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A typology of sustainable circular business models with applications in the bioeconomy

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As an approach to sustainable development, circular business models are increasingly being developed. However, many circular business models focus on environmental or technological contributions to sustainability rather than considering all dimensions of sustainability simultaneously. Based on existing sustainable business model archetypes, a hierarchical business model typology is developed that allows a stepwise exploration of sustainable business model innovation opportunities incorporating an environmental, social and economic dimension. An analysis of business model components generates a closer look on the six newly defined Sustainable Circular Business Models. Finally, a conceptual application for organic waste valorization technologies, supported by examples from literature, allows a practical view on the implementation of the business models in the bio-economy. The typology offers a guide toward sustainable business model design or innovation opportunities centered around technologies creating value from waste.

KEYWORDS

business models, business model innovation, bioeconomy, circular economy, anaerobic digestion

1. Introduction

Following the definition of the 1987 Brundtland report, sustainable development is defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Brundtland, 1987). An early framework that aimed to translate this definition to a business setting is the Triple Bottom Line (TBL) framework. The TBL posits that instead of focusing on one bottom line, companies should commit to focusing on people, planet and profit. During the Johannesburg Summit in 2002, the term "profit" got replaced by "prosperity" to provide a more nuanced interpretation that also includes societal growth (United Nations, 2002). This reasoning is also present in Porter and Kramer (2011) definition of shared value creation, who argue that it is integral to profit maximization that businesses create economic value in a way that also creates societal value.

More recently, the importance of circularity has entered the debate on sustainable development (Geissdoerfer et al., 2017), particularly in reference to agricultural and food systems. More specifically, the Circular Economy (CE) is an umbrella term that has emerged from pre-existing concepts such as waste management and industrial symbiosis. Various definitions of the circular economy exist. The Ellen MacArthur Foundation (EMF), an influential non-governmental organization that has influenced the conceptual thinking behind the topic of the circular economy, defines the circular economy as "an economy that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times" (EMF, 2015). Despite the recent burst in academic literature, the concept is not new. Pioneering author Walter Stahel described his vision of an economy in loops in 1981 (Stahel and Reday-Mulvey, 1981). McDonough and Braungart (2002) further endorsed Walter Stahel's philosophy by institutionalizing the term "cradle-to-cradle" as a sustainable alternative to the conventional "cradle-to-grave" approach.

CE principles distinguish between technical cycles involving non-renewable abiotic resources that cannot return to the biosphere, and biological cycles involving renewable biotic resources that can cycle in the biosphere (EMF, 2019; Navare et al., 2021). Biotic resources can return to the biosphere as nutrients nourishing ecosystems. In agricultural systems, for example, bio-based fertilizers can represent a circular alternative to the current chemical fertilizers (Chojnacka et al., 2020).

The transition to a CE does not only require innovative products and global networks, but also the development of new business models. Business model innovation is a key requirement for industry transformation related to the CE as well as sustainability (Geissdoerfer et al., 2017). Dantas et al. (2021) argue that a CE approach is very valuable to reach Sustainable Development Goals as it connects innovative technologies with new business models. The concept of the business model (BM) became popular with the rise of the Internet in the mid-1990's, when existing ways of earning a profit appeared unfitting for web-based products and services and a whole new range of opportunities for organizing business activities became available (Zott et al., 2011; DaSilva and Trkman, 2014). Meanwhile, the business model terminology has become widespread across all industries. Dozens of definitions have been proposed where scholars have mainly highlighted the notion of value, financial aspects and the network between the firm and its stakeholders (Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002; Morris et al., 2005). A well-known tool to describe business models by their components is the Business Model Canvas by Osterwalder and Pigneur (2010). They distinguish 9 building blocks of a business model: the value proposition, customer segments, customer relationships, channels, key partners, key activities, key resources, cost structures and revenue streams. Baden-Fuller and Morgan (2010) use the analogy of recipes to describe the function of a BM: recipes require ingredients, but BMs cannot just be defined as the set of elements they contain because that would ignore the fact that they function as recipes to draw the elements together.

Applied to the CE, Salvador et al. (2020) define Circular Business Models (CBMs) as "[business models that] seek maintaining resource value at its maximum for as long as feasible, and eliminating or reducing resource leakage, by closing, slowing, or narrowing resource flows". Reim et al. (2019) define a CBM as "one in which a focal company, together with partners, uses innovation to create, capture, and deliver value to improve resource efficiency by extending the lifespan of products and parts that thereby realizes environmental, social, and economic benefits". Several taxonomies and typologies for CBM exist (Bocken, N. M. P. et al., 2016; Urbinati et al., 2017).

CBMs are often considered to be a subcategory of sustainable business models (Antikainen and Valkokari, 2016; Geissdoerfer et al., 2017). In addition to the circular economy, other concepts within the sustainability domain are for example the green economy and the bio-economy, although they all contain elements from each other (D'Amato et al., 2019). However, it is often emphasized that there is an imperfect overlap between sustainable business models and circular business models (Geissdoerfer et al., 2018). For example, CBMs can induce negative consequences for the working conditions of employees (social impact) or they can involve higher material and energy usages than their linear alternatives (environmental impact). There are many reasons why circular business model adoption may not contribute to sustainability (Whalen, 2019), such as the possibility of rebound effects (Zink and Geyer, 2017). Therefore, circular business models are not necessarily sustainable.

A literature review by Geissdoerfer et al. (2017) reveals that, considering a sustainable CE, most authors focus on the environmental performance improvements rather than taking a holistic view on all dimensions of sustainability. Social responsibility receives less attention in the circular economy (Murray et al., 2015). The synergies between the triple bottom line, the CE and sustainable business models should be further researched (Khan et al., 2021). A sustainable circular business model includes a holistic view on all dimensions of sustainability. A clear typology of sustainable circular business models (SCBM) is missing. In this study, a holistic SCBM is defined as a business model that aims to keep products, components and materials at their highest utility and value and thereby realizes environmental, social and economic benefits.

Boons and Lüdeke-Freund (2013) identify three streams of sustainable business model innovation: (1) technological innovation to overcome barriers of clean technologies, (2) organizational innovation and (3) social innovation to maximize social profit. However, these streams of innovation do not stand for separate phenomena: they are interlinked. They stress that an innovation bears a sustainability potential, but the business model is the market device that allows to unfold this potential. Bocken et al. (2014) build on these streams of innovation to identify 8 sustainable business model archetypes, representing groups of innovative business models sharing similar traits (Figure 1). Despite being originally developed for the manufacturing industry, the archetypes are also suitable for other sectors such as the agricultural sector (Barth et al., 2021). Nevertheless, as already pointed out by Bocken et al. (2014), a business model can be sustainable on a technological, social and organizational level simultaneously. Therefore, it is useful to adjust this typology to include a decomposition into subsystems and arrive at more holistic sustainable business models.

As the butterfly diagram of the Ellen MacArthur Foundation illustrates, the circular economy is not only relevant to technical systems, but also to biological cycles (EMF, 2019). Thus, CBMs are not only useful to describe businesses in the manufacturing sector, but they can also be useful to describe, for example, agri-food businesses or businesses in the bio-economy. For instance, an established technology for bio-based energy and fertilizer production is anaerobic digestion, a process in which biodegradable material is broken down in an anaerobic environment while releasing biogas and digestate. The produced biogas can be used for energy or fuel, while the remaining digestate is a nutrient-rich substance that can be used as a fertilizer. Anaerobic digestion is a key technology in sustainably developing modern circular biowaste technologies (Jain et al., 2022). However, in order to fulfill its full potential in a circular bio-economy, anaerobic digestion plants will face several challenges, including the improvement of economic viability and life cycle impacts (Sherwood, 2020). Despite an increasing awareness of scholars (Donner et al., 2020; Dagevos and de Lauwere, 2021), holistic business model typologies in the bio-economy are still scarce.

Such holistic typologies reveal an uncomplicated overview of SCBMs and create categories for classification. A typology based on contributions to sustainability draws out the underlying technological, social and organizational dimensions of the business models. It offers insights to establish a foundation toward the development of new sustainable business models.

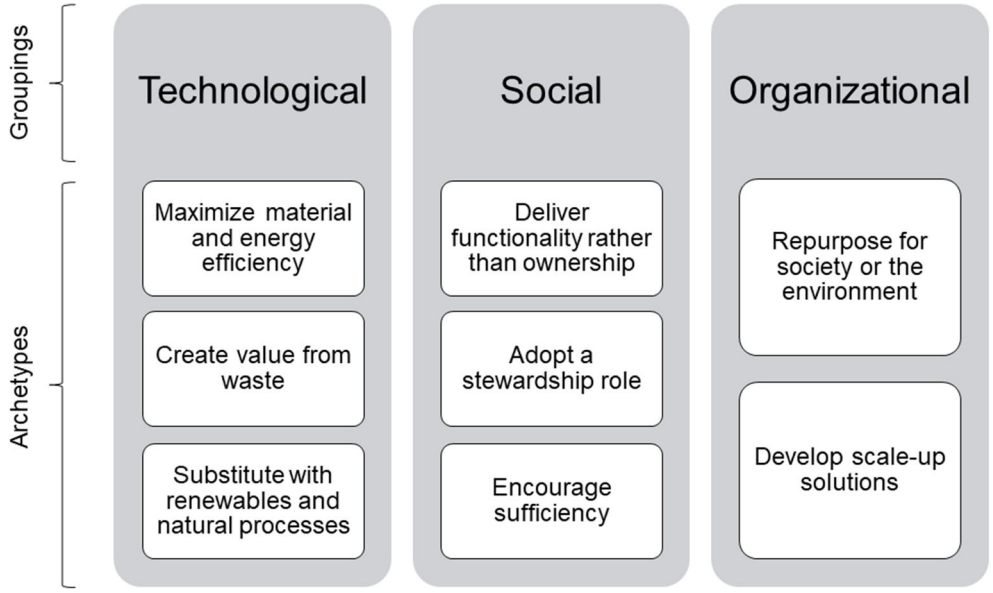

FIGURE 1
Sustainable business model archetypes adapted from Bocken et al. (2014).

The novelties compared to other business model typologies thus include the comprehensive and additive inclusion of multiple sustainability dimensions. This can be helpful for innovators who seek to develop business models for their technological innovations, as it provides guidance to include social and organizational innovations in their business model.

In order to develop such a holistic typology and show its applicability in the bio-economy, the research questions addressed in this paper are:

- What is a holistic typology for sustainable circular business models—and consequently, what are pathways for sustainable business model innovation?
- How can this typology be applied to the bio-economy, and more specifically, to anaerobic digestion as a source of technological innovation?

2. Conceptual framework

This paper aims to refine the sustainable business model archetypes developed by Bocken et al. (2014) to contribute to theory-building on the conceptualization of sustainable circular business models centered around technological innovations. Typologies are multidimensional and conceptual in their nature, but a good typology should be simple enough to allow a quick and easy comparison across types (Bailey, 1994). One way to model a complex system is to construct hierarchical structures and provide a decomposition in subsystems until the lowest level is reached (Simon, 1996). In this paper, the levels of innovation that distinguish the archetypes by Bocken et al. (2014) are interpreted hierarchically, allowing the development of a holistic typology.

2.1. Building a new typology

Starting from the sustainable business model archetypes as defined by Bocken et al. (2014), an adjusted categorization of sustainable business models can be derived by distinguishing three subsequent levels of innovation: (1) a technological level integrating the planet-dimension of the triple bottom line, (2) a social level integrating the people-dimension and an organizational level integrating the (3) prosperity-dimension (Figure 2). This is consistent with the definition of tri-profit by Upward and Jones (2015): a strongly sustainable business model should account for the sum of cost and revenues from activities in the environmental, social and economic context.

A first innovation level is the technological level: a circular innovation presenting solutions to achieve a sustainable future can focus on maximizing efficiency, creating value from waste or substituting materials or energy with renewables. Each technological innovation can be related to a stage of the "take-make-dispose" linear economy and presents a circular solution: substituting with renewables presents an alternative to the "taking"-stage by sourcing renewable inputs to design closed-loop systems. Maximizing efficiency brings a solution to the sustainability issues in the "making"-stage by narrowing resource loops. Creating value from waste brings a solution to the "dispose"-stage by closing resource loops (Bocken et al., 2014). These technological innovations are, however, not mutually exclusive: for example, a biogas digester can create value from biological waste while at the same time substituting fossil fuels with renewable energy from biogas. However, the business model typology should be regarded from the main aim of the business innovation. For example, if a biogas plant is established to convert crops that are grown with the sole purpose of turning them into biogas and fertilizer, the innovation aims at substituting with renewables. However, if a biogas plant is built to convert food waste from crops that have first gone through a consumption cycle, the innovation aims at creating value from waste.

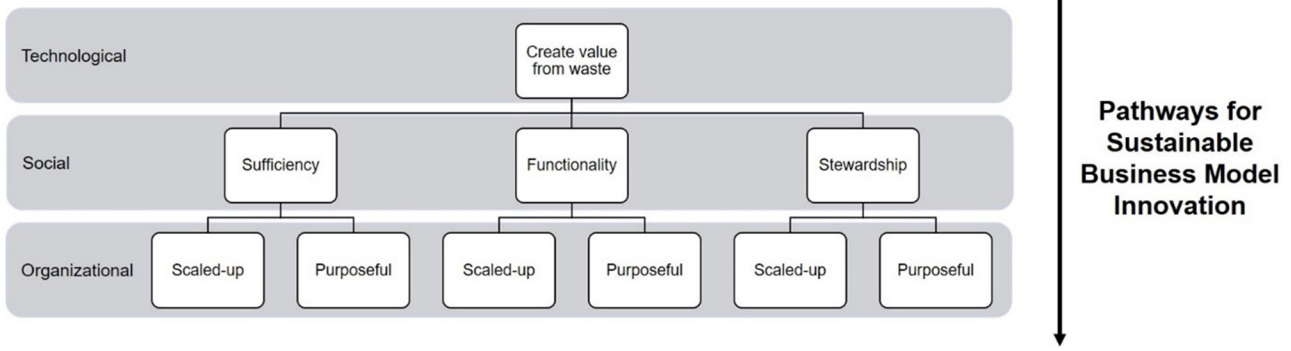

FIGURE 2
Hierarchical model providing a new typology of SCBMs.

Next, a business model adopting one of these technological innovations can provide social innovation. Social innovation, as defined by the European Commission (2013), indicates new ideas that meet social needs, create social relationships and form collaborations. This level of innovation can be looked at from the perspective of the provider of the technology and the value they create for their customers. The provider of a sustainable circular technology can either deliver functionality rather than ownership, adopt a stewardship role or encourage sufficiency. In all of these business models, social responsibility is not only emphasized by creating job opportunities but also by maintaining close social relationships within the supply network with a focus on trust and transparency. The social level is linked with the technological level through a part-whole relationship: the technological level represents an aggregation of different business model types on the social level. It can be noted that, in terms of circularity, the speed of the resource cycle can be impacted by the social level: by encouraging sufficiency, a firm can raise awareness about overconsumption (Bocken and Short, 2016). Firms that provide functionality have an incentive to prolong service life of products and may thus extend a product's life or use products more intensively to increase value to the firm (Tukker, 2015).

Finally, each business model can innovate organizationally by either repurposing its goals toward the delivery of social and environmental benefits rather than economic profit or scaling up sustainability solutions. A scaled-up sustainable business shows similarities to the definition of ecopreneurship by Schaltegger (2002) as these entrepreneurs focus on the mass market while being profit oriented and environmentally concerned at the same time. From a financial perspective, a company repurposing its goals will merely be focused on the survival of the company while a company scaling up its technology will aim for a stable income base. The organizational level forms a part-whole refinement of the social level by specifying whether or not the business model will be scale and profit oriented.

This hierarchy provides a new typology for SCBMs. A closer look allows to distinguish 6 SCBM archetypes for each technological innovation: purposeful functionality, scaled-up functionality, purposeful stewardship, scaled-up stewardship, purposeful sufficiency and scaled-up sufficiency. Based on the definitions of the sustainable business model archetypes by Bocken et al. (2014), the value propositions of these business models can be defined as follows:

- Scaled-up sufficiency is the reduction of demand-side consumption and hence production or the provision of high-quality durable products while scaling up sustainability solutions to maximize benefits for society and the environment;
- Purposeful sufficiency is the reduction of demand-side consumption and hence production or the provision of high-quality durable products while prioritizing the delivery of social and environmental benefits rather than economic profit;
- Scaled-up functionality is the provision of services that satisfy user needs without users having to own products while scaling up sustainability solutions to maximize benefits for society and the environment;
- Purposeful functionality is the provision of services that satisfy user needs without users having to own products, while prioritizing delivery of social and environmental benefits rather than economic profit;
- Scaled-up stewardship is the manufacturing and/or provision of products and/or services by considering the needs of a range of stakeholders and ensuring their long-term health and wellbeing, while scaling up sustainability solutions to maximize benefits for society and the environment;
- Purposeful stewardship is the manufacturing and/or provision of products and/or services by considering the needs of a range of stakeholders and ensuring their long-term health and wellbeing, while prioritizing the delivery of social and environmental benefits rather than economic profit.

2.2. Business model components

These newly defined business models can be further elaborated upon using business model elements as defined by the management literature. Morris et al. (2005) have synthetized the extant literature on business model into an integrative framework containing six components: (1) the value proposition, (2) the customer, (3) internal processes, (4) competencies, (5) competitive strategy and (6) entrepreneurial objectives, that are captured by six key questions. This section will address these components and link them to the definitions and descriptions of sustainable business model archetypes by Bocken et al. (2014), combined as described in 2.1. By answering the six questions for each newly defined business model separately,

the framework allows for a clear distinction of business models in their fundamental characteristics. The standardization of decisions at the foundation level provides the opportunity to make comparisons across models. A summary is provided in Table 1.

2.2.1. How do we create value?

In business models offering functionality, such as product-service-systems (PSS), the provision of services is essential: consumer needs have to be satisfied, but this does not necessarily involve consumer ownership (Bocken et al., 2014; Tukker, 2015). In business models offering stewardship, both products and services can be offered; the value proposition is centered around the engagement of stakeholders (Bocken et al., 2014). Finally, in business models offering sufficiency, high-quality products that encourage long product life are offered. However, these products can be complemented with services inducing reduced consumption (Bocken and Short, 2016).

2.2.2. Who do we create value for?

This question relates to the organizational level of the business model: relational selling is about long-term relationships and getting to know customers' needs and wants while transactional relationships are about short-term sales (Payne, 1994). A distinction can be made between business models that re-purpose or scale-up. Business models that re-purpose the business for society and/or environment will focus on long-term relationships because they prioritize social and environmental benefits over shareholder value and integrate with local communities. Business models that scale-up their sustainability solutions, however, will place a bit more weight on the short-term sales so that their business is economically sustainable as well. However, this is not to say that scaled-up business models will not have any long-term relationships. For example, a firm offering stewardship, whether purposeful or scaled-up, will need long-term relationships with its stakeholders to ensure their health and wellbeing.

2.2.3. What is our source of competence?

This question relates to the value creation and delivery of the business model. Business models offering functionality rather than ownership may include redesign for durability, repairability and upgradability (Bocken et al., 2014). Those firms may have intellectual or technological capabilities that allow them to redesign their technology in such manner. Business models offering stewardship may need reconfiguration of their network to alternative suppliers who deliver benefits to their stakeholders (Bocken et al., 2014), indicating that these firms acquire significant networking and resource leveraging capabilities as well as great supply chain management. Business models encouraging sufficiency, on the other hand, are focused on consuming less, wasting less and using products longer (Bocken et al., 2014; Bocken and Short, 2016), indicating that a great source of competence is the production process. Finally, for scaled-up business models, selling and marketing will be an important asset to reach a large customer base.

2.2.4. How do we competitively position ourselves?

Purposeful business models require intimate relationships to discover the needs of the stakeholders. Scaled-up business models on the other hand, aim to capture economies of scale (Bocken, N. M. et al., 2016) and are thus more focused on low costs and efficiency. Business models offering functionality position themselves by offering exceptional services, while business models offering sufficiency focus on high-quality products. Business models offering stewardship, on the other hand, strive for operational excellence to fit the needs of their stakeholders. All business models discussed here position themselves by introducing a technological innovation meant to create value from waste, maximize efficiency or substitute with renewables.

2.2.5. How do we make money?

Business models offering functionality such as Product-Service-Systems (PSS) mostly have a fixed revenue source such as a monthly subscription. Their operations require a large amount of fixed costs including investment in the technology, which brings a high operating leverage. Business models offering stewardship can offer products and services while aiming to adjust their offerings to the specific situations of individual stakeholders (Bocken et al., 2014), providing flexible revenue sources. Since fixed costs can be shared among many stakeholders, operating leverage can be low. Business models offering sufficiency can have fixed revenue sources stemming from the sale of their products, while their investment costs of the technology and thus the operating leverage are high. Scaled-up business models aim to produce high volumes to scale up the technology and reach large numbers of people (Bocken, N. M. et al., 2016). While purposeful business models may aim to reach many people to maximize social and environmental benefits (Bocken et al., 2014), they do not aim to scale up production.

2.2.6. What are our time, scope and size ambitions?

Purposeful business models are focused on delivering social and environmental benefits instead of shareholder value (Bocken et al., 2014). For organizations driven by a social mission, the importance of growth diminishes (Johanisova and Wolf, 2012). Therefore, they will likely adopt a subsistence model where their goal is to survive and meet basic financial obligations. In some cases, they can employ an income model to generate a healthy income stream. Scaled-up business models will most likely employ such income model but may also aim for growth to the point that the firm generates capital gain for the initial investors.

3. Applications in the bio-economy

3.1. Methods

To show the applicability of this typology, representative examples from the bio-economy are provided. In the following paragraphs, the SCBM typology is applied to the bio-economy by elaborating on exemplar business models centered around anaerobic digestion (AD) of organic waste into energy as well as bio-based fertilizer. Anaerobic digestion is a well-established process to treat organic waste and produce renewable energy. Navare et al. (2021)

TABLE 1 SCBM's unraveled using the foundation level of the integrative framework by Morris et al. (2005).

	Purposeful sufficiency	Scaled-up sufficiency	Purposeful functionality	Scaled-up functionality	Purposeful stewardship	Scaled-up stewardship
How do we create value?	Primarily products	Primarily products	Primarily services	Primarily services	Mix of products and services	Mix of products and services
Who do we create value for?	Relational	Relational and transactional	Relational	Relational and transactional	Relational	Relational and transactional
What is our source of competence?	Production	Production Selling/marketing	Intellectual capability and technology	Intellectual capability and technology Selling/marketing	Networking/ resource leveraging Supply chain management	Networking/ resource leveraging Supply chain management Selling/marketing
How do we competitively position ourselves?	Intimate relationship Product quality Innovation	Product quality Innovation	Intimate relationship Service quality Innovation	Low cost and efficiency Service quality Innovation	Intimate relationship Operational excellence Innovation	Low cost and efficiency Operational excellence Innovation
How do we make money?	Fixed revenue source High operating leverage Low volumes	Fixed revenue source High operating leverage High volumes	Fixed revenue source High operating leverage Low volumes	Fixed revenue source High operating leverage High volumes	Mixed/flexible revenue sources Low operating leverage Low Volumes	Mixed/flexible revenue sources Low operating leverage High volumes
What are our time, scope and size ambitions?	Subsistence or income model	Income or growth model	Subsistence or income model	Income or growth model	Subsistence or income model	Income or growth model

stress that, in order to assess the circularity of biological cycles, four criteria should be monitored: cascading, sustainable harvesting, closing nutrient cycles and impacting resource depletion or carbon flows. Cascading, i.e., the sequential use of resources, involves a quality assessment and a consideration of the lifetime of a product to establish the highest value-added application (Bezama, 2016). In terms of cascading, high value organic residue applications include pharmaceuticals, food and feed and bioplastics. When these valorization options are ruled out, it can be interesting to produce lower value application such as bulk chemicals, fuels, energy and heat. Considering harvesting in residue-based biogas production, renewable energy is sourced from waste. Regarding nutrient recycling as a circular economy approach in the bio-economy, the use of organic waste could be a solution to recover valuable fertilizer components that could in time replace chemical fertilizers (Chojnacka et al., 2020) and thereby reduce resource depletion. As a pillar of the circular and bio-economy, this study focuses on anaerobic digestion. The analysis will focus on SCBMs in the bio-economy by describing exemplar business models centered around proprietors of anaerobic digesters, creating energy and digestate (i.e., a biobased fertilizer) from waste.

To find relevant literature, we used the following string to search the Web of Science database: TS = [(biogas OR anaerobic digest* OR (energy AND fertili*er)] AND (business model) AND (agri* OR farm*) in May 2022. Although the keyword "business model" delivers only a small part of literature related to anaerobic digestion applications, it represents the narrative part of business model literature. This was explicitly searched for, as it often provides a description of technological, organizational and social value propositions. This yielded 70 publications. Studies that did not go into detail on anaerobic digestion business models in the agri-food sector, were left out of consideration. Finally, 15 studies were considered to verify the SCBM typology with exemplary business models.

3.2. Sufficiency business models

Since fertilizers and other bio-based products will organically break down, the concept of "encouraging sufficiency" is ambiguous. In their research on sufficiency business strategies in the food industry, Bocken et al. (2020) suggest that sufficiency business models encourage the waste hierarchy of "avoid, reduce and reuse". As a method of avoiding overconsumption and reusing organic material, anaerobic digestion can reduce the need for externally produced goods (i.e., energy and fertilizer). As such, AD plants are considered sufficiency BMs if their value proposition intends to contribute to an increase in on-farm or regional energy or fertilizer self-sufficiency.

3.2.1. Purposeful sufficiency

In businesses providing purposeful sufficiency in circular fertilizers, the entrepreneurs aim to become self-sufficient in the sense of being capable to provide the most essential resources by themselves, without prioritizing profit maximization. Ximenes et al. (2021) analyze a case study of a company that anaerobically digests fish, oil and vegetable residues in the Northeast of Brazil. While a direct increase in profits may not be visible in the short term, the company will build energy independence and security as well as a positive brand image (Ximenes et al., 2021). The authors argue that the adoption of small-scale biogas and fertilizer production technologies can drive small agro-industrial companies and their sector to transform (Ximenes et al., 2021). Hamid and

Blanchard (2018) investigate the viability of small community biogas businesses in rural Kenya. This plant produces biogas for cooking and lighting for 5 households, while one farmer acts as the entrepreneur who installs and manages the plant. The authors suggest that community biogas entrepreneurship projects can meet domestic needs at a low cost while contributing to social development (Hamid and Blanchard, 2018). Karlsson (2019) describes farm-based biogas production in Sweden as a voluntary investment aimed to contribute to environmental and social sustainability while improving the farm's reputation and brand value and developing new value propositions. Most farmers find business efforts delivering environmental and social benefits more important than short-term profit maximization and aim to reduce consumption and production by improving product durability, reducing waste and reusing raw materials (Karlsson, 2019). Finally, Li et al. (2016) explore the promotion of rural biogas digesters in Qinhuangdao City, China. The city constructed more than 2,450 household digesters. This project was combined with the development of ecological organic agriculture by encouraging individuals to use the digestate as a fertilizer in ecological and organic agriculture. Households were trained about maintenance and use of digesters. The business model aims to solve air pollution problems with new energy and agricultural models in rural areas (Li et al., 2016).

Consistent with the purposeful sufficiency business model in Table 1, these examples have in common that they provide mainly products (i.e., biogas and digestate) for firm- or household-level sufficiency: the business models revolve around farm- or household-scale digesters producing energy and fertilizer to decrease their own dependency and contribute to rural development. Since social stakeholder value is prioritized, the entrepreneurs focus on long-term relationships rather than short-term sales. The provision of these products is not only motivated by cost savings but also by an intrinsic drive to get the most out of present resources. This involves an agroecological approach to crop production, allowing the farmer to align with the ecological specificities of their crops and soils. The farmer optimizes the production of both fertilizer and crops to create a responsible and resilient system for themself and the natural environment. Their source of competence is the production of energy and an innovative bio-based fertilizer. However, this requires a substantial investment. Whether or not the farmer produces low or high volumes at low or high margins, depends on the time and scope ambitions. For example, a farmer adopting a purposeful business model could solely aim to survive and continue its operations while maximizing social and environmental benefits (i.e., subsistence model). However, they could also aim to generate a stable base of cost savings (i.e., income model).

3.2.2. Scaled-up sufficiency

In scaled-up sufficiency business models, the entrepreneur will still aim to provide some essential resources themselves, but also aims to create a profit in doing so. The organizational priority thus changes to profit maximization in addition to social and environmental value creation. In Table 2, two scaled-up sufficiency case studies are described. We zoom in on the exploration of a pig breeding enterprise that has transitioned to a circular business to respond to challenges of low profitability by Zhu et al. (2019). The farm has improved pig production by offering green and organic high-quality pork, and has diversified income streams with bamboo, fish and electricity sales. At the same time, the farm saves on energy and fertilizers. Moreover, the farm is self-sufficient in its energy use, and additional energy is sold to the grid while additional fertilizer is provided to neighboring farms (Zhu et al., 2019). As such, the farm aims to increase revenue streams and save costs while achieving ecological and social goals. Environmental objectives are an integral part of the business (Zhu et al., 2019). Similarly, Sgroi et al. (2018) describe a case study of a biogas plant in Sicily, Italy. This company operates in the agro-energy sector, and more specifically, raises livestock and processes agricultural waste through anaerobic digestion. For this purpose, livestock waste is supplemented by energy crops. The farm saves on energy and fertilizer costs and generates an income through electricity sales to the grid and excess digestate sales to a supermarket chain. Sgroi et al. (2018) name the owner a "transforming entrepreneur" who manages a whole short chain as the farmer produces electricity (i.e., a side-product of his core business) as well as the raw materials. In addition, the authors argue that cost optimization and environmental sustainability go hand in hand in the search for energy self-sufficiency in agriculture, and that energy self-production increasingly becomes a source of competitive advantage.

In all three cases, the farmers prioritize profit maximization and an increase in revenue streams while reaching their self-sufficiency goals. They organize their business activities as described in the foundation level of scaled-up sufficiency models in Table 1. To allow the innovation to be effective in the long term, the farmer needs close relationships with their partners and customers. However, managing operations with different partners and customers implies that contractual agreements become important too. In addition to optimizing the production process, marketing skills are required to reach a large audience. The farmer aims to offer a qualitative and innovative product. Direct revenues might stem from fertilizer sales. Nevertheless, the profit generated by the innovation may also stem from cost-savings in mineral fertilizer use or even increased sale of other product lines. The farmer may choose to strive for a stable base of cost savings or income but may also hope to recover some capital in order to grow its business.

3.3. Functionality business models

Functionality business models revolve around the provision of services. In terms of anaerobic digestion, these can be waste conversion services as well as energy or fertilizer production services. As such, we assume that the end-users of these products are important customers of the central actor in this business model.

3.3.1. Purposeful functionality

In businesses providing purposeful functionality in circular fertilizers, the entrepreneurs aim to provide waste conversion, energy or fertilizer services with an innovative ownership value proposition, without prioritizing profit maximization. In Table 2, two examples of purposeful functionality are summarized. Liu et al. (2018) present a case study of bio-natural gas production in China by distinguishing multiple business models. In the "Mutual Offsetting in Kind" or product offsetting business model, farmers buy a share of the project's products (i.e., biogas and fertilizer) at a lower price in return for straw or manure. A similar business model is discussed by Ehsan et al. (2016). The authors design a biogas based chain business model

TABLE 2 Case studies and their technological, social and organizational value proposition.

	Case description	Country	Social priority	Organizational priority	References
Purposeful sufficiency	Small local agri- and aquaculture biogas model	Brazil (Ceará region)	Expanding the enterprise's offer of fish, prawns, lettuce and tomato by producing energy and fertilizer	Environmental commitment with society rather than source of economic benefits	Ximenes et al. (2021)
	Community biogas entrepreneurship	Kenya	Contributing to energy sufficiency of local households	Social and economic benefits to households	Hamid and Blanchard (2018)
	Farm-based biogas production	Sweden	Encouraging production and consumption sufficiency	Voluntarily benefiting environmental and social sustainability rather than profit maximization	Karlsson (2019)
	Household biogas digesters	China	Saving energy costs, reducing emissions and employing ecological and organic agricultural practices	Low-carbon rural community development	Li et al. (2016)
Scaled-up sufficiency	Pig breeding farm	China	Producing high-quality products, saving energy and fertilizer and contributing to regional circularity	Increasing profitability while achieving ecological and social goals	Zhu et al. (2019)
	Farm-based biogas plant	Italy (Sicily)	Transforming entrepreneurship targeting energy self-sufficiency	Source of supplementary income and competitive advantage that goes hand in hand with environmental sustainability	Sgroi et al. (2018)
Purposeful functionality	Product offsetting	China	Innovative ownership by farmers buying a quota of the project's products at a lower price in return for selling straw to the project	Supporting rural energy development and improvement of energy access	Liu et al. (2018)
	Biogas based chain business	Bangladesh	Purchasing waste from communities and offering them electricity, gas and fertilizer at an affordable price in return	Sustainable development of rural community	Ehsan et al. (2016)
Scaled-up functionality	Blockchain-based ecosystem	China	Innovative ownership by establishing an exchange system based on digital coupons	Contributing to environmental sustainability with financial incentives and a large quantity of transactions	Zhang (2019)
Purposeful stewardship	Support structure	Europe	Coordination, networking	Helping companies and sectors to develop	Donner et al. (2020)
	Contracted management	China	Professional assistance to farmers (*Nongbaomu*) and support of biogas and organic fertilizer production plants (*Negbaomu*)	Supporting rural energy development and improvement of energy access	Liu et al. (2018)
Scaled-up stewardship	Company X	UK	Collaboration and continuous dialogue, building trustworthy relationships with local stakeholders	SME recovering value from waste to provide clean energy as a competitive advantage	Hussain et al. (2020)
	Biovakka (origination)	Finland	Lowering the cost of disposing of excess manure for 20+ stakeholders (i.e., "coalition")	Profitability while solving the manure surplus problem in the region	Åkerman et al. (2020)
	A'Green Energy BM	USA	Majority farmer-owned business cooperation with food processing industry developing co-digestion AD projects	Increased profitability of dairy farmers and provision of renewable energy to the community	Morris et al. (2010)
	Sigma cooperative, biogas network	Sweden	Network-level business logic with focus on stakeholder collaboration and communication	Development of a business case for sustainability while increasing long-term financial profit and promoting the growth of the network	Karlsson et al. (2018, 2019)
Hybrid business models	Biogas plant	Europe	Local production, sale and usage of heat and electricity Provision of waste treatment services Collaboration and joint infrastructure development	Increased sales and revenue streams	Donner et al. (2020)

for a community in Bangladesh. There, households can sell various wastes to an authority in return for affordable biogas and bio-based fertilizers. This business model can reduce environmental and health hazards related to chemical fertilizer application and lower odor and waste pollution. The authors mention that this model is extendable to other rural communities and developed countries. While the goal is to achieve sustainable development in rural communities, the entrepreneurs can also achieve economic benefits in the long run (Ehsan et al., 2016).

These exemplary business models aim to promote the development of a rural economy and environmental governance through biogas production. In all cases, the entrepreneurs offer innovative ownership (e.g., a share of the products or a mutual exchange of goods) to the end-user. In doing so, they apply the principles as described by the foundation level of purposeful functionality models in Table 1. In both cases, the business model evolves around an authority that provides simultaneous waste conversion and energy and fertilizer production services to farmers or households. To be able to adapt their services to their customers, the companies need close and long-term relationships with the regional farmers. Running such a company requires sufficient intellectual capability and technologies. These innovative technologies in combination with high quality customer service and close relationships can put the company in an attractive position compared to competitors such as mainstream fertilizer producers.

3.3.2. Scaled-up functionality

In scaled-up functionality business models, the entrepreneur will still aim to provide innovative ownership to the end-customers, but also aims to create a profit in doing so. The organizational priority thus includes profit maximization as well as social and environmental value creation. In Table 2, a scaled-up sufficiency case study is described. Zhang (2019) discusses the Yitong system in China, collecting agricultural waste and converting them into energy and fertilizers. The authors suggests that this business model can be expanded with blockchain technology measuring the quantity of received waste, which is translated (e.g., with a coupon system) to an amount of energy and fertilizer that is owed to the waste-providing farms (Zhang, 2019).

While these businesses also provide innovative ownership, the difference with purposeful business models is that these companies will aim to profit from economies of scale. In this case, consistent with Table 1, the focus partially shifts from building close relationships with customers to increasing sales. The company will still need intellectual and technological capabilities in order to manage its operations fluently, but selling and marketing resources become important too in establishing a competitive position. Much like a purposeful functionality business model, this company will gain its competitive position from the service quality it delivers in offering innovative solutions. However, low costs and efficiency become principal characteristics in order to capture the economies of scale.

3.4. Stewardship business models

As a stewardship business model stresses the wellbeing of stakeholders, their key value proposition revolves around coordination and cooperation of technological operations. This is a broad interpretation of stewardship that allows for innovative collective ownership and organizational structures.

3.4.1. Purposeful stewardship

Businesses providing purposeful stewardship aim to coordinate a network of stakeholders without prioritizing profit maximization. Table 2 shows two exemplary business models. In the Nongbaomu or contracted agricultural management business model as discussed by Liu et al. (2018), farmers are assisted by professional personnel in soil preparation, harvesting, biomass collecting, bundling, storing and transporting. The farmers, however, keep ownership over their products. In the similar Nengbaomu or contracted energy management business model, biogas plants or fertilizer producers are supported (Liu et al., 2018). In a support structure as mentioned by Donner et al. (2020), circular activities are coordinated and brought together to help companies develop their circular business models. They can do this by providing coordination and support as well as joining efforts in waste valorization. The local niche cluster, organized by a leading association such as an NGO, consulting company, incubator, etc., brings together disconnected players. This way, they aim to maximize social benefits for its members while creating environmental value (Donner et al., 2020).

As indicated in Table 1, the entrepreneurs in these business models offer a mix of products and services, including support and know-how: knowledge and skills are shared. To ensure the long-term functioning of such support network or cooperative, close cooperation and transparent communication between farmers is needed. This implies a need for considerable networking and resource leveraging capabilities. As such, the business models take on cooperative, multi-partner and network structures. A centralized management of the flow of goods and services is important to secure trouble-free operations. In addition to intimate relationships with members or clients, the entrepreneurs will need to achieve operational excellence to manage the shared utilization of the innovation. Since the investment can be shared, operating leverage can be relatively low.

3.4.2. Scaled-up stewardship

In businesses providing scaled-up stewardship, the entrepreneurs aim to provide coordination and networking activities while making a profit. Table 2 provides four examples. For instance, Hussain et al. (2020) elaborates on a case company that operates a waste-to-energy AD plant with a specific aim of becoming circular. In their network of waste companies and food processing plants, expired food from retailers and bio-liquid from waste serve as process inputs. These close cooperative relationships have brought financial and operational benefits. The strategic location in between stakeholders does not only provide a logistic advantage, but is also beneficial to the local carbon footprint and quality of life. Collaboration is strengthened through knowledge sharing, joint research and investments. The company aims for economies of scale and scope by taking in more food waste and products. In their optimized and diversified process, they produce digestate, biogas and plastics from several biomass sources (Hussain et al., 2020). Åkerman et al. (2020) describes the case of Biovakka, founded by a coalition of pig farmers in Finland to solve the problem of regional manure surplus. This idea was based on collective centralized biogas plants

as seen in Central Europe. While the main motivation of the business model was the recuperation of manure nutrients within the regional environmental constraints, the energy production provided a source of profits. Morris et al. (2010) elaborate on the business model of A Green Energy, a primarily farmer-owned business developing small-scale AD projects for on-farm co-digestion of manure and source-separated organics. Their value proposition centers around increasing profitability and providing renewable energy to the local community by establishing a cooperation between farmers and the food processing industry. Dairy farmers earn income from savings on energy usage, savings in fertilizer costs and sales of excess power to the local community. Additional revenue is made through contracts to accept food residuals from processing facilities (e.g., soup, seafood, or other products) at fees competitive to gate fees for landfill or composting. For processors, this cooperation increases sustainable procurement and credibility toward retailers (Morris et al., 2010). Finally, Karlsson et al. (2018, 2019) describe a Swedish farm cooperative with farm-based biogas production. In an attempt to solve their financial difficulties, the authors suggest moving toward a network-level business model in which farmers and stakeholders co-create value to establish a profitable plant that contributes to sustainable regional development. This collaborative business model relies on stakeholder relationships and the creation of a network in which risks and rewards are shared. Increased cooperation and novel partnerships drive improved marketing, sustainable brand creation and servitization (Karlsson et al., 2018, 2019).

In these business models, cooperative and network-structures can be recognized. However, the difference with purposeful business models is the focus on profits and economies of scale. Consistent with Table 1, transactional relationships become important as a larger installation or multiple input sources imply more managerial and practical agreements. On top of operational excellence in the provision of the innovation, low costs and efficiency become essential in order to capture economies of scale. To maximize their benefits, they will produce high volumes. They may aim for an income model that ensures a healthy income base, but they can also strive for growth opportunities that generate capital gain.

3.5. Hybrid business models

It should be noted that hybrid forms of these archetypes are possible. For example, a company can create value from waste while also maximizing efficiency or substituting with renewables. As mentioned previously in this paper, a biogas digester can create value from biological waste while at the same time substituting fossil fuels with renewable energy from biogas.

For example, Donner et al. (2020) describe a biogas plant as a key business model in the bio-economy (Table 2). The authors mention that both individual and collective infrastructures exist (Donner et al., 2020). Collective plants adopt stewardship characteristics by focusing on collaboration and joint infrastructure development. However, by locally producing, selling and using heat and electricity, a biogas plant can also adopt sufficiency characteristics. Finally, Donner et al. (2020) mention that farmers can – but do not necessarily have to – envisage waste treatment services as a source of income. In that case, the business model adopts a functionality value proposition.

As such, a business can create value in many ways simultaneously. However, the business model typology should be regarded from the main aim of the business innovation. Many businesses do not fit solely into one business model, but belong dominantly to one of them while they make use of elements of the others.

4. Discussion

By developing business model archetypes that incorporate sustainable innovations on a technological, social and organizational level, this paper aimed to distinguish pathways of sustainable business model innovation. To show its relevance, this typology was applied to 18 anaerobic digestion business models in the agri-food sector described by 15 papers in the literature search. The typology provides a part-whole overview of circular business models by focusing on three dimensions on sustainability.

Sufficiency anaerobic digestion business models, as suggested by this typology, are mostly farm- or household-scale digesters aiming to produce energy and fertilizer for (at least partial) self-consumption. While purposeful sufficiency business models focus on rural development, scaled-up sufficiency business models aim to diversify and increase revenues. Functionality anaerobic digestion business models focus on innovative ownership and service provision, either to encourage purposeful regional development or revenue diversification through a sustainable value proposition. Finally, stewardship anaerobic digestion models include cooperative, multi-partner and network business models. They can either be focused on sustainable regional or sectoral development, or network growth and long-term profit through economies of scale.

However, while the typology distinguishes a 3 fold sustainable value proposition within a circular business, the conceptualized SCBMs are not necessarily 100% sustainable. For example, a company adopting a business model that fits in the proposed typology by implementing a technological, social and organizational innovation does not necessarily treat its employees well and could still induce rebound effects. A good illustration is the business model of the Biovakka biogas installation in Finland, as described by Åkerman et al. (2020). This plant processed manure to improve its qualities as a fertilizer and produce energy. While this business model initially seemed a good approach to tackle the manure surplus, the business model was deemed unsustainable: since farmers were not interested in paying gate fees for manure, other feedstock had to be used, which lead to an increase in regional nutrient concentration worsening the surplus issue. The linkage to local pig farming became disconnected. The authors conclude that the regulatory framework was not in line with their ambitious goals. However, by integrating the sustainable business model archetypes by Bocken et al. (2014) in a stepwise approach, the business model will be one step closer to a holistic sustainable business model.

The application of a hierarchical model and the new typology of sustainable CBM contributes to the field of circular economy business models by proposing a new way to distinguish between sustainable CBM. It allows for a distinction of pathways to sustainable business model innovation that links innovative technologies to new business models by providing a clear storyline of how technological innovations can create, deliver and capture value in environmental, social and economic contexts. Therefore, a strength of this typology of sustainable business models is that it considers the three dimensions

of the Triple Bottom Line. By defining three levels, the typology offers a stepwise exploration of sustainable business model innovation opportunities as a practical guide. Furthermore, the provision of examples in the bio-economy in this paper not only helps to clarify the categories defined by the newly introduced typology, but also brings a more realistic approach toward the implementation of the proposed business models.

While the applications in this paper focused on the technological archetype of "creating value from waste" as described by Bocken et al. (2014), the typology could also be relevant for the technological archetypes of "maximizing material and energy efficiency" and "substituting with renewables and natural processes". For example, Huijben and Verbong (2013) distinguish three types of photovoltaic (PV) business models that were experimented with in the Netherlands: customer-owned PV business models, community solar PV business models and third-party business models. In this typology, the distinction between sufficiency, stewardship and functionality can be recognized.

5. Conclusion

This study set out to develop a holistic typology for SCBMs based on existing sustainable business model archetypes. The research has identified and elaborated upon 6 newly defined archetypes of SCBMs. Furthermore, the applicability within the technological dimension of "creating value from waste" was shown by applying the typology to the production of bio-based fertilizers and energy *via* anaerobic digestion.

The business models as identified by this typology represent different approaches to a sustainable circular transformation. They are not mutually exclusive, and their application may be tailored to local needs and circumstances. The typology can inspire practitioners, including the government, on how to convert sustainability and circularity values into business cases. As such, it is useful to explore innovation opportunities for newly developed technologies, particularly on social and organizational levels.

Future work includes research on the relevance of this typology for other categories of sustainable business models such as zero carbon technologies or short supply chains. It is likely that this typology could be relevant for other sectors such as the energy sector. Similarly, the search for case studies to test the relevance of the identified business models typologies in other sectors can be useful. Additionally, among other factors, policies and incentives behind geographically varying case studies can differ. Further research on such barriers and drivers for different archetypes in the typology can guide policy makers in supporting the sustainable implementation of innovative circular solutions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ED: conceptualization, methodology, analysis, and writing—original draft. EM: conceptualization, methodology, review and editing, and supervision. Both authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Åkerman, M., Humalisto, N., and Pitzen, S. (2020). Material politics in the circular economy: The complicated journey from manure surplus to resource. *Geoforum* 116, 73–80. doi: 10.1016/j.geoforum.2020.07.013

Amit, R., and Zott, C. (2001). Value creation in E-business. *Strat. Manag. J.* 22, 493–520. doi: 10.1002/smj.187

Antikainen, M., and Valkokari, K. (2016). A framework for sustainable circular business model innovation. *Technol. Innov. Manag. Rev.* 6, 5–12. doi: 10.22215/timreview/1000

Baden-Fuller, C., and Morgan, M. S. (2010). Business models as models. *Long Range Plan.* 43, 156–171. doi: 10.1016/j.lrp.2010.02.005

Bailey, K. D. (1994). *Typologies and taxonomies: An introduction to classification techniques* (Sage University Paper series on Quantitative Applications in the Social Sciences, series no. 07-102). Thousand Oaks, CA: Sage. doi: 10.4135/9781412986397

Barth, H., Ulvenblad, P., Ulvenblad, P. O., and Hoveskog, M. (2021). Unpacking sustainable business models in the Swedish agricultural sector– the challenges of technological, social and organisational innovation. *J. Clean. Prod.* 304, 127004. doi: 10.1016/j.jclepro.2021.127004

Bezama, A. (2016). Let us discuss how cascading can help implement the circular economy and the bioeconomy strategies. *Waste Manag. Res.* 34, 593–594. doi: 10.1177/0734242X16657973

Bocken, N., Morales, L. S., and Lehner, M. (2020). Sufficiency business strategies in the food industry—the case of oatly. *Sustainability* 12, 824. doi: 10.3390/su12030824

Bocken, N. M., Fil, A., and Prabhu, J. (2016). Scaling up social businesses in developing markets. *J. Clean Prod.* 139, 295–308. doi: 10.1016/j.jclepro.2016.08.045

Bocken, N. M. P., de Pauw, I., Bakker, C., and van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *J. Indust. Prod. Engg.* 33, 308–320. doi: 10.1080/21681015.2016.1172124

Bocken, N. M. P., and Short, S. W. (2016). Towards a sufficiency-driven business model: Experiences and opportunities. *Environ. Innov. Soc. Transit.* 18, 41–61. doi: 10.1016/j.eist.2015.07.010

Bocken, N. M. P., Short, S. W., Rana, P., and Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *J. Clean. Prod.* 65, 42–56. doi: 10.1016/j.jclepro.2013.11.039

Boons, F., and Lüdeke-Freund, F. (2013). Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. *J. Clean. Prod.* 45, 9–19. doi: 10.1016/j.jclepro.2012.07.007

Brundtland, G. H. (1987). *Report of the World Commission on Environment and Development: Our Common Future* (United Nations General Assembly document A/42/427).

Chesbrough, H., and Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Ind. Corpor. Change* 11, 529–555. doi: 10.1093/icc/11.3.529

Chojnacka, K., Moustakas, K., and Witek-Krowiak, A. (2020). Bio-based fertilizers: A practical approach towards circular economy. *Biores. Technol.* 295, 122223. doi: 10.1016/j.biortech.2019.122223

Dagevos, H., and de Lauwere, C. (2021). Circular Business Models and Circular Agriculture: Perceptions and Practices of Dutch Farmers. *Sustainability.* 13, 1282. doi: 10.3390/su13031282

D'Amato, D., Korhonen, J., and Toppinen, A. (2019). Circular, green, and bio Economy: How do companies in land-use intensive sectors align with sustainability concepts? *Ecol. Econ.* 158, 116–133. doi: 10.1016/j.ecolecon.2018.12.026

Dantas, T., de-Souza, E., Destro, I., Hammes, G., Rodriguez, C., and Soares, S. (2021). How the combination of Circular Economy and Industry 4.0 can contribute towards achieving the Sustainable Development Goals. *Sustain. Prod. Consumpt.* 26, 213–227. doi: 10.1016/j.spc.2020.10.005

DaSilva, C. M., and Trkman, P. (2014). Business model: What it is and what it is not. *Long Range Plan.* 47, 379–389. doi: 10.1016/j.lrp.2013.08.004

Donner, M., Gohier, R., and De Vries, H. (2020). A new circular business model typology for creating value from agro-waste. *Sci. Total Environ.* 716, 137065. doi: 10.1016/j.scitotenv.2020.137065

Ehsan, M. A., Das, C. K., and Hasan, M. (2016). "Biogas based chain business: A road to sustainable rural development," in *2016 4th International Conference on the Development in the in Renewable Energy Technology (ICDRET)*. doi: 10.1109/ICDRET.2016.7421505

EMF (2015). *Growth within: a Circular Economy Vision for a Competitive Europe.*

EMF (2019). *Circular economy diagram.* Ellen MacArthur Foundation. Available online at: https://ellenmacarthurfoundation.org/circular-economy-diagram (accessed August 26, 2022).

European Commission (2013). *Social Innovation.* Internal Market, Industry, Entrepreneurship and SMEs. Available online at: https://ec.europa.eu/growth/industry/strategy/innovation/social_nl (accessed August 26, 2022).

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., and Hultink, E. J. (2017). The circular economy – A new sustainability paradigm? *J. Clean. Prod.* 143, 757–768. doi: 10.1016/j.jclepro.2016.12.048

Geissdoerfer, M., Vladimirova, D., and Evans, S. (2018). Sustainable business model innovation: A review. *J. Clean. Prod.* 198, 401–416. doi: 10.1016/j.jclepro.2018.06.240

Hamid, R., and Blanchard, R. (2018). An assessment of biogas as a domestic energy source in rural Kenya: Developing a sustainable business model. *Renew. Energy* 121, 368–376. doi: 10.1016/j.renene.2018.01.032

Huijben, J. C. C. M., and Verbong, G. P. J. (2013). Breakthrough without subsidies? PV business model experiments in the Netherlands. *Energy Policy* 56, 362–370. doi: 10.1016/j.enpol.2012.12.073

Hussain, Z., Mishra, J., and Vanacore, E. (2020). Waste to energy and circular economy: the case of anaerobic digestion. *J. Enter. Inf. Manage.* 33, 817–838. doi: 10.1108/JEIM-02-2019-0049

Jain, A., Sarsaiya, S., Kumar Awasthi, M., Singh, R., Rajput, R., Mishra, U. C., et al. (2022). Bioenergy and bio-products from bio-waste and its associated modern circular economy: Current research trends, challenges, and future outlooks. *Fuel* 307, 121859. doi: 10.1016/j.fuel.2021.121859

Johanisova, N., and Wolf, S. (2012). Economic democracy: A path for the future? *Futures* 44, 562–570. doi: 10.1016/j.futures.2012.03.017

Karlsson, N. P. (2019). Business models and business cases for financial sustainability: Insights on corporate sustainability in the Swedish farm-based biogas industry. *Sustain. Prod. Consumpt.* 18, 115–129. doi: 10.1016/j.spc.2019.01.005

Karlsson, N. P., Hoveskog, M., Halila, F., and Mattsson, M. (2018). Early phases of the business model innovation process for sustainability: Addressing the status quo of a Swedish biogas-producing farm cooperative. *J. Clean. Prod.* 172, 2759–2772. doi: 10.1016/j.jclepro.2017.11.136

Karlsson, N. P., Hoveskog, M., Halila, F., and Mattsson, M. (2019). Business modelling in farm-based biogas production: towards network-level business models and stakeholder business cases for sustainability. *Sustain. Sci.* 14, 1071–1090. doi: 10.1007/s11625-018-0584-z

Khan, I. S., Ahmad, M. O., and Majava, J. (2021). Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. *J. Clean. Prod.* 297, 126655. doi: 10.1016/j.jclepro.2021.126655

Li, G., Song, Y., and Jing, C. (2016). "Diversification development and utilization of new energy in rural areas - taking Qinhuangdao city of Hebei province as an example," in *Proceedings of the 2015 4th International Conference on Sustainable Energy and Environmental Engineering*. doi: 10.2991/icseee-15.2016.99

Liu, H., Ou, X., Yuan, J., and Yan, X. (2018). Experience of producing natural gas from corn straw in China. *Resour. Conser. Recycl.* 135, 216–224. doi: 10.1016/j.resconrec.2017.10.005

McDonough, W., and Braungart, M. (2002). *Cradle to Cradle: Remaking the Way We Make Things (1st ed.)*. New York, NY: North Point Press.

Morris, C., Jorgenson, W., and Snellings, S. (2010). Carbon and energy life-cycle assessment for five agricultural anaerobic digesters in massachusetts on small dairy farms. *Int. Food Agribus. Manag. Rev.* 13, 1–8.

Morris, M., Schindehutte, M., and Allen, J. (2005). The entrepreneur's business model: toward a unified perspective. *J. Bus. Res.* 58, 726–735. doi: 10.1016/j.jbusres.2003.11.001

Murray, A., Skene, K., and Haynes, K. (2015). The circular economy: An interdisciplinary exploration of the concept and application in a global context. *J. Bus. Ethics* 140, 369–380. doi: 10.1007/s10551-015-2693-2

Navare, K., Muys, B., Vrancken, K. C., and Van Acker, K. (2021). Circular economy monitoring – How to make it apt for biological cycles? *Resour. Conserv. Recycl.* 170, 105563. doi: 10.1016/j.resconrec.2021.105563

Osterwalder, A., and Pigneur, Y. (2010). *Business Model Generation.* Hoboken, NJ, United States: Wiley.

Payne, A. (1994). Relationship marketing – Making the customer count. *Manag. Serv. Quality.* 4, 29–31. doi: 10.1108/EUM0000000003939

Porter, M., and Kramer, M. (2011). *Creating Shared Value.* Boston, MA, USA: FSG. Available online at: https://hbr.org/2011/01/the-big-idea-creating-shared-value (accessed August 26, 2022).

Reim, W., Parida, V., and Sjödin, D. R. (2019). Circular business models for the bioeconomy: A Review and new directions for future research. *Sustainability* 11, 2558. doi: 10.3390/su11092558

Salvador, R., Barros, M. V., Luz, L. M. D., Piekarski, C. M., and De Francisco, A. C. (2020). Circular business models: Current aspects that influence implementation and unaddressed subjects. *J. Clean. Prod.* 250, 119555. doi: 10.1016/j.jclepro.2019.119555

Schaltegger, S. (2002). A framework for ecopreneurship. *Greener Manage. Int.* 38, 45–58. doi: 10.9774/GLEAF.3062.2002.su.00006

Sgroi, F., Donia, E., and Alesi, D. R. (2018). Renewable energies, business models and local growth. *Land Use Policy* 72, 110–115. doi: 10.1016/j.landusepol.2017.12.028

Sherwood, J. (2020). The significance of biomass in a circular economy. *Biores. Technol.* 300, 122755. doi: 10.1016/j.biortech.2020.122755

Simon, H. A. (1996). *Sciences of the Artificial* (1st ed.). Cambridge, Massachusetts: The MIT Press

Stahel, W. R., and Reday-Mulvey, G. (1981). *Jobs for Tomorrow.* Amsterdam, Netherlands: Amsterdam University Press.

Tukker, A. (2015). Product services for a resource-efficient and circular economy – A review. *J. Clean. Prod.* 97, 76–91. doi: 10.1016/j.jclepro.2013.11.049

United Nations (2002). *Report of the World Summit on Sustainable Development* (A/CONF.199/20).

Upward, A., and Jones, P. (2015). An ontology for strongly sustainable business models. *Organiz. Environ.* 29, 97–123. doi: 10.1177/1086026615592933

Urbinati, A., Chiaroni, D., and Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *J. Clean. Prod.* 168, 487–498. doi: 10.1016/j.jclepro.2017.09.047

Whalen, K. A. (2019). Three circular business models that extend product value and their contribution to resource efficiency. *J. Clean. Prod.* 226, 1128–1137. doi: 10.1016/j.jclepro.2019.03.128

Ximenes, J., Siqueira, A., Kochańska, E., and Łukasik, R. M. (2021). Valorisation of agri- and aquaculture residues via biogas production for enhanced industrial application. *Energies* 14, 2519. doi: 10.3390/en14092519

Zhang, D. (2019). Application of blockchain technology in incentivizing efficient use of rural wastes: a case study on yitong system. *Energy Procedia* 158, 6707–6714. doi: 10.1016/j.egypro.2019.01.018

Zhu, Q., Jia, R., and Lin, X. (2019). Building sustainable circular agriculture in China: economic viability and entrepreneurship. *Manage. Decis.* 57, 1108–1122. doi: 10.1108/MD-06-2018-0639

Zink, T., and Geyer, R. (2017). Circular economy rebound. *J. Ind. Ecol.* 21, 593–602. doi: 10.1111/jiec.12545

Zott, C., Amit, R., and Massa, L. (2011). The business model: Recent developments and future Research. *J. Manage.* 37, 1019–1042. doi: 10.1177/0149206311406265