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From circular business models to circular business ecosystems

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Abstract

The circular economy aims to minimize resource inputs and waste and emission outputs of the economy and its organizational subsystems. This can benefit both financial and sustainability performance of companies. To analyze industrial implementation of the concept, the prevalent unit of analysis on the firm level is currently the circular business model. Our investigation of nine Swedish biogas companies and one branch organization indicates a range of conceptual shortcomings that challenges this approach. Our comparative case analysis points towards circular ecosystems being a more appropriate concept to describe the high level of coordination between different stakeholders necessary to implement circular systems. This increases the suitability to analyze, plan, and communicate circular economy systems on an organizational level, especially if value chain integration is low. An ecosystem perspective can thus support innovation and entrepreneurship in the context of the circular economy.

KEYWORDS

biogas, business ecosystems, business models, circular business models, circular economy, circular ecosystems, sustainability, unit of analysis

1 | INTRODUCTION

The circular economy continues to gain attention among policy makers, businesses and researchers (Pieroni et al., 2019). For example, the European Union (EU) and several governments including those in China, Finland, France, Japan, the Netherlands, the United Kingdom, and Sweden promote CE as an approach to transform the linear "take-make-dispose" economic model to an economy based on closed production and consumption systems (Korhonen et al., 2018). Similarly, businesses, including Google, Unilever, and Renault, advocate for the CE (Bocken et al., 2017). The discourse on the circular economy has resulted in numerous scientific articles and consultancy reports (Geissdoerfer et al., 2017).

Accounts of the circular economy distinguish between biological and technical cycles (Bocken et al., 2017). The biological cycles encompass materials from biological sources that can be safely returned to natural systems as well as the valorization of different kinds of organic material to produce energy (Hagman et al., 2019). Technical cycles contain synthetic materials intended to be used repeatedly while sustaining their value (Bocken et al., 2017). CE thus emphasizes product, component, and material reuse, sharing, refurbishment, remanufacturing, repair, cascading, and upgrading, as well as renewable and waste-derived energy utilization throughout the product value chain and cradle-to-cradle life cycle (Korhonen et al., 2018). Therefore, in essence, the aim of developing a circular economy is to slow and close resource cycles to reduce the amounts of natural resources extracted, waste disposed of in landfills, and greenhouse gasses emitted to the atmosphere.

Concepts around a circular economy are not new. Circular economy has its theoretical foundations in industrial ecology and related concepts (Blomsma & Brennan, 2017). In the 1990s, the Swedish government made a proposal for societal development based on eco-cycle and cradle-to-cradle thinking (The Swedish Parliament, 1992). Later on, Ayres and Simonis (1994) introduced the idea of industrial metabolism in which the metabolism of industry is the whole integrated collection of physical processes that convert raw material and energy plus labor, into finished products and waste in a (more or less) steady-state condition. Further on, McDonough and Braungart (2002) introduced the "cradle-to-cradle" concept, suggesting that industry should strive to preserve and enrich nature's biological metabolism while maintaining a safe and productive technical metabolism for high-quality use and circulation of organic and technical nutrients. The power of the circular economy concept is its ability to build synergy between previously related concepts and attract policy makers and businesses towards a unified effort to reduce the negative environmental impacts of production and consumption activities (Korhonen et al., 2018).

A transition to a circular economy will depend on the strategic actions of policymakers and businesses (Lewandowski, 2016). Companies need to innovate their business models based on circular economy principles to decouple value generation from resource consumption and environmental impacts (Bocken et al., 2016). The business model, that is, the architecture of value creation, delivery, and capture (Reim et al., 2015), is a means to extend the product life cycle and slow and close resource cycles. While the link between product life cycle, resource management, and the business model has been established in the literature, starting with sustainable business models and more recently with circular business models, the contributions are mostly conceptual and aim to develop typologies or taxonomies (see, e.g., Bocken et al., 2016; Lewandowski, 2016; Lüdeke-Freund et al., 2019). Empirical evidence and case studies are limited, which makes it challenging to understand how companies design and implement business models using circular economy principles (Fraccascia, Giannoccaro, Agarwal, et al., 2019).

Furthermore, previous contributions often use insights from the "traditional" business model literature that adopts a single firm view and extends this perspective to analyze circular business models (Evans et al., 2017). While this single firm view is useful for in-depth analysis of a focal firm engaged in circular activities, it can be limiting for a comprehensive analysis of business activities based on circular economy principles. Such activities often extend beyond organizational boundaries, cover entire value networks, and cut across several sectors and markets (cf. Corvellec et al., 2012; Magnusson et al., 2019). Thus, adopting circular economy often requires companies to move from a firm-centric focus in their operational logic towards intensive interaction with an ecosystem of actors (Pieroni et al., 2019). Thus, an ecosystem view of business models for circularity in which different actors, networks and institutions interact dynamically to create environmental and socio-economic value is necessary to advance and upscale circular economy (Zucchella & Previtali, 2019).

While the ecosystem perspective is implicit in a range of related concepts like business ecosystem (Iansiti & Levien, 2004a), industrial ecology (Ashton, 2008), industrial symbiosis (Chertow, 2007), and sustainable business models (Bocken et al., 2019), it is not made explicit in the current circular economy literature. Despite touching on underlying topics of circular business, the existing literature has only limited applicability in this context. For example, in the industrial symbiosis literature, the dominant focus is quite limited on the utilization of waste resources of one or few ecosystem actors as inputs for another (Chertow, 2007), which covers only a small range of possible actors and interactions in most circular economy scenarios, and which also includes remanufacturing or sharing models, among many others. Another example: the business ecosystem concept is often focused on the core business (Iansiti & Levien, 2004a, 2004b), while circular economy initiatives can happen anywhere in the ecosystem, including its fringes, for instance, by offering repair services or selling production waste (Geissdoerfer et al., 2020).

Since industrial ecology is a core theoretical root of circular economy, it can serve as a starting point for an ecosystem analysis of circular economy (Geissdoerfer et al., 2020). Industrial ecology presents the natural ecosystem as a metaphor for the design of industrial systems with the intention to close energy and material loops. A particularly relevant domain under the umbrella of industrial ecology is industrial symbiosis. Industrial symbiosis is the interaction of separate business entities through a cooperative network to exchange material, energy, water and byproducts as well as services and infrastructure to achieve competitive advantage and reduced environmental impacts (Chertow, 2000). Recently, there have been a few scientific articles that link the ecosystem view from the industrial ecology and industrial symbiosis literature to circular economy (e.g., Baldassarre et al., 2019; Fraccascia, Giannoccaro, & Albino, 2019). Specifically, Fraccascia, Giannoccaro and Albino (2019) adopted a system perspective to analyze the governance of a network of several firms implementing industrial symbiosis. Further on, Baldassarre et al. (2019) applied industrial ecology and circular economy as conceptual lenses to analyze an industrial symbiosis cluster with the objective to explore their commonalities and differences.

This article, extending upon these previous contributions, addresses two research gaps related to circular business models. First, there is a risk of underestimating the multiple sources of value creation and capture for firms implementing circular economy when using the firm perspective. Second, even though the industrial ecology and industrial symbiosis literature present an ecosystem view, they do not pay particular attention to the analysis of industrial ecosystems from a business perspective, but rather their development over time and impacts (Baldassarre et al., 2019). We address these gaps by analyzing companies with business activities based on circular economy principles from an ecosystem and business perspective using the industrial symbiosis and business ecosystems literature.

Specifically, we analyze cases related to biogas production and use that are underpinned by circular economy principles. We focus on biogas production and use because they are a core part of the biological cycles of the circular economy (Ellen MacArthur Foundation, 2015). Furthermore, the literature on circular business models is dominated by analysis of technical cycles such as product-service systems or models of collaborative consumption (cf. Fraccascia, Giannoccaro, Agarwal, et al., 2019). Finally, though our cases are based on biological cycles, our discussions are purposefully abstracted to be relevant for circularity in general. Thus, analyzing activities related to technical cycles such as remanufacturing and reuse can benefit from the ecosystem view presented in this article.

1.1 | Basics of biogas production and use

Biogas is produced when organic materials are digested by microorganisms to release methane and carbon dioxide under anaerobic conditions and temperatures ranging from 32°C to 57°C (Wellinger et al., 2013). The composition of the produced raw gas, depending on the digested organic material, has, on average, 50%–70% methane and 30%–50% carbon dioxide together with minor amounts of water and hydrogen sulfide (Wellinger et al., 2013). The feedstock can range from animal manure, industrial and municipal organic waste, sewage sludge, and agricultural residues to energy crops, depending on the local conditions (Lazarevic & Valve, 2020). The raw gas can be combusted under controlled conditions and used for the generation of electricity and heat. Often, in small-scale biogas production, the raw gas can also be used for cooking or lighting. To obtain biomethane, the raw gas has to be upgraded by removing the carbon dioxide and other traces of contaminants. This upgraded gas (97% methane) can be injected into natural gas grids and used as vehicle fuel (Lantz et al., 2007).

The purposeful production of biogas has a long history, and many societies have produced biogas for fuel (He, 2010). Current examples of biogas production include the collection of landfill gas, anaerobic treatment of sewage sludge, and co-digestion plants in which various types of organic material from industrial or municipal organic waste, together with agricultural crops or residues, are digested (Abbasi et al., 2012). Biogas production is more than just energy production. After the anaerobic digestion process, nutrient-rich organic material remains, referred to as digestate. The digestate can potentially replace mineral fertilizer as it contains plant nutrients such as nitrogen (N), potassium (K), and phosphorous (P). Thus, anaerobic digestion enables resource recovery and recycling from organic waste and biomass. Biogas production and use is a relatively flexible and mature technology that can be adapted to specific local conditions serving multiple societal functions related to the use of biogas as an energy carrier (electricity, heat, vehicle fuel, lighting, cooking), nutrient recycler, climate change mitigation, and waste management technology (Lazarevic & Valve, 2020). Biogas solutions can be described as complex product systems that remain highly local and often entirely customized to fit the user needs and context (Tsvetkova & Gustafsson, 2012).

By analyzing biogas businesses using an ecosystem view, we attempt to provide a comprehensive analysis and understanding of business models for circularity compared to a single-firm view adopted in the traditional business model literature, which assumes that the boundaries of the business coincide with the boundaries of the company. In Section 2, we present our analytical framework based on a review of the industrial symbiosis and business ecosystems literature. Section 3 then presents the research method. Next, the empirical cases studied are presented in Section 4. In Section 5, we analyze and discuss the studied cases using the analytical framework. Finally, in Section 6, we conclude and highlight the practical implications of our studies for businesses strategy.

2 | ANALYTICAL FRAMEWORK

This section reviews the literature on business model conceptualizations—(i) the firm perspective from the business model literature and (ii) the ecosystem perspective from the business ecosystems and industrial symbiosis literature. The section ends with a synthesis of dimensions that can be used to analyze circular business models and provides insights on the benefits of moving beyond a single-firm perspective to an ecosystem perspective.

2.1 | Firm-level perspective—Circular business models

The business model concept emerged in the 1970s and gained wider popularity in the 1990s following the information communication technology boom (Wirtz et al., 2016). The business model served as a communication tool to pitch business ideas to investors (Zott et al., 2011). The concept has since attracted attention from a wide range of scholarly fields and has evolved into a managerial discipline in its own right (Foss & Saebi, 2017). Its conceptualizations and definitions vary considerably (e.g., in scope and focus), but most conceptualizations converge around the notion of a value generation logic of an entity (e.g., organization, value chain, and industry sector) represented by different elements (Wirtz et al., 2016). A business model is a strategic tool for designing business activities as well as for comprehensive, cross-company description and analysis (Fraccascia, Giannoccaro, & Albino, 2019). It reflects the firm's realized strategy and encompasses the combination of product and market factors needed to realize a strategy, and the functions of all involved actors. Traditionally, the business model concept has been used predominantly in relation to how a firm creates and appropriates economic value (Osterwalder & Pigneur, 2010).

More recently, the notion of circular business models has emerged with a range of definitions propounded by different scholars (Geissdoerfer et al., 2020). For example, Bocken et al. (2016) define circular business models as "business model strategies suited for the move to a circular economy [based on the] taxonomy of slowing, closing, and narrowing resource loops" (p. 317). Linder and Williander (2017, p. 183) define a circular business model as "a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings." On a different note, Zucchella and Previtali (2019, p. 275) state that a circular business model's "key role is to incorporate the circular economy principles into a design or redesign of business activities and partnerships and to create a cost and revenue structure, which is compatible both with sustainability and with profitability." Compared to the traditional business model, the value proposition in a circular business model can include social and environmental values, as described in the so-called sustainable business models (Boons & Lüdeke-Freund, 2013).

These different definitions combine the conventional conceptualization of the business model concept. This usually starts with Richardson's (2008) value logic, based on three elements covering the value proposition, value creation and delivery, and value capture logic, combined with circular economy principles and can also include sustainability-focused elements (Geissdoerfer et al., 2018). The characteristics of circular business models include geographic proximity and external coordination to transport and exchange biological material (Prosman et al., 2017), long payback periods and price fluctuations (Siskos & Van Wassenhove, 2017), value co-creation with several stakeholders that requires proactive multistakeholder management, and the closing, slowing down, intensifying, dematerializing, and narrowing of material and energy loops (Geissdoerfer et al., 2018).

2.2 | Ecosystem-level perspective—Industrial symbiosis and business ecosystems

Combining the traditional business model perspective with the circular economy has so far been accomplished using the single-firm perspective (Fraccascia, Giannoccaro, Agarwal, et al., 2019). The firm perspective is particularly limiting for the characteristics of circular business models that encompass several value networks, cutting across different sectors and markets. In fact, some scholars, including Amit and Zott (2001), conceptualize the business model as transcending the focal firm and its boundaries, essentially placing the business model closer to the network in which the firm is involved. Many of the value creation and capture will not be exclusively undertaken by the focal firm but rather include an extended network of suppliers, partners, and customers. Understanding how this complex network of activities is organized is particularly important for understanding circular business models (Geissdoerfer et al., 2020). Therefore, some business model conceptualizations include systemic dimensions such as supply chain, value networks, customer interface, and governance (see Fraccascia, Giannoccaro, & Albino, 2019). These conceptualizations cover elements beyond the classical elements concerning the core strategy and the strategic resources of the firm.

Furthermore, the industrial ecology and industrial symbiosis literature present relevant ecosystem perspectives for analyzing circular business models (Baldassarre et al., 2019). Industrial symbiosis, recognized as an approach to reach a circular economy, describes the engagement of a network of firms in the exchange of material and energy resources that intend to generate economic, social, and environmental benefits. IS can be adopted on several geographical levels such as within a facility, among co-located firms, and among companies not in close proximity (Chertow, 2000). These networks of companies represent an industrial symbiosis network that allows firms to exchange waste resources and develop symbiotic relationships across borders of the traditional supply chain with companies belonging to different industries that might not cooperate in traditional business models (Bansal & McKnight, 2009). Even though the industrial ecology and industrial symbiosis literature present an ecosystem view, they do not pay particular attention to the analysis of industrial ecosystems from a business perspective but rather their development over time and impacts (Baldassarre et al., 2019). We address this limitation by complementing the industrial ecology and industrial symbiosis literature with the business ecosystem literature.

The business ecosystem concept continues to gain popularity in the strategy, innovation, entrepreneurship and management literature (de Vasconcelos Gomes et al., 2018). The concept highlights interdependencies between different organizations and provides a lens to analyze value co-creation. Specifically, business ecosystems do not follow the linear value creation process and, thus, many of the actors in such ecosystems are outside the scope of the traditional value creation chain (Iansiti & Levien, 2004b). In the business ecosystem, different companies cooperate (and sometimes compete) to deliver a service or product to a customer underpinned by a value chain with a network of several horizontal relations (Moore, 1996). Furthermore, the members in an ecosystem deliver value through an interrelated system of interdependencies rather than as independent entities. Thus, in its basic form, a business ecosystem is a nested commercial system with several different types of players contributing a specific component to an overarching solution (Christensen & Rosenbloom, 1995) or ecosystem-level goals (Nambisan & Baron, 2013).

Moore (1996) identifies different actors in the business ecosystem based on their relation to a focal firm including actors at the core of the value creation (e.g., direct suppliers and distribution channels), an extension of actors from the core such as suppliers of suppliers, suppliers of complementary products or services, and the broader business ecosystem composed of organizations that influence the context such as competitors, government agencies, regulatory authorities, and investors. In relation to other concepts, the business ecosystem incorporates both production and demand-side participants, which differentiates it from concepts such as innovation ecosystems, clusters, and innovation networks that focus on either the production or consumption-side participants (Thomas & Autio, 2012).

In short, the business ecosystems can be characterized by (i) a joint approach to value creation for customers, (ii) value networks that are not necessarily limited to a particular geographical location, and (iii) a locus of coordination driven by key actors, such as large companies, keystone organizations and platforms, who invest in the ecosystem and integrate innovations from other participants and encourage the formation of new markets.

2.3 | Synthesis

From the reviewed literature, we developed a framework that we can then use to analyze circular business models. In doing so, we synthesize elements from the traditional business model literature, which adopts a firm-level perspective and elements from the industrial symbiosis and business ecosystem literature that adopt an ecosystem perspective to analyze the same set of cases (see Table 1).

To develop our analytical framework, we started with the cornerstones of the traditional business model literature. According to Richardson (2008), a business model is defined by (i) value proposition, (ii) value creation and delivery, and (iii) value capture. For firms engaged in biogas production and use, the value proposition, that is, the firm's basic approach to competitive advantage, is determined by the multifunctionality of biogas solutions as energy carriers, nutrient recyclers, and climate mitigation technologies (Lazarevic & Valve, 2020). By extension, biogas companies operate on different customer segments and markets (Ottosson et al., 2019) using different configurations of activities to meet customer needs. The value capture, that is, how a firm generates revenue and profit, is also different among biogas companies (e.g., gate fees for waste treatment, sales of biogas, and sales of organic fertilizer). From the ecosystem perspective, a joint approach to value creation for customers underpinned by value networks (i.e., a set of actors creating economic and social and environmental value) is essential for such a multifunctional solution such as biogas, which creates social and environmental value in addition to economic value. Another essential ecosystem dimension is coordination since there are several actors that have to be aligned for proper ecosystem functioning (cf. Barrie & Kanda, 2020). The need for coordination is also accompanied by centralization of control, that is, the extent to which a central actor manages the entire system of relationships (Fraccascia, Giannoccaro, & Albino, 2019).

3 | METHOD

The empirical data used to write this article was collected using interviews with nine companies and one branch organization engaged in business activities related to biogas production, distribution, and use. A case study-inspired approach with a comparative setting (cf. Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Yin, 2009) was used to collect and analyze empirical data from the case companies and branch organization. This approach emphasizes comparison within and across cases to draw from causalities in connection with previous literature and has been used in the study of business models and circular economy (see e.g. Zucchella & Previtali, 2019).

TABLE 1 Firm-level vs. ecosystem-level dimensions in business model conceptualizations

Firm-level dimensions (adopted from Richardson, 2008)	Ecosystem-level dimensions (inspired by industrial ecology, industrial symbiosis and business ecosystem literature)
• Value proposition	• Value network
• Value creation and delivery	• Coordination
• Value capture	• Centralization of control

To identify and select cases for interviews, we first developed a database of the Swedish biogas sector. Sweden is a compelling context in which to study biogas solutions and circular business models for two main reasons. First, Sweden has 54% of the gross energy consumption from renewable energy sources, the highest share of renewables among the EU member states (Eurostat, 2018). This is a result of extensive investment in the production of renewable energies such as biogas that has led to a number of renewable energy production facilities, world-leading technology and knowledge development, and the creation of a sector with active public and private companies (cf. Ammenberg et al., 2018). Second, the Swedish biogas sector consists of an advanced value chain of actors, from the pretreatment of raw materials to biogas production to utilization for different purposes (Lantz et al., 2007). These characteristics made it possible to identify a diversity of companies operating within the Swedish biogas sector and their associated business models for further analysis. Using both publicly available and private data, we gathered information on companies in the biogas sector, including their main offerings, their location in Sweden, web site addresses, electronic contacts, and business activities, if available. The final database consisted of 85 companies that offered consulting, landfill gas extraction, substrate digestion, biogas upgrading, digestate handling, biogas distribution, and (bio)gas-driven vehicles.

Following our initial mapping, we purposively selected nine companies and one branch organization for in-depth interviews based on the extent of their business activities and their availability for interviews and willingness to provide access to information (cf. Yin, 2009). The selected cases have extensive business experience, both locally and internationally, regarding biogas production, distribution and use. We used a purposeful sampling approach to identify relevant cases and make effective use of our research resources. We then conducted interviews with these companies using a semi-structure interview guide. We chose interviewees who were actively engaged in the strategic development of business activities related to biogas production, distribution and use. The interviews, which focused on biogas production and use, lasted between 60 and 90 min. The main questions discussed included the companies' business activities, their perceived drivers and barriers for biogas business development, their business strategies for overcoming these barriers, the unique characteristics of biogas solutions, their key set of actors, markets, customers they engage with in their business activities, and the cash flow in their business activities. The interviews were recorded and transcribed for further analysis. An overview of the case companies is presented in Table 2.

To analyze the interview transcript, we followed four steps for qualitative content and thematic analysis suggested by Vaismoradi et al. (2016). Our steps are illustrated in Figure 1. First, we thoroughly read the interview transcripts and highlighted meaningful, recurring ideas and key issues in the transcripts of relevance for our research aim (e.g., specific characteristics of biogas technologies, barriers in biogas business development, and actors' relations in biogas business development). This first step of thoroughly reading through the interview transcripts is described by Vaismoradi et al. (2016) as immersion

TABLE 2 Overview of selected cases and interviewees (in 2016)

Company/branch organization	Focus area	Position of interviewee(s)	Revenue (1000 SEK)	Number of employees
1. Scandinavian Biogas Fuels International AB	Design and operate biogas plants	• Research and business developer	266,178	68
2. Svensk Biogas AB	Biogas production and distribution	• Chief executive officer	79,141	3
3. Puregas Solutions AB (A Wärtsillä company)	Biogas upgrading technologies	• Global product line manager	142,753	22
4. Hifab AB	Project management and strategic advice in construction and civil engineering	• Department manager	326,749	203
5. Purac AB	Biogas production technologies	• Sales director • Technical director	876,790	63
6. Malmberg Water AB	Biogas upgrading technologies	• Director business area biogas	323,901	116
7. Swedish Biogas International AB (now Gasum)	Biogas production and distribution	• Project manager and process engineer		
8. Envac Optibag AB	Raw material pre-treatment technology	• Marketing manager	40,809	12
9. Scania AB	"Sustainable" transport solutions provider	• Sustainability director, buses and coaches • Senior technical advisor, buses and coaches • Senior advisor sustainable transport solutions	68,284,000	13,382 (2017)
10. The Swedish Waste Management Association	Branch organization for waste management in Sweden	• Business developer	47,374	19

and distancing. Maintaining closeness to the data by reading it thoroughly several times is required to develop a valid representation of the interviewees' perspectives. However, we also distanced ourselves from the transcripts from time to time to allow for self-criticism, discussion with other researchers, and also to enhance the possibility of approaching the phenomenon from a new angle. In the second step, we proceeded by reducing the extensive amount of raw data to manageable sections of data relevant for analyzing the scope of circular business models. We labeled these manageable sections of data in connection to themes such as key actors, market segments, material and cash flow, and interrelations between key stakeholder in biogas business. In the third step, we then related these labeled themes to established knowledge on biogas industrial ecosystems (e.g., Tsvetkova & Gustafsson, 2012) to be able to develop a storyline regarding the development of biogas business. Though we had conducted a review of existing literature prior to the data collection as a basis for formulating interview questions, analyzing the empirical data also required an in-depth review of relevant literature. This approach allowed us to link the themes that we had identified in step two to theoretical models as a basis for developing storylines in step four (see Figure 1). In the fourth step, four different storylines were developed for biogas production, distribution and use based on the line of business the cases we studied engaged in, that is, substrate digestion technology (e.g., Purac AB), raw gas upgrading technology (e.g., Malmberg Water AB, Puregas Solutions AB), biogas process knowledge and biogas system solution providers (e.g., Scania). These four business scopes that we describe are not theoretical synthesis but are based on the actual business activities of the studies cases as mentioned above. Furthermore, the four business scopes are not exhaustive (e.g., we do not include nutrient recycling companies) but do provide a variety of business scopes for further analysis. Based on our aim, we analyzed these four business scopes using the firm-level perspective and ecosystem-level perspective presented in Section 2.

4 | RESULTS

We studied nine companies and one branch organization engaged in activities related to the production, distribution, and use of biogas. From these cases, we abstracted four generic business set-ups for biogas production, distribution, and use. These four categories include the business set-up for companies offering (i) substrate digestion technologies, (ii) raw biogas upgrading technologies, (iii) biogas process knowledge, and (iv) entire system solutions for biogas production, distribution, and use. From the cases studied, these business set-ups depict the scope of their business activities, their direct and indirect interactions with different stakeholders and markets, and the different material and financial flows.

4.1 | Business scope of companies offering digester technologies

As depicted in Figure 2, in this business set-up, the digester technology provider has transactions mainly with the biogas producer (e.g., farmers, municipal waste management companies, and

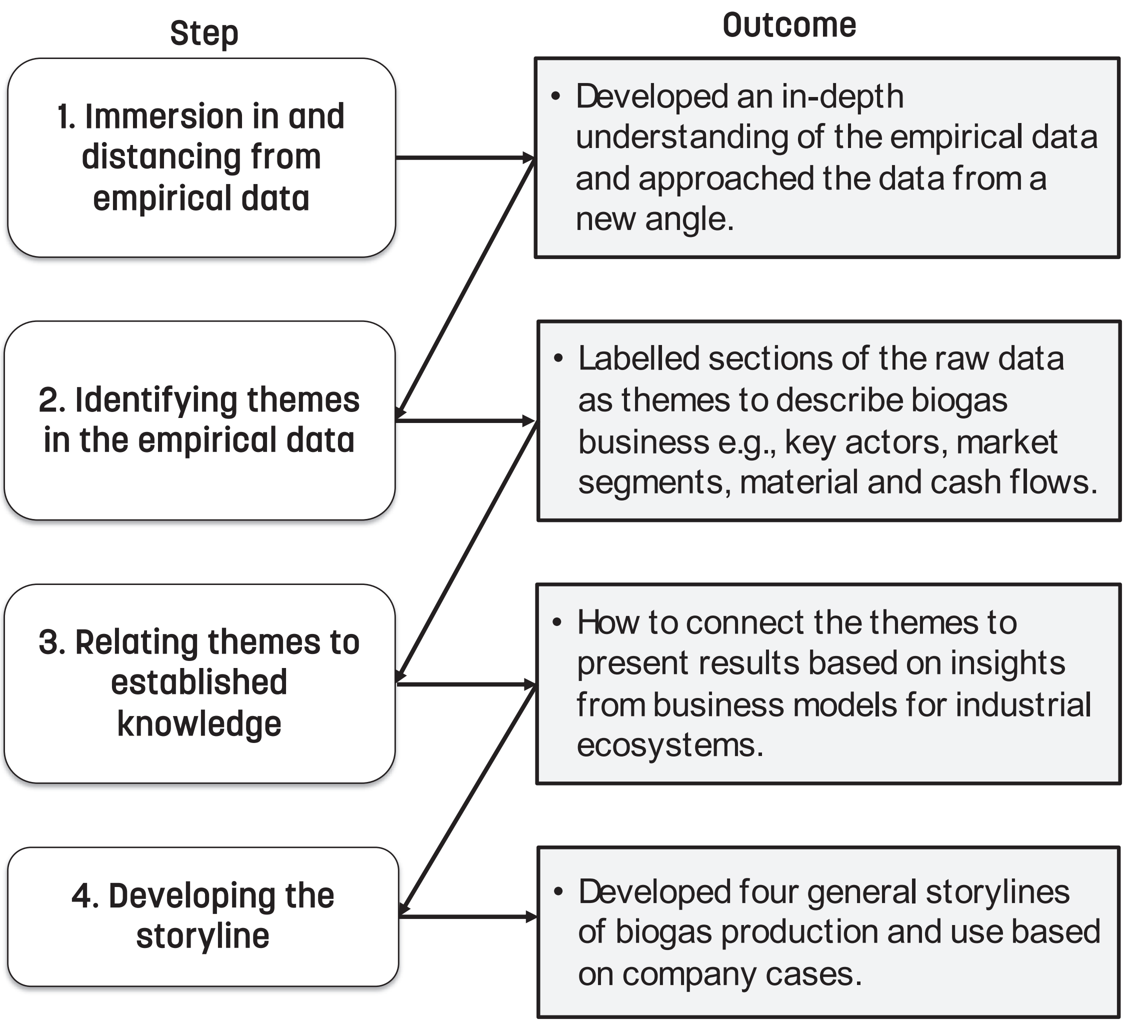

FIGURE 1 Analysis of empirical data (inspired by Vaismoradi et al., 2016). Detailed activities in each step are described in the text

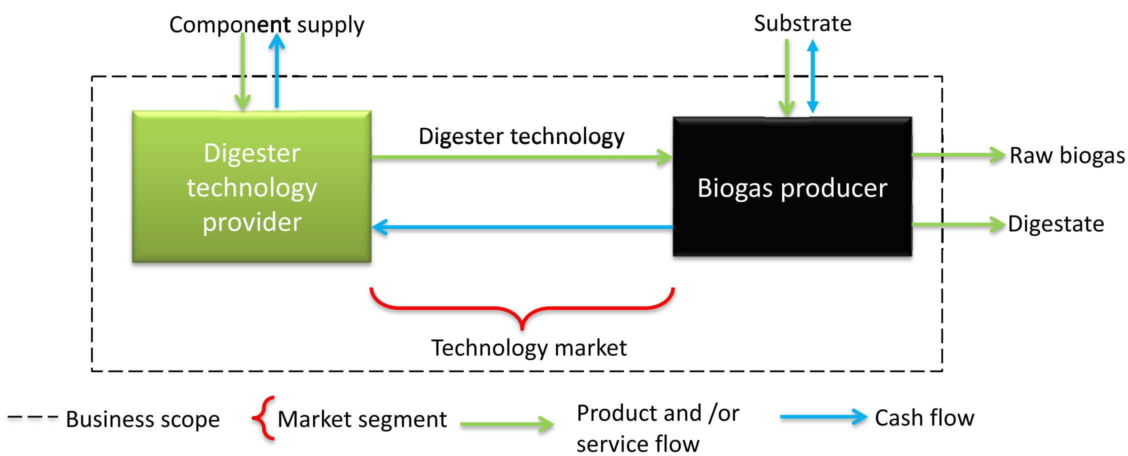

FIGURE 2 Business scope of companies offering digester technologies [Colour figure can be viewed at wileyonlinelibrary.com]

industries) by providing technology for the digestion of organic materials. As mentioned by a technology provider, their target customers (i.e., biogas producers) can be in different sectors and have different types of substrates "… when it comes to biogas, we do basically many different things. We work within traditional biogas [wastewater treatment] – municipal digesters. We also have industrial biogas treatment for specific sectors such as breweries, pulp and paper, food, sugar. Then we have digestors for municipal organic waste and agricultural waste. Most of our digestors are multi-purpose in that case taking in different types of substrates" (interview, Purac AB technical director). The technology is developed in dialogue with the customers (e.g., specific capacity and energy production) with some degree of customization to fit their substrate characteristics. The technology provider has no direct transactions with other actors in the ecosystem such as raw material suppliers, for example, farmers, waste management companies, and also the potential users of the biogas. However, the activities and interests of these "background" actors in the ecosystem affect the offering of the technology provider and thus require considerable knowledge and awareness from the technology supplier. The main source of cash flow is the offer of digesters to biogas producers. In certain instances, the provision of digesters can also involve construction works, electrical installations and after-sales service to provide a turn-key solution to customers.

4.2 | Business scope of companies offering raw biogas upgrading technology

As shown in Figure 3, the upgrading technology provider has transactions with biogas producers who purchase technology to upgrade the raw biogas for injection into the natural gas grid or as a vehicle fuel for public and private transportation. Thus, the focus is on the upgrading hardware, and hence, the core technology could be designed, manufactured, and sold to customers with very limited customizations to fit the qualities of the raw and upgraded biogas. As the director of biogas business area from Malmberg Water AB indicated, "We have a standardised product (a CE-marked product) that helps us quite easily to meet the European terms and conditions for machine certification and so on. So, for us, it's quite easy to sell inside Europe. That way, we are quite stable." This business is often conducted in markets where the use of biogas for vehicle fuel is dominant. As depicted in Figure 3 below, the technology supplied does not take care of the substrate nor the digestion of the organic material but is mainly focused on the upgrading of the raw gas to at least 97% biomethane content. From the technical aspect, the upgrading technology provider interacts with those producing the raw gas and with the injection station, mostly the grid owners, as described by the director of biogas business area from Malmberg Water AB: "From the technical aspect we interact with those producing the biogas (the raw biogas), and we are also interacting with the injection station, mostly the grid owners. It's normally regulated in the contract, but we all meet in project meetings to discuss if time schedules are fitting, technical details are fitting, etc. But we don't interact in making the business, for example, in the form of joint quotations." The typical customer for this type of upgrading technology provider is energy companies and biogas production companies.

4.3 | Business scope of companies offering biogas process knowledge

This business set-up focuses on transactions between the company offering biogas process knowledge and biogas producers (see Figure 4). The company offering biogas process knowledge possesses the knowledge to optimize the biogas production process as well as chemical additives to optimize the process and receives revenue for this offering. Knowledge about the biogas production process can be offered remotely as well as through physical visits to the production facilities. However, since biogas is a flexible solution that often has to be localized to the specific context (Lazarevic & Valve, 2020), it can be challenging for companies offering process knowledge to expand into new geographic contexts. As mentioned by an interviewee, "It is much easier to sell your hardware than to sell your knowledge because people tend to view knowledge as very local and that if you have done it at one place, that does not mean you can do it everywhere since you cannot generalise knowledge in that sense since every plant looks different from the next one."

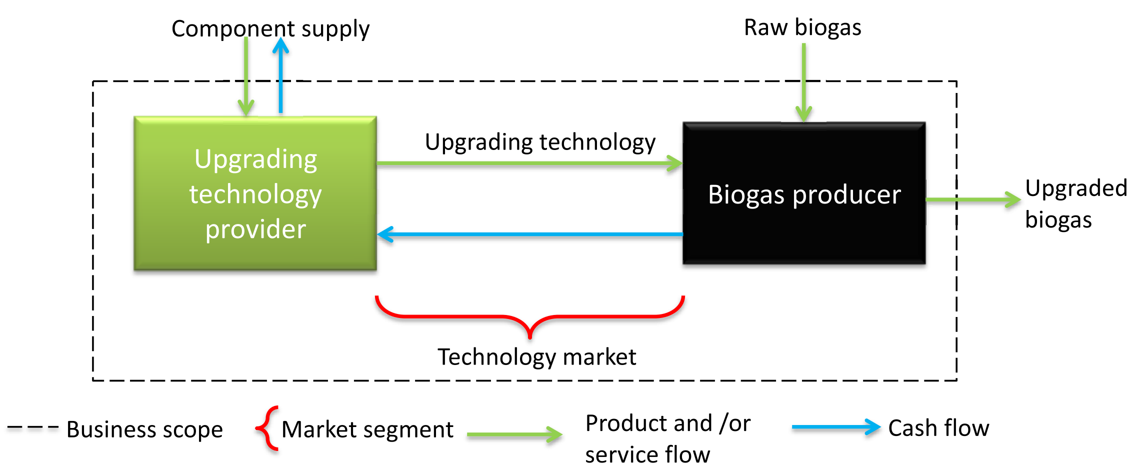

FIGURE 3 Business scope of companies offering raw biogas upgrading technologies [Colour figure can be viewed at wileyonlinelibrary.com]

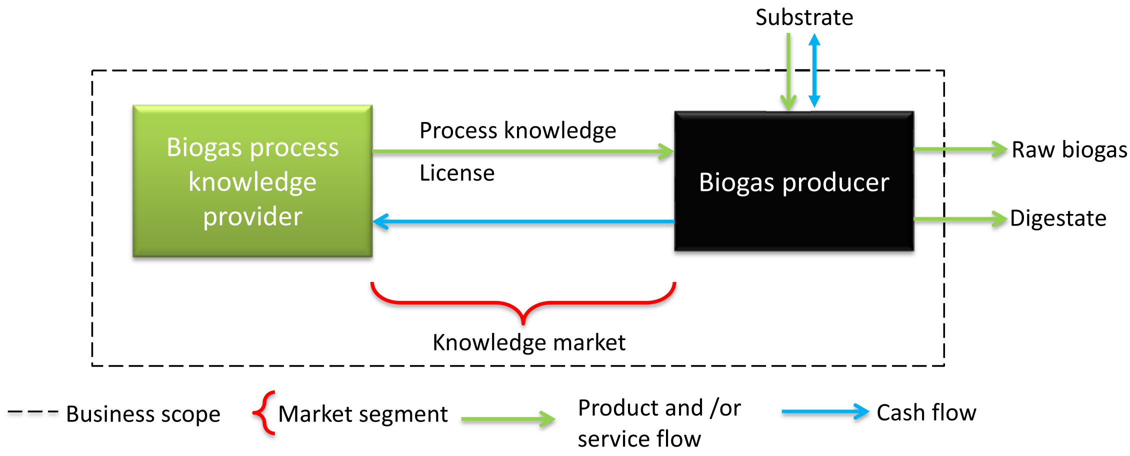

FIGURE 4 Business scope of companies offering biogas process knowledge [Colour figure can be viewed at wileyonlinelibrary.com]

Another approach to offering knowledge to biogas producers is through licensing. The company offering biogas process knowledge could license, for example, specific recipes to customers or sell such offerings through intermediate companies that are active on different markets and receive a fee. Thus, the company offering biogas process knowledge has no direct transaction with the substrate suppliers and the potential end-users of the biogas. With a licensing approach, the company intends to transfer the risks and financing responsibilities to the customer and licensee.

4.4 | Business scope for companies offering system solutions for biogas production and distribution

With this type of business set-up, the company's activities seek to cover the entire network of activities from substrate collection and treatment to digestion to producing raw gas to upgrading it into biomethane and its distribution to end-users (see Figure 5). By-products such as digestate can also be important components of this business scope if they can be valorized as bio-fertilizer to generate extra income. This business set-up involves interactions with substrate producers such as farmers and waste management companies, and interactions with the potential end-users of the biogas, be it for transportation, heating, or electricity production. The company is also under direct influence from the contextual factors such as subsidies for biogas and regulations on these different markets (e.g., waste market and energy market including heat and electricity). Ultimately, this business set-up represents a more complex and challenging activity, and the companies that adopt this approach mostly engage in markets where they have a good understanding of the local context (i.e., waste sorting, subsidies, biogas usage, and policies). The business set-up requires getting access and securing contracts for substrates, technically solving how to digest the substrates, upgrading the raw biogas, and generating revenue on the commercial market involving different stakeholders, their demands, and regulations.

The complexity in this business set-up relates to the need to create economic value from organic material and digestate that otherwise would be discarded. However, there are challenges related to creating economic value from organic waste since there may be no established markets for their exchange including prices and quality, and farmers might be reluctant to purchase digestate originating from certain facilities such as waste management plants (containing sewage sludge) due to concern over pollution risks with heavy metals, harmful organic compounds, pharmaceuticals and microplastics. An interviewee from a system solution provider highlighted the complexity of adopting such a wide business scope: "You make biogas from waste, and there is never a waste market. Surrounding waste is a lot of regulation … so it's hard to calculate your price and also foresee the changes in the regulations. Also, since you produce biogas from substrates with quite a lot of water in it, they cannot be transported over long distances economically, so it becomes a regional market for the substrate. Biogas utilization differs between markets and also to be competitive, it needs to be subsidised, and that can change quickly, which means that the uncertainties are quite big. Finally, on the bio-fertilizer side, it is also a matter of not always so transparent regulation regarding the use of biofertilizer, and also the acceptance of biofertilizer can be different from region to region and also within one country." Thus, in Sweden, companies employing such wide business scopes are often municipally owned companies (with potential partnerships with private companies) with the responsibility for municipal waste management and public transportation. Private companies with extensive resources such as Scania also adopt such a wide business scope in certain markets offering sustainable transport solutions together with waste management in the context of sustainable city development.

5 | ANALYSIS AND DISCUSSION

The circular economy concept requires an expansion of the firm-level perspective to an ecosystem-level perspective (Pieroni et al., 2019).

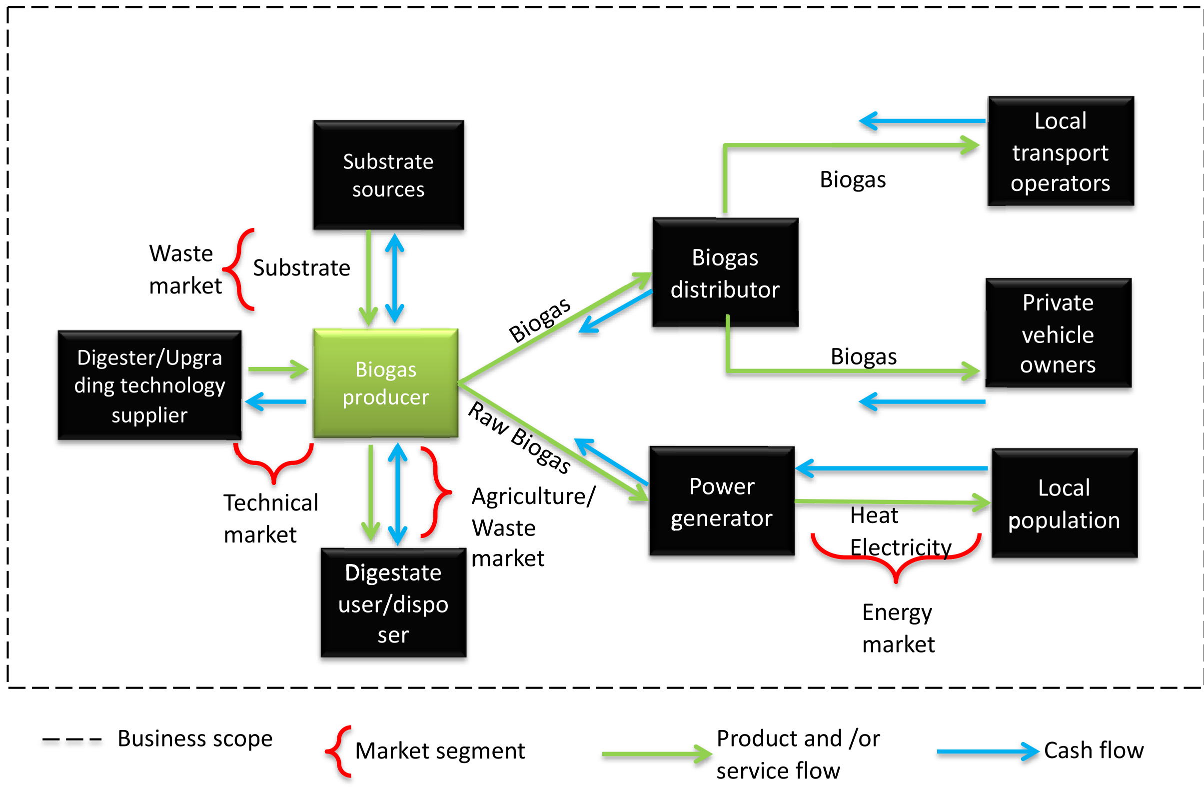

FIGURE 5 Business scope for companies offering system solutions for biogas production, distribution and use [Colour figure can be viewed at wileyonlinelibrary.com]

To this end, the traditional business model approach, which regularly adopts a single product or business unit view in its analysis and often assumes that the boundaries of the business coincide with the boundaries of the firm, needs further development (cf. Evans et al., 2017). Business activities based on circular economy principles, like cycling, extending, intensifying, and dematerializing resource loops (cf. Bocken et al., 2017; Geissdoerfer et al., 2020), can be comprehensively analyzed using an ecosystems-level perspective analogue to the industrial symbiosis and business ecosystem literature.

In our empirical cases, the business scope of the technology provider is based on providing technology for digesting organic substrate to biogas producing companies. This, in turn, is represented in the technology provider's value proposition in Table 3. In return for providing the technology, the company gets paid for the purchased technology plus associated construction and implementation services. Consequently, the main revenue stream comes from developing digester technology for the biogas producer, who, in turn, can produce raw gas for different end uses. With this comparatively narrow business scope, circular economy principles are not explicitly considered in the business activities. The business activities, rather, follow a traditional business transaction between a technology provider and a customer. There is no explicit consideration of product-life cycle management (e.g., remanufacturing and integrated product-service systems offerings) or other circularity considerations in this business scope. As a result, potential innovation of the technology (e.g., design for maintenance or disassembly) to improve its sustainability performance and provide access to new markets and customer segments could be limited (cf. Hansen et al., 2009). Thus, in line with the conventional business model literature, the value creation is dominantly economic in nature and the value capture is limited to a few actors in the business transaction, especially business owners and customers.

For upgrading technology providers, the business faces similar challenges of narrow business scope. Here, the value proposition covers technology to upgrade raw biogas into biomethane, which is provided to biogas producers, who, in this case, can include energy or waste management companies. Similarly, analyzing this business scope from a traditional business model perspective reveals no obvious element of circularity, even though the technology in itself fits into a broader ecosystem of closing resource loops through the production of biogas from waste and upgrading into biomethane for transport. Since these technologies are often developed as turn-key solutions, there is very little degree of customization on the part of the technology supplier to fit the local conditions of the customer. Thus, potential sustainability improvements of the technology might be overlooked when adopting a narrow business model view. In contrast, by adopting an ecosystem-level perspective for both digester technology and upgrading technology providers, a new set of suppliers, customers, and institutions come into play, which can provide incentives and input for sustainability-oriented innovation of the technology (e.g., remanufacturing, integrated product-service offering), potentially linking circular activities with sustainability (cf. Geissdoerfer et al., 2017).

TABLE 3 Differences in business scopes for biogas technology and knowledge suppliers

Level of analysis	Digester technology provider	Upgrading technology provider	Biogas process knowledge provider	System solutions provider for biogas production, distribution, and use
Firm-level dimensions				
Value proposition	Technology for digesting organic substrate.	Technology to produce biomethane instead of raw gas.	Knowledge to optimize the biogas production process.	• Waste management • Transport fuel • Heat and power generation • Organic fertilizer
Value creation and delivery	• Component supply from sub-contractors. • Digestor technology delivery to raw biogas producers.	• Component supply from sub-contractors. • Upgrading technology delivery to biomethane producers	• In-house knowledge accumulated through research and development • Knowledge provided to biogas producers • Chemical additives delivered to biogas producers	• Coordinating and securing contracts between a network of actors (e.g., governing authorities, technology providers, substrate providers, biogas producers, biogas distributors, biogas users, and digestate users) to produce, distribute and use biogas
Value capture	Technology sold to raw gas producers together with potential revenue from construction works, and electrical installations related to the turn-key solution.	Technology sold to biomethane producers with potential revenue from construction works, and electrical installations related to the turn-key solution.	Consultancy service fees for providing process knowledge as well as license fee for chemical additives sold to raw gas and biomethane producers.	Revenue from one or more of the following: • Gate fees for waste treatment • Sales of biomethane • Sales of heat and power • Sales of organic fertilizer
Ecosystem-level dimensions				
Value network	The core actors are the digester technology providers and biogas producers.	The core actors are the upgrading technology providers and biogas producers.	The core actors are the biogas process knowledge providers and biogas producers.	A network of actors including governing authorities, technology providers, substrate providers, biogas producers, biogas distributors, biogas users, and digestate users
Coordination	Coordination limited to the core actors (digester technology providers and biogas producers.).	Coordination limited to the core actors (upgrading technology providers and biogas producers).	Coordination limited to the core actors (biogas process knowledge providers and biogas producers).	High-level coordination due to resource and strategic interdependence between an ecosystem of actors for value proposition, value creation and delivery, and value capture.
Centralization of control	No central organization manages the transactions between the digester technology and biogas producer.	No central organization manages the transactions between the upgrading technology provider and biogas producer.	No central organization manages the transactions between the process knowledge provider and biogas producer.	• Possibility for a centralized authority that coordinates the relationships in the ecosystem (e.g., local municipality responsible for waste management and public transport) • Possibility for a private company that has a central role in the ecosystem (e.g., Scania working with sustainable city development)

For the biogas process knowledge provider in our sample, the business set-up is also narrowly defined based on the interaction between the company and potential customers. Thus, the value creation activities are based on consultancy services and the sales of chemical additives to optimize the biogas production process. In this case, the knowledge and chemical additives offered can be customized to a degree to fit the conditions of the customer. Again, as with the previous two business set-ups, this case highlights the challenge of adopting a narrow traditional business model view, when integrating sustainability and circularity into business models. It is evident from the three different business set-ups that by adopting a traditional business model view to analyze business activities in the context of the circular economy, opportunities for technology innovation based on circular economy principles may fall out of the domain of the analysis. Specifically, the focal business might be oblivious of the dynamic complexity of the circular economy, the interactions between several stakeholders, and the possibility to exchange different kinds of resources, leading to new markets and customer segments (cf. Zucchella & Previtali, 2019).

Companies offering entire biogas production and distribution systems for various purposes such as waste management, transport fuel, heat and power generation, and organic fertilizer represent a wide business scope. In this case, the company interacts directly with several other actors such as substrate suppliers (e.g., farmers and waste management companies) and actors connected to the different uses of biogas such as transportation and the generation of heat and power, as well as potential users of the digestate such as farmers. The complex nature of this business set-up means that the activities cut across several sectors such as waste management, energy, transportation, and agriculture, and is influenced by the local conditions as well as the institutional conditions related to these different sectors.

Analyzing entire biogas production and distribution systems from an ecosystem-level perspective reveals the complexity of circular business models. Biogas systems thrive on interdependencies between several actors (e.g., companies, municipalities, and consumers) and sectors (e.g., agriculture and meat industry) producing and transacting organic waste. Thus, in biogas systems, there is a complex set of actors which create, deliver, and capture value. The complexity of such value networks differs from other circular economy strategies such as product-service systems or collaborative consumption in which a few companies and consumers can take central roles. Biogas systems can be developed based on industrial symbiosis principles in which material, energy and water generated as waste by one production process can be used as input to other production processes (cf. Fraccascia, Giannoccaro, & Albino, 2019). This network approach to create and capture value invokes operational and strategic interdependence between actors in biogas systems. Neglecting this complexity and multiple relationships by adopting a single firm-perspective limits the understanding of the sources of value creation, value delivery and value capture for firms implementing circular economy, and in particular, those based on industrial ecosystem thinking such as biogas systems.

From the ecosystem perspective, a value network (i.e., a set of actors creating economic, social and environmental value) is essential for biogas systems. The need for a value network arises from the operational and strategic interdependencies among different actors in biogas systems. The single-firm perspective is limiting for circular business models that encompass several value networks, cutting across different sectors and markets. Many of the value creation, delivery, and capture is not exclusively undertaken by the focal firm but rather include an extended network of suppliers, partners, and customers. Understanding how this complex network of activities is organized is particularly important for understanding circular business models. Thus, conceptualizations of circular business models need to transcend the focal firm and its boundaries, essentially placing the business model closer to the network in which the firm is involved.

There are also coordination challenges relating to the supply of organic waste and demand for biogas and biofertilizer. Since waste is a by-product of production processes, securing a guaranteed quantity and quality over an extended period of time can be challenging. There can be competing solutions for the organic waste (e.g., composting and landfilling), the organic waste may require pre-treatment (e.g., sorting), and the digestate can require further treatment (e.g., dewatering). These additional processes can introduce the need for third parties, the need to comply with additional policies and thus the need for coordination. For example, biogas related policies (economic, regulatory, and voluntary), cut across several sectors, administrative levels, affect different parts of the value chain and change over time. This complex dynamic emphasizes the need for coordination and coherence when adopting an ecosystem view. Furthermore, the interdependencies of different actors pose strategic challenges regarding future business development. However, the level of interdependence and coordination in the biogas system is likely to vary based of the flexibility to produce biogas in-house or transact organic waste on markets if they exist (cf. Fraccascia, Giannoccaro, & Albino, 2019). In instances where biogas is produced in-house from generated waste, interdependence, and coordination with external actors maybe low, but producers must find an internal use for the biogas or sell it on the market to generate revenue. The ecosystem view on circular business models expands upon industrial symbiosis in which the dominant focus can be limited to the utilization of waste resources of one or few ecosystem actors as input for others (Chertow, 2007), covering only a small range of possible actors and interactions in most circular economy scenarios. Furthermore, industrial symbiosis focuses on exchanges between geographically proximate actors while an ecosystem view for circular business models can extend even beyond national border (e.g., Biogas produced in Denmark is increasingly sold in Sweden due to policy gaps; Gustafsson & Anderberg, 2020). Thus, an ecosystem perspective highlights both core and noncore business activities as relevant analytical foci for comprehensively understanding circular business models (Geissdoerfer et al., 2020).

Another dimension from the ecosystem perspective is the centralization of control, that is, the level to which a central actor manages the system of relationships in such business set-ups. From our empirical cases, we find examples of both high and low centralization to deliver biogas system solutions. In certain cases, municipalities responsible for the management of household waste influence which companies become part of the ecosystem and which relationships are established with these actors. In other instances, resource-endowed companies such as Scania can orchestrate a decentralized biogas system solution in which relationships are regulated by contractual mechanisms negotiated by several companies working together to create and capture value around sustainable transport solutions.

Altogether, adopting a business ecosystem view reveals the complexity of business activities based on the circular economy. Table 3 illustrates the key differences between the narrower traditional business model view and the broader business ecosystem view. In particular, the biogas system examples illustrates that circular economy business activities cut across different markets and sectors, revealing the complexity of value co-creation, the necessity of proactive multistakeholder management, and governance mechanisms (cf. Geissdoerfer et al., 2017; Zucchella & Previtali, 2019), aspects which might be less pronounced from a traditional business model perspective which focus on value proposition, value creation and delivery, and value capture. The value co-creation and multistakeholder management include securing substrate supply at a competitive price, securing revenue streams for different biogas uses (which can be dynamic over time based on competition from other technologies), and understanding institutional and local conditions across several sectors and levels.

Thus, a company with business activities based on the circular economy is influenced by several different market conditions—for example, selling and buying solid waste, electricity, heat, agricultural products, and technical equipment—including their fluctuating demands and regulations. It is also dependent on a large set of actors outside its organizational boundaries to secure a functioning business model. Thus, the company needs to develop knowledge and competence of the local conditions on these different markets, build trust with external actors, and manage different kinds of relations that might be completely different and thus more complex to manage than in a traditional business model.

6 | CONCLUSIONS AND PRACTICAL IMPLICATIONS

There has been a shift in the focus on the business model concept, from the business unit to the inclusion of other stakeholders in the organizational environment (cf. Bocken et al., 2013; Geissdoerfer et al., 2016). To this external perspective, an internal perspective is emerging: business model portfolios in multibusiness organizations (e.g., Aversa et al., 2017). Due to their characteristics, this shift to ecosystem thinking is compounded for circular business models since they usually strongly depend on the coordinated interaction of different stakeholders in complex value networks (Geissdoerfer et al., 2020). In this article, we argue that many of the questions that require higher degrees of coordination in the context of the CE, like the set-up of a joint collection center that different businesses use, the development of reverse logistics, the integration of product and service offerings, and the exchange of waste material, energy, and services are hard to cover with even the current advancement in the conceptualizations of the business model innovation.

The business ecosystem view can help in solving issues of complexity and coordination that characterize business models for circularity. Furthermore, it shows the interdependence of the various components of the ecosystem on each other, and thus changes in one component induce changes in other components, which in turn influence the business model of the involved companies. This ecosystem view, however, requires more capabilities from companies to be able to manage these different system components. The business ecosystem view helps to elucidate system benefits such as environmental benefits from waste management, the replacement of fossil fuels, and fossil fertilizers that would otherwise be missed from the traditional business model perspective. For example, if only reviewing a biogas producer from a traditional business model perspective, the setup would concentrate on a few key suppliers and miss smaller or unconventional ecosystem players like local farms or algae start-ups or could not incentivize meaningful engagement with these actors because of a too narrow conceptualization of value propositions for various network stakeholders. However, these interrelations between different entities are not only an opportunity but also entails challenges such as interdependence, transaction costs, and power relations, and the need for intermediation in the system (cf. Kanda et al., 2020) to create, deliver, and capture value.

Thus, this ecosystem perspective, including the interrelations between the different entities, is how a company can move beyond economic value creation to include social and environmental value and use it as a competitive advantage. Since the individual entities within the system are potentially viable businesses in themselves, the added benefit of the ecosystem view lies in the interactions between the various entities. Furthermore, the ecosystem view can provide essential support for start-ups and corporate venturing to develop business models based on circular economy principles by adopting a broad view with venturing activities. For companies adopting business ecosystem thinking for their business models, our contribution calls for the need to look beyond entities with which the company has direct interactions but also to investigate the broader ecosystem for potential connections to different industries and value chains, which is fundamental for sustainability and the circular economy. Essentially, our contribution calls for broader boundary definition when dealing with business models for circularity where traditionally disconnected value chains may be interlinked, which is especially important for business models based on the circular economy to be able to create and distribute system-wide value.

For a theoretical contribution, our article provides insights into the interlinkages between biological and technical cycles in the circular economy. While the circular economy is often conceptualized as being restorative and regenerative by design, research combining both biological and technical cycles seems limited (Morseletto, 2020). Starting with biogas production and use which fits into the broader biological cycle through anaerobic digestion of organic material, we highlight several opportunities related to circularly in technical cycles which may be overlooked by the silo-approach to technical and biological cycles prevalent in the current literature. Our article therefore highlights the need to pay attention to the technical components of biological cycles through the application of restorative concepts such as product-life cycle management, product-service systems, remanufacturing to cycle, extend, intensity, and dematerialize resource loops (Geissdoerfer et al., 2020). The interlinkage between technical and biological cycles can be facilitated by adopting an ecosystem view which provides the opportunity to detect unconventional stakeholders connected to a business.

There are also limitations to this research that represent further research avenues. The most important being that the eco-system level dimensions that we used to analyze our four business scopes make the scopes seem very similar to each other for three of them, while the fourth being considerably different. This similarity is inherent in the nature of the cases that we studied and thus an empirical rather than an analytical limitation of the ecosystem-level dimensions. At the same time, the focal industry of our analysis, while being particularly suited for the phenomena investigated is considerably limited in the diversity of firm sizes, operating models, markets, and so forth. This, together with the single industry focus of this study, indicates that further research needs to be undertaken to confirm the findings of this study with its observed need for a shift in units of analysis, and to derive generic perspectives, frameworks and ultimately tools for business strategy in the context of the circular economy. Therefore, we recommend future research to investigate more diverse business cases from both biological and technical cycles in different industries, company sizes, and geographies to expand upon the ecosystem-level dimensions for analyzing circular business models.

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