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RESEARCH ARTICLE

Market Dynamics in the Circular Economy: A Case Study of the Adjacent Biofertilizer and Biogas Markets

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Abstract

This study explores the interlinked development of Sweden's biogas and biofertilizer markets as part of efforts to close resource loops in a circular economy. While biogas benefits from robust policy support and a clear energy narrative, biofertilizers face persistent challenges related to marketization, pricing, certification, and public perception. Applying a constructivist market studies approach together with a lens of concerned markets, the paper investigates how societal and sector-specific concerns interact with market-shaping processes. Findings show that market formation is shaped by evolving exchange practices and material reconfigurations, efforts to validate biofertilizers through experimentation and certification, and shifting narratives that reposition biofertilizers from waste by-products to valuable contributors to soil health and circularity. The paper calls for integrated policy frameworks that align energy and nutrient recovery to support more balanced and sustainable market infrastructures

Keywords

Market Shaping · Concerned Markets · Biofertilizer · Biogas · Adjacent Markets

Introduction

From an expanding biogas market, a nutrient market is emerging. What was initially considered a waste product of the biogas system and, at best, argued to be a valuable by-product is now slowly becoming a product in its own right. This shift has not happened spontaneously but is the result of evolving priorities, including environmental goals, agricultural needs, and innovations in how these materials are processed and used. Biogas, which began mainly as a part of waste management, has evolved into diverse business models (Lazarevic & Valve, 2020; Valve et al., 2021). In Sweden, biogas has become a part of the public sector's strategy to achieve a fossil-free society and it has been promoted as an ideal form of circularity (Ottosson et al., 2020). The Swedish state has supported the ambitious aims for increasing biogas production from 2 GWh to 10 GWh by 2030 (Regeringskansliet, 2022) through various policy instruments. However, this support has not been problem free and has been criticized for a lack of long-term thinking, resulting in hampered growth(Lantz et al., 2007; Nevzorova & Kutcherov, 2019). Figure 1 shows a typical example of the representation of the circularity of a biogas system, with two products being produced, a nutrient rich hummus and energy in the form of biogas. Although the vision portrays the physical circular potential, it also represents nutrients on equal footing with the energy.

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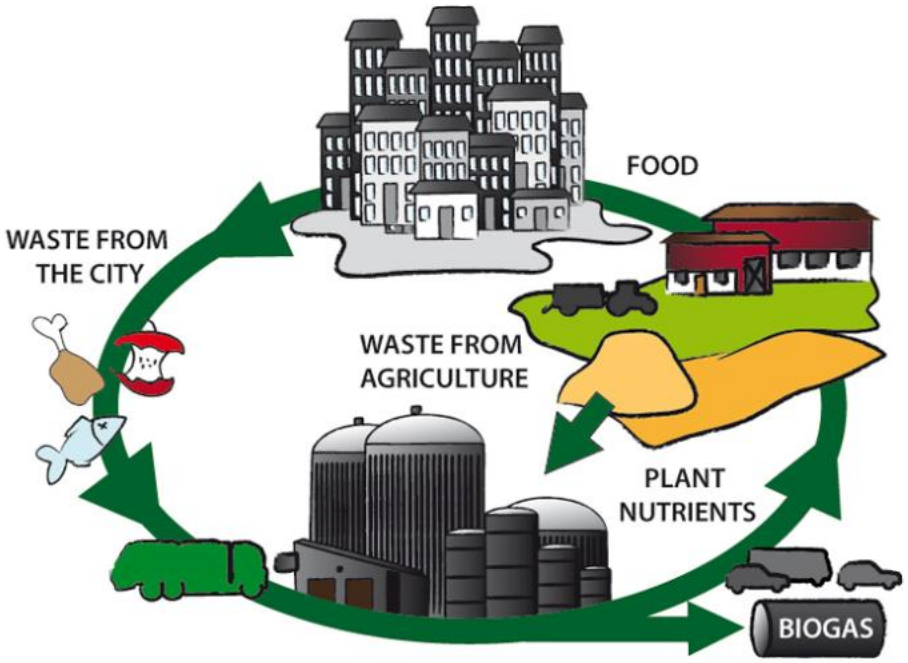

Figure 1 Representation of a Biogas System (Swedish University of Agricultural Sciences, 2024.) Printed with permission

To make this representation a reality, the digestate must be managed properly. Circularity is achieved when the digestate is returned to agriculture, replacing synthetic fertilizers. As has been problematized (Peng & Pivato, 2019), it is essential that as the biogas market grows, the digestate must be adequately marketized to realise the circularity that advocates of a biogas system promise. This is not unique to biofertilizers but is a crucial component when moving from a linear to a circular economy. Waste must be managed. This can, to some extent, be addressed through policy, regulations, and laws, but ultimately, the goal is a marketization of matter that was once considered waste (Gregson et al., 2013). Waste is not a given attribute of an object, but, as Lehtokunnas & Pyyhtinen (2023) argue, an objects status is 'fluid matter' constantly shifting depending on how it is perceived, valued, and handled. Waste coming into the biogas plants must be made into an asset, and this is not only a technical issue but a sociocultural practice that needs to occur. This results in continuous boundary-making to keep the border between 'valuable matter to problematic excess' (ibid., p. 286).

While expanding the biogas market represents a valid goal in a transition away from fossil fuels, there is an equally important need for alternative sources of nutrients for agriculture. From this perspective, the challenge could be framed as ensuring a functioning nutrient market that views the produced biogas as a beneficial by-product. The benefits of biofertilizers are vast. While synthetic fertilizers have been instrumental in the exponential increase in agricultural productivity and feeding the expanding population, it has come with numerous and dire problems (Kumawat et al., 2021). Biofertilizers, compared to synthetic fertilizers, brings with it numerous benefits, from increased plant yield, soil health, and overall environmental impact (Du et al., 2018; Feiz et al., 2022; Joshi & Gauraha, 2022). Furthermore, synthetic fertilizers are linked to geopolitical issues that affect the limited supply of finite resources such as phosphorus. This scenario leads to price instability and security concerns (Vu et al., 2023). Internationally, there is a growing awareness of the value of digestate from biogas production. In Africa and South America, small-scale biogas reactors not only contribute to improved environmental conditions but can play an important cost-reduction for small farmers when digestate replaces costly synthetic fertilizer (Mdlambuzi et al., 2022; Sharma et al., 2023).

In Sweden, the market for biofertilizers varies in its maturity and form throughout the country. In some cases, farmers provide manure as a substrate to biogas producers and retrieve the digestate. In other cases, biogas producers must absorb the handling and transport costs of the digestate when it is sent to farmers, and in other areas, farmers have begun to pay for the product (SOU, 2019). A market analysis by the Swedish

Agricultural University in 2015 found that barriers to increased biofertilizer use were primarily due to associated costs. Despite farmers' positivity towards biofertilizers, 'willingness to pay' was insufficient (Odhner et al., 2015). A similar situation was found in Italy, where Selvaggi et al., (2022) noted that although increased knowledge regarding digestate improved farmers' willingness to pay, the effect was limited. While price remained comparable, manure was preferred, suggesting that previous experience plays a role in decision-making.

The view that the digestate is a mere by-product is slowly changing. In Finland, it has been observed that new business models are evolving which highlight the increased importance of nutrients (Valve et al., 2021). In that case, nutrient recycling drives the technology choice, location selection, and overall business plan of the biogas plant. Similarly, in Sweden, academic interest has focused on the strategic placement of biogas plants to both to manage excess nutrients from animal manure and to facilitate the redistribution of these nutrients as substitutes for synthetic fertilizers (Feiz et al., 2021; Larsson et al., 2023). However, this transition remains in its infancy, and a critical gap persists; while established markets exist for biogas energy production, no comparable market infrastructure has developed for biofertilizers.

This paper addresses the challenge of developing viable markets for waste-derived products in the broader context of the transition from a linear to a circular economy. We focus on the evolving relationship between the adjacent markets for biogas and biofertilizers, using a constructivist market approach. In particular, we explore how societal and environmental concerns act as formative forces in shaping these emerging markets (Geiger et al., 2014). While the academic literature have previously addressed challenges and barriers to the biofertilizer market (Dahlin et al., 2015; Lamolinara et al., 2022) this paper takes a novel approach by investigating how societal concerns interact with the process of market shaping in sustainable markets. To fulfil the aim, we pose the following question: how do the concerns of the actors from both the biofertilizer and biogas markets affect the shaping of the market for biofertilizers? Understanding the connection between the concerns of biofertilizer and biogas markets can be productive for practitioners and decision-makers who aim to develop or expand either of these markets.

Theoretical background

In this paper, we combine the concept of a concerned market with the literature on sustainable market construction. The constructivist market studies literature foregrounds the material and social work needed by a cross-section of actors and devices for markets to exist and be maintained (Araujo, 2007; Callon, 2007; Doganova & Karnøe, 2015). Within the literature the assumption that markets are not merely something that exists 'out there' to be discovered by a business has steadily grown over the last two decades (Nøjgaard & Bajde, 2021). Markets have degrees of plasticity and are always in a process of change, affected by both the materiality and social practises (Kjellberg et al., 2012; Nenonen et al., 2014; Vargo & Lusch, 2004). This perspective emphasizes that market configurations arise from continuous processes of negotiation and contestation among various stakeholders who bring different perspectives on what should be valued and prioritised (Flanagan et al., 2023). Building on these foundational insights about the constructed and negotiated nature of markets, academic interest has begun to discover how some markets become organised around shared concerns and collective values.

Concerned markets are centred around political and social goals, such as renewable energy or food security. A part of the shaping of the market occurs due to societal or collective concerns that become embedded within a market (Geiger et al., 2014). Incorporating collective concerns is an important step in creating a well-functioning market (Callon, 2007). Examples of this are seen through the introduction of new narratives in order to position a product as green by enrolling societal concerns and entwining them into the products' qualities (Reijonen & Tryggestad, 2012). In this sense, market arrangements that attend to new concerns are not merely the result of reconfiguring actors, products, and customers to produce new 'facts'; rather, they emerge through the entanglement of values, meanings, and materialities (Callon, 2007; Latour, 2005).

The biogas and biofertilizer markets are part of a broader category of markets contributing to society-wide sustainable transitions and often cited as idealized examples of circular economy practices (Sica et al., 2023).

To analyse these markets meaningfully, it is essential to view them as surrounded by wider societal contexts, where political, environmental, and ethical concerns shape both market dynamics and legitimacy (Geels & Schot, 2007). This perspective moves beyond a narrow economic view of markets as mechanisms for matching supply with demand. Instead, it emphasizes how markets are actively constructed through processes in which collective values are not only acknowledged but also entrenched into policy, regulation, and public narratives.

This analysis has used the framework based on (Ottosson et al., 2020) which has its roots in the market-shaping model from Kjellberg & Helgesson, (2007) but aims specifically to address sustainable markets. The authors argue that sustainable markets are "differentiated as they are situated between the political, economic, and scientific" (Ottosson et al., 2020, p. 304) and require a broad mapping of actors and processes. The authors describe the shaping of the market occurring in three interrelated processes: enabling exchange, proving and experimenting, and narrative building.

Enabling exchange includes the activities that facilitate trade of which price setting, in all its complexity, is only one part. Previous literature on the challenges for biofertilizers produced from biogas has focused on the role of prices. Within the market-shaping literature, however, enabling exchange processes goes beyond price setting (Caliskan, 2007), not least in green or sustainable markets. Enabling exchange also includes creating and shaping the conditions of trade along with the negotiation and agreement of value. *Proving the system* includes how the system reacts to experimentation. This stage includes practices that validate the system. This can be considered a key phase as it provides the space for repetitive and stable transactions (Callon et al., 2002). Lastly, *building the narrative* involves actions that shape the market through vision-building, promotion, lobbying, and education. While the framework by Ottosson et al. (2020) attends to the movement of expected and demonstrated value, our application of the framework is inspired by the concerned market literature and traces societal and sector concerns.

Method

We have approached the research aim by using a mixed data collection methodology (Small, 2011) consisting of interviews, media analysis, and notes and transcriptions from biofertilizer sector events. As the aim of this paper is to understand how concerns shape the biofertilizer market in relation to the biogas markets, we selected biogas and biofertilizer companies operating in Sweden to include a variety of sizes and maturity. An overview of the methodology is shown in Figure 2

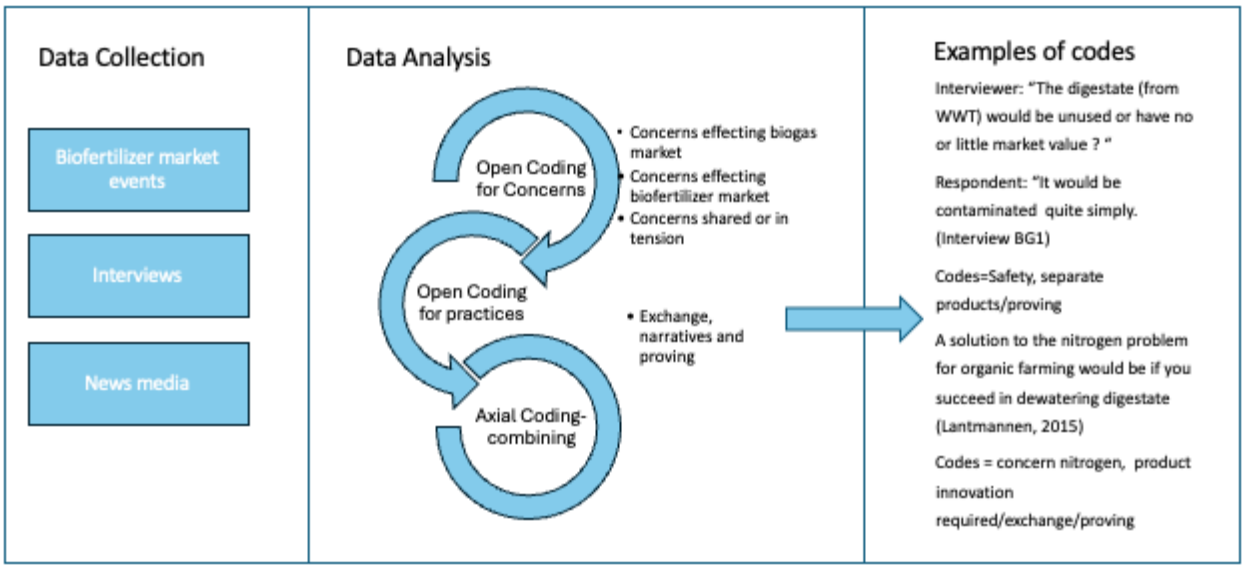

Figure 2 Methodological Approach

We based the selection of interviewees on predetermined criteria for purposeful sampling (Patton, 2014). For this study, this meant that it was desired to include actors using different business models and digestate management, operating in Sweden. Eleven interviews were conducted which lasted between 45 minutes and one and a half hours and were recorded with permission and transcribed. All interviews, except one, were conducted in Swedish. The first biofertilizer company (BF1) has been operating since 2006 working with digestate produced by biogas plants. The second company (BF2) produces biofertilizer in a pelletized product, from its biogas plant. The third biofertilizer company provides a nutrient recovery technology for biogas plants, whereby they buy back recovered nutrients to sell as concentrated nutrients (BF3). The fourth biofertilizer company had a business model similar to BF3 in terms of selling or leasing equipment that allowed digestate processing (BF4). It was operational from 2011 but was liquidated in 2021. Also included in the study is a company, intermediating between the waste producers and the biogas plants (WM1). The company is owned by 14 municipalities in the south of Sweden and works within a wide range of waste management.

Three biogas producers were chosen to examine different approaches to handling the digestate. One plant has partnered with an external party to handle the digestate (BG1). The other two plants (BG2 and BG3) have worked with more informal methods and are still formalizing their business model regarding digestate. The respondents' details are shown in table 1.

Table 1 Interviews Conducted

Group	Actor	Code	Business model
Biogas Producers	Producer-1a	BG1A	Digestate provider
	Producer-1b	BG1B	Digestate provider
	Producer-2	BG2	Digestate provider (ad-hoc)
	Producer-3	BG3	Digestate provider (ad-hoc)
Biofertilizer Producers	Biofertliser1a	BF1A	Broker
	Biofertliser1b	BF1B	Broker
	Biofertliser1c	BF1C	Broker
	Biofertliser2	BF2	Seller
	Biofertliser3	BF3	Equipment provider/nutrient sales/
	Biofertliser4	BF4	(divested) equipment provider/nutrients sales
Substrate Providers	Waste management	WM1	Supplier to biogas production

Additionally, we have included notes and transcripts from three biofertilizer events between 2021 and 2023. The meetings were arranged by a biofertilizer company and open to the public. The meetings were recorded and available online. It was a space where various market actors, including biofertilizer sales representatives, farmers, biogas actors and researchers, could discuss problems, trends and opportunities. These meetings functioned initially as an immersion activity for the researchers to understand the biofertilizer sector and its actors. Subsequently, upon analysing the notes and recordings, it was treated as data and analysed in conjunction with the interviews and media.

A media analysis was performed using the news archive platform Retriever. The aim was to bring forward how the two markets have been represented within the agriculture and waste sectors when discussed together.

The four highest circulating magazines covering the industry were selected. We selected a 10-year period in order to provide adequate history. We used both the search strings ("biogas" AND "biofertilizer") and ("biogas" AND "digestate") which resulted in a total of 214 articles, of which 158 remained after screening for relevance. The aim was to bring forward how the biofertilizer and biogas markets have been represented within the agriculture and waste sectors when discussed together. The sources of these media articles are shown in table 2

Table 2 Media Sources: 06-2013 to 06-2023

Branch Magazine	Readership	Sources
Lantmannen	225,000	28
Land	147,000	31
ATL	72,300	41
Avfall	2,300	85

Coding of the interview transcripts, media articles and event notes was performed in cycles. The general approach to coding was guided by reflexive thematic analysis, which emphasizes both semantic and latent meanings uncovered through the identification of patterns (Braun et al., 2019). The first cycle was performed using open coding (Saldaña, 2015) with a focus on the concerns and how concerns were associated with biogas, biofertilizers, or both. Concerns were identified by expressions of a problem (Flanagan et al., 2023). The next step was to consider market-shaping processes as per the framework proposed by (Ottosson et al., 2020). Using this framework ensured that the different phases of market shaping were investigated together with potential differences in the representation of concerns in different processes. Text segments were identified as belonging to exchange practices, the proving or experimenting phase, or a part of narrative building. Lastly, we worked with axial coding to find linkages and nuances between the codes (Scott & Medaugh, 2017). This stage of analysis included considering which market-shaping activities were associated with the specific concerns

Results

The three categories of practices enabling, proving the system, and narrative building described in section 2, are used to structure the results. However, it is important to stress that the three processes are linked, and finding discrete separation points is neither possible nor desirable. Instead, the distinction enables us to show that markets are constructed on various levels at the same time. Each category of practice and the concerns associated with it are described below.

Market Formation through Exchange Practices and Material Reconfiguration

The exchange practices involving the digestate cannot be entirely removed from the substrate's exchange process. The substance changes in materiality as it moves from a substrate to digestate, but it also changes and undergoes both social and material processes where the digestate becomes a biofertilizer. These processes are dependent on concerns such as increased gas production, diversifying substrate sources, reliable disposal, profitable business models and soil health. The exchange practices in focus in this paper are the practices of acquiring substrate for biogas production, the disposal of the digestate, relationship building, and the production of alternative fertilizer products

A common exchange practice within the biogas market involved municipalities or industries paying gate fees to the biogas plants. However, alternative arrangements have since emerged. For example, in southern Sweden, it is now the waste management companies that receive these fees. After pre-treating and separating the waste, they produce a slurry that is then sold to biogas plants. This marks a shift from supplying slurry to biogas producers free of charge to recognizing its value as a partially processed and marketable resource.

"Today we send slurry... or not send, we don't send, we sell slurry because today you want to pay for it, it wasn't like that from the beginning. Then, it was waste management". (Interview: WM1)

As the biogas market grows, the biogas producers are becoming more concerned with the geographically sensitive nature of access to the substrate materials. This means that biogas companies are aware of the need to diversify their substrate sources (Interview: BG1A, BG2A). This concern was also connected to tensions between the priority of producing high volumes of gas or quality digestate for fertilizers. Biogas producers, however, tend to choose substrates beneficial for biomethane production. Hence, the digestate might end up with less favourable ratios of nitrogen, phosphorus and potassium (NPK) which is a concern from within the market.

The disposal of the digestate was initially a concern for biogas producers who needed to find actors willing to take this by-product. This situation can be seen as similar to how substrates are positioned; as waste material that must be managed or disposed of. Biogas plants had difficulty during the months when farmers could not spread the digestate to find those willing to collect as the farmers would be responsible for storing it until needed. As one respondent from BF1 explained, the farmers' have been resistant to paying for the handling of the digestate.

"[farmers say] It is a municipal waste. And you have to transport it here. I have a well that I built. I have to stir the well. I need I need compensation for soil compaction. You have to pay me x amount of money per ton to make it work." (interview: BF1C)

As the potential for monetary valorisation of the digestate began to become evident, third-party actors started to see value in a business model by which they could act as brokers for the digestate. Digestate started to resemble traditional commodities, leading to the development of new exchange practices. To address concerns and challenges related to waste storage, the brokerage company prioritized building strong relationships with buyers and providing consulting services to ensure that the biofertilizer, which varies in nitrogen, phosphorus, and potassium (NPK) content, aligned with farmers' needs. While respondents stressed the importance of this social relationship, it also required the use of proof of utility for the farmers. Spreadsheets were used to demonstrate the economic benefit, and extensive calculations were used to legitimize the price of the biofertilizer product which created trust between farmers and the biofertilizer sales team.

To combat the problem of storing the voluminous digestate, other companies focused on providing the equipment for dewatering and focused on concentrated forms of digestate, for example pellets, to enable and simplify exchange. The pricing model, however, is different from the 'management of excess' model described above. The products were intended to be traded based on the price of synthetic fertilizer and the content of NPK in the pellets. For BF3 and BF4, the business model was based on providing an add-on to a biogas plant or a composting facility and using various physical or chemical procedures to extract nutrients from organic material. For BF2, a pellet-producing company, the nutrients are the main product, and the only product exchanged. With the introduction of pellets, the exchange process is transformed from one based upon individual contracts built upon relationships and long-term partnerships to one where pellets can be sold as a standardized product.

Tying the price-setting mechanism to the synthetic fertilizer market became a concern to the respondents, noting the price volatility linked to geopolitical insecurity and energy prices. For synthetic fertilizers, farmers also have access to a wide range of tools to determine the optimal quantity and price, all of which are easily accessible and free online by large suppliers. In contrast, biofertilizer estimations were portrayed as more complex for which the companies had to develop tools such as cost-benefit analysis as an essential part of the sales process (Interview: BF1A, BF1B).

The raw biofertilizer from the biogas plant is a more complex product than synthetic NPK. It has been posited to be positive in terms nutrient content, environmental impact, crop yield, and soil health. (Caterino et al., 2024; Vaneeckhaute et al., 2018). The interviews along with the biofertilizer events revealed these benefits of biofertilizers to be overlooked and undervalued. Actors described how it is becoming important that benefits

of the soil improvement are clear to the buyers. Advocates for biofertilizers have tried to address this by shaping the marketing towards soil health. Importantly, this was a newer theme within the media analysis. It has also been a pull from the buyers to have a product that can have a double function of fertilizing and improving the soil at the same time.

"There has been a much greater interest in it. ...people have now started talking about soil health, which they didn't do before." (Interview BF2)

This paper focuses mainly on the exchange of digestate from biogas production, the biofertilizer. However, it is inevitably so that at least two other exchanges are notable in the empirical material, namely the acquiring of substrate for the biogas production and the monetary exchange for the biogas. The exchange of biogas does not directly affect the biofertilizer market according to the interviewees, nor is it widely discussed in newspaper articles or at the biofertilizer events but is considered as something which is required for the profitability of producing the digestate.

Validating Biofertilizer through Experimentation, Certification, and Product Innovation

Proving the market includes activities that provide evidence on how the market has gone from the abstract to the actual exchange of goods. Whereby the biogas market saw considerable experimentation by local and municipal actors to prove its viability (Fallde & Eklund, 2015; Ottosson et al., 2020), the public sector has had less direct involvement within the biofertilizer market. Instead, the private sector has taken a vital role in experimenting and proving the biofertilizer market as a part of the biogas system. Three examples of events which demonstrate market shaping embedded within concerns, are found in the material which have functioned as proving or experimenting within the system. The first is the introduction of a concentrated product, followed by the controversies of the collection bags made of plastic, and lastly, the role of the certification programmes for biofertilizers.

The most recent approach to prove the system has been the introduction of a more concentrated form of the biofertilizer. The digestate's water content and subsequent weight have been a concern due to the cost of transportation and spreading. The concentrated nutrient product produced by two of the vendors was cited for reducing water content between 70-95%, depending on the vendor. This was a vital development according to the actors in terms of the product's acceptance and economic viability (Interview: BF2, BF3). The concentrated version of the product is also sold by BF1 but is in the early stages and was designed with the direct-to-consumer market in mind. In all cases, the concentrated form of the product is still in its early phases. This early market phase was noted to be one of the reasons BF4 decided to liquidate the company and noted that although the technology was adequate, the economic conditions were difficult. The respondent noted that the synthetic fertilizer price one year after liquidation could have significantly impacted the company's success (Interview: BF4).

Another practice which has been a part of proving the system is the use of certifications of biofertilizers. The importance of certification in addressing concerns regarding product standardization, safety, and public confidence was a recurring point in the media analysis. Certifications were also brought forward on multiple occasions in the biofertilizer events. Certification firstly impacts the biogas producers, who should adhere to a specific certification programme (SPCR120) if the digestate is to be used as a biofertilizer, which currently includes 27 of 36 plants in Sweden (Augustinsson et al., 2022). In addition to this, the digestate can be certified for ecological farming using the Swedish standard KRAV.

In ecological farming, synthetic fertilizers are prohibited, and there are limited options for NPK. Biofertilizer is therefore positioned as a local and suitable replacement. For this to happen, the biogas plants must assume the responsibility of attaining certification and impact the substrates which may be used. For the Swedish ecological certification, the regulations significantly limit the use of waste from slaughterhouses and other animal waste in biogas production and fertilizer use. If using animal waste, the biogas plants must be KRAV-certified, and only a restricted share of digestate made from animal waste or non-approved manure can be used in the certified farming and never on the edible parts of crops (Krav, 2023, 2025).

Certifications were viewed not only as tools for standardizing products but also, at times, as obstacles to market development.

"It is such old-fashioned regulations, such as certified organic and ecological, it does not keep up with development. It has also meant that the products are very expensive, and it meant that the final product is very expensive. In times as today, you exclude it directly, I met (food producer) today, they said, 'we are stopping with organic products because there is no interest from the consumer'" (Interview: BF3)

Labelling and certifications such as ecological, for example KRAV in Sweden, are a known market tactic for addressing wider societal concerns. Our data also indicate that certification schemes play a role in demonstrating the viability of the system and can be seen as part of ongoing experimentation. For example, BF2 viewed obtaining ecological certification as a strategic priority, aligning with consumer expectations for ecological standards. In contrast, BF3 expressed concern about a declining interest in certification programmes such as KRAV, instead arguing that the concept of "locally produced" was perceived as more important to end-consumers. Beyond the growing scepticism around the price premium of ecologically certified products, additional concerns have emerged regarding the limitations imposed by certification schemes. These programmes have been criticized for being overly cautious. For instance, the use of certain polymer compounds which could significantly reduce the weight and volume of digestate remains contested, thereby limiting the product's economic viability.

Finally, the plastic bags used for collecting food waste continue to pose a challenge for biofertilizer application, as residual fragments in the digestate result in what is commonly termed "visible contamination". The media analysis showed that the biogas industry found it difficult to change the collection process, citing that they depend on other actors in the chain, such as waste collectors. They argued that biogas producers could not afford to say no to the substrate collected in plastic bags, even when it could hurt the quality of the digestate (ATL,2021). More recently, the biofertilizer certification programme SPCR120 introduced a new requirement stipulating that only bags deemed safe for food contact may be used by certified plants. The issue of plastic contamination is also connected to a separate waste stream, as biogas plants frequently process industrial waste, including packaged food. While the presence of plastics does not significantly affect biogas production, it poses a challenge for producing high-quality digestate and must therefore be carefully managed.

Shaping Market Narratives: From Energy-Centric Framing to Nutrient Recovery and Soil Health

Narratives are an important part of societal change (Holden et al., 2018) and constructing new markets for circular products (Leipold et al., 2021). In our study, narratives are not treated as isolated practices but as outcomes of activities such as articulation, framing, and reasoning which can be found in the media coverage, interviews, and biofertilizer-related events. We find that biofertilizers are connected to narratives of being a bonus product, fossil-free futures, circularity, and a soil improvement.

The media analysis showed that biofertilizers were often presented as a secondary benefit of biogas production and often found as described with "in addition" or "as well" when highlighting the advantages of biogas for agriculture and society. The dominant narrative continued to frame biogas primarily as a source of fossil-free, locally produced energy, with limited attention given to its role in enhancing nutrient recycling or reducing reliance on synthetic fertilizers. Within this framing, nutrient recovery was often portrayed as a fortunate side benefit rather than a core objective. This perspective was consistently echoed by interviewees, reinforcing the perception of biofertilizers as secondary to energy production. Several stakeholders acknowledged the societal importance of biofertilizers, even as they questioned their current economic value. As one interviewee put it,

"Biofertilizer is a by-product, a very important part of society, but not of the economy" (Interview BG1A)

The viability of the biogas sector was repeatedly tied to the ability to manage or find value in the digestate, with the energy component clearly prioritized. Yet, concern emerged over the long-term sustainability of biogas production if solutions for digestate use remained insufficient:

"Because if you cannot do something with the biofertilizer, you cannot produce biogas either. That seems to be the biggest threat" (Interview BF1C)

For the biofertilizer market, the concern for synthetic fertilizers and the use of recycled nutrients is the heart of the market. It drives the narrative of the biofertilizer market, where nutrient recovery, with or without a connected biogas plant, is often portrayed as the perfect example of circularity.

"When talking about a circular society, biofertilizer is the ideal image." (Avfall Sverige, 2018)

"You notice more with farmers that it is more environmental thinking. Circular economy, resource recycling. They have become more focused on these issues." (interview: BG2)

Part of the effort to reposition biofertilizers as a value-added product involved rethinking the terminology used to describe them. In Swedish, the name '*rötrest'* translating loosely to rotting leftovers, is commonly used in media sources. This was found problematic by proponents of biofertilizers, noting that the name did not capture the product's value (Interview: BG3). The product's naming was noted by BF2, who observed that even in English, the line between digestate and biofertilizer is unclear and can cause problems. The desire to move away from the term digestate was partly connected to the desire to differentiate from the digestate produced by wastewater treatment facilities.

Connected to biofertilizers is the concern for human health and food safety. Sewage sludge, which technically can be digested in the same biogas reactor, has had a controversial history in Sweden regarding nutrient use in food production (Ekman Burgman & Wallsten, 2021). This has meant that that the digestate from food waste and manure must be distinguished from the sludge from sewage treatment to avoid being connected to concerns over pharmaceuticals, heavy metals, etc. However, the importance of this distinction differs among biofertilizer companies. While companies that handled both sewage sludge and biofertilizers were sceptical of the distinction, those that only handled biofertilizers felt that classification was a crucial value-added factor.

"They are very similar products. But biofertilizer is accepted on the market, and sludge is a waste" (Interview BF1B)

"[B]ecause slurry [from wastewater treatment] is, of course […] a digestate if it comes from a biogas plant. However, the use and the value are much different, and it should be much different." (Interview BF2)

Discussion

The question posed at the beginning of this paper was how concerns in the biogas and biofertilizer markets were part of shaping these connected and adjacent markets. The results show that societal concerns influence market shaping by creating pressure, incentives, and rewards for change. However, actors within the market produce their own concerns, or interests. As warned by D'Antone & Spencer, (2014) the concerns of society will become intertwined with the interests of market actors. This gives rise to new tensions and outcomes. Using the three categories of practices, we examined the biofertilizer market and its connection to biogas. This interplay between concerns originating from actors within the biogas and biofertilizer market and wider societal concerns is represented in figure 3.

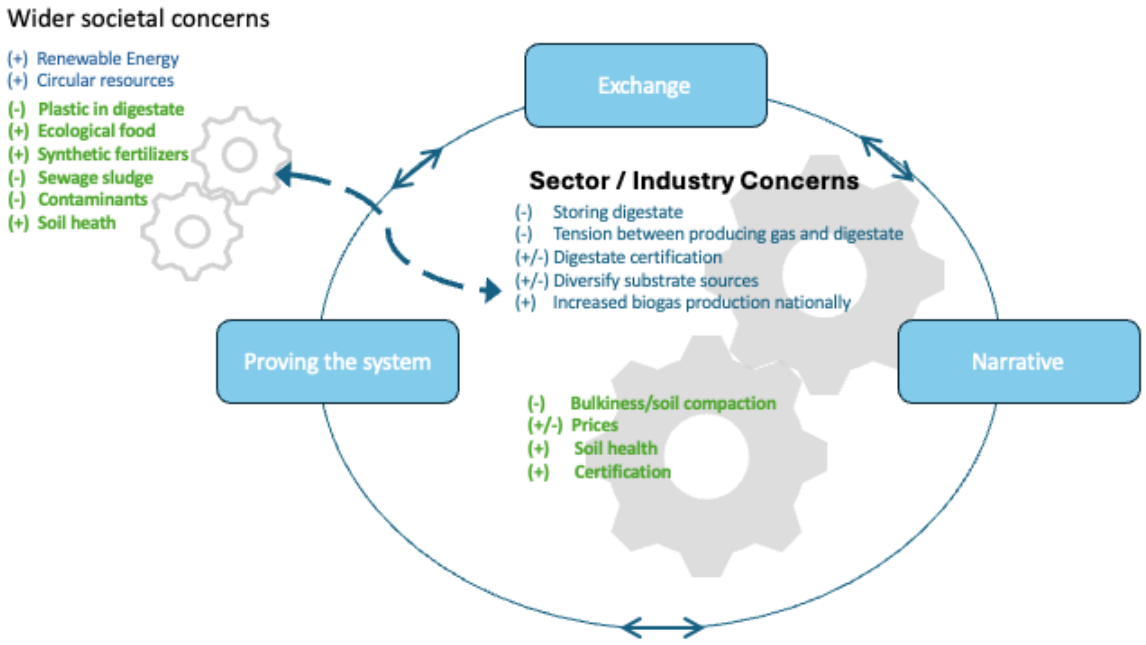

Figure 3 Schematic of the Conceptual Framework. Green(bold) text represents concerns originating in the biofertilizer sector, and blue(italics) represents concerns from the biogas figure. The plus or negative indicates if the concern has had a positive or negative impact on the biofertilizer market

Exchange practices were shaped by issues such as increased gas production, soil health, substrate diversification, reliable disposal, and viable business models. In efforts to validate the biofertilizer market, actors focused on synthetic fertilizer prices, ecological food production, bulkiness, and plastic contamination. Narrative construction centred on reducing dependence on fossil gas and synthetic fertilizers, as well as distinguishing biofertilizer from sewage sludge. Many of these issues relate to the broader goal of expanding biogas production. However, it is important to recall that the biogas market initially emerged from the need to manage and reduce organic waste (Brett et al., 2023; Olsson & Fallde, 2015). Over time, it has become associated with broader societal goals, particularly the push for local, fossil-free energy. Yet, as noted by actors in this study especially in the media analysis this shift has offered little direct benefit to the biofertilizer market and has reinforced its perception as a secondary by-product. This was evident in practices such as giving digestate away for free and in narratives that framed biofertilizers as a welcome bonus to the more prominent biogas sector. Ultimately, concerns around maximizing gas production have overshadowed the development of a biofertilizer market primarily focused on safe and reliable nutrient reuse.

This study demonstrates that, despite the rapid growth of the biogas market, the development and visibility of the biofertilizer sector have not progressed at a comparable rate. Although markets can serve as powerful policy instruments, their success requires more than mere establishment; they must be actively supported and guided by targeted policy measures (Frankel et al., 2019). While societal concerns regarding synthetic fertilizers and nutrient recycling gain some attention, the biofertilizer market remains underdeveloped and continues to receive limited policy attention. At present, it is largely addressed only indirectly through policy mechanisms focused on the expansion of biogas production, which have primarily aimed at reducing dependence on fossil fuels.

Biogas producers recognize that a robust biofertilizer market is essential for scaling up biogas production in alignment with circular economy principles, which prioritize waste valorisation. However, their primary concern remains the economic viability of biogas itself, often sidelining biofertilizer valorisation in their core business strategies. Stakeholders in the waste management and biofertilizer sectors acknowledge that increased

biogas output could positively impact their operations. Yet, they voice concerns that the biogas market's volatility driven by shifting regulations and policy frameworks could heighten the vulnerability of the biofertilizer market. While the biogas sector has historically been propelled by the goal of fossil-free energy, recent discourse increasingly highlights the importance of circular resource use. In this evolving context, integrating nutrient recovery alongside energy production strengthens the circularity of biogas systems. Nonetheless, the prevailing energy-centric narrative often overlooks the complex and multifaceted role that biofertilizers play within these systems. Realizing their potential requires supportive business models that extend beyond technical solutions and engage with the broader dynamics of circular economies (Bocken et al., 2016)

One notable shift in the biofertilizer market has been the strategic emphasis by actors on broader societal concerns, particularly soil health and the potential to position biofertilizers within ecological food production. While this alignment with ecological agriculture opens new market opportunities, it simultaneously introduces new concerns, most notably around product safety and quality assurance. To address these, certifications and regulatory frameworks have been mobilized not only to validate the product but also to stabilize and differentiate biofertilizers from both synthetic and other organic fertilizers. In this way, certifications, despite the problems discussed earlier, function as market devices (Callon et al., 2002), facilitating exchange by rendering the product legible, trustworthy, and comparable. However, these certification schemes are not neutral; they are sites of contestation. Actors have actively sought to influence their design and implementation, particularly in relation to contentious issues such as the use of plastic collection bags, the inclusion of sewage sludge, and the prohibition of certain polymers. These debates reflect broader tensions in the circular economy, where efforts to close material loops often encounter sociocultural (Kirchherr et al., 2018), regulatory, (García-Quevedo et al., 2020) and economic barriers (de Jesus & Mendonça, 2018)

While there are similarities and dependencies between the biogas and biofertilizer markets, there are also points of difference brought to the foreground in this study. The biogas market has been established to reduce fossil fuel, primarily built upon the material equivalence of the upgraded biogas to fossil gas (Ulmanen et al., 2009) In contrast, digestate cannot directly substitute synthetic fertilizers. Even when processed into more refined forms such as pellets, biofertilizers do not occupy the same functional or market position as synthetic alternatives. As a result, actors in the biofertilizer market cannot adopt the same strategies that enabled the growth of the biogas sector, which benefited from clear material and infrastructural parallels with fossil gas. Instead, they must develop distinct approaches and policy instruments that address the specific environmental and agronomic concerns associated with synthetic fertilizer use.

The recent pandemic-related border closures and the war in Ukraine have brought renewed attention to the geopolitical dimensions of synthetic fertilizer supply (Alexander et al., 2022; Ekman Burgman & Wallsten, 2021). Synthetic fertilizers have increasingly been highlighted through a more critical view, not only due to their environmental impact but also because of their implications for national security. These events have disrupted market dynamics, influencing both the stability and pricing of competing products. At the same time, they have enabled the biofertilizer sector to craft a new narrative: positioning biogas and its by-products as key contributors to both food and energy security. This shift aligns with research suggesting that crises create windows of opportunity for market-shaping, as markets become more flexible and open to transformation (Nenonen & Storbacka, 2020). The current uncertainty around price and supply thus presents a strategic moment to reconfigure the biogas and biofertilizer markets not only to address climate change, but also to confront broader environmental challenges such as resource depletion, eutrophication, and soil degradation.

Conclusion

This study has demonstrated how societal and sector-specific concerns shape the development of adjacent markets within the circular economy, using the case of biofertilizers and biogas in Sweden. By applying a constructivist market studies lens with a focus on concerned markets, we have demonstrated that market shaping is not only a matter of technical innovation or economic incentives but also of aligning diverse concerns across sectors. The biofertilizer market, although materially linked to biogas production, is shaped

by a distinct set of concerns including soil health, food safety, and nutrient security which are not always prioritized within the biogas sector.

Our findings contribute to circular economy scholarship by highlighting the importance of inter-market dynamics and the uneven distribution of policy and institutional support. While biogas has benefited from strong policy narratives around fossil-free energy, biofertilizers remain under-supported, despite their potential to close nutrient loops and enhance agricultural sustainability. This asymmetry underscores the need for integrated policy frameworks that recognize the co-dependence of energy and nutrient recovery in circular systems.

For decision-makers, this indicates that supporting circular transitions requires more than the promotion of individual products such as biogas. It also necessitates investment in and support for the institutional infrastructure, certification systems, and business models that facilitate the valorisation of residual outputs, such as digestate from biogas production. Policies that explicitly connect energy production with nutrient recovery, whether through linked output targets or integrated certification frameworks, could help align incentives across different sectors. Future research could investigate how similar dynamics unfold in other circular systems where multiple markets intersect. Comparative studies across national contexts may also provide insights into how varying regulatory environments influence the co-evolution of interconnected markets. Additionally, further work is needed to examine how narratives and naming conventions shape the legitimacy and adoption of circular products, particularly in contested areas such as waste-to-resource transitions.

Declarations

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Data availability
The interview data generated and analyzed during this study are not publicly available due to ethical restrictions, as participants consented to share their information exclusively with the research team. Therefore, the transcripts cannot be shared outside of the research team. However, the media analysis data that support the findings of this study are available upon reasonable request from the corresponding author.

Competing interests
The authors declare no competing interests.

Author contributions

Nancy Brett: Contributed with Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Visualization
Linus Ekman Burgman: Contributed with Conceptualization, validation, Writing – Review & Editing

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