“The dark side of the circular economy: The value uncaptured in bioeconomy business models”

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THE DARK SIDE OF THE CIRCULAR ECONOMY: THE VALUE UNCAPTURED IN BIOECONOMY BUSINESS MODELS

Abstract

The bioeconomy, grounded in the shift from fossils to bio-based resources, plays an important role in the Net Zero 2050 scenario. However, even if rooted in circular thinking, bioeconomy business models are not free from environmental, social, and economic concerns. This paper deals with the causes of the unsustainability of business models in the biofuels sector, embracing an unconventional approach that focuses on the uncaptured value. The value uncaptured is the negative aspect of value, and it consists of creating too much or not enough value during the product lifecycle. Value uncaptured can threaten the sustainability of circular business models, which is why it constitutes the 'dark side' of circular strategies. Starting from a gap in the existing literature and supported by theoretical background, this study aims to suggest a theoretical framework to identify the causes of the negative value in the biofuel sector. The paper uses a qualitative tool, namely a case study analysis. The findings reveal that circular business models can suffer from value uncaptured, which can take the form of value absence, value destroyed, value surplus, and value missed. Identifying these forms of value can transform them into opportunities for value creation. These results enrich the research on the circular economy with a new and unconventional approach. The elaborated theoretical framework can become a qualitative tool to identify what causes companies' circular business models to underperform.

Keywords sustainability, climate change, product lifecycle, biofuels, SDGs

JEL Classification Q01, M21, Q20

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INTRODUCTION

The linear economy has dominated the world's economic model since the Industrial Revolution. Ellen MacArthur Foundation (2015) defines linear economy as a model for producing and consuming that follows the take-make-dispose pattern. The final aim of this model is to sell as many products as possible to consumers at a price that at least covers the costs. This should ensure an adequate return to the company without focusing on the problem of resource scarcity. This model will be clearly unsustainable in the long term, considering that the total quantity of material resources used in 2021 was 100.6 billion tons, growing by 68.04% if compared to 2018, in proportion more than the population growth (Circle Economy, 2022). The exponential growth of natural resources' prices and their volatility have increased the unpredictability of changes and, consequently, the costs. Hence, the linear economy is also one of the causes of the current global economic concerns.

The circular economy participates in the debate on climate change because it has a key role in the green transition. In fact, decoupling the production processes from the depletion of natural resources favors the achievement of the SDGs and the goals announced with the

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European Green Deal. The Ellen MacArthur Foundation (2015) officially brought the circular concept into international understanding by providing a comprehensive definition of this economy and offering related guiding principles.

Circular economy considers a product's life as a whole, assessing both the value created and the negative impacts in every phase of its existence (lifecycle assessment), from its cradle to its grave. In this context, circular strategies (known as R-strategies) can extend the product lifecycle as much as possible to maintain its value for a longer time and, whenever possible, return it to nature. R-strategies consist of refusing waste, rethinking products for more intense use, reducing resources and being more efficient, reusing, repairing, restoring and updating products, remanufacturing discarded products for goods with the same functions, repurposing discarded products for goods with other functions, recycling, and recovering energy from materials which cannot be submitted to other R-strategies.

Changing traditional production and consumption behaviors is crucial to switching to a circular economy. It requires adopting a different view in production systems to unlock the value inherent in the product lifecycle by means of one or more R-strategies. For this reason, companies engaged in these strategies should make their business models circular using innovative business models. Companies need to add environmental and social dimensions to their circular business models or integrate traditional design thinking with lifecycle value management. However, scholars still pay scarce attention to the negative concept of value uncaptured, i.e., the potential value that companies cannot reach. This is also true for bioeconomy business models, many of which suffer from underperformance.

Thus, it is crucial to offer a theoretical framework rooted in the value uncaptured to determine different sources of negative value for each phase of the biofuel lifecycle. The framework should emphasize both the circularity approach, aimed at closing the loop, and the sustainability mindset, aimed at focusing on economic, social, and governance aspects.

1. THEORETICAL BASIS

The literature studied the concept of business models and how to innovate them to make them sustainable according to circular principles. The conventional approach uses the identification of the value proposition (what one is offering to clients and customers), value delivery (how one is organizing business to deliver on the proposition), and value capture (how the value is created thanks to the proposition and delivery comes back to the business). Research on circular business models adopted this traditional approach, emphasizing the need to consider these value components along the product lifecycle to extend its life and close the loop with one or more R-strategies.

A new trend of research is developing on the negative face of the value embedded in business models, the so-called value uncaptured, which can reduce the potential sustainability of a circular approach to business. Since these sources can negatively impact the environment, society, and economic performance, firms should be aware of them when designing their business models.

1.1. From traditional to circular business models

Using business models, a manager successfully creates, delivers, and captures value (Osterwalder & Pigneur, 2010). The switch from traditional to circular business models requires significant efforts as the latter replaces the product end-of-life concept with the R-strategies (Kirchherr et al., 2017; Gennari & Cassano, 2020; Salvioni et al., 2022).

Geissdoerfer et al. (2020, p. 7), viewing the previous literature's contributions, consider that circular models "are cycling, extending, intensifying, and/or dematerializing material and energy loops."

According to Girotra and Netessine (2014), Lewandowski (2016), Daou et al. (2020), Geissdoerfer et al. (2020), Koilo (2021), and Santa-

Maria et al. (2021), several tools have emerged to move from linear to the circular economy. Bocken et al. (2019) stressed the need to define circular business models and provide managerial tools for such a transition.

In this vein, the main reference remains the established Canvas business model by Osterwalder and Pigneur (2010), circularly upgraded to obtain the Ecocanvas business model (Daou et al., 2020), which adds the triple perspective of sustainability (environmental, social, and economic) by Elkington (1994). Ecocanvas' main advantage is considering environmental, social, and economic dimensions. The model proposes the original building blocks of Canvas, but rethought according to sustainability and circularity principles.

Similarly, the framework by Antikainen and Valkokari (2016) integrates the traditional Canvas model with the level of business ecosystem, the sustainability costs and benefits, and the circularity evaluation using lifecycle assessment tools. However, the Ecocanvas business model, as the other business model frameworks focused on circularity (Mendoza et al., 2017; Konietzko et al., 2020), does not emphasize the core concept of circular economy, that is, the multiple cycles that a product launches during its lifecycle.

The switch from a linear economy is not simply limited to the integration of the traditional business strategy with the social and environmental concerns (Lewandowski, 2016). On the contrary, it entails the adoption of a closed-loop view for all business model elements, considering also the circular value creation during the lifecycle of products, services, and materials (Nußholz, 2018; Cerantola, 2019; Daou et al., 2020). The product lifecycle is one of the basic concepts of circular economy (Ellen MacArthur Foundation, 2015), and it is considered a fundamental approach to designing circular business models. The single-use cycle approach needs to be replaced by a new business vision, which creates and recreates product value, nurturing multiple business models.

According to this view, Nußholz (2018) depicts a visualization approach of cycles that enlarge the useful life of products and eliminate material loops to identify circular business models. This approach has the merit of emphasizing the need, in designing the business model, to shift attention from a single-use toward multiple cycles that feed various value systems, according to the concepts of circular economy. It is configured as a tool incorporating the "idea of value management along the product lifecycle" (p. 188).

The cited scientific contributions include the matter of circularity and product lifecycle in the traditional vision of value, characterizing the core of the business model (Boons & Lüdeke-Freund, 2013). Nevertheless, they do not discuss the negative meaning of value.

1.2. The value uncaptured

Bocken et al. (2015) attempted to understand the negative aspect of value. The study introduced multiple forms of value: value captured (positive outcomes for stakeholders), value missed (failures in catching the value), value destroyed (negative business outcomes), and value opportunities (novel solutions due to the adoption of a multi-stakeholder approach). Although often underestimated, value's negative forms can lead to the failure of circular business models in the market (Geissdoerfer et al., 2016). Hence, the concept of value is strictly related to its opposite face, the value uncaptured showing up in one of these four forms (Yang et al., 2017):

- value surplus – value that is not required (for instance, overproduction and waste);
- value absence – value that is necessary but does not exist (for instance, lack of space or labor);
- value missed – value that exists but is not exploited (this usually refers to the value that is inadequately captured);
- value destroyed – something that exists and undermines the value and has negative consequences (such as pollution).

A clear relationship between value captured and uncaptured can be highlighted: the latter increases value capture in innovative business models.

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Furthermore, sources of value uncaptured can be clustered according to the product life cycle: the beginning of life refers to the design and production, the middle of life relates to the purchase and use, the end of life refers to the end (Jun et al., 2007; Cao & Folan, 2012). In the beginning stage, the main cause of value uncaptured in the design is identified; in the middle, the use of the product is the most recurrent cited source of value uncaptured, while at the end, a lot of value is uncaptured in the recycle, reuse or remanufacture processes (Yang et al., 2017).

Only some contributions in the academic literature focus on this field of research. Osterwalder et al. (2014) view value uncaptured as a real challenge in manufacturing that can be solved by changing the perspective with sustainable business models. Bocken et al. (2015) highlight the need to rethink or redesign the business models starting from the concept of value destroyed. Wagner and Kabalska (2023) have raised future research challenges on value uncaptured. Therefore, the literature review emphasizes the negative value perspective as new trends in sustainability (Gennari, 2022a; Méndez-León et al., 2022), particularly regarding the circular economy. According to Salvador et al. (2020) and Broccardo et al. (2023), research should seek ways to solve theoretical and practical challenges.

1.3. Bioeconomy circular business models

Academic literature recognizes the contribution of bioeconomy to sustainability (Reim et al., 2017). The importance of developing a political and institutional framework for bioeconomy to enhance its contribution to the achievement of Agenda2030 SDGs was also recognized by the European Union in 2012, which launched the first bioeconomy strategy, updated in 2018 (European Commission, 2018). European Commission (2012) defined the bioeconomy as creating value-added products (i.e., bioenergy, food, and bio products). Using products from biological resources and minimizing the consumption of virgin resources can nurture circular cycles, promoting the circular bioeconomy (European Commission, 2018). Hence, this sector is assuming a pivotal role in the green transition process for Net Zero by 2050, able to replace fossil fuels with biofuel on a large scale (Kuzior et al., 2023).

Salvador et al. (2021) revealed that the research about business models in circular bioeconomy is not well developed and, when existing, is not well identified. The shift from linear economy-based business models to circular bio-based business models remains a difficult task because of many challenges related to the required cross-disciplinary skills, the high production costs of bio products, the uncertainty in the governments' incentives, and the commercialization issues (Donner et al., 2021; Bröring & Vanacker, 2022).

Bröring and Vanacker (2022) identified three main typologies of bioeconomy business models:

- the 'substitute products' model is appropriate when a fossil-based product can be easily replaced with a bio-based resource that performs the same functions (this is the case of biofuels);
- the 'new products' model refers to bio products with new functionalities (this is the case of synthetic organisms created in the laboratories);
- the 'services' model is based on offering additional services (for example, reforestation or planting) or on replacing ownership with the concept of pay-for-use.

Regarding biofuel, the business model is focused on offering alternatives to fossil fuels with new processes involving the value chain. The main challenges relate to problematic market acceptance, low trust in substitute products in terms of quality and performance, and the need for large quantities of biomass resources. This situation impacts the economic side, questioning the profitability of investing in biofuel (Bröring et al., 2020). Furthermore, the sustainability of biofuel production systems is under debate because of environmental and social concerns related to fertile land use, impacts on forests, biodiversity loss, and pollution issues (Rathore et al., 2016). In some cases, the bioeconomy even appears to conflict with the SDGs (Bröring et al., 2020). For this reason, designing high-performing business models requires companies to become aware of their challenges and potential uncaptured areas of value.

1.4. Value uncaptured in circular business models: A theoretical framework

Previous research provides frameworks for sustainable business models, emphasizing particular aspects to be considered. However, the literature lacks a theoretical framework rooted in the concept of value uncaptured for circular business models.

Yang et al. (2017) emphasized the analysis of the sources of negative value along the product lifecycle, but what is missing is the circularity approach that closes the loop, making the end of one cycle the beginning of another cycle. Instead, this concept is stated by Nußholz (2018), whose framework remains rooted in the traditional value approach. Also, the business model for biofuel suggested by Bröring and Vanacker (2022) emphasizes the main sources of value created in new processes for managing bio-based resources and new value chain partners for procuring biomass resources. Still, it does not mention the problems related to the potential existence of value uncaptured.

Based on previous findings of the theoretical literature, this paper proposes a fresh approach by identifying for each phase of the product lifecycle and the main types of value uncaptured, according to the circular approach. Furthermore, considering that the circular economy has been promoted as an effective contribution to sustainable development, the framework suggests grouping the different sources of value uncaptured (Yang et al., 2017) that occur at each stage of the product lifecycle, under ESG (environmental, social and governance) approach (Elkington, 1994).

In particular, the framework (Figure 1) comprises three connected macro-areas that coincide with the three phases of the product lifecycle: the beginning of life, the middle of life, and the end of life. Each macro-area has a two-dimensional matrix: vertically, there are four categories of value uncaptured, and horizontally, three are the three dimensions of sustainability. The aim is to emphasize the 3D approach that characterizes circular business models, going beyond the traditional lifecycle assessment, which develops in multiple linear cycles. Every single phase of the product lifecycle should be managed considering the close relationships with the two others, according to the circular principle of the lifecycle "from the cradle to the grave." The value uncaptured in one phase can generate other forms of value uncaptured in other phases of the product life. Furthermore, the impacts of the different sources of value uncaptured on ESG dimensions are highlighted to make companies aware of their global responsibility (Gennari, 2022b).

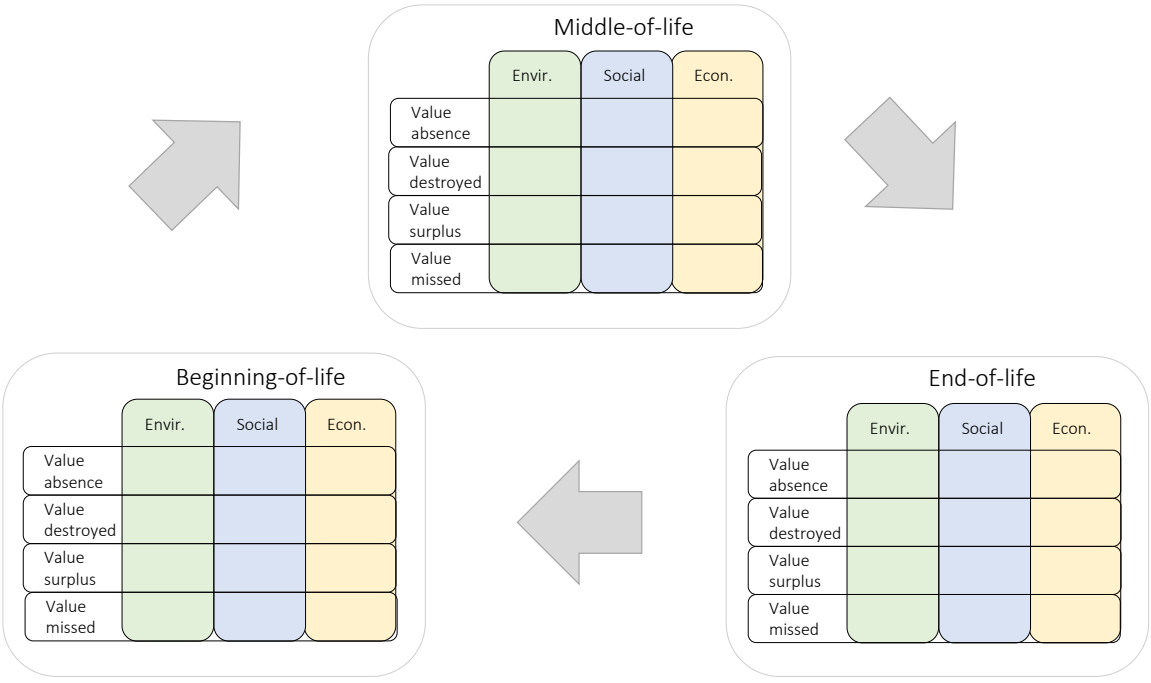

Figure 1. Theoretical framework for the identification of value uncaptured

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2. METHODOLOGY

The theoretical framework was validated using a qualitative content analysis applied to a case study. According to deductive thinking, this method is suitable for assessing the model (Hyde, 2008). The case study, despite its limitations (Baškarada, 2014), allows scholars to explore relevant issues of a phenomenon, using a variety of data sources providing supportive or non-supportive evidence for theoretical propositions. Therefore, the boxes within the suggested theoretical framework were used as a coding protocol to analyze the secondary source text data (Cavanagh, 1997).

Validity and reliability (Jones & Shoemaker, 1994; Bengtsson, 2016) were ensured by referring to different public sources (website information, reports, and press conferences discussing the analyzed case study). The use of secondary sources of information, typical of content analysis applied to a case study, implies the risk of greenwashing (focusing on positive actions and giving little negative information), particularly for industries characterized by high environmental and social impacts. However, some features of the company taken as a case study guarantee substantial reliability of information, particularly the presence of government controlling shareholders, the compliance of the reporting system with internationally recognized standards, and the leadership position in many ESG indexes and ratings. The data analysis was completed with an interview with a company manager using open-ended questions (Sofaer, 1999). The inductive attitude was used for data collection, while the deductive approach was employed within the interview, thus reflecting the perspective of grounded analysis (Maxwell, 2005; Flick, 2009; Hennink et al., 2020).

The case study, from February to April 2023, consisted of the circular project of a multinational firm (from now on, 'the Company') operating in the biofuel sector. The project involved the redevelopment of a refinery into a bio refinery aimed at using vegetal and animal waste oils to produce bio oil, useful as fuel for many different sectors. The main difference between a traditional refinery and a biorefinery is the inputs that go into the refining process. Within a traditional refinery, the main (if not only) input is represented by crude oil, which is separated into its main components and then treated to obtain commercial products sold on the market. In a biorefinery, however, the input is biomass, defined as any organic material; the biomass is appropriately treated inside the plants and, subsequently, bio oil and biofuel are obtained. The refinery, from 2009, had registered huge losses, so the Company decided to invest about 700 million euros for the requalification of the site to recover its economic sustainability and switch from traditional oil products to bio oil. The conversion process started in 2016 and has been completed in 2019. The biorefinery has high operational flexibility, capable of processing second-generation materials from food production waste and regenerating used edible oil, animal fats, and vegetable oil byproducts. The biorefinery is powered by raw material, mostly from a foreign country where the organic waste and residues from the food chain are previously processed and treated. In this way, they are transformed into materials that can be used in the production process of the biorefinery. In this foreign country, the Company has involved the government and institutions to build a partnership and to bring benefits to society.

3. RESULTS

The value uncaptured at the beginning of life includes all those elements and phases that precede the sale and subsequent use of the product by the customer. It includes not only the production process's operations but also all those central and collateral elements that contribute to the product design and sale. For biofuel, the beginning of life corresponds to the transformation of biomass, which are biological substances also deriving from dead or decomposed organisms obtained from animals and plants. There are some main categories of biomass: wood, energy crops, agricultural residues, food, and industrial waste. The potential value uncaptured hidden at this stage is shown in Table 1.

Value uncaptured in the middle of life refers to those elements and phases that characterize the product's life after the company has produced it

Table 1. Beginning of life of biofuel: Transformation of biomass

	Negative impacts of value uncaptured		
Forms of value uncaptured	**Environmental**	**Social**	**Economic**
Value absence	Standardized production of biomass: The soil is devoted to the production of biomass, causing a lack of research for improving agriculture production (new products with innovative and lower-impact techniques)	No knowledge improvement in the agricultural field due to the standardized production of biomass and low interest in starting other cultivations. Bad working conditions, depending on the biofuels' demand stress and related need to increase the production	Need for additional warehousing to stock biomass in case of demand's volatility and seasonality
Value destroyed	Deforestation and indiscriminate use of water resources due to increased demand for biofuels and related biomass production. Emissions from agriculture activities and transport activities from the place of biomass production to the place of their transformation. Standardized cultivations and the consequent need for more polluting fertilizers cause infertile soil. Increasing production of waste to sustain bio-circular business model (circular business model paradox)	High dependence on the food supply chain (when the waste is used as a resource) and related sensitivity to food production and consumption patterns. Changes in food customs for having more biomass to nurture the biofuel plants (circular business model paradox)	Logistics and transportation are additional costs for moving biomass to the location of productive plants; this can cause a higher final product price. Additional costs of processes (particularly in the waste pre-treatment phase), plants, and maintenance. Risk of not satisfying the consumers' needs for biofuels
Value surplus	Waste of heat and energy from production processes and overproduction	Unnecessary overworking related to overproduction	Useless costs or missed revenue for excessive production and related waste of heat and energy
Value missed	Technology problems related to waste of components that cannot be reused, recycled, or remanufactured. Scarce investments in the development of innovative solutions due to the use of one type of cultivation or the use of waste as a resource	Low investments in workers' education and support for the local community	Low investments in the existing technologies to reduce the impacts of the agrifood sector and to support the local economy

and delivered it to customers through different channels. The critical role of distribution and after-sales service, training, inspections, preventive maintenance, and repairs is becoming increasingly relevant in this phase. Hence, value uncaptured refers primarily to how a firm distributes its goods and how clients use them. For biofuel, this stage refers to the way the product is available to consumers; the information flows by a firm to the market and vice versa, and the product's final use (Table 2).

The end of life can be seen as the stage of the product life most involved in the circular approach. The linear approach considers products disposable when they are no longer able to fulfill their primary use. On the contrary, there is no real end of life phase for the circular economy: it begins when the product no longer satisfies the initial buyer and can be subjected to circular strategies. Since biofuels are burned, they cannot feed a subsequent life initiation phase. However, even in this phase, some problems are configured as causes of potential value uncaptured and are linked to negative externalities due to the use of the product, consumer behavior, and cost-effectiveness problems (Table 3).

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Table 2. Middle of life of biofuel: Distribution and use

	Negative impacts of value uncaptured		
Forms of value uncaptured	**Environmental**	**Social**	**Economic**
Value absence	Lack of innovation in the search for different types of resources, which could have different performances in the production phase. Consumers' education problems are related to linear consumption culture, and potential value loss is still embedded within the product	Customers' and retailers' incorrect perception of product's benefits due to lack of communication about the characteristics of biofuels	Company's misunderstanding of consumers' needs about biofuels. Network problems related to low level of services by suppliers. Management problems related to the inability to manage circularity
Value destroyed	Biofuels' low power generation and performance and consequent overuse. Problems related to contact between biofuels, specific plastics or rubber materials, and consequent emissions. Unclear communication to consumers about the real environmental impacts of biofuels. Process problems related to inefficient retailers' operations	Higher price of biofuel components and decreased well-being of customers. Not compensation for seasonality and related price volatility. Scarce engagement of value-chain partners	Costs related to biofuels' underperformance. Problems related to contact between biofuels, specific plastics or rubber materials, and consequent investments are required. Demand's volatility. Costs related to inefficient company and retailers' processes and operations. Inability to motivate clients and missed revenues
Value surplus	Regulation for the use of biofuels can also increase the use of fossil fuels. Market problems related to the inability to understand and elaborate demand's trend: unjustified use of resources and related unjustified environmental impacts	Uncertainty in the regulation of biofuels can create confusion in biofuels' benefits perception. Unjustified additional work due to inability to understand and elaborate on demand's trend	Unjustified costs related to the inability to understand and elaborate on demand's trend. Uncertainty in the regulation of biofuels can slow down the investments in circular economy
Value missed		Problems related to customers' and retailers' correct perception of biofuels' benefits due to lack of information and communication activities. Missed opportunities related to not sharing information within the network	Missed revenues due to miscommunication with customers and retailers. Missed revenues related to biofuels' price perceived as unacceptable by consumers. Missed revenues related to the inability to motivate clients. Costs related to inefficient design of delivery operations

Table 3. End of life of biofuel: Externalities

	Negative impacts of value uncaptured		
Forms of value uncaptured	**Environmental**	**Social**	**Economic**
Value absence	Missed opportunities in saving the environment (and consequent early interruption of product lifecycle) due to linear consumers' culture and low knowledge about circular practices	Missed opportunities to contribute to solving the problem of climate change due to linear behaviors by consumers	Inefficient technologies to support competitive prices of bio-based products. Profit coming from government incentives instead of circular product performance.
Value destroyed	Emissions and pollution due to scarce attention to product lifecycle. Environmental issues related to increased waste to nurture the beginning-of-life stage (circular business model paradox). Early interruption of product lifecycle and pollution caused by the disposal of products defined unsuitable for R-strategies by regulation	HR problems related to the risk of job loss caused by circular transition and change in production processes	Costs related to limits in recovering products defined as waste by regulation

Table 3 (cont.). End of life of biofuel: Externalities

	Negative impacts of value uncaptured		
Forms of value uncaptured	**Environmental**	**Social**	**Economic**
Value surplus	Adopting R-strategies without a clear knowledge of their environmental impacts	Circularity 'on the façade' (greenwashing)	Difficult in selling well-performing bio-products due to the consumers' wrong perception of them
Value missed	No consumers' appreciation of circular practices and interruption of product lifecycle	Missed opportunities for new jobs needed by a circular economy because of ignorance about laws. Perception problems related to the idea that bio products are more expensive but less performing: low value attributed to circular practices and scarce attention towards the circular transition. Scarce collaboration within the value chain	Missed investment opportunities because of ignorance about laws. Missed revenues due to problems related to the inability to communicate the right price for bio-based products. Economic problems related to the inability to manage the reverse logistics and to restart the product's lifecycle

4. DISCUSSION

In bioeconomy, renewable resources are produced, and waste is converted into biological products and bioenergy. Bioenergy production requires innovative business models due to challenges related to the value chain, technology, product quality, product availability, market, geography, economy, regulation, and organization (Bröring & Vanacker, 2022). Bioenergy represents 55% of global renewable energy and 6% of global energy supply. Growth is expected in 2024, particularly in emerging economies. Biofuels will be mainly in demand because they meet policy goals on greenhouse gases and feedstock in both the United States and Europe (International Energy Agency, n.d.).

However, the main problem that the biofuel industry, and the bioenergy sector in general, faces is a typical ethical and social challenge related to raw materials: human/animal destination or alternative energy source? This competition is crucial for the price volatility of agricultural products. Although biofuels are produced using biomass and waste by-products coming from agro-food chains (such as animal fats, vegetable oils, and edible oils) not in competition with the agro-food sector, many economic, environmental, and social issues arise during their life cycle. The suggested framework, based on both the value uncaptured during the lifecycle of the product and the impacts on the sustainability dimensions, revealed that some sources of value uncaptured are known but not managed within the circular business models as potential value opportunities.

Considering the environmental dimension, the main value uncaptured emerged by results is related to:

- soil depletion caused by the specialized and standardized cultivation for nurturing the transformation plants significantly affects biodiversity and low soil fertility, requiring the increasing use of fertilizers and generating additional environmental impacts. The lack of crop diversity is dangerous for the health of the soil due to the scarce interest in researching different and lower-impact cultivation techniques (Groom et al., 2008);

- pollution, waste of energy, and negative externalities as the results of operational and logistic processes for collecting and transporting waste and biomass. This phenomenon is amplified in the growing demand for biofuel, opening the debate about the so-called circular economy paradox. The dependence of biofuel producers on the food supply chain can cause lock-in situations: when the demand for biofuel increases, producers need more waste deriving from food consumption. If the circular economy aims to minimize waste production in the supply chain, stimulating food consumption to have more waste to use contradicts the basic pillar of the circular economy of zero waste. Therefore, it is not pragmatic to encourage big industries to use food waste (Karmee, 2016; Keßler et al., 2021);

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- product's characteristics: biofuels have a lower power-generating capacity and performance than fossil fuels (CTI, n.d.). This situation can cause their excessive use, with related environmental impacts. Furthermore, biofuels can create problems when they get in touch with specific types of plastic and rubber. Nowadays, biofuels are blended with traditional fossil fuels within traditional engines: this implies that the increase in demand for biofuels could derive from an increase in demand for traditional oil and not from a real demand for green transition;

- inefficient production and logistics processes caused by unjustified overproduction linked to the seasonality of raw materials. The dependence on specific types of production in a country subject to drought stresses production in certain periods of the year, with significant pressure on the soil. Eggemann et al. (2020) also addressed this problem, highlighting the problematic balance between soil potential and demand volatility;

- incorrect consumer behavior due to a linear mindset prevents the resumption of the product lifecycle. This mindset is often linked to the situation when consumers do not understand the positive side of a circular economy. This is a well-known issue in the debate about the circular economy because the final consumer has a pivotal role in achieving R-strategies (Beames et al., 2021; Ncube et al., 2023). In the biofuel industry, there is no possibility of restarting the product's lifecycle because the oil is burned. However, even in this situation, correct consumer education on using the product is essential to protect the environment (for example, to reduce the emission level through proper and attentive driving behavior).

The main sources of value uncaptured concerning social dimension refer to:

- disappearance of the innovative impetus in agricultural technology. Even if the Company's project created thousands of jobs for local farmers and workers, it makes the territory dependent on the required supplies, causing little interest in investing in agricultural technologies and in the education of workers in new know-how. Getting used to known activities and technologies can have a negative impact in terms of knowledge development (Tura et al., 2019; Sartirana et al., 2021; Zuccaro, 2023);

- stress on workers in the event of increased demand for biofuel. The Company does not mention any strategy directed to potential peaks in the increasing demand for biofuels. Given the fact that people cannot be forced to consume a higher quantity of food to have more waste to transform into bioenergy, the solution could be to force farmers for a higher amount of cultivation. This pressure on farmers to increase productivity also has negative impacts on the environment;

- incorrect eating habits caused by promoting food consumption to benefit from more waste to be transformed into bioenergy. This issue is contextualized in the circular paradox, which underlines the different degrees of sustainability of the different actors in the value chain. The fact that the scale of the economy poses limits and physical problems, which often move along the product lifecycle, calls into question some principles on which the circular economy is based (Mah, 2021). Instead, this form of value uncaptured can be transformed into value opportunities (as the Company does) with information campaigns and projects for the correct collection of used vegetable and animal oils to avoid their disposal in the sewers;

- ineffective communication along the value chain leads to a misperception of circular economy benefits. That is why it is necessary to communicate with stakeholders, i.e., to involve the actors belonging to the different steps of the product value chain. This is particularly true for circular products, which, in general, are characterized by a higher price than traditional products: this higher price should be communicated as a higher value inherent in sustainable products. Otherwise, the linear mindset tends to prevail due to the lack of knowledge of the characteristics of products and processes (Beames et al., 2021; Szilagyi et al., 2022);

- impact on the labor market. Although the employment growth rate may increase with the circular economy due to the shift from material-intensive to labor-intensive practices, there is still some mistrust about the benefits for workers. An OECD (2020) report states that the effects on the labor market are still unclear and difficult to measure, and the related literature is scarce.

Results about the economic dimension put into evidence the following potential causes of value uncaptured:

- additional costs related to circular processes. Raw materials are subject to seasonality, which entails the need for storage with increased production costs. Even in the case of food waste, considered a zero-cost resource, additional costs may arise for transport (from land to production plants), the maintenance of high-tech systems, and the waste pre-treatment phase. These costs could increase the price of biofuels, making them less accessible and also causing an indirect increase in the demand for traditional fuels (Cheng & Timilsina, 2011; Karmee, 2016; Dhiman & Mukherjee, 2021; Leggett et al., 2023);

- additional costs related to circular products. The use of biodiesel alone (without mixing it with fossil fuels) requires specific engines: this could be not economical for consumers and may prevent the transition to biofuels. The higher price of biofuels compared to traditional ones produces more value within the value chain but, in the short term, could have negative social impacts by decreasing the well-being of communities that bear greater burdens (Timilsina et al., 2011). Furthermore, the intensive use of biofuels and the consequent proliferation of microorganisms responsible for the formation of algae inside vehicle engines (CTI, 2023) will induce drivers to purchase additional products to prevent their formation, with potential negative impacts on costs and the environment. For circular products in general, also the costs related to the reverse logistics, which allows the product to restart its lifecycle according to R-strategies, should be considered;

- missed revenues because of a lack of understanding of the demand trend. This may be due to ineffective communication about the benefits of circular products and/or a misjudgment in pricing a correct and acceptable product. For this reason, corporate communication is a crucial tool for nurturing the confidence of the stakeholders within the value chain;

- missed opportunities. Regulation of biofuels is the subject of attention from policymakers. However, the frequent changes in the timeline for renewable energy, the updating and revisions of rules and laws, and the uncertainty of new measures, even if justified by the attempt to achieve the SDGs, risk slowing down the investments in circular practices;

- apparent convenience of the circular economy due to public incentives that hide the real performance of the products. This topic is also debated in the literature, considering that government incentives can encourage the adoption of circular practices even by companies rooted in linear thinking and not genuinely committed to circular principles (Testa et al., 2020).

As the results confirm, many of the critical issues of circular projects that emerged from the case study are also debated by scholars. Nevertheless, they are not overviewed systemically as starting points to assess the sustainability of circular business models. Hence, a few directions could be derived in analyzing the case study.

The sustainability of circular business models cannot be taken for granted. Such models must consider the impacts they have on the value chain. This requires a network collaboration, where the main actors of the chain (as the producers of biofuels) discuss business models with stakeholders to identify potential sources of value uncaptured hidden in the product lifecycle.

The perceived value of circular products can be different from the real one. Circular products can be misunderstood by consumers, who are used to thinking from a linear perspective and mainly focus on the product's price as a signal of value. Therefore, consumers should be educated to assess

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the product's value considering its lifecycle, and companies should evaluate the social acceptability of their products to turn the value surplus into value captured.

Circular business models should consider the opportunity costs of the value chain. This type of cost (i.e., the lost revenues or missed opportunities for future development as a result of choosing one alternative rather than another) can occur anywhere in the value chain because it can be related to different stages within the product lifecycle and take the form of value uncaptured. Many ethical problems raised regarding the circular economy are mainly linked to opportunity costs, and some literature is debating whether the use of biofuels contributes to climate protection (Fehrenbach et al., 2023).

CONCLUSION

The circular economy literature has grown within the last decades, paying attention to the innovation of traditional business models to transform them into circular business models capable of creating economic benefits and environmental and social advantages. However, there is little attention in the academic literature on the negative sides of value inherent in circular business models. The study sought an approach to describe the value uncaptured in circular business models for biofuels sectors. In fact, transitioning from fossil fuels to biofuel will help combat climate change and make the EU climate-neutral by 2050. The novelty of this framework consists of emphasizing the circularity of the product lifecycle from the perspective of sustainability and bringing the negative aspects of value to the surface.

The case study revealed many potential sources of value uncaptured, even in well-designed circular business models. These sources were grouped according to the three dimensions of sustainability, emphasizing that the value uncaptured can impact value chain performance in many different ways. The negative value that affects the environmental dimension refers to the negative externalities derived from the behavior of biofuel producers and consumers. The social impact of uncaptured value is the relocation of unsustainability. Uncaptured value can also occur in the economic dimension as cost opportunities that distort the correct evaluation of circular projects and strategies.

This study contributes to nurturing the debate about the value uncaptured, suggesting a novel framework for circular business models. Furthermore, the conceptual framework can have practical implications when used as a tool for redesigning circular business models, considering the negative concept of value, and removing the obstacles to turning this negative value into opportunities for value creation.

This study is not exempt from limitations. First, the notion of value uncaptured can be subject to change, considering that the same concept of circular economy is still developing. Decoupling between circularity and sustainability is the main cause of uncaptured value generation, leading to unsustainable circular businesses. Further contributions from scholars in this field are therefore necessary. Future research could focus on adjusting the conceptual framework for different sectors and its completion with specific key performing indicators, respecting the characteristics of the various industries. For the bioeconomy sector, there is still a list of indicators to evaluate the sustainability of circular business models, which could be combined with the suggested framework.

Second, the paper suffers from the limitations of qualitative content analysis with secondary data sources. In particular, some scholars critique the case study method because it is not rigorous, and the findings can be challenging to justify. Secondary data can face corporate external declaration instead of corporate actual operations. Also, the unstructured interview, used to complement the secondary data content analysis, is a method that suffers from participants' experiences, attitudes, and beliefs. Considering these limitations, future research and potential applications of the tool, with testing activities in other industries, are suggested to obtain broad feedback on its validity.

AUTHOR CONTRIBUTIONS

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