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From Waste to Value: A Bibliometric-Systematic Review of Biogas and Biomethane Business Literature

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ABSTRACT

In response to escalating environmental challenges and the growing demand for sustainable energy solutions, the agri-food sector is increasingly exploring business models grounded in circular economy (CE) principles based on the production of biogas and biomethane. This study conducts a bibliometric-systematic literature review (B-SLR) to examine how organisations in this sector integrate CE and sustainability into their operations. The main objective is to assess the state of the art in the literature regarding the integration of CE strategies and sustainability dimensions—economic, environmental and social—into the business practices of biogas or biomethane producers. The analysis identifies three main thematic clusters: (i) sustainability and biogas, (ii) renewable energy and (iii) business models and CE. Findings reveal a predominant emphasis on economic and environmental aspects—such as cost-efficiency, profitability and energy self-sufficiency—while social dimensions, including community acceptance, remain under-researched. Furthermore, business model innovation and stakeholder networks emerge as crucial enablers for overcoming financial, technical and social barriers. Notably, collaboration at the network level allows small and medium-sized enterprises to access knowledge, resources and economies of scale otherwise unattainable individually. This paper provides a structured synthesis of the emerging management literature on renewable energy within agriculture, offering insights into how circular and sustainable business practices are conceptualised, implemented and assessed. It also highlights gaps in current research, particularly the lack of social impact evaluation and the need for clearer policy frameworks. Future studies should explore strategies for community engagement and improved public-private coordination to ensure socially inclusive bioenergy transitions.

1 | Introduction

In recent years, the diffusion of biogas and biomethane in the agri-food sector has become feasible by exploiting sustainable feedstocks composed of biomass residues and waste products from agriculture and agro-industries. By producing renewable energy in this way, it is possible to contrast global issues such as climate change, fossil fuel depletion, the increasing price of energy due to the Ukraine–Russia war and the low availability of raw materials, which emphasises the high level of dependence of some countries on others to import energies, such as gas, oil and solid fossil fuels (Bentivoglio et al. 2022; Stempfle et al. 2022). In the agricultural sector, energy self-sufficiency is linked to the need to minimise the costs of using production factors and to achieve environmental sustainability in the countryside. This will be a source of competitive advantage (Sgroi et al. 2018).

In the agri-food sector, the objective is to reach a 'near zero-waste' by focusing on strategies that allow the conversion of agricultural waste and by-products such as manure and cereals into bio-based products. It is essential to develop new business and marketing concepts for the valorisation of agricultural by-products (Donner et al. 2020).

The production of biogas by farms has contributed to creating green energy, promoted local possibilities for sustainable growth and favoured the circular economy (CE) diffusion in rural areas. Notwithstanding the biogas benefits, it is essential to consider that farmers often face financial difficulties due to high investment costs, limited market size, falling prices and short-term subsidies, which have hampered revenues. To overcome all these obstacles, it has been necessary to design new business models (BMs) (Karlsson et al. 2019), which are tools firms use to describe how they create, capture and deliver value (Bocken et al. 2014).

While most BMs traditionally focus on a single firm, biogas production in agriculture often requires collaboration across multiple actors (Karlsson et al. 2018). Therefore, some scholars have argued for a shift towards network-based models that enable knowledge sharing and the co-creation of value. However, for the purposes of this study, the emphasis is placed primarily on how BMs—whether individual or collaborative—integrate sustainability and circularity principles in practice (Karlsson et al. 2019).

The CE plays a key role in the agri-food sector in achieving sustainability (Stempfle et al. 2022) by adopting sustainable production models to produce bioenergy and bioproducts, characterised by the organised management of resources, the valorisation and reuse of by-products and waste (Bentivoglio et al. 2022).

From a managerial and business perspective, most of the existing literature on biogas/biomethane in the agri-food sector focuses on how to make this business profitable without harming the environment. For this reason, several BMs have been developed with the help of frameworks such as the business model canvas (BMC); moreover, the CE has been implemented into these BMs, and the framework has evolved into the circular BMC.

This study is the first to conduct a bibliometric-systematic literature review (B-SLR) of biogas/biomethane BMs and to examine these themes from quantitative and qualitative perspectives using the three-step procedure proposed by Caputo and Kargina (2022) and merging Scopus and Web of Science datasets.

Despite the growing interest in sustainable energy and CE, there is still a limited understanding of how the business literature has conceptualised and operationalised the integration of circular strategies into BMs through biogas and biomethane technologies. Given the increasing pressure on agri-food firms to reduce environmental impact while maintaining economic viability, it becomes crucial to understand how these renewable gas solutions are adopted, implemented and evaluated within business-oriented research. Investigating this perspective can help clarify the extent to which CE practices are embedded in business strategy, which factors facilitate or hinder this integration, and which sustainability dimensions are prioritised.

Accordingly, this study aims to answer the following research question:

RQ. How has the business and management literature addressed the integration of CE strategies and sustainability dimensions—economic, environmental and social—into the business practices of organisations producing biogas and biomethane?

Beyond mapping the existing literature, this review also aims to clarify the managerial and policy implications emerging from current research on circular bioenergy systems. In particular, it informs decisions on investment in biogas and biomethane initiatives, on the governance of supply and stakeholder networks, on the design of partnerships across agricultural value chains and on the development of innovative BMs that integrate CE principles. These aspects are especially relevant for organisations operating in the agri-food sector, where technological, organisational and social factors jointly influence the viability of circular bioenergy projects.

Furthermore, by combining bibliometric mapping with a qualitative synthesis, the study highlights several underexplored dimensions in the literature, most notably social sustainability, stakeholder acceptance and governance mechanisms. Understanding these aspects is essential for scaling circular bioenergy transitions, as the diffusion of biogas and biomethane systems depends not only on technological feasibility and economic viability but also on institutional coordination and social legitimacy.

This paper is organised as follows. Section 2 presents the literature framework and explains relevant concepts. Section 3 describes the paper's research methodology by adopting the 10-step methodological approach proposed by Marzi et al. (2025) for the B-SLR. Section 4 presents the results. In the end, Sections 5 and 6 discuss the results of the bibliometric-systematic analysis and define the conclusions. Finally, Section 7 presents suggestions for future research.

2 | Literature Background

2.1 | The Circular Economy Concept

The CE is important in transitioning toward a sustainable and regenerative system in the agri-food sector (Poponi et al. 2023). It is considered a strategy to address environmental impacts arising from the business-as-usual linear system (Stempfle et al. 2022).

The linear model 'take-make-use-dispose' has proved to be unsustainable in the long term (Ellen MacArthur Foundation 2012), as it focuses on producing infinite output without considering that some resources (e.g., fossil fuels) are available in a limited quantity.

The Ellen MacArthur Foundation (EMF) defines the CE as 'an industrial system that is restorative or regenerative by intention and design' (Ellen MacArthur Foundation 2013). The CE aims to reduce the use of virgin resources, waste and dangerous emissions. Moreover, creating new value chains through reusing, recycling and cascading end-of-life resources leads to economic development (Stempfle et al. 2022). In the CE, inputs are held at their highest value longer in business cycles, while waste acquires value as input for further cycles (Ellen MacArthur Foundation 2012; Ellen MacArthur Foundation 2013). Waste-to-energy (WTE) is a CE model in which businesses exploit waste from everyday activities and the supply chain such as anaerobic digestion, which is used to produce biogas and biomethane, representing the cheapest and environmentally friendly energy generation method (Hussain et al. 2019).

2.2 | The Business Model Concept and Its Evolution in the Literature

Despite the usage of the term 'business model (BM)' can be traced back to the early 60s of the XX century (Jones 1960), until the first decade of the XXI century, this concept was often studied without an explicit definition (Zott et al. 2011). Different understandings, definitions and building blocks proposals emerged around 2000 (Timmers 1998; Venkatraman and Henderson 1998; Hamel 2000; Amit and Zott 2001; Magretta 2002).

It is with the seminal work of Osterwalder (2004) and its subsequent theorisation of the BMC (Osterwalder and Pigneur 2010) that the concept finds a precise and shared content perimeter. According to the BMC framework, BM consists of four essential issues: (1) product, (2) customers interface, (3) infrastructure management, (4) financial. These four essential issues can be broken down into nine interrelated building blocks: (i) value proposition, (ii) customer relationship, (iii) customer segment, (iv) channel, (v) key activities, (vi) key resources, (vii) key partners, (viii) cost structures and (ix) revenue stream.

The BM can be considered as a tool that shows how a firm does business and can be used for analysis, comparison, performance evaluation and communication. Moreover, it describes a competitive strategy and how the firm converts resources and capabilities into economic value (Bocken et al. 2014). A BM is a set of choices made by the firm and also the point of contact between the design and the implementation of a firm's strategy. It is the vehicle through which the strategy is practically translated (Donner et al. 2020) and a dynamic concept that can change and evolve over time. The BM must create value, and it includes three elements: (i) value proposition, (ii) value creation and delivery and (iii) value capture (Richardson 2008). The value proposition is a set of goods and services offered to customers which generate profits. Value creation and delivery focus on entering new markets and generating new income. Value capture refers to the returns from selling products and services to customers (Bocken et al. 2014).

Usually, a traditional BM focuses on a single firm, emphasising economic value rather than environmental and social value; thus, it does not prioritise sustainability (Karlsson et al. 2019).

Firms began redesigning their BMs to integrate sustainability into their businesses, doing so through business model innovation (BMI), which changes 'the way you do business' rather than the value proposition. In this case, the BM focuses not only on firms but, above all, on a wide range of stakeholders who shape a value-network perspective necessary for innovation and transformation within the BM (Bocken et al. 2014).

The BMI for sustainability aims to increase positive and mitigate adverse environmental and societal impacts. For this reason, the organisation must change its value network, create, deliver and capture value or transform its value propositions. To face an unpredictable sustainable future, innovations are fundamental to change BM to tackle unsustainability at its source before spreading its negative output. Thus, BMI aims to maximise environmental and social benefits rather than solely generate economic profits (Bocken et al. 2014).

In recent years, scholars have paid attention to circular business models (CBMs), a specific type of sustainable BMs that implement circularity (Bocken et al. 2014) and apply strategies to close, narrow, slow, or regenerate material loops (Bocken et al. 2016). It differs from traditional BMs because its target is not reaching economic performance. Still, it aims to close the energy and material loops by ensuring the firm's long-term viability (Donner et al. 2020). CBMs are designed through the circular business model canvas (CBMC), proposed by Lewandowski (2016), which aims to accelerate the implementation of circularity. This framework represents a development of BMC of Osterwalder and Pigneur, and its building blocks are revised to incorporate CE principles; moreover, two other supplementary blocks are added: (i) take-back systems and (ii) adoption factors. The first new block includes material loops, in which materials can be reused after being collected from consumers or buyers. Instead, the second new block is supported by internal and external factors necessary to adopt CBM (Lewandowski 2016).

2.3 | The CE and BM Integration: First Considerations From the Biogas and Biomethane Literature

Increasing academic and practical attention is being directed toward how the CE can be embedded into BMs. This is particularly true in the agricultural sector, where waste treatment, energy dependence and economic imbalance are relevant issues for many organisations.

The literature on biogas and biomethane has started to investigate the possible connections between CE and BM.

The first aspect emerging from CE and BM integration concerns the economic and financial impacts of the CE (and, for the sake of this paper, biogas initiatives) and its BM implications. According to this perspective, the economic and financial performance of biogas initiatives are examined through the usage of accounting indicators such as the operating income, the relationship between net income and shareholder's equity, the Ebitda, the return on sales, the return on capital used, the return on equity and the level of debts (Bourdin et al. 2024).

Moreover, from an economic perspective, it is argued that biogas plants can foster revenue diversification, providing farmers with an additional source of income and helping them preserve their long-run viability (Brudermann et al. 2015; Mautz et al. 2008).

TABLE 1 | Ten-step methodological approach to bibliometric-systematic analysis.

Step	Activities
1: Research question and boundaries of the study	a. Informal literature scanning b. Identification of a research gap c. Definition and refinement of the research question d. Definition of inclusion/exclusion criteria
2: Search query definition	a. Identification of keywords b. Development of the search string
3: Database selection	a. Test of the string b. Choice of database(s): Scopus and Web of Science
4: Data screening and data cross-checks	a. PRISMA Flow Diagram is used to screen the documents to be included in the dataset and to remove duplicates and ineligible articles. Phases of identification and screening
5: Data cleaning and export	a. Data cleaning b. Prisma flow diagram: phases of eligibility and inclusion. c. Convert Scopus and Web of Science datasets to bibliography files (.bib files) d. Convert Scopus and Web of Science .bib files to Bibliometrix format (Excel files) e. Merge the two datasets manually from Excel f. Authors' keywords cleaning
6: Bibliometric approach	a. Bibliometric approach choice b. Preliminary bibliometric analysis: first approach to performance analysis and science mapping analysis
7: Clusters' topic identification	a. Cluster's identification through biblioshiny b. Graphical analysis of clusters
8: Sample ordering and selection	a. Ordering and selecting dataset documents within each cluster previously identified
9: Systematic literature review	a. Specific clusters' analysis for themes
10: Developing a theoretical contribution	a. Discussion of the findings b. Future research c. Limitations of this study

Source: Adapted from Marzi et al. (2025).

This kind of indicators provide an appreciation of the economic health of a company informing entrepreneurs of their strengths and weaknesses and supporting investors in their investment choices. Moreover, they allow to know the differences, at economic and financial level, of the different kinds of players, that is, farmers versus industrialists (Bourdin et al. 2024).

Furthermore, the economic and financial analysis of the biogas initiatives embedded in the BM can be very useful from a policy point of view to help policy makers to take decisions related specific policies, regulations, incentives, and so on (Hakawati et al. 2017).

Remaining in the business perspective, a crucial item of biogas implementation is related to investments. Biogas plants, for example, require huge investments in plants that can, in the short term, negatively affect the economic and financial sustainability of companies due to the asynchrony between construction phase and revenue generation. However, in the long term, the complex effect can be positive most of all when economic sustainability is enhanced and risk is reduced due to public support in the form of feed-in tariffs and green bonuses (Sgroi et al. 2018; Špička 2018).

In addition to the economic and financial analysis of the CE and BM convergence, the social and sustainability aspects of that item have been studied in the literature, reinforcing the evolution of the BM concept towards a BMI that embeds, beyond the economic perspective, also the social and environmental ones. As for the social aspects, public concerns about sustainability of biogas are frequent and interest different step of the chain and different group of stakeholders (Horschig et al. 2020). Also, in this sense, there are several implications for both firm communication and policy-maker decisions. As for sustainability, the biogas initiative can play a strategic role in making energy systems more resilient in a context characterised by sudden changes, especially in countries with structural vulnerability related to fossil resources. Furthermore, sustainability provides policy, managerial and social implications, showing that the complete diffusion of biogas can foster security and decarbonisation of the energy system. It can also create new business opportunities at the local level, promoting a circular and bio-based economy (Karlsson et al. 2017; Sica et al. 2023).

3 | Methodology: The 10-Step Methodological Approach

This study adopted a 10-step methodological approach for a B-SLR proposed by Marzi et al. (2025). The 10 steps are represented in Table 1.

The bibliometric methodology applies quantitative techniques to bibliometric data to create objective structural images of research fields. The bibliometric analysis investigates the social and structural relationships among research components, such as authors, countries, or institutions (Donthu et al. 2021). This approach uses two techniques: (1) performance analysis and (2) science mapping (Donthu et al. 2021; Zupic and Čater 2015). The first focuses on the contributions of research constituents to a given field, such as the number of publications, while the second focuses on the relationships among research constituents by revealing the structure of scientific fields. Science mapping, when combined with network analysis, can enrich the outcomes of the bibliometric analysis (Donthu et al. 2021).

Science mapping examines relationships between fields, disciplines and papers in a particular research area, and it aims to represent the structure of the research area using partition elements such as documents, authors, words, or journals (Zupic and Čater 2015).

This study has adopted co-word analysis and one network analysis technique, clustering. The target is to create thematic clusters to understand how a research field manifests and develops.

Co-word analysis uses documents' keywords to create relationships and build a conceptual structure of the domain. When words frequently co-occur in documents, it means that those words are closely related. The output is a network of keywords with their relations. Result quality depends on factors such as keyword quality and the scope of the database. Bibliometric data were analysed using Bibliometrix, a tool used for science mapping analysis (Aria and Cuccurullo 2017) included in the R package (http://www.bibliometrix.org).

The systematic literature review involves a qualitative analysis of academic documents to develop new theoretical frameworks to analyse events. It uses traditional methods that require some papers to be reviewed in the tens to low hundreds. It suits confined or niche research areas (Donthu et al. 2021).

The B-SLR blends quantitative and qualitative methods to analyse the literature by using metrics of interconnections among contributions and focusing on the replicability and transparency principles characterising systematic literature review. In this way, it is possible to benefit from the advantages of bibliometric analysis and systematic literature review and minimise their drawbacks (Marzi et al. 2025). This combined approach has been increasingly adopted in sustainability and CE research to map fragmented research streams and connect bibliometric patterns with qualitative interpretation of thematic developments (e.g., recent bibliometric–systematic reviews on carbon accounting and CE transitions) (Di Vaio et al. 2025).

While the first step is defined above in the introduction, the next paragraphs report from Step 2 to Step 5 in this methodology section, then from Step 6 to Step 9 in the results, and finally, Step 10 in the last paragraph of the manuscript.

3.1 | Search Query Definition

This step identified a specific keyword combination to develop a search query for the databases to retrieve documents represented as articles. The research focuses principally on biogas or biomethane, with particular attention to organisational implications, that is, understanding how biogas or biomethane production can be introduced in a business and its ecosystem to obtain results in terms of higher sustainability of the system and better performance of the organisation.

The search string developed is as follows:

$$\left(\text{circular OR sustainab}^{*}\right) \text{ AND (business OR firm OR organization OR organisation) AND (biomethane OR biogas).}$$

The research was conducted in November 2024, and the period is from 2015 to 2024; the document type is a scientific article in English.

3.2 | Database Selection

In this step, the database has been selected and the search string tested. Two databases, Scopus and Web of Science, have been used because they are suitable for management studies, as they provide extensive bibliographic data and research materials (Marzi et al. 2025).

The results were the following: Scopus scheduled 138 articles, and Web of Science scheduled 205 articles. Therefore, the total number of articles identified through database screening was 343.

3.3 | Data Screening and Data Cross-Checks

As suggested by Caputo and Kargina (2022), the use of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al. 2009), represented in Figure 1, was necessary to identify and act on cleaning steps to make the data exported more consistent and accurate. PRISMA, represented by a Flow Diagram, involves four steps: (i) identification, (ii) screening, (iii) eligibility and (iv) inclusion.

The identification step involved database searching in Scopus and Web of Science, and the first dataset was obtained using a search string.

The Screening step involves eliminating duplicates. The first screening excludes articles that did not meet the inclusion/exclusion criteria regarding language, research area, and so forth.

The Eligibility step involves reading the abstracts and full articles to determine whether an article should be included or excluded from the analysis. Once this step is reached, it is possible to export results from Scopus and Web of Science into the Bibliometrix format.

The Inclusion step involves exporting and analysing the final publication dataset.

This phase focuses on the first two steps, while Phase 5 concentrates on eligibility and inclusion. In the identification step, a dataset comprising 343 articles from Scopus and Web of Science was obtained. In addition to the records retrieved through the database search, two further articles were identified through a forward- and backwards-citation search (snowballing) conducted on key publications emerging during the screening phase. This complementary search strategy was used to ensure that potentially relevant

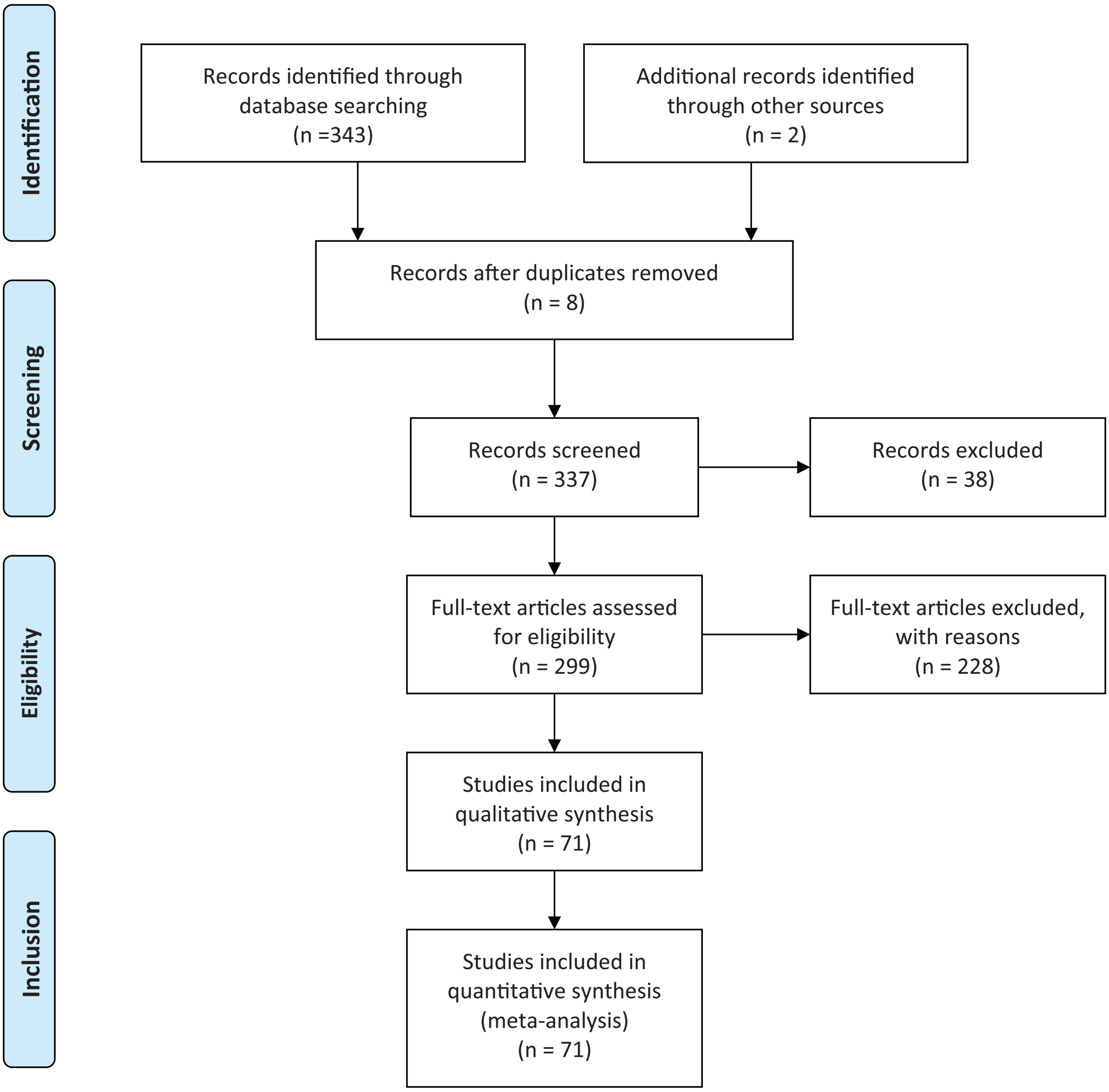

FIGURE 1 | PRISMA flow diagram. *Source:* Our elaboration.

contributions not captured by the database query were considered. These articles were included only after verifying that they satisfied the same inclusion and exclusion criteria applied to the main dataset, including the publication type (peer-reviewed journal article), language (English), thematic relevance to biogas/biomethane in relation to CE or sustainability and the defined time window. The use of snowballing as a complementary identification method is consistent with systematic review practices and helps reduce the risk of omitting relevant studies that may not be fully indexed through keyword-based database searches.

In the second step, 337 articles were screened and 38 were excluded due to the inability to download and analyse them. Excluding articles due to access limitations could threaten the transparency and completeness of the review process. Although this constraint was operational rather than conceptual, it may introduce a limited selection bias, and to mitigate this issue, several alternative access routes were explored. These included searches through institutional library services, academic repositories and alternative indexing platforms. Despite these attempts, a subset of articles remained inaccessible and therefore could not be evaluated during the eligibility stage. While the number of excluded articles is relatively small compared with the initial dataset, this limitation should be acknowledged when interpreting the results, as it may slightly affect the representativeness of the final sample.

3.4 | Data Cleaning and Export

This phase describes the third and fourth steps of the PRISMA flow diagram, which are intended to clean and export the dataset.

Manual screening for inclusion assessment has been adopted for each article, with titles and abstracts read to identify articles that address biogas or biomethane topics and analyse them from a management or business perspective. In the eligibility step, 228 articles were excluded from the 299 full-text articles assessed for eligibility.

It is important to note that, during the identification phase, filters have been applied to the research area in both databases to emphasise the managerial and business aspects of research, with the

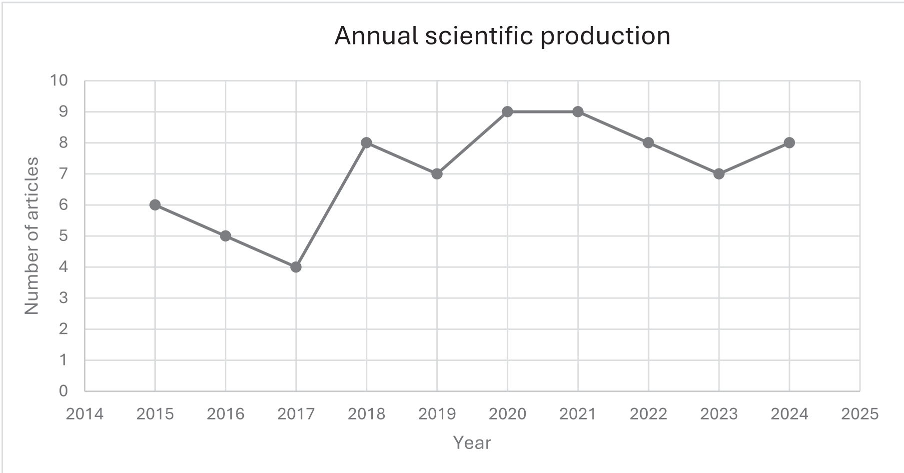

FIGURE 2 | Publications trend per year. *Source:* Our elaboration.

aim of focusing on organisations that produce biogas/biomethane. Although these filters were applied, a further extensive deletion of articles was necessary because economic perspectives were still based on engineering or other technical studies.

Finally, in PRISMA's fourth step, 71 articles were included in a qualitative and quantitative synthesis. So, the focus of the bibliometric analysis of the metadata provided concerned 71 articles.

As two databases have been used to get the dataset, it was necessary to find a way to merge both datasets to create a unique file.

Caputo and Kargina (2022) developed a method to merge Scopus and Web of Science datasets in a three-step procedure that works for bibliometric analyses run with Bibliometrix. This method, which allows merging the two datasets from Excel, was developed by Echchakoui (2020).

At the end of this fifth phase, it was necessary to clean authors' keywords and keywords plus from the merged dataset because, for example, there were words in either singular or plural form that, if not unified, would be represented by Bibliometrix as two different keywords. Moreover, the authors unified keywords with similar meanings that were represented by various word combinations.

The keyword cleaning process involved standardising singular and plural forms, harmonising spelling variants (e.g., British and American English) and merging semantically equivalent expressions referring to the same concept (e.g., 'business model' and 'business models'). This step was conducted manually to ensure conceptual consistency across the dataset. The co-word analysis was performed using the Bibliometrix package in R through the Biblioshiny interface.

The network construction was based on authors' keywords, applying a minimum occurrence threshold to include only terms appearing multiple times in the dataset. Keyword relationships were normalised using association strength, a common method in science mapping to balance the weight of frequent and less frequent terms.

Clustering was performed using the default community-detection algorithm implemented in Bibliometrix, which groups keywords based on their co-occurrence patterns to identify thematic structures within the research field. The resulting network was then visually inspected to interpret the clusters and assign thematic labels.

4 | Results

4.1 | The Bibliometric Analysis

First, some descriptive information about the collected documents analysed is provided. The collection contains 71 articles, and the timespan considered is 2015:2024. The author's keywords are 215. Keywords plus have not been used because they were missing in 22.54% of 71 articles. The mean annual growth rate in the number of articles is 3.25%.

Figure 2 shows the trend in annual scientific production with slight increases and decreases characterised over the period considered. Overall, we can affirm that the attention of scholars to this theme is increasing but without particular peaks.

The analysis shows that the scientific production of articles regarding the biogas theme differs across various countries based on the first author's affiliation. The countries responsible for the highest number of publications are spread around the world, especially in Sweden (15 publications), China (12 publications), the United Kingdom (12 publications), Italy (10 publications) and Poland (10 publications).

The co-occurrence analysis aims to establish the most relevant biogas keywords and investigate their belonging to a particular cluster. Each cluster contains direct or indirect themes linked to biogas, as shown in Figure 3.

The dominant approach is co-word analysis, in which two or more specialised keywords related to a particular research topic co-occur within the same academic field thesis, and it is generally believed that they are associated (An and Wu 2011).

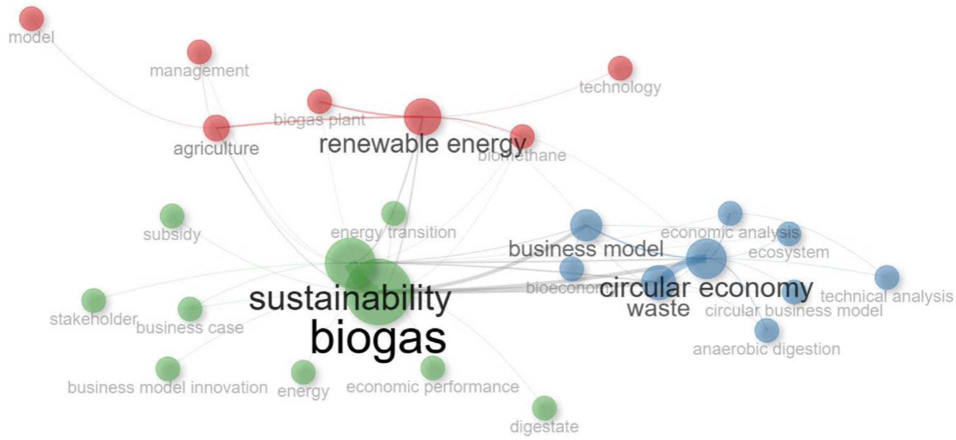

FIGURE 3 | The co-occurrence network of authors' keywords. *Source:* Our elaboration.

According to Donthu et al. (2021), the node size refers to the keyword occurrence; instead, links between nodes state keyword associations, with link thickness referring to the degree of co-occurrence.

The co-word network analysis is fundamental to understanding the details of the co-occurrence network map. In network analysis, nodes can be evaluated using different centrality measures to interpret the structural importance of keywords within the research field. In particular, this study considers degree centrality, betweenness centrality, closeness centrality and PageRank. Degree centrality refers to the number of direct links between a keyword and other keywords, indicating how frequently a concept co-occurs with others in the literature. Betweenness centrality measures the extent to which a keyword acts as a bridge connecting different thematic areas in the network. Closeness centrality indicates how close a keyword is to all other nodes, reflecting how quickly information associated with that concept can spread through the network. Finally, PageRank captures the relative influence of nodes within the network by considering both the quantity and the quality of their connections. Figure 3 shows the co-occurrence of the authors' keywords and, therefore, the relationships between authors' keywords in the dataset examined. Each keyword is considered as a node. Three clusters are recognisable for their different colours: green, red and blue. Each colour represents papers that deal with the topic in several ways. The thicker the ties, the more a topic is linked to another. In our study, biogas is closely linked to sustainability, and the CE is closely linked to waste. Moreover, there are meaningful connections between biogas and the CE, as well as between biogas and waste. They refer to papers which belong to different clusters. The bubble dimension represents the frequency with which a topic is repeated. The bigger the bubble size, the more a topic appears in the dataset. This indicates how prevalent a topic is within the overall body of literature.

Cluster 1 (green) is centred around the keywords *biogas* and *sustainability*, which show the highest centrality values in the network. Their high betweenness centrality indicates that these concepts act as connectors between multiple thematic areas, highlighting their pivotal role in structuring the literature. Their relatively high closeness centrality further suggests that these topics are closely linked to other keywords in the network, reinforcing their central position in the research field.

Cluster 2 is represented by the red colour. Its principal keywords are renewable energy and agriculture. Compared with Cluster 1, the keywords in Cluster 2 present lower centrality values, indicating a more specialised thematic area focused on renewable energy production and agricultural contexts.

A blue colour represents Cluster 3. Its principal keywords are CE, waste and BM. Cluster 3 focuses on CE and BM themes, highlighting the growing attention to organisational and strategic aspects of biogas systems within CE frameworks.

4.2 | The Systematic Literature Review

According to Winquist et al. (2019), 'Biogas could ideally serve both as a renewable energy product and an efficient sustainability product, an integral element of circular economy'. This affirmation clearly explains the relationship between biogas, sustainability, renewable energy and CE, represented in the co-occurrence network in Figure 3 that emerged from this study. In this phase, the goal is to examine the three clusters identified in the previous step from a managerial and business perspective. Following recent systematic literature review practices in sustainability and CE research, the qualitative synthesis aims to connect bibliometric clusters with the main research themes and managerial implications emerging from the literature (Di Vaio et al. 2024). To provide a structured overview of the qualitative synthesis, Table 2 summarises the main thematic focus of each cluster, the key issues addressed in the literature, and representative studies included in the analysis. This synthesis helps clarify how the research field is organised and highlights the main streams of inquiry emerging from the bibliometric mapping.

4.2.1 | Cluster 1: Sustainability and Biogas

The production and adoption of biogas aim to achieve sustainability, but their effects on the environmental, economic and social dimensions differ.

TABLE 2 | Thematic synthesis of the literature clusters.

Cluster	Main thematic focus	Key issues addressed in the literature	Representative studies
Cluster 1: Sustainability and biogas	*Sustainability implications of biogas systems within agricultural and rural contexts*	Environmental benefits (GHG reduction, waste valorisation); economic performance of biogas plants; policy incentives and subsidies; social acceptance and community opposition; stakeholder perceptions of sustainability governance	Karlsson et al. (2017); Cavicchi (2016); Sica et al. (2023); Horschig et al. (2020); Bourdin et al. (2024)
Cluster 2: Renewable energy and agricultural production systems	*Economic and operational dynamics of biogas production within renewable energy systems*	Farm-level investments and profitability of biogas plants; role of feedstock availability; influence of subsidies and energy policies; logistical and environmental constraints of biomass supply chains; scale and social acceptability of biomethane projects	Sgroi et al. (2018); Bentivoglio et al. (2022); Muradin and Foltynowicz (2018); Boudin and Delcayre (2024)
Cluster 3: BMs and Circular Economy	*Business model innovation and circular economy strategies in biogas systems*	Circular business models for waste-to-energy systems; value creation from agricultural residues; stakeholder networks and ecosystem governance; collaboration and partnership structures across the biogas value chain	Karlsson et al. (2018); Karlsson et al. (2019); Kanda et al. (2021); Donner et al. (2020); Budzianowski and Brodacka (2017)

Source: Our elaboration.

From an environmental perspective, Sica et al. (2023) and Karlsson et al. (2017) outline that biogas is considered an energy source, which allows mitigating GHG emissions and pollution on the planet (Brudermann et al. 2015; Cavicchi 2016; Herbstritt et al. 2023).

From an economic perspective, according to Sica et al. (2023), biogas production creates local businesses and jobs, reducing the country's energy dependence on others. Cavicchi (2016) claims that the firm's income increases opportunities from biogas; in addition, the consumption of self-produced energy reduces energy costs. Bourdin et al. (2024) affirm that the biogas economic performance depends on the type of producer: farmers have better economic performance due to the possession of crucial resources such as organic waste and crops, while industrialists, who must buy the raw materials, have better financial performance due to their ability to raise funds by negotiating payment terms and interest rates. They can reduce energy production costs by investing in production facilities and achieving economies of scale. However, the most critical performance factor is the guaranteed availability of electricity and gas prices set by the State to avoid market price volatility and encourage banks to grant loans to biogas entrepreneurs. Špička (2018) evaluates the impact of investments on subsidies. Adopting subsidies in biogas plants makes agricultural firms less profitable in the short term, due to high debt and inadequate revenues during the construction phase; therefore, investment costs are often higher than the asset's value. In the long term, the biogas plants have had a positive effect because the firm receives revenues from power and heat sales through feed-in tariffs or green bonuses. Thus, subsidies improve the farm's cash flow.

From the social dimension point of view, Cavicchi (2016) affirm that even if new biogas plants allow job creation, the drawbacks are more than the benefits because biogas production generates negative impacts on the local community, such as bad smells and social opposition, conflicts between farmers, inhabitants, municipalities and biogas producers.

Finding an agreement between these three dimensions with contrasting targets is difficult. In addition, the difficulties of achieving the triple bottom line in the biogas sector stem from the limited role of local governments and the lack of cooperation and synergies among the government, firms and the research sector.

Horschig et al. (2020) examined value chain phases and analysed stakeholders' perceptions of biogas sustainability and their expectations of sustainability governance. The study indicates that these actors prefer sustainability regulation at the national level rather than at the local or international level, and that certifications and standards serve as tools for compliant sustainability governance; moreover, transparent and clear government rules are perceived as necessary to achieve sustainability.

Karlsson et al. (2017) analysed BMI and found that innovation is a challenge for organisations, especially for SMEs, which lack the resources and competences to implement changes; thus, they accept changes only when they are compelled to survive. These authors identified six BMI success factors for farm-produced biogas in the agricultural sector. They affirmed that BMI enables public-private actors to build the networks needed to raise capital and secure expertise for investing in biogas production. In this way, they can offer new opportunities to firms in the agricultural sector. Stakeholders should have a long-term perspective and must achieve economic, environmental and social benefits that do not manifest in the short term. Instead, partners should be carefully selected to build long-term relationships based on cooperation.

According to Honcharuk et al. (2024), digestate, a by-product of anaerobic digestion, can be used and sold as fertiliser to generate income and increase the fertilisation level of agricultural land. Innovations in technologies finalised to improve digestate transport and injection systems have enabled it to reduce transport, spread and fuel costs.

According to Budzianowski and Brodacka (2017), Sgroi et al. (2018) and Stempfle et al. (2022), the development of BMs should consider policies such as economic incentives for biogas plant investments, which are fundamental to ensuring financial sustainability and generating income. Pereira et al. (2023) affirm that rural properties could also use incentives to invest in waste recovery to produce energy. Moreover, it is also essential to consider environmental regulations and taxation. Otherwise, investment difficulties could arise.

4.2.2 | Cluster 2: Renewable Energy and Agricultural Production Systems

Farms can get supplementary income through biomass use by selling electric and thermal energy and saving money using their waste; most articles in this cluster analysed the impact of technical aspects on biogas firms' management.

Sgroi et al. (2018) analysed a farm investment to create a biogas plant and its future economic effects on the company. Access to low-cost biomass sources provides a competitive advantage, as firms can produce energy at lower cost, which is an incentive for building biogas plants. The investment became profitable after a certain number of years; thus, it is essential to avoid increased spending that could lead to financial issues in the first period. After this period, firms achieve a reasonable level of income. Incentives play a key role as energy policy tools, as they provide an additional income source for the enterprise.

Boudin and Delcayre (2024) affirm that the size of renewable energy projects matters, but it is not necessarily an obstacle to implementing more significant projects. However, it can cause social issues regarding acceptability. Large-scale projects are favoured to maximise biomethane production and reduce GHG emissions. Still, they led to significant resistance from local communities, which prefer small-scale projects. The authors emphasise the role of local ownership in mitigating the adverse effects of a biomethane plant: they state that local leaders and key stakeholders, such as local authorities and residents' associations, should be involved in the project's management to support it. In this way, these projects can create economic benefits for residents and are better accepted.

According to Bentivoglio et al. (2022), converting the biogas plant into biomethane is not profitable if the digester's diet remains unchanged. Profitability depends either on the diet or on subsidy supply. The first should ensure high performance with minimal impact from an environmental point of view, while the latter should guarantee adequate remuneration to the producers.

Muradin and Foltynowicz (2018) affirm that the logistics of loading feedstock for agricultural biogas plants cause the principal environmental problems. Some logistical issues concern the length of the transport route and the means of transport used. It is essential to consider that the significant negative ecological effect concerns transporting liquid raw materials, such as manure, using a farm tractor and tanker. This problem could be resolved by substituting it with pipeline transport.

4.2.3 | Cluster 3: BMs and Circular Economy

According to Karlsson et al. (2017), at the beginning of biogas diffusion, the BM approach was not widely adopted because this type of production was mainly seen as a means to reduce industrial waste rather than an innovative business. Thus, the scientific output of biogas BMs and BMI themes was limited.

By recognising the benefits of biogas, scientific production arose in the management and business fields. This shift reflects a growing awareness that biogas systems can be more than waste treatment technologies—they can become enablers of sustainable innovation.

Karlsson et al. (2018) and Karlsson et al. (2019) describe the biogas producers' difficulties in achieving profitability when biogas began spreading in the agricultural sector, due to production, distribution and marketing barriers, as well as competition with other energy producers. BM and BMI are designed through frameworks such as the BMC or the Flourishing Business Canvas (FBC), which are used to create prototypes. Hoveskog et al. (2018) state that traditional BM is more oriented toward stakeholders' interests from an economic perspective, whereas FBC promotes sustainability across its three dimensions.

According to Bourdin et al. (2024), the biogas BMC provides a framework for understanding how income and costs are generated. Biogas production offers three value propositions: (i) it deletes waste from livestock and, therefore, reduces GHG emissions, and it enables organic waste treatment from agro-industry; (ii) it produces electricity or biomethane that can be sold to local firms and communities; (iii) it produces digestate, which is a waste product that can be used as a high-quality fertiliser and sold to get income.

Karlsson et al. (2019) affirm that firms must join a network that allows them to achieve both business objectives and realise the sustainable benefits of farm-based biogas production. That is because single companies have limited resources, knowledge, or expertise. Network-level BM success depends on creating good stakeholder relationships and sharing risks and rewards. The goal is to create positive outcomes such as sustainable value co-creation and long-term competition. Collaboration is the key factor that enables organisations to tackle sustainability projects together and realise short-term economic benefits, which can be challenging given the diversity of stakeholders.

Budzianowski and Brodacka (2017) suggest to create a partnership between stakeholders such as the national Government, regional and municipal authorities, media, grid operators, vehicle manufacturers, individual end users and consumers. Moreover, according to Karlsson et al. (2017), this type of network makes it easier to obtain resources such as investments, competencies, expertise and knowledge. These developments mark a transition from firm-centric strategies toward more integrated and systemic BMs. As environmental pressures and policy expectations increase, firms are gradually shifting from traditional models to ones that embed CE principles at their core.

Kanda et al. (2021) affirm that implementing circularity in the biogas BM requires adopting an ecosystem-level perspective, where the value network plays a key role, as the biogas system comprises several actors across different sectors and markets. Because of the interdependencies among firms across sectors, municipalities and consumers, proactive management and governance are indispensable. This reconfiguration signals a broader evolution in how value is conceived—not just in terms of economic output but also environmental and social impact.

These interconnections highlight how biogas BMs are evolving from linear, firm-centred approaches toward more circular and systemic configurations.

This complexity increases when CE principles are embedded into the BM, noted by Kanda et al. (2021), who argue that the interdependencies among diverse actors make the adoption of circular strategies more challenging than in other sectors.

Different actors should collaborate, cooperate and be properly coordinated, as they span various phases of the supply chain, such as suppliers, manufacturers, retailers and consumers (Stempfle et al. 2022; Donner et al. 2020). Collaborative capabilities of different stakeholders, such as local government, industry and academia, should be involved (Vanhamäki et al. 2020).

Kanda et al. (2021) affirm that through the implementation of circularity in the BM, a firm's focus passes from the traditional BM to a business ecosystem perspective whose dimensions are (i) a value network, (ii) coordination and (iii) centralisation of control. The first is considered the pillar of biogas systems due to the interdependencies among different actors, which create difficulties in organising activities. The second refers to the high level of coordination required for the supply of organic waste and the demand for biogas and fertiliser, particularly when biogas is sold on the market for income. The third refers to control centralisation, where a centralised authority coordinates the relationships in the ecosystem.

In this CBM approach, the emphasis shifts from value delivery to value co-creation, where, by building different relationships, the organisation can acquire knowledge of market conditions and competencies to build trust with external actors.

5 | Discussion

This study provides a structured overview of how the business and management literature has addressed biogas and biomethane within the broader transition toward circular and sustainable energy systems. Most articles analyse biogas in engineering and chemical disciplines, whose aim is to find the best technical solutions to improve the processes. As for business and management literature, the number of articles is limited and still immature and mainly focused on three themes: (i) sustainability, (ii) renewable energy and (iii) CE.

This study shows that different attention is given to the three dimensions of sustainability in the biogas sector: that is, economic, environmental and social. This imbalance reflects a broader pattern observed in sustainability-oriented business research, where economic and environmental dimensions tend to dominate the literature while governance and social legitimacy aspects remain comparatively underexplored. Recent systematic literature reviews in related sustainability domains have highlighted similar gaps and emphasised the need to better integrate managerial, reporting and governance perspectives when analysing transitions toward sustainable BMs (Di Vaio et al. 2025). Indeed, several authors have examined the economic side of sustainability to evaluate the economic viability and production performance of biogas/biomethane using specific economic indicators. It is possible to affirm that the economic dimension is more developed than the other two, probably because it represents the first contribution that characterises the business field, distinguishing it from the hard sciences. The conditions under which a biogas organisation makes a profit to ensure its long-term continuity are typical business topics.

As for the environmental side of sustainability, studies shed light on how biogas/biomethane organisations are driven by the need to meet regulatory requirements and by a desire to improve the quality of life and the safety of our planet. The environmental dimension is so closely linked to the economic one that it can be difficult to clearly distinguish the boundaries between the two sides of sustainability. Often, in fact, the analysis of the environmental dimension stresses the cost-savings aspect, due to the possibility of self-producing power and heat for self-consumption, and to income increases from selling the electricity surplus on the grid and from digestate as a soil improver or high-quality fertiliser (Cavicchi 2016).

Contrary to the economic and environmental dimension of sustainability, the third aspect of the 'triple bottom line', the social one, is poorly examined. Few authors have analysed the diffusion of social opposition, accompanied by committees created to hinder and stop the spread of biogas/biomethane, making biogas and biomethane plant installations more complicated (Boudin and Delcayre 2024).

Communication initiatives with the various stakeholders involved in biogas plants could enhance awareness of the opportunities and benefits of adopting biogas and biomethane projects (Cavicchi 2016; Boudin and Delcayre 2024).

In synthesis, implementing biogas initiatives coherently with the triple bottom line is complicated, as the three sustainability dimensions aim at different targets, each with distinct and not always convergent interests and motivations (Cavicchi 2016).

Regarding renewable energy, biogas and biomethane production are feasible and encouraged in the agri-food sector through the use of biomass. However, also in this case, the choice to produce renewable energy depends on the ability to generate income. As with every investment decision, the biogas sector is no exception: the return concept is crucial; the reduction of adverse environmental effects is a necessary but not sufficient condition for investing in biogas or biomethane initiatives (Bentivoglio et al. 2022).

Concerning the CE, producing renewable gases for bioenergy is tightly linked to waste elimination. Organisations must design an effective BM by implementing circular practices to achieve all the goals of sustainability: economic, environmental and social. In this sense, it is possible to say that the objectives of reshaping BMs towards the CE in the biogas sector are related to profit generation and, at the same time, to solving environmental and social problems faced by agricultural enterprises (Karlsson 2019). The exploitation of biomass in this type of business represents an additional income source that does not substitute for the main activity of producing agricultural products for the market (Sgroi et al. 2018) but can help diversify and, consequently, reduce risk.

In synthesis, the bibliometric and systematic review developed in this paper sheds light on how the impacts of biogas initiatives could, and probably should, find a position within the organisation's BM, most of all in its sustainable evolution. The three clusters identified are a clear expression of the interpretation of biogas initiatives within the BM borders, because they shed light on all the elements composing a BM: the product, the customer and generally speaking, the stakeholder interface, the infrastructure (such as plants and their technical features) and financial implications.

Another relevant insight is that stakeholders' collaboration and cooperation are fundamental to ensuring the biogas-adopting organisation's long-term profitability and the BM's success. This situation is challenging to reach, as it involves different actors with distinct characters and objectives, sometimes in conflict, that operate across various value chain phases. Thus, an equilibrium between their interests is necessary to reach the common goal. Adopting partnerships or network initiatives allows biogas organisations to save money and acquire expertise, competences and resources that are otherwise difficult to obtain, particularly for SMEs (Karlsson et al. 2017).

6 | Conclusions

From a theoretical perspective, this review contributes to the literature by offering a structured synthesis of how biogas and biomethane initiatives are conceptualised within business and management studies. It advances the academic debate by identifying under-researched areas—particularly those related to social sustainability and ecosystem-level collaboration—and by proposing a future research agenda to bridge these gaps.

For the first time, this study analysed biogas and biomethane themes using a bibliometric and systematic approach, adopting the 10-step methodological approach introduced by Marzi et al. (2025). Furthermore, the three-step procedure proposed by Caputo and Kargina (2022) has been adopted to merge Scopus and Web of Science datasets to obtain a broader final dataset of articles.

In the agri-food sector, biogas production can eliminate waste by creating a closed loop in the production cycle, thus leading to CE implementation and reaching a 'near zero waste' target.

Most previous studies used the BMC to design BMs. Moreover, some authors have used an evolved form, such as the CBMC, to implement circularity.

The bibliometric analysis showed that only a few scholars had analysed biogas/biomethane from a managerial and business perspective from 2015 to 2024. The co-occurrence network revealed three distinct clusters related to sustainability, renewable energy and CE.

The systematic analysis focused on the three clusters identified in the bibliometric analysis. From the cluster on sustainability, it emerged that even if biogas-adopted organisations would like to embrace sustainability in its three dimensions, they primarily focus on economic and environmental dimensions, neglecting the social one. The renewable energy cluster showed that the spread of renewable energy depends, above all, on the ability of this kind of business to generate profits. The mitigation of adverse environmental effects is the driver of these initiatives, but generating income is essential for their effective implementation on a large scale. Finally, the CE cluster underlines the importance of strategically designing CBMs—through frameworks such as the BMC or other BM frameworks—to transform waste into value and support sustainability through system-wide collaboration.

Some studies showed that collaboration through partnerships or networks is crucial to achieve the common goal of sustainability because only by sharing knowledge and expertise, it is possible to exploit economies of scale, save money and time.

On a practical level, the study offers actionable insights for business practitioners and policymakers.

The gap highlighted in this literature review is particularly relevant in sectors such as bioenergy, where technological feasibility and economic viability alone are insufficient to ensure the successful diffusion of circular solutions. The implementation of biogas and biomethane initiatives often depends on coordinating multiple actors, designing appropriate governance mechanisms and building trust and legitimacy within local communities. Recent bibliometric and systematic reviews in sustainability-related domains have similarly highlighted the importance of integrating organisational, governance and reporting perspectives when analysing the transition toward sustainable and circular BMs (Di Vaio et al. 2024; Di Vaio et al. 2025).

It underscores the need to foster cross-sector partnerships and network-level strategies, especially for small and medium-sized enterprises, in order to overcome resource limitations and enhance the success of circular bioenergy transitions.

This study presents some limitations related to the bibliometric techniques adopted, particularly the co-word network analysis used to interpret the co-occurrence map. First, some journals' data do not contain keywords, which may reduce the completeness of the keyword-based network. Second, when analyses rely primarily on authors' keywords, an indexer effect may occur, meaning that the structure of the network depends on how authors select and report keywords and on how well these terms capture the core themes of the articles. To mitigate this limitation, the interpretation of the bibliometric clusters was complemented with a qualitative examination of the titles, abstracts and full texts of the articles included in the dataset. This triangulation helped ensure that the thematic interpretation of the clusters was not driven solely by keyword indexing practices. Finally, although alternative approaches such as text mining based on abstracts or full texts could provide additional insights, these methods may also introduce methodological challenges, as algorithms cannot always distinguish the relative importance of terms within large bodies of text (Zupic and Čater 2015). Despite these limitations, the combined use of bibliometric mapping and qualitative interpretation provides a robust overview of the intellectual structure and main thematic developments of the literature on biogas and biomethane BMs.

7 | Developing a Future Research Agenda

Despite the growing literature about the bioeconomy and CBMs in the agri-food sector, there is still a wide margin for improvement.

Building on the results of the bibliometric-systematic review, which identified three thematic clusters reported above, this study proposes the following research agenda:

1. *Comparative studies across countries and contexts*: Most contributions in Cluster 1 focus on technical implementation and regulatory barriers, particularly in specific national contexts (e.g., Italy, Germany and Scandinavian countries). However, comparative analyses across countries are rare. Future studies should examine how different institutional and policy environments shape the design and viability of circular biogas BMs. For instance, Sgroi et al. (2018) highlighted how energy self-sufficiency can be a source of competitive advantage in Italian farms, while Stempfle et al. (2022) examined the role of sustainable production models in broader European contexts. Comparative approaches could deepen our understanding of policy-driven innovation dynamics.
2. *BMI and dynamics*: Cluster 2 highlights the centrality of sustainable and CBMs (e.g., Bocken et al. 2014; Karlsson et al. 2019), but much of this literature remains conceptual or static. Longitudinal research is needed to capture how these models evolve over time and how firms adapt to changing economic, environmental and policy conditions. For example, Bentivoglio et al. (2022) point out that shifting prices and geopolitical tensions (e.g., the Ukraine-Russia war) affect market viability, but their implications for BM adaptation are underexplored. Tracking these dynamics could reveal strategies for resilience and long-term sustainability. Future studies should also explore how firms in the biogas/biomethane sector can balance and innovate across the triple bottom line performance within their BMs;
3. *Socio-environmental impact assessment*: While Cluster 1 and 2 touch upon environmental benefits and business potential, few studies offer multidimensional assessments of the social and environmental impacts of biogas systems at the local level. Mendes et al. (2023) note the role of waste valorisation and near-zero waste strategies, but empirical validation of their effectiveness remains limited. Future work should focus on the development and application of integrated performance metrics to assess the real outcomes of circular BMs in rural communities, going beyond economic indicators to include ecosystem services and social equity.

   In particular, to avoid social tensions caused by the diffusion of biogas and biomethane plants (Karlsson et al. 2017), it is necessary to find effective ways to share benefits with local residents, such as job creation, improved local infrastructure, or community investment. A failure to do so may result in additional costs, project delays and reduced stakeholder trust due to public opposition. These dynamics warrant focused empirical attention, particularly in rural areas where acceptance is critical for implementation.
4. *Stakeholder engagement and ecosystem governance*: Cluster 3 emphasises the importance of collaboration and ecosystem-level thinking in CE transitions (e.g., Kanda et al. 2021). Yet, there is limited empirical work on how stakeholders interact and co-create value across the biogas value chain. Karlsson et al. (2019) argue for the need to rethink BMs as networks rather than firms, a perspective aligned with this agenda point. In this context, public actors such as municipalities can play a crucial role in mitigating social resistance and facilitating constructive dialogue. Future research should explore governance models that actively involve local stakeholders—not just as passive recipients but as co-creators of value—and investigate how different configurations of actor involvement influence project outcomes and social legitimacy.
5. *Digitalisation and circular transitions*: Although not yet prominent in the reviewed literature, digital tools and digitalisation in a wide sense could play a transformative role in supporting CE practices in agri-food energy systems. As biogas plants' performance often depends on monitoring and optimisation of diverse inputs and outputs, integrating digital technologies could improve transparency, traceability and efficiency. This represents a potential extension of the insights in Cluster 2, which already discusses the evolution of the BM toward a circular framework. Moreover, digital platforms could also support better communication

with residents and stakeholders, facilitating transparency, social inclusion and timely conflict resolution. This line of research could help identify digital strategies that reduce opposition, enhance participation and accelerate the energy transition in rural areas.

The points outlined above represent the main reflections on the gaps in the existing literature and give insights into the further development of this line of research. These topics, if explored through empirical and multidisciplinary approaches, could significantly enhance our understanding of how sustainability and CE principles are integrated into BMs related to biogas and biomethane, particularly within the agri-food sector. Moreover, they offer promising avenues for the development of innovative solutions that, beyond improving the economic and environmental performance of the organisations involved, could also foster greater social acceptance and more inclusive governance of energy transition processes.

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