Riordan & Williamson, 1985), which in turn determines the nature of their ecosystem interdependencies. For instance, where the resources that an actor controls have specific uses or relationships with other actors, such as power generation, waste recycling or public transport, actor agency is both enabled and constrained by these specific assets and resources. Thus, for ecosystems that consider the flow of materials, actor agency is almost always embedded in the local physical, economic, and institutional environment, and thus is enabled and constrained by it. We discuss each type briefly and give examples.

Industrial ecosystems consider the physically located systematic contexts within which circular resource flows occur, comprising various manufacturers, service providers, resource providers, and utilities (Hess, 2010; Korhonen, 2001; Lifset & Graedel, 2002; Lowe & Evans, 1995). CE industrial ecosystems look to non-human “natural” ecosystems as models for industrial activity (Hess, 2010), as biological ecosystems are especially effective at recycling resources and, thus are held out as exemplars of efficient (re)cycling of materials and energy in industry. In doing so, industrial ecosystems are a location-specific approach to developing closed-loop systems that recycle matter and address the energy cascade in industrial parks or regions (Korhonen, 2001; Lowe & Evans, 1995). Consequently, the system-level outcome of a CE industrial ecosystem is sustainable industrial production. We define CE industrial

Table 17.1 *Overview of CE ecosystems*

Ecosystem category	Material flow		Knowledge flow		Value flow
Category description	Ecosystems that enable sustainable energy and material flows within a geographically defined context		Ecosystems that enable the production of CE knowledge within a geographically defined context		Ecosystems that enable the sustainable production of economic value
Ecosystem type	<i>Industrial ecosystem</i>	<i>Urban ecosystem</i>	<i>Knowledge ecosystem</i>	<i>Entrepreneurial ecosystem</i>	<i>Innovation, platform, and business ecosystems</i>
Ecosystem outcome	Sustainable production	Urban amenity	New knowledge	New business models	Value proposition
Location Specificity	Location specific	Location specific	Mostly location specific	Location specific	Non-location specific
Ecosystem definition	Production of sustainable industrial goods and services in symbiotic collaboration and resource use	Collective production of sustainable urban amenities	Collective translation of advances in research knowledge into sustainable products and services	Collective facilitation of start-up and scale-up of entrepreneurial new ventures focused on sustainable business opportunities	Delivery of a sustainable value proposition through collaboration
Ecosystem actors	Manufacturers, service providers, resource providers, utilities	Utilities, local government, city government, transportation authorities, service providers, consumer–citizens residents	Universities, public research institutions, for-profit firms	Investors, accelerators, coworking spaces, makerspaces, educational and research institutions, government	Focal firm, complementors, suppliers, consumer-prosumers
Implications for agency	Embedded in the institutional and economic environment	Mostly embedded in the institutional and economic environment	Distributed among ecosystem actors	Distributed among ecosystem actors	Driven by focal actors via various coordination structures (such as platforms) and shared among the rest of the ecosystem members
Key source literature	Frosch & Gallopoulos, 1989; Korhonen, 2001; Lowe & Evans, 1995	Decker et al., 2000; Lovell & Taylor, 2013	Clarysse, Wright, Bruneel & Mahajan, 2014; Järvi et al., 2018	Isenberg, 2010; Autio et al., 2018	Adner, 2017; Iansiti & Levien, 2004; Jacobides et al., 2018; Thomas & Autio, 2020
Empirical examples	Eco-industrial parks; Eco3	Hiedanranta, Smart cities	Telakeju and textile waste circulation projects	FRUSH	Neste; Netlet; ResQ Club

Table 17.2 CE ecosystem implications

Ecosystem category	Material flow		Knowledge flow		Value flow
Definition	Ecosystems that enable sustainable energy and material flows within a geographically defined context		Ecosystems that enable the production of CE knowledge within a geographically defined context		Ecosystems that enable the sustainable production of economic value
Ecosystem type	<i>Industrial ecosystem</i>	<i>Urban ecosystem</i>	<i>Knowledge ecosystem</i>	<i>Entrepreneurial ecosystem</i>	<i>Innovation, platform, and business ecosystems</i>
Ecosystem outcome Application of 3R framework	Sustainable production	Urban amenities	New knowledge	New business models	Value proposition
	Production of industrial goods and services through resource recycling, reuse, or reduction	Delivery of sustainable urban services that recycle, reuse, or reduce resources	Creation of new knowledge related to resource recycling, reuse, or reduction	Creation of new business models that enable recycling, reuse, or reduction	Delivery and capture of value and competitive advantage through resource recycling, reuse, or reduction
Application in sustainability and CE context and key characteristics: Goal and rationale for existence Actors, structure and the agency	Focus on energy and material flows – often regional – between complementary companies	Focus on regional collaboration between the city/region and companies and consumer–citizens of the region: e.g. regarding municipality solid waste; wastewater, construction Often has links to the smart city approach	Focus on developing and sharing CE knowledge between diverse private companies and industry actors, and public organizations, including government institutions	Focus on generating and accelerating start-ups and new small businesses with support of multiple complementary actors that can include private and governmental actors	Focus on delivery of systemic value propositions by diverse value network actors that enable circular and sustainable business flow and exchange from production to delivery and the potential loop
	System aims for sustainable resource flows; materials and other resources are circulated efficiently in a local, regional system	System aims for sustainable resource flows; materials and other resources are circulated efficiently in a local, regional system	System aims to jointly solve grand challenges and develop knowledge that enables improving the sustainability of the individual actors and the system	System aims to develop and support new, more sustainable businesses in society	Systems aim to develop new, more sustainable businesses and turn resources and technologies into businesses

ecosystems as *a regional community of hierarchically independent, yet interdependent heterogeneous set of actors who sustainably produce industrial goods and services in symbiotic collaboration and resource use.*

An example of a CE industrial ecosystem is the eco-industrial park (EIP), which are established in regions to implement resource circularity at the meso-level (Martín Gómez, Aguayo González, & Marcos Bárcena, 2018; Uusikartano, Väyrynen, & Aarikka-Stenroos, 2021). Perhaps the most famous of these industrial ecosystems are Kalundborg in Denmark, Rizhao REDA in China, and the emerging Eco3 in Finland. EIP initiatives are usually undertaken by the public sector to drive sustainable methods of production in a certain sector, as well as improve overall business performance. In an EIP, multiple actors (such as manufacturing companies and service providers) collaborate by forming an industrial symbiosis. The purpose of an EIP is to improve economic performance through efficient utilization of resources, while diminishing waste generation and pollution. The industrial producers participating in an industrial symbiosis typically share energy, material flows, information, or other resources (Allenby, 2000).

Urban ecosystems refer to the built environment and infrastructure within which circular energy and material flows occur, and which consist of non-hierarchically related actors, such as utilities, local and city government, transportation authorities, service providers, and consumer–citizen residents. Theoretically, although many of the insights have been derived from the energy and material flow characteristics of industrial ecology (Bai, 2016; Decker et al., 2000; Morris, Weissburg, & Bras, 2018), these are transposed to the perhaps more complex urban environment. Urban ecosystems in CE settings are dominated by humans and focus on the inflow of energy, capital, information, and people, and not only consider how they can support the sustainable production of goods and services, but also consider the support of urban amenities, such as societal activities, quality infrastructure, and the physical environment. In CE settings, the level of sustainability within an urban ecosystem is driven by policy, governance, culture, and individual and collective behavior (Bai, 2016; Bonato & Orsini, 2018). We define CE urban ecosystems as *a regional urban community of hierarchically independent, yet interdependent heterogeneous set of actors who collectively produce sustainable urban amenities.*

Although much research has been conducted on urban ecosystems around the world (e.g. Decker et al., 2000; Zhang, Yang, & Yu, 2006), few scholars consider CE issues directly. An example of a CE-driven urban ecosystem is the city of Tampere in Finland that is building up the city district of Hiedanranta to produce more than it consumes. To achieve this ambitious goal, sustainable living labs, experiments and pilots develop and promote smart technology, urban sustainability, and CE solutions in the urban ecosystem. For example, the nutrient recycling living lab with a dry toilet system that includes about 20 toilets and urinals is a significant pilot project in Finland and the Nordic countries.

Flow of Knowledge: Entrepreneurial and Knowledge Ecosystems

Beyond resource flows, CE ecosystems can also enable the production of CE knowledge within a geographically defined context. Arising from the entrepreneurship literature, *entrepreneurial ecosystems* consider how actors can cultivate a shared knowledge base regarding “what works” in harnessing advances in digital technologies and infrastructures to develop novel sustainable business models (Autio & Thomas, 2018; Cohen, 2006). Relatedly, *knowl-*

edge ecosystems have arisen primarily in the innovation management literature, and feature the research and development of CE knowledge, reflecting the increasingly open processes of R&D and innovation (Bogers et al., 2017; Järvi et al., 2018; Von Hippel, 2007).

Ecosystems that consider the flow of knowledge are most often distributed in terms of agency. While some actors will have specific assets and technologies which are dependent on other actors, in general actor roles, and hence their level of agency, often emerge and evolve through ongoing negotiation and sensemaking between actors in the ongoing collaborative process of new knowledge creation (cf. Thomas & Ritala, 2021). Thus, in ecosystems typified by the flow of knowledge, the interdependencies between the actors are not necessarily fixed, and hence agency can also evolve. This is due to the fact that the ecosystem outcomes are often unknowable *a priori*, and hence the development of knowledge, technologies, and opportunities relies on multiple simultaneous, yet diverse, inputs by different ecosystem actors (Garud & Karnoe, 2003).

Entrepreneurial ecosystems in CE settings are regional entrepreneurial clusters where ecosystem actors harness the resource recycle, reuse, and reduction opportunities created by digital technologies to support the creation and scale-up of new ventures (Autio et al., 2018). Therefore, CE entrepreneurial ecosystems have sustainable business model innovation instantiated as new ventures as their system-level outcome. CE entrepreneurial ecosystems consist of venture capital, educational and research institutions, and the government, as well as specialized actors not found in other types of ecosystems, such as new venture accelerators, coworking spaces, and makerspaces, reflecting the specialization on facilitating business model experimentation and associated horizontal knowledge spillovers. Although CE entrepreneurial ecosystems are specific to CE settings, they are mostly focused on entrepreneurial opportunities outside the ecosystem (as opposed to being intrinsic to the ecosystem). We define a CE entrepreneurial ecosystem as *a regional community of hierarchically independent, yet interdependent heterogeneous set of actors who facilitate the start-up and scale-up of entrepreneurial new ventures focused on sustainable business opportunities*.

For example, in Finland, the Häme University of Applied Sciences and Forssan Yrityskehitys Oy collaborate through the FRUSH ecosystem to support growth and start-up enterprises around CE opportunities.² It organizes, for example, a national event and brings together growth-seeking enterprises, start-ups, investors, cities, university researchers, and students in diverse fields and disciplines.

Knowledge ecosystems refer to loosely coupled collectives where actors seek to develop new CE-related knowledge in a pre-competitive, pre-commercialization setting (Clarysse et al., 2014; Järvi et al., 2018). CE knowledge ecosystems are usually (but not always) regional research clusters consisting of non-hierarchically related actors, such as universities, public research institutions, and non- and for-profit firms (Clarysse et al., 2014; Järvi et al., 2018; Valkokari, 2015; van der Borgh, Cloudt, & Romme, 2012). In CE knowledge ecosystems, the actors collaboratively explore new knowledge about the CE as their central activity and outcome (Järvi et al., 2018; van der Borgh et al., 2012). We define a CE knowledge ecosystem as *a regional community of hierarchically independent, yet interdependent heterogeneous set of actors who advance the translation of advances in CE research knowledge into sustainable products and services*.

An example of a CE knowledge ecosystem is the Telaketju ecosystem aiming to generate knowledge and build businesses for a CE of textiles.³ Telaketju develops and shares understanding of novel CE opportunities aiming for better material efficiency and increased material

and product life in textile sectors, as well as business related to textile recycling, on national and regional levels. The ecosystem is organized through a continuum of projects that involve companies (e.g. municipal waste management and private waste management companies, fashion and textile companies, and service providers), non-profit organizations (such as organizations supporting the unemployed), municipalities, research institutes and universities, policy makers and regulators, funding providers, consumers, and media.

Flow of Value: Innovation, Platform and Business Ecosystems

Beyond CE ecosystems that focus on the flow of materials and knowledge, a third category of CE ecosystems focuses on the flow of economic value between actors. Derived from strategy research, *innovation ecosystems* are multi-stakeholder venues for the co-production of sustainable value propositions focused on reuse and recycling, or completely new innovation ecosystems created to focus on reduction. CE innovation ecosystems have a focal firm and a set of components (upstream) and complements (downstream) that support the focal firm to deliver the sustainable value proposition. CE innovation ecosystems have a clear supply–push emphasis (Adner, 2017; Adner & Kapoor, 2010; Hannah & Eisenhardt, 2018; Jacobides et al., 2018), but differ from conventional supply chains in that the sustainable value proposition depends on the availability of complementary products and services (Adner, 2017; Ceccagnoli, Forman, Huang, & Wu, 2012; Teece, 2018). CE innovation ecosystems often have a platform (thus, leading to the notion of the *platform ecosystem*) or a set of shared technological compatibility standards that enable actors to deliver the outcome (Adner, 2017; Autio & Thomas, 2014; Jacobides et al., 2018; Thomas et al., 2014). When the analytic emphasis is on the broad environment that a focal firm must monitor and react to, an innovation ecosystem has generally been called a *business ecosystem* (Thomas & Autio, 2020). We define a CE innovation ecosystem as *a community of hierarchically independent, yet interdependent heterogeneous set of actors who collectively deliver a sustainable value offering typified by resource recycling, reuse, and/or reduction*.

In ecosystems typified by a flow of value, often a dominant agency role is allocated to the central actor (also called a hub actor, keystone, or ecosystem orchestrator), who coordinates the ecosystem for the system-level outcome of a sustainable value proposition (Adner, 2017). In such ecosystems, other roles can be determined by the dominant agent, can be shaped by level of asset specificity of each actor, and can emerge through ongoing sensemaking between ecosystem actors (cf. Thomas & Ritala, 2021), or through some combination of all three. Thus, the nature of the interdependencies is shaped by ecosystem governance, which drives the agency of individual actors.

An example of a CE business ecosystem is Neste. Neste is an oil refining company, founded in 1948, that has approximately 5 000 employees and operations in 15 countries. The firm is listed on the Helsinki Stock Exchange. To produce renewable diesel, Neste reinvented its business ecosystem to collect more than ten different feedstocks from around the world. These feedstocks are then purified and processed in specialized refineries that have the technical capability to utilize 100% waste and residue fats and oils. An example of a platform ecosystem in the CE setting is Netlet, a start-up operating in the construction industry, whose business idea is to increase resource efficiency of usable construction materials and enable waste reduction among construction industry actors via a digital and physical platform.⁴ The Netlet value proposition involves collecting surplus materials from large construction indus-

try players before the materials become “waste” and selling them via its platform to smaller players and consumers. This provides cost savings for construction companies by cutting their waste management costs and creates a new supply chain for the surplus. By providing the service platform, the company and customers can reduce carbon emissions and participate in developing a CE ecosystem in the construction industry.

Now that we have discussed the diversity of CE ecosystems, we summarize the common pattern across the ecosystems and propose an inclusive definition of ecosystems in the CE that captures the key characteristics and commonalities but also allows variation to emerge.

A circular economy (CE) ecosystem is a multi-actor entity in which interdependent actors play complementary roles. Actors include for-profit companies, public services, governmental bodies such as ministries, municipalities and cities, universities, non-profit organizations, and citizen–consumers. A CE ecosystem emerges or is created around a common, system-level goal related to resource circularity, and may involve the creation of CE knowledge, CE businesses, and economic value. Agency varies from focal actor-driven ecosystems to being widely distributed, and the ecosystem structure varies from tightly coordinated CE business models to loosely coupled affiliation structures oriented around CE goals.

IMPLICATIONS AND FUTURE RESEARCH

In this chapter, we investigated the concept of ecosystems in CE settings. We have proposed that CE ecosystems can be grouped into three distinct categories, with five distinct types of ecosystems. We provided definitions for each ecosystem type and a comprehensive definition. Each category and ecosystem type have distinct characteristics, including ecosystem outcomes, location specificity, ecosystem actors, implications for agency, applicability to CE studies, and CE impact. We also detailed key theoretical literature and provided empirical examples of each. The typology illustrates how CE initiatives can be supported by various types of ecosystems, in which each build on distinct assumptions and scholarly traditions.

This chapter has a number of implications. First, the conceptualization of a CE ecosystem is a fundamental issue for any research project based on this theme. CE ecosystems can be characterized by features of different ecosystem types, as discussed in this chapter. The move to a CE requires a socio-technical transition that touches on actors across many levels of analysis (Geels, 2010; Geels & Kemp, 2007). Therefore, related ecosystem initiatives cannot be isolated, either. For this reason, many CE phenomena might comprise elements from different types of ecosystems – such as knowledge creation at the same time as a business ecosystem adopts circularity principles. This poses a major challenge for CE and ecosystem researchers. For this reason, we have included a heuristic that differentiates CE ecosystem types and proposed specific terminology to disambiguate the various CE ecosystems (see Figure 17.1 and Table 17.3).

First, our heuristic (see Figure 17.1) provides a clear exposition of the typology and is an easy-to-use tool that assists scholars and practitioners in identifying different types of CE ecosystems and in understanding their individual characteristics that also determine and shape actors’ interactions and ways of coping with the focal ecosystem. The proposed terminology is CE specific and should provide a robust baseline for future cumulative and theoretically coherent research.

Figure 17.1 *A heuristic to disambiguate CE ecosystems*

Table 17.3 *CE ecosystem terminology*

Term	Definition
CE Industrial Ecosystem	A regional community of hierarchically independent, yet interdependent heterogeneous set of actors who sustainably produce industrial goods and services in symbiotic collaboration and resource use.
CE Urban Ecosystem	A regional urban community of hierarchically independent, yet interdependent heterogeneous set of actors who collectively produce sustainable urban amenities.
CE Entrepreneurial Ecosystem	A regional community of hierarchically independent, yet interdependent heterogeneous set of actors who facilitate the start-up and scale-up of entrepreneurial new ventures focused on sustainable business opportunities.
CE Knowledge Ecosystem	A regional community of hierarchically independent, yet interdependent heterogeneous set of actors who advance the translation of advances in CE research knowledge into sustainable products and services.
CE Innovation Ecosystem	A community of hierarchically independent, yet interdependent heterogeneous set of actors who collectively deliver a sustainable value offering typified by resource recycling, reuse, and/or reduction.

Second, although we recognize the variety of CE ecosystems and provide empirical examples, how such ecosystems emerge and evolve remains a question. Where to draw the boundaries of the ecosystem, what is the relevant structure, and how the ecosystem evolves are important questions (see also Phillips & Ritala, 2019). All this boils down to the issue of *agency*. Agency in an ecosystem is determined by the role of the actor, which itself is often determined by the level of asset specificity or through an ongoing process of sensemaking and negotiation. As a consequence, different actors exercise agency in ecosystems. Sometimes, the agency is driven by powerful central actors, while, in other instances, the agency is distributed. In the CE, it is important to note that the agency of actors is fundamentally enabled

and constrained by both the specificity of the underlying assets of each actor (see Riordan & Williamson, 1985) and the institutional environment (see also Ranta et al., 2018). Thus, CE researchers should focus on the interplay between the agency of individuals and organizations with the essential institutional environment to understand and explain the emergence and evolution of CE ecosystems.

For managers and policy makers, we have shown how the agency of different ecosystem actors is constrained and enabled by the different ecosystems in which the actors operate. This can provide useful guidance for how to engage different actors and stakeholders in a common goal, how to structure interaction and collaboration in CE ecosystems, or how to organize and cope with diverse CE ecosystems with differing goals, structures, and rationales.

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NOTES

1. See <http://www.symbiosis.dk/> (accessed 5 April 2021).
2. See <https://frush.fi/> (accessed 5 April 2021).
3. See <https://telaketju.turkuamk.fi/en/front-page/> (accessed 5 April 2021).
4. See <https://www.netlet.fi/sv/hem/> (accessed 5 April 2021).

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