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Research Paper

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Actors and supply chain strategies in the circular economy: A guideline for circular business model design and innovation

The circular economy transforms fundamental, well-known business logics. To remain competitive and seize new business opportunities, companies are forced to implement innovative, circular business models. However, the current literature on circular business models still lacks a comprehensive perspective on options for companies to engage in various positions and functions along circular supply chains and how to develop corresponding business models. Therefore, a major challenge for companies remains in the identification of business opportunities, i.e., the positioning within emerging circular economy ecosystem, and how to adapt business models accordingly. Addressing this gap, this article provides a novel conceptual framework for circular business model patterns. First, the framework proposes three key actors (manufacturer, integrator, enabler) and three key supply chain strategies (creating, stretching, sustaining cycles) within a circular economy to derive nine circular business model patterns. Second, based on innovation strategies (closed, open) and intensities (low, high), this article characterizes four novel approaches to circular business model innovation. Finally, the framework is illustrated using the case of the emerging electric vehicle battery industry shifting towards a circular economy.

Introduction

For the past few years, companies have been increasingly facing a fundamentally transformative, socio-economic challenge: Sustainable values defined by environmental and social dimensions increasingly complement the dominant economic dimensions and drive the transformation of industries (Boons and Lüdeke-Freund, 2013; Joyce and Paquin, 2016; Lüdeke-Freund et al., 2018). Therefore, companies need to adapt internal business processes to provide innovative and sustainable products and services to customers, and align stakeholders with adapted strategies. In particular, established companies in manufacturing industries have been systematically introducing new strategies aimed at increasing sustainable value within the company and beyond (Kortmann and Piller, 2016). Regulations on sustainability and customer demand alike are forcing established companies and start-ups to innovate in order to seize upcoming market opportunities. A focus of corporates' innovative thinking and acting is the creation of a circular economy (Kirchherr et al., 2017; Kirchherr et al., 2023a; Kirchherr et al., 2023b). Compared to previous linear economies, the circular economy is based on a fundamental paradigm shift in economics and reflects new business logics for a more sustainable development (Stahel, 2016; Geissdoerfer et al., 2017).

Take, make, use, dispose - this is the conventional way in which companies 'do business' (Bocken et al., 2016), or simpler – "bigger, better, faster" (Geissdoerfer et al., 2017). The underlying paradigm of economic growth accomplished by increased production and consumption is linked to the irreversible and destructive exploitation of global finite resources, the increasing production of waste, and, eventually, the loss of material value. A circular economy can make economic growth

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independent of consumption and depletion of resources (Ellen MacArthur Foundation, 2013). The circular economy provides companies with new business opportunities by new value creation logics using alternative resources, such as waste, and alternative processes, such as repairing or reusing (Bocken et al. 2016; Lüdeke-Freund et al., 2018).

The relevance of a future sustainable economy has resulted in the circular economy receiving increasing interest from society, academia and industry, and has influenced policymaking (Bocken et al. 2016; Kirchherr et al., 2017). For example, caused by the fact that 40 million tons of waste ended up in landfills in California solely in 2019 (CalRecycle, 2019), the government of California initiated a comprehensive waste management program including recycling, reuse and reduce of waste. Similarly, to handle the current 2.2 billion tons of annual produced waste sustainably, the EU decided to intensify and expand waste management regulations towards a circular economy until 2050 (European Commission, 2023).

However, even if the regulatory foundations to engage in the circular economy have been laid, companies still struggle with seizing business opportunities and identifying strategies within circular supply chains across industries (Geissdoerfer et al., 2020; Bocken and Ritala, 2022). Thus, both start-ups and existing companies face challenges and opportunities for **re-positioning** and **re-aligning** in re-defined industries with innovative, circular business models. However, scholarly literature on circular business models still lacks a perspective on various actors - characterized by functions in supply chains - and supply chain strategies. Thus, so far, prior studies do not offer sufficient guidance for **re-positioning** in the circular economy and **re-aligning** business models.

The framework provided in this article addresses this gap and proposes two guidelines for strategic decision-making in developing and innovating business models within emerging circular economy ecosystem of a company's partners and stakeholders. First, we identify three key actors (manufacturer, integrator, enabler) and three key supply chain strategies (creating, stretching, sustaining cycles) within a circular economy and derive nine circular business model patterns that support companies in **re-positioning**. Second, by mapping innovation strategies (closed, open) and intensities (low/high), we propose a systematic guideline for companies to **re-align** based on four circular business model innovation approaches. Finally, we illustrate the derived framework of circular business model patterns and innovation approaches using a prominent case: the circular economy transformation of the electric vehicle (EV) battery industry.

Literature background: Supply chain strategies and actors in the circular economy and the emergence of circular business model concepts

Business models and the necessity to innovate them

The concept of the business model has been widely discussed and addressed in the literature in the past, and a large variety of definitions and characteristics have emerged as the concept has gained increasing interest (Zott et al., 2011). In general, a business model describes how a company "does" its business characterized by offering a convincing narrative to customer (customer value proposition) and achieving profitable numbers to sustain a business (Magretta, 2002). Fundamentally, every business model consists of three main elements: value proposition, value creation and delivery, and value capture (Richardson, 2008). By reflecting and realizing a company's strategies (Casadesus-Masanell and Ricart, 2010), the business model may be a main source of sustainable, competitive advantage (Magretta, 2002; Afuah, 2004; Teece, 2010). Thus, the development of an appropriate business model is essential for capturing new customer value for companies, thus, in achieving advantageous firm performances through the implementation of innovation (Chesbrough and Rosenbloom, 2002; Teece, 2010; Chesbrough, 2010). While established companies need to regularly assess and re-think current business models to sustain a competitive advantage through innovation (Chesbrough, 2010), for start-ups the business model represents "a core building block of the entrepreneurial enactment process" (George and Bock, 2011, p. 102). Therefore, to seize market opportunities, creating a business model is key in the entrepreneurial process. For example, Zott and Amit (2007) found that the performance of an entrepreneurial firm is enhanced by novelty-centered business models.

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Besides the strategic importance for companies, the business model can function as a unit of systematic analysis and external communication (Zott et al., 2011). Due to its importance but abstract and theory derived definition, several practical frameworks emerged to systemize and analyze business models for practitioner, such as the **Business Model Canvas** presented by Osterwalder and Pigneur (2010) consistent of nine building blocks, or the **four-boxes-framework** proposed by Johnson et al. (2008).

Although developing new business models pose many challenges for companies, business model innovation is important to capture value of innovative technologies by adapting existing business model and seize new business opportunities by creating new business models (Chesbrough, 2010; Osterwalder and Pigneur, 2010; Amit and Zott, 2012). Business model innovation is defined as "the search for new logics of the firm and new ways to create and capture value for its stakeholders; it focuses primarily on finding new ways to generate revenues and define value propositions for customers, suppliers, and partners" (Casadesus-Masanell and Zhu, 2012, p. 464). Institutionalized business model innovation processes can provide companies with a sustainable competitive advantage, enable companies to react on technology and market developments, and prevent disruption by other companies (Chesbrough, 2010; Osterwalder and Pigneur, 2010; Amit and Zott, 2012; Foss and Saebi, 2017). However, business model innovation gained a lot of attention from researchers and practitioners recently, but still lacks unified conceptualization and definition (Foss and Saebi, 2017). In industries and sectors shifting towards new customer value defined be environmental, social, and economic factors, business model innovation is crucial for companies to maintain competitive advantage by re-configuring internal capabilities to create, deliver and capture sustainable value (Boons and Lüdeke-Freund, 2013; Geissdoerfer et al., 2020). Thus, business model innovation is critical to leverage and implement the circular economy on an organizational business level (Rashid et al., 2013).

Circular economy

The circular economy is an "industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" (Ellen MacArthur Foundation, 2013, p. 7). The development towards a circular economy represents a fundamental, disruptive economic shift that changes the established model of production and consumption (Esposito et al., 2018). In the scholarly literature, numerous definitions of the circular economy emerged with different components such as supply chains strategies (Kirchherr et al., 2017). In general, the concept of circular economy is closely connected to sustainability, but fundamentally represents a means to enhance the sustainable transition of an economy or industry (Geissdoerfer et al., 2017). Thus, circular economy principles are widely applied in sustainability strategies by policymakers and companies to create a more sustainable economy towards separating economic growth from the consumption of natural resources (Ellen MacArthur Foundation, 2013), act in accordance with economic, social, and environmental value (Geissdoerfer et al., 2018), and address international sustainability guidelines, such as the 17 Sustainable Development Goals defined by the UN (United Nations, 2023).

All definitions imply the fundamental logic of eventually closing resource loops (Kirchherr et al. 2017; Geissdoerfer et al., 2017). However, individual definitions of the circular economy also include perspectives on systematic economy thinking to improve sustainability by including further principles, such as intelligent decentralization to increase systematic efficiency (Stahel, 2016), dematerialization by digitization of products to services to reduce material demand (Geissdoerfer et al., 2020), long-lasting products to enhance product value (Bocken et al., 2016), or sharing models to increase material usage efficiency (Geissdoerfer et al., 2020). Through these definitions, the range of supply chain strategies within the circular economy is broad. Next to recycling of waste and end-of-life (EoL) products and materials, other functions such as testing and determining product and material quality after use, remanufacturing, reuse, repair or repurpose provide companies with various options for implementing circular economy principles. In addition, new circular material flows require logistics from decentralized customers to centralized circular economy product or service providers to be re-thought to increase efficient linking of various stakeholders. However, the various strategies and functions pose

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managers and policymakers with issues of decision-making and prioritization, which is not sufficiently addressed by research so far either. First approaches by policy and research are based on prioritizing logics of waste reduction and recovery at the end of a products' life cycle resulting in a cascading of consecutive supply chain strategies, such as reducing, reusing, repairing, remanufacturing, and finally recycling (Achterberg et al., 2016; Campbell-Johnston et al., 2020; Kirchherr et al., 2023a).

By providing a broad variety of emerging supply chain strategies for use and EoL management of products and materials, the circular economy entails both challenges and opportunities for companies. First, new supply chain strategies result in emerging actors with new functions within value chains in circular economy ecosystems. The circular economy poses threats of disruption of existing industries by creating new circular technologies and processes (Kirchherr et al., 2023c) (e.g., repairing, reusing, or recycling instead of mining and processing raw materials). Therefore, successfully (re)positioning of companies is required to sustain competitive advantages. However, due to the nascent stage of the circular economy in many industries, it is still unknown what actors take on new tasks of reverse logistics, recycling, reusing, repairing or remanufacturing, and what partners and competitors will emerge based on different business models. Finally, companies face strategic issues of new positioning or integrating several value chain steps in existing and new industries or entering partnerships with emerging actors. Thus, new concepts for business models are required including various actors and supply chain strategies within a circular economy to inform strategic decision-making of managers on designing suitable business models.

Second, seizing new business opportunities within a circular economy requires adaptation of business models according to new supply chain strategies and actors. In the business model innovation process towards implementing circular economy supply chain strategies, companies are faced with numerous challenges, such as deciding on whether to adapt existing business models by considering individual business model elements or developing new business models. Furthermore, against the background of emerging actors in a circular economy, new cooperations and partnerships with suppliers and customers may be required that can influence business model innovation processes. Thus, concepts for business model innovation approaches in the circular economy based on innovation intensity and involvement of external partners are required further to inform managers on how to (re)align business models, which is not yet addressed by research in detail.

Circular business models and circular business model innovation

The term of circular business model emerged from the sustainable business model literature and raised interest of numerous scholars and practitioners, recently (Geissdoerfer et al., 2018; Bocken et al., 2014). A circular business model is defined as "how an organisation creates, delivers, and captures value in a circular economic system" (Den Hollander and Bakker, 2016, p. 2). Previous studies primarily showed different circular business model strategies and archetypes of circular business models and categorize them into frameworks (Geissdoerfer et al., 2020). The results conceptualize the term of circular business model theoretically, but also offer companies practical guides to develop circular business models, and thus support in engaging of circular value chains. For example, Stahel (2016) differentiated circular business model strategies into two types: the recovery of materials through recycling and the continued utilization of products through reuse, remanufacture, repair, upgrades, and retrofits. Bocken et al. (2016), however, defined three resource strategies for a circular economy (slowing, closing, and narrowing resource loops) and proposed different circular business models to implement these circular resource strategies, for example extending resource value or industrial symbiosis for closing resource loops. More recent frameworks also refer to the basic definitions and frameworks of the business model itself to realize circular strategies. Based on Osterwalder and Pigneur (2010), Lewandowski (2016) introduced the circular business model canvas which defines eleven key elements of a circular business models without showing circular strategies. Besides the nine building blocks of the Business Model Canvas, take-back system and adoption factors are proposed as further elements of a circular business model (Lewandowski, 2016). In contrast, based on a comprehensive review, Geissdoerfer et al. (2020) introduced four circular strategies (cycling, intensifying, extending, and dematerialising) and corresponding business models.

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In addition to categorizing circular business models, different approaches for practitioners to innovate their circular business model have been investigated initially. Circular business model innovation "incorporates principles or practices from circular economy as guidelines for business model design" (Geissdoerfer et al., 2020, p. 8). However, solely initial research on circular business model innovation has been conducted that primarily focused on different outcomes of circular business model innovation. For example, Geissdoerfer et al. (2020) proposed four types of circular business model innovation. Whereas processual perspectives on circular business model innovation primarily focus on the transformation of large and established firms towards circular economy (Frishammar and Parida, 2019; Suchek et al., 2022), and do not sufficiently provide various approaches of circular business model innovation for different actors and supply chain strategies in the circular economy.

Thus, prior research has focused on the developing of circular business model and circular business model innovation frameworks as practical guidelines for companies from a holistic view but neglect individual perspectives of various actors within the circular economy and designing and developing appropriate circular business models according to different supply chains strategies. Although the influence of circular economy characterizations, such as national and international policies, on different actors in circular value chains have been investigated (Ranta et al., 2018), there is still a lack of design and innovation of circular business models resulting in companies struggling to create business models according to positions and functions within a circular economy. This article aims to address this theoretical gap and managerial problem by providing a guideline for companies to support the design and innovation of corresponding circular business models.

Circular business model patterns: Mapping key actors and supply chain strategies

As shown, so far, established concepts and frameworks of circular business models lack a perspective on company functions or positions in circular economy supply chains. Based on initial differentiation between actors in the literature (Ranta et al., 2018), we define three key actors within the circular economy: **manufacturer, integrator** and **enabler** (Figure 1).

Manufacturers are companies that increase the value of materials and products that are ultimately delivered to the customer through processing. Manufacturers include various companies along a value chain that produce materials or manufacture intermediate and final products. **Integrator** refers to companies that take over EoL or waste products and, through various processes, guarantee the further use in form of products, individual components, or materials. These products, components, or materials can be integrated back into the value chain to manufacturers or users (customers). **Enablers** represent firms that support and enable the realization of a circular economy by providing key complementary services, for example, logistics or digital services. Compared to a linear economy, where service suppliers along value chains are also crucial for a profitable business model, the circular economy

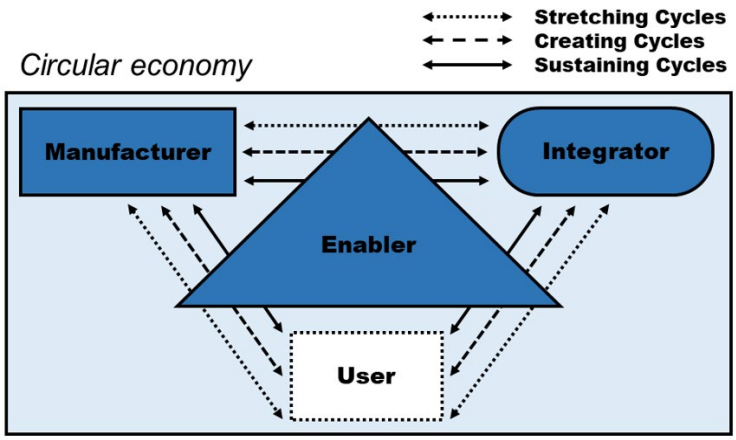

Figure 1: Key circular economy actors (manufacturer, integrator, enabler) and supply chain strategies (stretching, creating, sustaining cycles).

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poses additional challenges such as necessary reverse material streams back from decentralized customers, intensified collaboration, additional organizational efforts, and required data streams across actors that need to be supported by enablers.

Next to functions or positions, companies can engage in a circular economy by pursuing various strategies. Based on previous definition of circular economy strategies (Bocken et al., 2016; Geissdoerfer et al., 2020; Frankenberger et al., 2021; Morseletto, 2020), we propose three supply chain strategies: **creating, stretching,** and **sustaining cycles** (Figure 1).

The supply chain strategy of **creating cycles** refers to the different ways of finally returning EoL and waste materials and products back into value chains. EoL and waste materials and products can be reintroduced to manufacturer at various points along the entire value chain. In recycling, products are broken down into individual materials in order to serve as basic resources for products of equal or other applications and industries (so-called 'upcycling' or 'downcycling'). In remanufacturing, products are rebuilt for the same use. For this purpose, discarded products are broken down into sub-products, which are then reassembled to the original product by combining them with new or repaired individual components. In contrast to recycling, in the remanufacturing process products are not fully broken down to a material level but disassembled into components. Thus, remanufactured products are returned to manufacturers located further downstream in the value chain compared to recycled products or materials (Achterberg et al., 2016). Finally, in refurbishing, products are subjected to a quality-assuring overhaul and restoration for the purpose of further use and remarketing. Refurbishing also includes the reconditioning and renovation of individual defects in the functions or characteristics of products that are rather simple to remove.

Stretching cycles includes reusing, repairing, and prolonging as well as guaranteeing an intentionally long life (longevity) of products or individual components. Reusing is the process of continuing to use products in similar applications or other applications of similar functional models after they have been deployed in a first-life application. Reusing is often preceded by a quality check to determine optimal options for further use. During repairing, in particular, the cycles of individual components are stretched. Defective individual components or products are processed by means of repairing to ensure further use in the intended application. In repairing, as in reusing, products and individual components are not returned to the value chain but are returned or sold directly to users or customers. Prolonging focuses on long use through optimal utilization. The principles of prolonging include maintenance and monitoring of the functions and performance of individual components or products in order to extend their service life and maximize efficiency. Longevity, on the other hand, refers to the intentionally long-lasting design of products and the avoidance of defects by ensuring quality assurance in advance.

Sustaining cycles refers to strategies that support, improve, and ensure existing cycles. Strategic options include reducing, regenerating, restoring, co-using, digitalizing, and connecting. Existing cycles are dependent on the flow of materials and the reintegration of products. Cycles can be stabilized and made more sustainable by reducing the number of materials used or related factors such as energy requirements. The principle of reducing is a cornerstone of sustainable strategies and is considered as a fundamental strategy of the circular economy (Kirchherr et al., 2017; Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2013). Regenerating and restoring primarily relate to strategies for balancing or absorbing linear depletion through reverse linear processes (Salonen et al., 2025). In these strategies, materials are partially extracted from existing cycles and reintegrated as a natural reserve. This concept, which is still in its early stages, can primarily be found in energy (e.g., water/hydrogen) and biological (re-planting) cycles. Co-using intends to increase the efficiency of use of products and materials and thus save additional necessary resources. Classic sharing, reservation, or multi-way models are examples of co-using for both individual users and companies. Digitalizing aims to replace physical transactions and activities with digital services and processes. Digitalizing not solely allows material and product requirements to be reduced, but also helps to map and support complex inter-actor processes in a circular economy. Finally, connecting describes the support of processes within the circular economy in order to link individual activities and actors within one or more cycles and, thus, make product and material cycles more efficient and sustainable.

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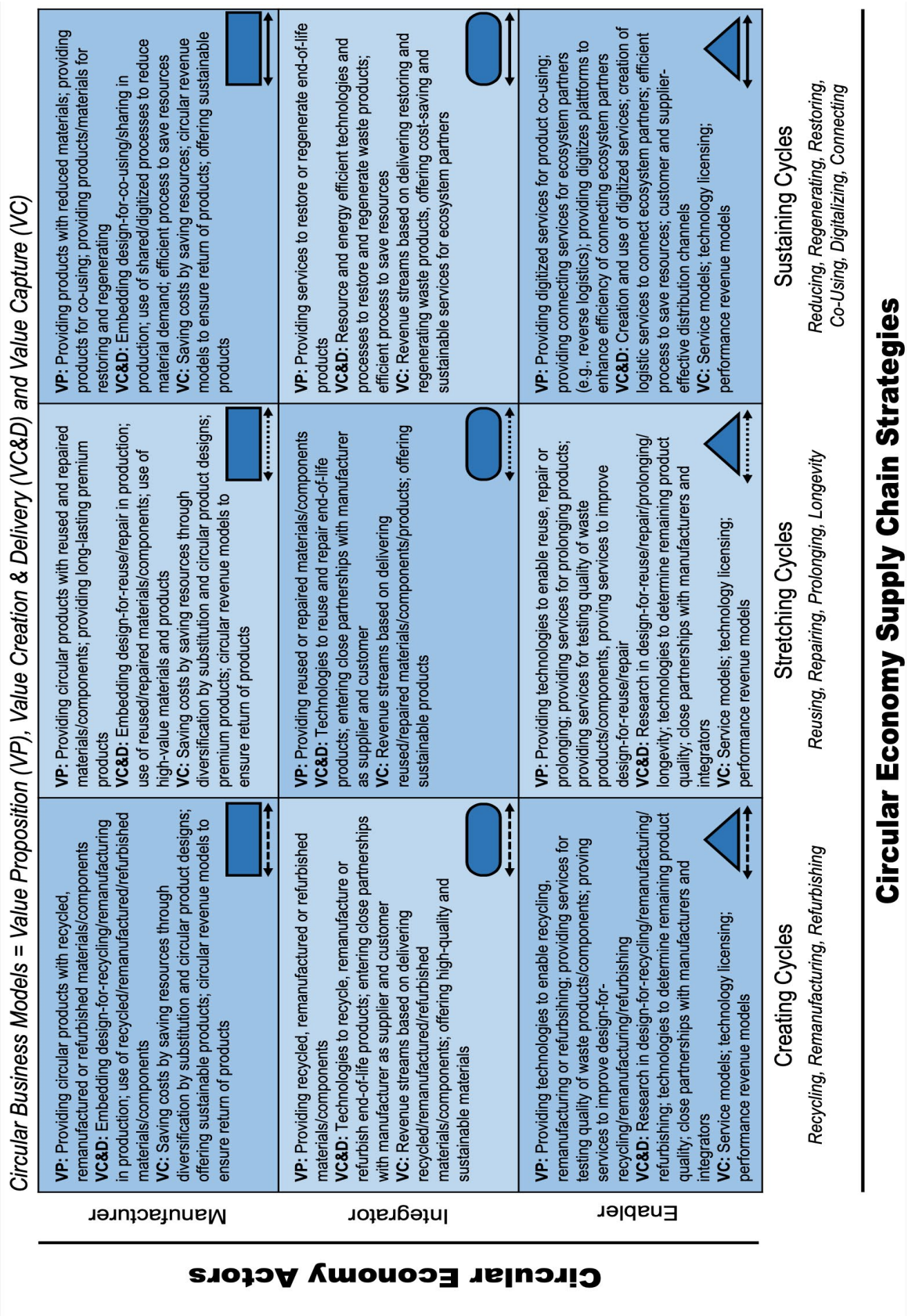

Figure 2: Nine circular business model patterns.

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By mapping actors and supply chain strategies, we propose a novel concept of nine circular business model patters, shown in Figure 2. These patterns provide a practical guideline to develop suitable circular business models defined by various value proposition and logics for value creation and delivery and value capture (Chesbrough and Rosenbloom, 2002; Richardson, 2008; Osterwalder and Pigneur, 2010).

Furthermore, the nine circular business model patterns demonstrate which types of circular business models and corresponding characteristics of their elements are suitable in the respective circular economy strategies (creating, stretching, and sustaining cycles) for key actors (manufacturer, integrator, and enabler) in the circular economy. However, companies may opt for developing multiple business models and, thus, are not limited to individual strategies and functions within the circular economy. For example, companies may pursue multiple supply chain strategy options to capture value, such as recycling and reuse, depending on remaining quality and inherent value. In addition, vertical and horizontal integration of companies into positions and strategies within the circular economy leads to the integration of new circular business models and diversification of an existing business model portfolio through the design options of circular business models shown in Figure 2.

Four strategic options for circular business model innovation

Although the derived circular business model patterns show various outcomes for business model development processes, it does not yet contain a perspective on how companies may innovate their business model to adopt a suitable circular business model pattern. Companies can develop a circular business model applying various options of circular business model innovation. We derive options for circular business model innovation by answering two key questions: (1) 'How intensively should or must the business model be adapted towards a circular economy?' and (2) 'Should a company approach innovation from resources within the company or should external partners be involved in the innovation process?' Thus, we categorized circular business model innovation by **circular business model innovation intensity** (1) and **circular business model innovation strategy** (2).

Circular business model innovation intensity refers to how radically the business model is to be adapted. The business model is a configuration of the different elements or building blocks of value proposition, value creation and delivery, and value capture. Within these elements, further sub-elements or characteristics can be defined - for example, cost structure and revenue streams within value capture or key resources and partners within value creation elements (Osterwalder and Pigneur, 2010). A low-intensity, or incremental, circular business model innovation can therefore relate to individual elements or characteristics of these elements. High-intensity, or radical, circular business model innovations, on the other hand, may affect the entire architecture of elements in an existing business model. The advantages of low-intensity circular business model innovations are, for example, low risk and the efficient reuse of internal resources and knowledge, whereas high-intensity business model innovations offer access to new markets and may provide further profit and growth opportunities.

Circular business model innovation strategy comprises two fundamental approaches to innovation: closed and open. The concept of open innovation developed by Chesbrough (2003) is characterized by the inclusion of external stakeholders in the innovation process. In contrast to closed innovation, in which companies carry out the innovation process internally without external partners, the results of open innovation are usually not limited to individual companies but are rather intended to be used across firm boundaries (Chesbrough, 2003; Chesbrough, 2010). Closed innovation primarily offers companies control over processes (Bocken and Ritala, 2022), whereas open innovation promises more efficient incorporation of customers' and partners' demand as well as stable integration into complex emerging ecosystems such as a circular economy.

Figure 3 maps circular business model innovation intensity and strategy to derive four options for circular business model innovation: **circular re-configuration, circular re-design, circular co-configuration,** and **circular co-design**.

Circular re-configuration, as proposed here, corresponds to the internal reorganization of the business model by adapting individual business model elements to implement circular economy principles. Circular re-

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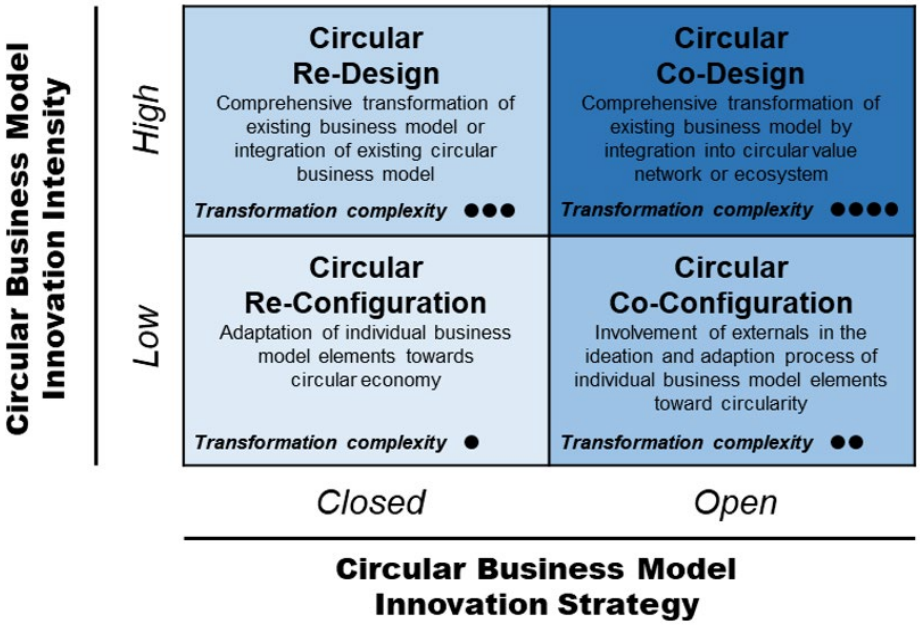

Figure 3: Four strategic options for circular business model innovation.

configuration, for example, can be realized within value creation and delivery by replacing linear resources with circular materials from recycling or reuse. Another option is to convert revenue streams within the value capture towards access or leasing models to ensure the return flow of products. Individual elements can generally be adapted incrementally using the options outlined in the circular business model positioning framework in Figure 2.

Circular re-design represents the holistic and comprehensive transformation of the business model, in which all the elements of value proposition, value creation and delivery, and value capture of a business model are newly defined and tailored simultaneously towards the circular economy through internal processes. In addition, circular business models can also be integrated into the existing business model portfolio through a company's own activities in spin-offs (diversification) or acquisitions (Geissdoerfer et al., 2020).

Circular co-configuration refers to the involvement of individual external participants in a circular economy, such as customers or partners, in the active development of new business model elements. Accordingly, the customer can be involved in the circular business model innovation process in order to redefine and adapt the value proposition, often also referred to as customer co-creation (O'Hern and Rindfleisch, 2010). Furthermore, for example, circular co-configuration can be used to redefine value creation by suppliers of materials in terms of circular principles and find joint solutions. Organizational forms of circular co-configuration can include, for example, the establishment of joint ventures.

Circular co-design, in contrast to circular co-configuration, involves the adaptation of the entire business model with partners and stakeholders in one or more circular supply chains and therefore requires the adaptation and integration of the business model into a circular value network or ecosystem. Due to the complex structures and difference of various players, the circular business model innovation as circular co-design takes place holistically and with the involvement of various actors and stakeholders in the value network (Zott and Amit, 2010; Centobelli et al., 2020) or ecosystem (Murray et al., 2017; Adner, 2017; Konietzko et al., 2020; Pietrulla and Frankenberger, 2020).

The case of the electric vehicle battery industry: A transformation towards circular economy

A prominent example for an emerging industry shifting towards a circular economy is the EV battery industry. The EV battery industry is rapid developing by technology adoption, corporate strategies, and shifting external boundaries, while new actors and supply

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chain strategies emerge to increase sustainability by integrating circular economy principles. Although product life cycle studies generally show that electrified mobility is environmentally beneficial compared to combustion-engine vehicles, the current linear sourcing of battery raw materials still pose major challenges for a sustainable industry (Wesselkaemper et al., 2024).

Today, battery raw material mining is associated with social issues for local workers and residents (e.g., artisanal cobalt mining in DR Congo (Nature, 2021; Baars et al., 2021), requires vast amounts of water (e.g., lithium mining in South America (Nature, 2021; Haddad et al., 2023), and consumes considerable energy in global transportation (e.g., most refining process and capacities in battery production are currently located in China (Cheng et al., 2024). Moreover, raw materials are main battery (Wesselkaemper et al., 2026; Gutsch and Leker, 2024) and EV cost drivers (Mauler et al., 2021), caused by rising and fluctuating prices (e.g., the nickel price exploded in March 2022 due to the Ukraine-invasion of Russia, a large nickel producer (Nature, 2021).

To improve the sustainability of EVs, policymakers and companies increasingly adapt a circular economy of EV batteries and their materials. Circular economy principles such the remanufacturing, recycling, and reuse of batteries make battery supply chains less dependent on environmentally, socially, and economically critical raw materials like lithium, cobalt, and nickel (Wesselkaemper et al., 2025). Global regulations, such as the Inflation Reduction Act in the US (Trost and Dunn, 2023), electrification and recycling targets in California (Wesselkaemper et al., 2025), or the updated EU Battery Directive (European Union, 2023), are promoting EV sales, while supporting an EV battery circular economy and corresponding circular business models. Driven by the shift of the cost-sensitive EV industry towards a circular economy, established companies, such as German car producer Volkswagen, Belgium recycler Umicore, Swiss mining giant Glencore, Chinese EV battery production market leader CATL, or US-based manufacturer GM, are trying to re-organize and re-define positions by exploiting innovative, circular business models. In addition, due to emerging market opportunities, the industry faces a vast majority of entrants, including numerous Chinese EV and battery manufacturers like Nio and BYD, emerging recyclers like Ascend Elements (US), Cylib (Germany), or Brunp (China), and companies integrating multiple steps in circular supply and value chains like Redwood Materials (US), which tries to couple recycling and reuse with its battery production business model. Furthermore, new market opportunities attract innovative business models like platforms (e.g., offered by the German start-up Circunomics) supporting efficient circular material flows by linking waste supplier and customers, and required reverse logistics systems after use phase to guarantee the reintegration of waste materials back into the value chain. These examples underline the ongoing development of business models suitable for a circular battery economy, despite of companies facing major challenges in innovating circular business models in emerging circular economy ecosystems (Wesselkaemper and von Delft, 2024).

Given this transformation, in the following, the case EV battery industry is used to illustrate companies' positioning strategies in an evolving circular economy, corresponding circular business models patterns (see Figure 2), and applied circular business model innovation options as derived in this study (see Figure 3).

Nine circular business model patterns in the EV battery industry

Creating cycles in the EV battery industry is currently primarily focused on the recycling of batteries as an influential shift in value proposition, value creation and delivery, and value capture of various business models. Large EV manufacturers such as Tesla and VW, as well as EV battery manufacturers such as CATL, LG Chem and Panasonic, are continuously integrating recycling as circular economy strategies into their own business models. Tesla and VW, for example, are currently building own battery factories (so-called gigafactories) that produce EV batteries in which production follows a design-for-recycling approach to simplify battery disassembly and recycling after use. In this way, manufacturer transform their value proposition. Additionally, in new key processes within the value creation logic, battery materials are planned to be increasingly sourced from recycling, which is why recyclers have been identified as key suppliers by manufacturers, strengthening collaboration with both integrators and enablers as key partners in a circular economy. Even though many manufacturers strategically aim to integrate recycling into their own portfolio, which offers extended value propositions

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and value creation and delivery, a large proportion of spent EV battery materials are received by recycling companies (integrators). Recycling integrators such as Ascend Elements or Redwood Materials offer value propositions to suppliers and customers characterized by services for handling and recycling spent batteries to secondary materials such as lithium, cobalt and nickel supplied to their customers, i.e., manufacturers. By implementing new, circular revenue streams such as recycling-as-a-service, value capture and delivery is enhanced. Similarly, partially defective batteries are dismantled and remanufactured as part of value proposition and creation of integrators such as Redwood Materials, or manufacturers such as Nissan. By reassembling, batteries can be sold directly to EV manufacturers without passing manufacturing, saving costs and supporting the value capture logics of various stakeholders. Next to manufacturer and integrator, enabler emerge. For example, the Luxembourg-based start-up Circu Li-Ion supports creating cycles of batteries through an automated technology that tackles current challenges of complex spent battery disassembly. By providing a so-called machine-as-a-service, Circu Li-Ion acts as an enabler with its value proposition of providing technology to manufacturer to remanufacture batteries, and to integrators to recycle batteries more efficiently. Next to disassembly, another operating challenge in circular material flows is the transport of hazardous batteries after EV life from customers to manufacturers and integrators. Driven by varying regulations, this requires special knowledge on spent batteries and logistics, which offers new value proposition opportunities for actors. Both integrators and enablers are approaching this challenge and try to seize opportunities with innovative business models. Various recyclers partner with local reverse logistics provider to transport decentralized customers' EV batteries to recycling plants. For example, though having filed bankruptcy recently, Li-Cycle has approached an innovative value creation model, the so-called spoke-and-hub model, by regionally splitting the recycling value chain supporting value capture by reducing costs.

Stretching cycles in the EV battery industry is mainly characterized by reuse strategies and design strategies for long-life EV batteries (longevity). Various battery manufacturers, such as Tesla or the Chinese start-up Nio, increasingly focus value propositions on long-life battery technologies. For example, Nio supports longevity with new value creation and delivery and value capture logics that involve exchanging discharged with charged batteries with bespoke swapping infrastructure. By regularly checking the batteries after replacement, battery lifetimes can be extended (prolonging) and battery parts can be replaced through repairing if necessary. The integration of design-for-longevity of batteries and battery technologies into the value proposition and value creation also often implies a prolonged usability of batteries after EV life. In the reuse of EV batteries, 2nd use, batteries that no longer meet the performance requirements of EVs at the end of their life cycle are reused in applications with lower performance requirement profiles. These include applications in balancing and absorbing grid loads, in stationary home storage systems or in charging infrastructures. Manufacturers, integrators and enablers alike have implemented reuse in existing business models or are currently developing new business models for reuse. As an EV manufacturer, Renault, for example, offers new leasing models in the value capture logic that guarantee the return of batteries to the manufacturer, which, in turn, supports value delivery. Discarded batteries are sold by Renault generating new revenue streams and installed in large-scale energy storage systems to capture business opportunities driven by growing applications in grid usage and stationary energy storage. In addition, Renault diagnoses its own returning batteries to be able to repair individual defective parts of the battery, thereby continuing to stretch cycles by applying new value creation logics. In the B2U, integrators act as users of stationary battery storage systems who increasingly rely on the application of spent batteries. One example is the Finnish company Fortum, which aims to use energy storage system solutions from spent EV batteries to store energy from hydropower plants, relieving grid loads while generating revenue. The battery industry is seeing an upswing in new enablers whose business model consists of taking old EV batteries, testing them, and repurposing and selling them for reuse in large-scale applications. Particularly young start-ups, such as Voltfang from Germany or B2U Energy Solutions and RePurpose Energy from the US, are developing business models to profit from stretching EV battery cycles through reuse by new value propositions and value capture and delivery logics. The German start-up Betteries, for example, reuses EV batteries to produce mobile stationary storage systems for usage in remote

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locations around the world. In addition, Betteries ensures recycling in the end of the reused battery life by a battery-as-a-service revenue model.

Finally, **sustaining cycles in the EV battery industry** is characterized by a diverse strategy field in which manufacturers, integrators and enablers operate through a variety of business models. Potentially, with sufficient supply of secondary materials from recycling, companies may consider restoring and regenerating of critical battery materials, but business models for these strategies are comparatively unexplored and not yet being applied. However, other strategies in sustaining cycles, reducing, co-using, digitizing and connecting, are found in the EV battery industry. The reduction of materials used in batteries is particularly important among manufacturers. Many of the materials are either very expensive (e.g., cobalt, nickel, lithium) or hazardous, which effects value capture. Therefore, manufacturers are looking for novel production methods to reduce materials and minimize waste through cyclical material flows in production implying new circular value creation logics. Besides reducing the extensive use of water through capturing and reusing, one example of this is the reduction of expensive, toxic and environmentally harmful liquid solvents in the process, which can be drastically reduced by so-called dry coating methods, such as explored by VW, innovating value creation logics. Next to reducing, several manufacturers have implemented co-using business models by car-sharing models in urban areas to intensify and optimize the material usage and requirements of charging infrastructure by applying new revenue streams in the value capture logic. This may be further optimized through innovative value propositions and additional revenue streams such as vehicle-to-grid solutions, in which the EV battery is source of power for grid loads, and which manufacturer like VW investigate. Services provided by manufacturers, enablers and integrators are also increasingly being made more efficient through digitalization and become attractive for customer. EV manufacturer Porsche, for example, uses digital twins of vehicles to optimize maintenance and design processes and, thus, save resources in key processes of value creation. As an enabler, Circunomics creates digital battery twins that contain information along the value chain to sustain other circular strategies such as recycling or reuse, thereby offering new value propositions and value creation and delivery logics. In addition, Circunomics sustains cycles by connecting material cycles of batteries. Using a platform business model, Circunomics connects suppliers and customers of used batteries (value proposition) to optimize the efficient reuse of batteries between multiple stakeholders along the battery value chain. As enabler, besides the disassembly technology, Circu Li-Ion also provides a battery diagnosis technology for sustaining battery cycles, saving resources and increasing efficiency.

Four circular business model innovation options in the EV battery industry

Circular re-configuration in the EV battery industry often is the first step to integrate circular economy principles into their business models of established companies. As mentioned in numerous examples above, individual elements of the business model are realigned to realize a circular economy. Examples of this include the circular re-configuration of value capture logics at Renault by switching to a leasing model and generating new revenue streams from the sale of discarded batteries to reuse integrators and enablers. Other cases of circular re-configuration are the switching to the use of circular, recycled materials, and the establishment of material cycles in the production of EV and battery manufacturers.

Primarily, examples of **circular re-design in the EV battery industry** can be identified in the large number of new integrator and enabler start-ups that are tailoring the entire business model to a circular economy by establishing a new circular business model. However, start-ups such as Cylib or Redwood Materials, as well as established companies such as Tesla, Daimler, and VW, are also integrating new circular business models through diversification, as they aim to recycle batteries independently in the future. Redwood, which is currently primarily active in the reuse and recycling of batteries, intends to produce battery materials itself from the recycled materials in future, thereby independently establishing and integrating an integrated business model in the battery cycle. Redwood also provides an illustrative case of business model innovation by acquisitions. By acquiring the German recycler Redux, Redwood diversified the company into new markets in Europe, in the course of which new circular business models are being integrated into the company.

Circular co-configuration in the EV battery industry is currently a common approach for companies

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to integrate circular principles into their business model and participate in a newly emerging circular economy. In particular, joint ventures are emerging from a wide variety of partners to create synergies and share knowledge to remodel individual elements of business models. For example, the US-based recycler Redwood, General Motors, and the South Korean battery manufacturer LG Energy Solutions formed a partnership to jointly recycle battery production waste in an energy-efficient manner. Another example is Fortum, which, as mentioned above, reuses batteries to store energy from hydropower. On organizational level, this is realized through a joint venture with EV manufacturer Volvo Cars and the cleantech company Comsys.

Finally, **Circular co-design in the EV battery industry** has not yet been realized. Main reasons are complex circular systems around EV batteries and their redefinition of material flows through reuse, repair, remanufacture or recycling, for example, have yet to be established and mature in the next decades. Companies that want to participate in this complex system of multiple cycles in the future through a corresponding business model will be forced to coordinate their business model with varying players to be able to deliver added value to the value network or ecosystem.

Discussion and implications

Theoretical implications

This article offers theoretical contributions on circular business models and circular business model innovation. Business model innovation is a key driver for sustaining competitive advantages in known industries, realizing successful strategies in emerging industries, and creating value for companies and customer from new technologies and product innovations. As shown, thus, the new economic logic and paradigm of circular economy forces companies to create innovative, circular business models to implement circular strategies and introduce new processes, products or services based on new customer value. A circular economy offers a wide variety of strategies based on the fundamental aim of efficient and sustainable cycling of EoL products, intermediate components, or raw materials. The economic cycling principle requires new value chain activities that emerge and, therefore, offer companies new integration and market opportunities. Although academic research has addressed this issue with first practical guidelines of circular business model development, a key perspective on different actors and supply chain strategies within a circular economy and corresponding resulting business models has been lacking so far. As a result, although initial circular business model patterns emerge in industries, companies still struggle in developing business models according to new positions and functions based on different circular supply chain strategies. This study takes on this gap and offers a practical guide for the development of circular business models by providing a value-chain positioning perspective of actors and strategies. Three fundamental circular economy strategies (creating, stretching, and sustaining cycles) and three key actors (manufacturer, integrator, and enabler) are identified and mapped to derive novel circular business model patterns. This guideline provides nine patterns of circular business models, and their element characterization options for value proposition, value creation and delivery, and value capture. Furthermore, strategic options for companies to approach circular business model innovation are proposed. Based on different circular business model innovation strategy (open, closed) and intensity (low, high), four circular business model innovation options are defined: circular re-configuration, circular re-design, circular co-configuration, and circular co-design.

Managerial Implications

The conceptual guideline for circular business model design and innovation presented in this article have several practical implications for managers and practitioners of established companies as well as for entrepreneurs and start-up managers. The business model patterns and innovation strategies improves managers' understanding of business model options offered by the circular economy based on different functions of actors and supply chain strategies. The guideline presented can be applied by firms that face major industrial transformations to a circular economy or aim to seize new business opportunities in an emerging circular economy. However, the application of the framework has different implications for managers and companies, dependent on whether the circular business model development process of an established company or a start-up is aimed at.

Primarily, an established company must develop circular business models in mainly two scenarios. First, companies adapt their established business

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model according to current positions in the industry to further sustain their competitive advantage in a circular economy by, for example, manufacturing products or intermediate components. The proposed guideline offers several implications for the development of the circular business model. On the one hand, it proposes circular business model transformation outcomes by providing business models element options characterized through value proposition, value creation and delivery, and value capture. On the other hand, it supports strategic decision-makers in the understanding of how other players in the industry can develop their business models based on current or future position and functions in value chains. This supports companies in identifying suitable position within the circular economies, and, furthermore, provides a guideline to inform whether strategies and business models of former partners are aligned with the targeted circular business model, laying the foundation to identify new partners and stakeholders that fit to business models, which is required to succeed in complex networks and ecosystems of emerging circular economies.

In the second scenario, established companies seek to integrate circular value chain steps or functions (e.g., integration of enabler or integrator activities by a manufacturer) or supply chain strategies (integration of stretching and creating cycles through reusing and recycling of materials simultaneously). In this scenario, the presented guideline offers a structured approach to assess current business models and mapping new circular business model options based on the integration of additional functions or supply chain strategies. This article informs managers and practitioners about business model patterns, what elements characterize them, and which beneficial or disadvantageous capability, stakeholder and resource allocation potentials arise to improve outlining integration strategies and derive requirements for horizontal and vertical integrations.

In both scenarios, understanding circular business models patterns of the focal firm, partners and competitors is essential. In addition, the proposed four circular business model innovation options (circular re-configuration, circular re-design, circular co-configuration, and circular co-design) offer a strategic guideline on how to tackle circular business model development. A transforming as well as an integrating company face circular business model innovation challenges that arise from key issues of closed or open business model innovation and incremental (low intensity) or radical (high intensity) business model innovation diversity. The guideline identifies different options for managers and practitioners and characteristics of these options along with transformation complexity. Thus, the proposed guideline supports the transitions leading from circular re-configuration to circular co-creation.

Finally, this article supports entrepreneurs with the creation of new start-ups in a circular economy by providing nine circular business model patterns. These patterns serve as a tool to categorize different actors and supply chain strategies in the industry and support the assessment of potential competitors and partners in order to successful engage in an industry shifting towards a circular economy. Against the background of transformation and integration challenges of established companies, managers of start-ups can design business models according to different positions and supply chain strategies within the new circular economy from the outset.

Outlook

As new principles and business logics arise from the circular economy, companies are still struggling to position themselves in new circular economies and to develop suitable circular business models accordingly. In this article, we derive nine circular business model patterns based on three key actors (manufacturer, integrator, and enabler) and three key supply chain strategies (creating, stretching, sustaining cycles) in a circular economy. Further, we propose four approaches to circular business model innovation considering innovation intensity (low, high) and strategy (open, closed): circular re-configuration, circular re-design, circular co-configuration, and circular co-design. In doing so, this article aims to inform managers and practitioners in strategic decision-making of circular business model development processes. Although, as shown, these patterns and innovation options are found in current industries transforming towards the circular economy, such as the EV battery industry, they are not mutually exclusive and can be integrated in several ways by established companies and start-ups that try to seize new business opportunities.

Overall, the guideline presented in this article contribute

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to academic literature that results in managerial problems by providing a perspective on different actors engaging in different supply chain functions and corresponding business models based on supply chain strategies, as well as a approaches to circular business model innovation. However, the early status of the emerging circular economy in various industries is constantly facing scholars and practitioners with challenges and opportunities. Thus, the provided patterns should be applied in the strategic circular business model development process and further integrate established and emerging concepts against the background of the rapidly developing, reactionary, and complex networks within circular economies.

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