Does size matter? The effects of biomethane project size on social acceptability

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Does size matter? The effects of biomethane project size on social acceptability

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Abstract:

This article examines the influence of the size of renewable energy projects on their social acceptability. To do so, it focuses on biomethane in France. Using a qualitative approach based on interviews and press analysis, we reveal that the perception of project size varies considerably according to territorial context and associated emotional impacts. The results show that even large projects can be socially acceptable if they are properly integrated with their objectives aligned with local expectations. The study highlights the tension between ambitions for large-scale biomethane development and local preferences for human-scale initiatives. The article proposes strategies for improving the social acceptability of biomethane projects, taking account of local specificities and promoting in-depth consultation with communities.

Keywords:

Energy transition / Size / Biomethane / Biogas / Territorial dialogue / Social acceptability / Local autonomy

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1. Introduction

The world faces a climate emergency and the depletion of natural resources, and the energy transition is an essential response to these challenges (IEA, 2021). According to the Ellen MacArthur Foundation (2021), extractivism, characterised by excessive exploitation of resources, needs to be reassessed as part of our quest for a circular economic model that is less dependent on fossil fuels. In Europe, the energy transition is one of the pillars of the Green Deal for carbon neutrality by 2050. In France, the transition to a greener energy mix, one incorporating a significant proportion of renewable energies, has become a government priority, as illustrated by the Multiannual Energy Programme adopted in 2020 (Ministry of Ecology[1]).

At the heart of this transition, biomethane is emerging as a promising technology for producing renewable energy while promoting the circularity of energy flows (Atchike et al., 2022). Used to treat organic waste of various origins, it offers a dual opportunity: the production of both biomethane and digestate (Kabeyi and Olanrewaju, 2022). On the one hand, it enables the production of renewable and local energy, reducing dependence on fossil fuels and promoting the energy autonomy of territories (Lyytimäki et al., 2021). Biomethane also makes a significant contribution to reducing greenhouse gas emissions, by capturing the methane that would otherwise have been released into the atmosphere (Paolini et al., 2018). In addition, the recovery of organic waste through biomethane supports the principles of the circular economy, transforming what was once considered waste into valuable resources: energy, in the form of biomethane, and digestate, used as an organic soil improver (Ellacuriaga et al., 2021).

In France, the sector originally focused on producing biogas, which was mainly used for electricity and heat generation (cogeneration). Biogas, produced through anaerobic digestion, typically contains 50 to 70% methane. However, there has been a significant policy shift in recent years towards biomethane, a purified form of biogas with methane content exceeding 90%. This change is a result of French energy policies that increasingly favor injecting biomethane into the gas network, considering it more efficient for energy recovery and greenhouse gas emissions reduction. Additionally, the introduction of guaranteed feed-in tariffs for biomethane injection has made it economically more appealing for producers. By the end of 2023, France will have over 1 700 production units, with 652 sites producing biomethane for grid injection compared to 514 in 2022 and 214 by the end of 2020. However, the increase

[1] Plan 2019-2028, adopted the 21th, April 2020 https://www.ecologie.gouv.fr/politiques-publiques/programmations-pluriannuelles-lenergie-ppe#la-ppe-2019-2028-1

in biomethane production raises specific concerns, particularly due to the tendency of projects to scale up, which can intensify environmental and social challenges at the local level.

Indeed, despite the undeniable advantages of biomethane in the context of the energy transition, its expansion is raising major questions about its social acceptability. At the heart of these concerns is the environmental impact, with real fears such as odour nuisance, increased road traffic, the problem of landscape integration, the risk of accidents, and the potential pollution associated with these facilities (Bourdin et al., 2020a). These concerns are exacerbated by an often-negative perception of the siting of such projects near where people live, a phenomenon commonly referred to by the acronym NIMBY ('Not In My BackYard') (Mazzanti et al., 2021; Mancini and Raggi, 2022). In addition, issues of social and distributive justice come into play, raising debates about the fairness of the economic benefits generated by biomethane projects (Faulques et al., 2022; Bourdin and Chassy, 2023). Finally, issues in territorial dialogue and local governance may also explain problems of social acceptability (Bourdin et al., 2020b; Niang et al., 2022a, Niang et al., 2022b).

Although the academic literature sheds light on the challenges associated with the social acceptability of these projects, the impact of the size and scale of the projects on local opposition has been largely overlooked. The hypothesis that the 'industrial' scale of projects may represent a significant obstacle to their acceptance highlights a field of research that remains insufficiently explored (Soland et al., 2013; Mazzanti et al., 2021). This situation reveals the need for a more in-depth understanding of how the size of biomethane plants and the calibration of projects influence their social and territorial integration. Indeed, the territorialisation of the energy transition – which aims to adapt renewable energy projects to local circumstances – gives rise to a paradox: the need for massive deployment of these technologies comes up against the reluctance of residents to see large-scale facilities in their immediate vicinity. This paradox requires particular attention if we are to achieve the ambitious biomethane production targets expected in Europe, set at 35 billion cubic metres by 2030. In 2024, France will have just over 1,700 biomethane units. By 2030, France is targeting to inject 10% renewable gas into the gas grid. To achieve these ambitious targets, it is therefore likely that the thinking behind new biomethane projects will shift towards a more industrial development approach, with projects destined to grow in scale. However, the urgency of the energy transition and the need to accelerate the deployment of larger biomethane installations are coming up against local opposition to large-scale projects. This tension between national objectives and local preferences highlights the importance of developing our understanding of

how the size of projects interacts with their acceptability, thereby making it possible to better reconcile the urgent need to expand biomethane to meet the challenges of the energy transition with local people's desire for initiatives on a more human scale that respect their local environment.

This article aims to fill this gap by addressing the following questions: How is project size perceived by stakeholders, and to what extent does the size of biomethane projects affect their social acceptability? To do so, we adopt a qualitative approach based on interviews and press articles.

From a theoretical point of view, this article broadens the frame of reference by exploring how the size of renewable energy installations influences their social acceptability. In the context of renewable energy, the perception of project size can vary widely depending on the territorial context and the associated emotional impacts. For instance, Soland et al. (2013) found that local acceptance of existing biogas plants in Switzerland was influenced by the perceived project size, but did not thoroughly investigate the nuances of this perception. Similarly, Rodríguez-Segura et al. (2023) examined the social acceptance of renewable energy developments in Spain and emphasized that larger projects often encounter more resistance due to their visual and environmental impacts. Our study aims to expand on these findings by offering a more detailed understanding of how project size influences social acceptability of renewable energies, in the specific context of biomethane in France. From this perspective, our approach helps enrich academic debate on energy transition issues by offering a new perspective on the challenges associated with local opposition. Empirically, the study provides concrete data and in-depth analyses of the interaction between the sizing of biomethane projects and their reception by residents. The results of this research can help to develop policy strategies that not only respect the environmental and energy ambitions of the European Union and France, but also consider the preferences and well-being of local populations. By providing a knowledge base on the interaction between the size of projects and their acceptability, this article aims to shed light on the path to successful social and territorial integration of biomethane initiatives by suggesting suitable mechanisms for consultation, compensation, and citizen involvement.

In the rest of the article, we first present a literature review and then the methodology. We then present and discuss our main findings. We conclude the article by suggesting several recommendations and avenues for future research.

2. Literature review

We begin by reviewing the concept of the social acceptability of energy projects and then discuss the specific externalities associated with biomethane that have been identified in the literature. Finally, we address the question of the size of biomethane projects and issues of social acceptability.

2.1. Social acceptability of energy projects: theoretical perspectives and conceptualisation

The social acceptability of energy projects, particularly those involving renewable technologies or innovations in resource management, cannot be summed up as static data or a simple indicator of support or opposition. It is the complex product of interactions between social norms, individual perceptions, and collective negotiation processes (Fournis and Fortin, 2017; Evensen et al., 2018). It refers to the approval, tolerance, and even support of stakeholders and the public for a given project (Upham and Shackley, 2007). According to the normative approach, social acceptability is defined as the state in which a project or technology is deemed acceptable by society (Simard, 2021). This perspective emphasises the importance of the norms, values, and ethical principles prevailing in a local community or in society. Normative acceptability is based on a project's compliance with societal expectations and its alignment with established environmental and social standards. Social acceptability can also refer to a cognitive approach. Thomas et al. (2019) approach social acceptability from the angle of perception and individual judgement. From this perspective, acceptability stems from a cognitive assessment of the project by individuals and groups, based on an understanding of the associated benefits, risks, and impacts. Cognitive acceptability is influenced by personal knowledge, beliefs, and attitudes towards the project (Arning et al., 2019; Huan et al., 2024). In environmental psychology, the term "cognitive" refers to studies that examine how individuals perceive, understand, and react to their surroundings. These cognitive processes involve the interpretation of environmental information, which directly influences individuals' attitudes and beliefs regarding a specific project or initiative. For example, an individual's prior knowledge about environmental impacts and their personal values can significantly influence their acceptance or rejection of a new environmental project (Maehr et al., 2015). Finally, social acceptability can be approached from a sociopolitical perspective, viewed as the outcome of a negotiation and decision-making process involving multiple stakeholders, including decision-makers, local communities, businesses, and non-governmental organizations (Wolsink, 2018;

Niang et al., 2022b). This perspective emphasizes the importance of engaging various actors in dialogue and collaboration to achieve consensus. The process often involves balancing conflicting interests and values, addressing concerns and objections, and ensuring that all voices are heard and considered. This perspective highlights the dynamic and interactive nature of social acceptability, where different visions, interests, and powers come into play and are negotiated (Bourdin et al., 2020a).

The notion of the social acceptability of an energy project is intrinsically marked by a diversity of perceptions that vary significantly according to the different stakeholders involved (Wüstenhagen et al., 2007). For residents, concerns often centre around the direct impacts of these projects on their immediate environment, such as possible environmental consequences, noise and odour nuisance, and the implications for the value of their property. These tangible impacts on their quality of life and heritage are at the heart of their apprehensions (Batellier, 2015). By contrast, public authorities look at energy projects from the point of view of collective benefits, assessing their contribution to local economic spin-offs, job creation, and improved regional or national energy security. Their perspective tends to value benefits on a wider scale (Wolsink, 2018). Project developers, on the other hand, focus mainly on the economic aspects, seeking to maximise the financial return on investment while minimising risks of opposition that could hinder project implementation (Niang et al., 2022a).

2.2. Factors determining social acceptability

The NIMBY phenomenon is often invoked to explain local communities' opposition to biomethane projects. It reflects the idea that residents are generally in favour of the implementation of environmental projects or necessary infrastructures provided these are not located in the immediate vicinity of the residents (Devine-Wright, 2014). However, this conceptualisation has several significant limitations. Applied to biomethane, Soland et al. (2013) explain that NIMBY does not capture the complexity of motivations behind opposition, which may include legitimate environmental concerns, public health concerns, or aesthetic issues. Furthermore, in their study of the diversity of perceptions of biomethane plants in Central and Eastern Europe, Kulla et al. (2022) explain that the NIMBY label can be used to discredit and oversimplify the claims of local communities, without seeking to understand or address their real concerns.

From this perspective, environmental distributive justice theory offers a more nuanced approach to examining the impacts of biomethane projects on local communities. Schumacher and Schultmann (2017) use the case of the Trinational Upper Rhine Region to explain that citizens may oppose biomethane projects because they feel there are inequalities in the distribution of negative environmental impacts and economic or social benefits. Consequently, several authors have highlighted that to address these issues of distributive justice, several key principles could be pursued (Dobers, 2019; Bourdin et al., 2020b). On the one hand, particular attention must be paid to fair distribution of the benefits generated by biomethane projects. On the other hand, it is crucial to ensure the active participation of local stakeholders in decision-making processes so that their voices are heard and considered (Niang et al., 2022b). Additionally, as emphasized by Prosperi et al. (2019), conducting a pre-assessment of social acceptance is essential, especially in small-scale agro-energy systems. The study conducted in southern Italy highlights the significance of "benefits" and "reassurances" in shaping stakeholders' perceptions. Thus, incorporating community engagement and democratic participation in energy policy processes can greatly contribute to enhancing the social acceptability of bioenergy projects.

Another important aspect addressed in the literature on the social acceptability of projects concerns the local context specific to the siting and the issue of territorial governance. Several studies have shown that in-depth knowledge of the socioeconomic dynamics and specific features of the area is essential, as these have a direct influence on how residents perceive the project (Dobers, 2019; Bourdin et al., 2020a). In some areas, particularly rural areas, attachment to place may be stronger, and the arrival of a biomethane plant may be perceived as an externality that changes the living environment of residents (Devine-Wright, 2009). This sentiment is echoed in the work of Labianca et al. (2024), who emphasize the significance of strategic planning and engagement with local stakeholders in selecting the locations for agro-biomethane plants to support the REPowerEU energy policy. Their study highlights that factors such as local resources, existing infrastructure, and territorial characteristics must be considered to ensure the successful implementation and social acceptance of these renewable energy projects.

Finally, the quality of territorial governance, characterised by the project developer's ability to engage in constructive dialogue with citizens and effectively integrate their contributions into decision-making and manage the project fairly, is crucial (Niang et al., 2022a). Governance that values the active participation of stakeholders and is committed to respecting and promoting

common interests can significantly improve the social acceptability of biomethane projects, thus facilitating better integration within the territories concerned (Bourdin et al., 2020a). Furthermore, building trust through open and regular communication ensures that residents' concerns and expectations are not only heard, but actively considered (Niang et al., 2022b).

2.3. Size of biomethane projects and issues of social acceptability

The literature examining the relationship between the social acceptability of renewable energy and project size is relatively limited and is heavily dependent of the local context and the prevailing perceptions of stakeholders (Batel, 2020). Devine-Wright (2020) suggests that the implementation of energy projects influences the emotional reactions of affected populations towards renewable energy initiatives. Therefore, it is possible that social acceptance may decline as the size of a technological installation increases. Larger biomethane projects are often associated with increased environmental and social impacts, such as higher levels of noise, more frequent traffic disruptions, and greater visual intrusion (Dobers, 2019). These factors can exacerbate opposition from local communities. On the other hand, it is assumed that smaller projects are generally perceived as less intrusive and more manageable, leading to higher levels of acceptance.

Most existing studies on biomethane have focused on identifying the primary factors that contribute to people's reluctance in installing new biomethane plants (Soland et al., 2013; Bourdin, 2020a; Bourdin et al., 2020b; Mancini and Raggi, 2022; Bourdin and Chassy, 2023). Among the potential negative externalities, both perceived and real, are issues such as odors, increased traffic, property devaluation, and the risk of explosions or leaks (Bourdin et al., 2020). However, there is a lack of studies directly addressing the issue of project design. Rodríguez-Segura et al. (2023) explain that the scale of renewable energy projects is a critical factor that directly impacts public acceptance. In the context of biomethane, only one quantitative study has specifically examined the impact of project size on social acceptability.

The study by Zemo et al. (2019) in Denmark analyses the influence of biomethane plants on rural property prices based on a detailed analysis of property data, employing a spatial generalised additive model. The research distinguishes between small-scale farm-scale biomethane plants and large-scale plants. The former have an average treatment capacity of 25,000 tonnes of manure and other substrates per year. They are typically owned by a single farm and process the biomass produced on that farm. Industrial-scale plants can have a

processing capacity of up to 500,000 tonnes of substrate per year. Unlike farm-scale facilities, they are owned by agricultural co-operatives, energy companies, or other private investors and process manure from 40 to 100 farms. The results show that large-scale biomethane plants have a marked negative impact on rural residential property values. According to the authors, this adverse reaction at the local level is mainly attributable to negative externalities, including unpleasant odours, visual pollution, and noise generated by the transport of manure by heavy lorries. In contrast, smaller facilities have a significant positive effect on property values. This positive perception is due to the lower prevalence of negative externalities compared with larger facilities. In addition, smaller facilities are often perceived as beneficial to the local community due to their contribution to the efficient management of agricultural waste and the production of local renewable energy.

Although this study contributes to understanding the effect of the size of biomethane projects on their social acceptability, it is specific to Denmark, where biomethane projects are very large compared with other countries. Consequently, the understanding of what is considered a "large" project differs. Furthermore, the study is quantitative and looks only at size in terms of input capacity. However, the emotional, ideological, and social dimensions associated with size can vary from one resident to another and from one area to another. These limitations underline the need for complementary approaches, particularly qualitative ones, to provide a richer, contextualised understanding of the dynamics of the social acceptability of biomethane projects.

Finally, some studies on the social acceptability of renewable energy projects have indicated that the concept of local ownership plays a crucial role in reducing negative perceptions associated with project size (Segreto et al., 2020). Local ownership refers to the involvement and participation of local communities in the development, operation, and benefits of renewable energy projects (Niang et al., 2020b). This participation can take various forms, such as local financial investment, community governance of the project, or direct use of the energy produced by residents and businesses (Batel, 2020; Bourdin et al., 2020a). Azarova et al. (2019) have demonstrated that when local communities have a sense of ownership over a project, they are more likely to support it, as they perceive direct benefits and a greater degree of control over its impacts. Consequently, the size of biomethane projects can significantly affect local ownership. According to Schumacher and Schultmann (2017), larger biomethane plants often struggle to gain social acceptance due to concerns about environmental inequality and a lack of local control. Projects seen as "industrial" rather than "community-scale" tend to face

more opposition as they raise fears of losing local autonomy and heritage (Kulla et al., 2022). On the other hand, smaller-scale projects, which are often viewed as extensions of existing agricultural activities, are more easily integrated into local settings and tend to be more widely accepted (Bourdin et al., 2020a).

Table 1 categorizes and describes the key factors that influence the social acceptance of renewable energy projects. The categories include social perception, environmental impact, economics and governance, and stakeholder engagement. Within each category, specific factors such as the NIMBY phenomenon, local context, perceived environmental impact, project size and scale, strategic planning, and public engagement are discussed.

Table 1. An overview of the main factors affecting the social acceptance of renewable energy projects

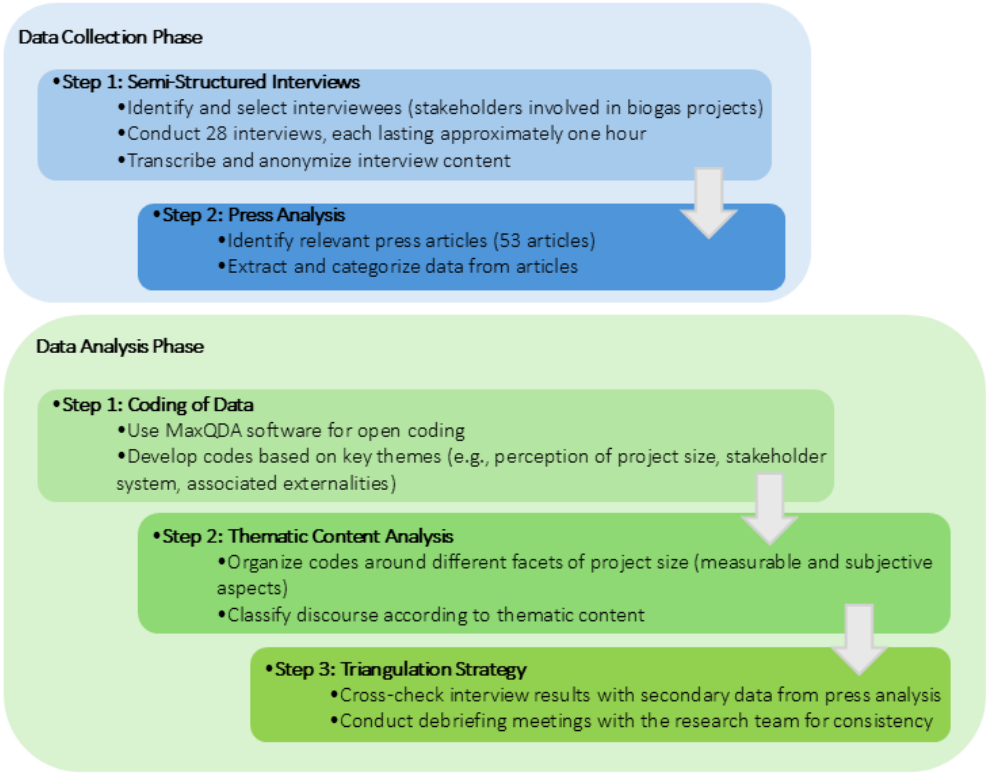
Category	Factors	Description	Key References	Insights
Social Perception	NIMBY Phenomenon	Opposition to projects based on proximity concerns rather than project merits.	Devine-Wright (2014)	NIMBY can oversimplify local concerns which may include valid environmental and health issues.
	Local Context and Place Attachment	The specific socio-economic and cultural context of the project site.	Devine-Wright (2009); Dobers (2019)	Projects must consider local dynamics and attachment to place to mitigate opposition.
	Historical Context and Path Dependency	The influence of past local projects and movements on current project perceptions.	Boschma & Martin (2007); Mazzanti et al. (2021)	Historical local opposition or support can shape current project acceptability.
Environmental Impact	Perceived Environmental Impact	Concerns about odours, noise, traffic, and landscape changes.	Bourdin et al. (2020a); Paolini et al. (2018)	Projects must address specific environmental concerns to gain local support.
	Project Size and Scale	The perceived and actual size of the project and its infrastructure.	Rodríguez-Segura et al. (2023); Zemo et al. (2019)	Large-scale projects may face more resistance due to visual, traffic, and environmental concerns.
	Strategic Planning and Location	Choosing locations based on strategic planning and stakeholder engagement.	Labianca et al. (2024); Bourdin et al. (2020b)	Strategic location selection and planning are vital for minimizing opposition and enhancing support.
Economic and Governance	Environmental Distributive Justice	Fair distribution of environmental benefits and burdens.	Schumacher & Schultmann (2017); Dobers (2019)	Addressing perceived inequalities in impact and benefits is crucial for social acceptability.
	Economic Benefits and Local Development	Contribution to local economy, job creation, and regional development.	Lyytimäki et al. (2021); Bourdin et al. (2020a)	Demonstrating clear economic benefits can enhance acceptability.
	Regulatory Compliance	Adherence to environmental and safety regulations and standards.	Bourdin et al. (2020b); Soland et al. (2013)	Compliance with regulations can improve perceived legitimacy and trust in the project.

	Local Ownership and Human Scale	Projects perceived as manageable and beneficial at a community level.	Bourdin & Chassy (2023); Labianca et al. (2024)	Emphasizing local ownership and small scale can improve social acceptability.
Stakeholder Engagement	Public Engagement and Trust	Building trust through consistent, transparent communication and involvement of local stakeholders.	Wolsink (2018); Niang et al. (2022b)	High levels of public engagement and trust-building are essential for project success.
	Pre-assessment of Social Acceptance	Assessing social acceptance prior to project implementation.	Prosperi et al. (2019); Soland et al. (2013)	Pre-assessment helps in tailoring projects to local needs and concerns.
	Territorial Governance	The quality and inclusiveness of decision-making processes.	Bourdin et al. (2020a); Niang et al. (2022a, 2022b)	Effective governance requires active local stakeholder participation and transparent processes.

3. Material and methods

The methodology consists of two main phases, each with several sub-steps, as shown in Figure 1. The first phase involves the methodical gathering of data through semi-structured interviews and press analysis. The second phase entails coding and content analysis of this data using MaxQDA software, which leads to the extraction of key themes and insights. The following sections provide a detailed description of each of these phases and their respective sub-steps.

Figure 1. Methodology flowchart



3.1 Data collection

To examine the impact of the perceived size of biomethane projects on their social acceptability, we adopted a qualitative approach. Two sources of data were collected over the course of 2023–2024 from a French case study: semi-structured interviews (28 in total) and articles from regional and national daily press (53 in total). The duration of interviews was approximately one hour, and their content was anonymised and faithfully transcribed. Interviewees were selected based on their involvement in biomethane projects and their ability to provide a range of perspectives on these projects. We used the snowball method, allowing interviewees to recommend other potential participants (Parker et al., 2019). (i) Energy operators who are either project leaders or are involved in multiple biomethane projects of different sizes in France. This type of stakeholder mostly supports medium to large-scale projects; (ii) We also interviewed a person responsible for financing biomethane projects in a major bank, as well as development directors or managers of companies involved in biomethane. Selecting this type of stakeholder is advantageous because they have a comprehensive view of the successes and failures of projects; (iii) We interviewed professionals from the biomethane sector in France who provided an overview of the industry ; (iv) Farmers leading projects of varying sizes were also included in the interviews; (v) Additionally, we interviewed local councillors who have a biomethane plant in their area, as well as two heads of environmental associations.

For each group targeted by our study, interview guides were developed, focusing on several key themes. These themes aimed to explore the notions of social acceptability and perception of the size of biomethane projects, with foci on the following aspects: (i) a full understanding of what the issue of project size represented; (ii) the stakeholder system in place; (iii) the associated externalities; as well as (iv) the relationship of interdependence between local elected representatives and their territories.

Secondly, an exploration of secondary qualitative data was undertaken (Ruggiano and Perry, 2019), in line with growing practice in the study of social acceptability (Segreto et al., 2020). This approach aimed to compensate for the difficulties encountered in engaging with critics of biomethane projects. To this end, we used press articles as secondary sources. Our analysis focused on the daily written press, a choice dictated by the advantage of not requiring transcriptions, unlike audiovisual media. The local daily press proved to be particularly relevant for grasping the media treatment of a subject (Benoit et al., 2022). Media discourse, particularly in the press, is characterised by its polyphony, reflecting a diversity of voices and points of view

that journalists collect and transmit (Meredith et al., 2014). It can be categorised into three genres: the reported, the commented on, and the provoked event, requiring careful analysis of the nuances between directly quoted words and journalistic commentary. However, this approach can oversimplify the discourse, a pitfall inherent in the written press that we considered in coding and analysing the press articles. Using the EuroPress database, we identified 53 articles mentioning the terms “biomethane” or “biogas” and “social acceptability” or “size”, or “dimensioning”, or “XXL” in their title or in the body of the text, covering a period between 2023 and 2024. We have decided to concentrate solely on this period to align with the timeframe of the interviews. This is done to guarantee that the facts described in the press articles correspond with the interviewees’ statements at the time of their responses.

3.2. Data analysis

We employed a qualitative approach, which enables us to thoroughly investigate complex phenomena and grasp the intricacies of human experiences and perceptions (Seamon & Gill, 2016). This method proves particularly valuable in comprehending the contextual and subjective aspects of social acceptability in biomethane projects. Moreover, qualitative research is inherently flexible and adaptable, granting researchers the ability to refine their approach as new insights arise (Lichtman, 2013).

To process the data collected, we adopted an iterative approach, oscillating between the data collected, existing theoretical references, and an empirical classification constructed through repeated and in-depth analysis of the data (Elliott, 2018). We focused on two dimensions of analysis. In terms of perception, we explored how the dimensions of the projects were perceived by the various players involved. In terms of effect, we studied the influence of project size on project acceptability. We used MaxQDA[2] software to code the data (see Annex 2 for the Coding Table).

Various steps were taken. We started by importing all interview transcripts and press articles into the software. Next, we conducted a thematic content analysis (Belotto, 2018) of our data. This analysis included an initial round of open coding to identify preliminary themes, and a second round based on the concepts and factors identified in the literature review. Additionally, we engaged in axial coding to refine these themes and explore relationships

[2] MaxQDA is a cutting-edge software package for qualitative and mixed-methods data analysis. It is used to code, organize, and interpret data from various sources, including interviews, focus groups, and texts, which helps with in-depth and systematic analysis. The functionality of MaxQDA allowed us to utilize the software’s memo feature to annotate significant text segments, enabling a better understanding of the different perspectives of stakeholders. https://www.maxqda.com/

between them. Our objective was to analyse the variation in the perception of size and its impact on social acceptability among different stakeholder groups. The final stage consisted of selective coding to develop a coherent narrative around the key findings.

To ensure the reliability of our coding, debriefing meetings with the research team were held regularly to review and discuss the coded data, ensuring its accuracy and consistency. In addition, following Oleinik's (2011) recommendations, we employed a triangulation strategy, cross-checking the results from our interviews with those from the secondary data. Triangulation improves the rigor and credibility of the research by incorporating various data sources and methods (Bans-Akutey & Tiimub, 2021). Through the combination of interviews, thematic content analysis, and secondary data, such as press articles in our case, we were able to gain a comprehensive understanding of the relationship between size and social acceptability. This approach has the advantage of confirming the results, enhancing the data's validity, and providing a more comprehensive picture of the studied issues (Flick, 2004).

4. Results

In this section, we analyse how the perceived size of biomethane projects affects their social acceptability. The first subsection examines how specific criteria related to the project's size influence its acceptability. The second subsection focuses on the emotional and relational impact of the project's size. In the final subsection, we highlight how the territorial context can influence the perception of project size and its associated acceptability.

4.1. Tangible elements for defining the scale of a project and their influence on social acceptability

Defining the size and scope of biomethane projects can be based on tangible criteria, such as the potential for injection into the gas network, compliance with ICPE (Installation Classée pour la Protection de l'Environnement) standards, and the tonnage of inputs processed. These elements are regularly put forward by economic and institutional players as reliable indicators because they are governed by a precise regulatory and standards framework. According to an energy operator, these regulatory thresholds are essential for "defining what is small, medium and large, and that's precisely what the regulations are there for" (interview, energy operator 6). In France, the ICPE regime is decisive, and many project developers choose not to exceed certain size thresholds, to avoid additional constraints on project design and obligations in

terms of public consultation. One project owner commented: “When you make a declaration, they don’t have much to say” (interview, farmer 3). Smaller projects, which comply with the first-order regulatory thresholds, are therefore perceived more favourably: “Generally speaking, a small, declared project is relatively easily perceived by 80% of people as a farm extension.” (interview, energy operator 5). Project owners may also refer to the injection potential of the biomethane produced when talking about the size of projects: “The first symbol of a large project is the injection rate. It’s the first reference that speaks to us between a small, medium, or large project”, reported an energy operator (interview, energy operator 4). The same person told us that he was behind a project of “reasonable size” in his words: “We have a small unit in operation today that we commissioned in 2020. We injected 115 standard cubic metres into the network”.

Moreover, the perception changes significantly when the project exceeds a certain number of farms. As one industry professional put it: “For me, a big project is one that involves more than 10 farms” (interview, energy operator 5). This increase in the number of farms contributes to a perception of the project as a large-scale undertaking, often associated with industrial rather than agricultural concerns. If the projects are perceived as an extension of existing agricultural activity and not as industrial additions, then this can have a positive effect on social acceptability. One energy company representative explained: “Projects on a human scale are those that are the same size as the farm and that ultimately fit in with the existing buildings, following on from the farm buildings” (interview, energy operator 4).

Another tangible factor is the size of the infrastructure and its potential impact on the landscape. Large-scale projects tend to require the construction of new infrastructure and more available land. For example, in the case of collective biomethane projects, enlarging the input supply area often means constructing input storage buildings to optimise the cooperative dynamics between the players. These additional infrastructures, which are necessary depending on the logistics and road network, can change the perception of the size of the project. A few project promoters talked about the size of their project in terms of floor area or building volume. However, even if these physical measurements provide objective data on the scale of the project, they can fuel opposition to the projects, added to the potential environmental risks. For example, in a press article, a project being contested by opponents is first presented in terms of the exorbitant size of the project, before the argument of the potential pollution risks for the local environment is put forward. (Jacquerie Média, 2023). When these figures seem too large, they can often provoke local resistance, as one energy

company owner pointed out: “The size of the project was the subject of much debate and, in my opinion, contributed to the project not going ahead. People saw that there were going to be big buildings that could harm the landscape” (interview, energy operator 1).

Another tangible aspect raised concerns the size of the project in terms of the waste collection radius and the volume of lorries needed to transport these inputs. This logistical consideration is essential in assessing the local impact and perceived size of projects. As explained by a bank account manager specialising in the financing of biomethane projects, it is vital that waste collection remain within a limited perimeter in order to minimise the environmental footprint and strengthen local acceptability: “Waste doesn’t have to come from 150 kilometres around to be treated in a biomethane plant for the project to be truly local, it has to be within a 30-kilometre radius” (interview, banker). In addition, the same interviewee pointed out that “everything we see, the projects where there are problems or appeals, one of the main criteria is traffic”. These observations were corroborated by an energy company representative, who added that the size of the project had a direct influence on public perception, particularly in terms of the volume of lorries transporting the biomass to be methanised: “So the size also involves a transcription or projection of what the traffic is and will be” (interview, energy operator 6).

The organisational scale of biomethane projects, marked by the number and diversity of players involved, also contributes significantly to perception of their size. An analysis of press articles reveals that this argument is often used by residents to justify their opposition. One energy company representative noted that when the project is not supported exclusively by farmers, the perception changes drastically: “As soon as the project is not supported exclusively by farmers, in people’s minds it’s a big project, an industrial thing with lots of people involved” (interview, energy operator 1). And sometimes, when the project is led by farmers, the perception of the scale of the project is exacerbated by the number of farms involved according to a mayor: “The number of farms involved in the project is obviously not the same, a project with 10 or so farmers is not at all the same as a project with 30, 35, or 60 farmers” (interview, elected official 7).

Moreover, with numerous and various stakeholders involved, as is inherent in these large-scale projects, a multiplicity of views on the project is generated and therefore a potential divergence of views. This is likely to increase the risk of social protest, particularly when the project seems to be dominated by interests that are not those of local farmers. A professional from an environmental association expressed this concern: “We are against big cooperatives that are

no longer in the hands of farmers but in the hands of shareholders" (interview, Head of an environmental association 1).

Along the same lines as the size of the projects in terms of governance, we note that large-scale biomethane projects pose specific challenges, such as the existence of a distance between the project leader and the residents, because "project X [a project led by a group of 28 farmers] has the disadvantage of being led in terms of image, by one or two people who are not necessarily available or present all the time" (interview, energy operator 1).

According to this biogas industry professional, this distance in day-to-day management means that large-scale projects need to equip themselves with the right skills to make up for this shortcoming: "The bigger the project, the more it needs to be supported, so this distance needs to be compensated for by skills that are there to ensure dialogue and the reliability of communication tools".

Our initial results show that tangible criteria such as the volume of inputs processed, energy production in kWh, land area, building size, number of farms involved, input collection radius, and the number and diversity of stakeholders involved in project governance are essential in defining the scale of projects and will influence social acceptability. However, they do not always capture local perceptions, where visual and organisational impacts can provoke negative reactions from residents. This discrepancy between regulatory aspects and social perceptions highlights the importance of incorporating more subjective considerations when assessing the acceptability of biomethane projects.

4.2. Subjective dimensions of perceptions of project size and their implications for social acceptability

The perception of the size of biomethane projects varies between individuals and territories for several reasons. It is not just a question of physical size or technical capacity but is also influenced by subjective and relational factors. One energy company project leader emphasises the emotional impact of the size of projects on residents: "I've seen people who were afraid of certain projects, which were really big" (interview, energy operator 5). This testimony reveals how the perceived size of a project can generate anxiety or resistance among residents, regardless of the project's technical characteristics.

Although the various tangible parameters invoked provide an objective basis for assessing projects, their ability to encapsulate local perceptions of the size of initiatives may be limited.

Indeed, “tangible”/quantitative references can be misunderstood or misinterpreted by residents, who have their own social, psychological, and ideological perceptions of what constitutes a large-scale project. One industry professional underlined this dissonance: “When we see project promoters saying, ‘here we come, the project isn’t big, it’s 30 tonnes, etc.’, it’s not really the same thing. But for the average local resident, tonnage is irrelevant. On the other hand, the size, the perception of what it may or may not represent in terms of its industrial nature, does. So, the question of perception is important” (interview, Biogas industry professional 2). This divergence between objective measurements and subjective perceptions is crucial to capture, particularly in contexts where there is opposition. As one energy producer interviewed noted: “Apart from certain associations that know a little about biomethane, I don’t think that local residents have any idea of the size of a project, or that it remains rather vague for them” (interview, energy operator 4). Another energy company representative went even further, saying: “When you tell them that the biomethane plant will process 10 000 or 100 000 tonnes a year, it’s abstract for them. On the other hand, when we tell them that there are going to be 10 lorry passages a day, that already speaks to them a bit more” (interview, energy operator 3). This lack of a clear understanding of tangible figures can lead to erroneous or exaggerated interpretations of the potential impact of a project, fuelling the concerns that residents may have.

On the other hand, the notion of “human scale” often emerges in discussions. This is a scale of a project that is perceived as acceptable and integrated into the local fabric. One project owner expressed this idea when he said: “So you’re doing well in terms of registration. You still have a profitable project; you know what I mean? And it’s still on a human scale” (interview, energy operator 2). This quote illustrates the balance sought by the promoters between economic profitability and social acceptance, where the size of the project must be sufficiently moderate to maintain its accessible and non-threatening nature for residents.

In addition, our interviews reveal that the direct personal benefits that residents derive from biomethane installations significantly influence their perception of the size of a project. A functional relationship between residents and the project can transform the perception of the size of the infrastructure, thereby modulating the likelihood of social protest, even for large-scale projects. From this point of view, local economic spin-offs play a crucial role in this perception. As one press article points out, “consumption of green gas is set to grow, with the Deux-Sèvres aiming to reach over 30% by the end of 2026” (La Nouvelle République, 2024). This significant contribution to local energy self-sufficiency is seen as a direct advantage for the

elected representatives and residents interviewed in the article. Similarly, one project owner notes the positive impact of their initiative: “20% of local gas consumption comes from our methaniser. It’s a first step towards energy independence” (interview, farmer 2). The economic aspect is also highlighted by a local councillor, who emphasises the economic advantages of biomethane: “Today, we are 3 times cheaper than the world price. The decorrelation of biomethane prices is an essential issue that will also make it easier for projects to be socially acceptable. It’s about redistributive ecology, which is why we’re working on self-consumption and the idea of developing an energy community of citizens” (interview, elected official 4). Three arguments are put forward. Firstly, a cost difference can make biomethane particularly attractive to residents looking for more affordable and sustainable energy solutions. Secondly, by decoupling biomethane costs from the fluctuations of traditional energy markets, projects can offer financial stability to local users. Thirdly, the idea of equitable sharing of ecological and economic benefits is also raised, where residents are not just passive beneficiaries but active players in the management and use of the energy produced. In this way, initiatives aimed at highlighting the positive externalities for citizens are essential for acceptability. As one project promoter put it: “And then, to mark out our local roots, we opened a €150 000 equity fund” (interview, farmer 4). This investment allows residents to participate financially in the project, reinforcing their commitment and sense of ownership, which can reduce the perception of size as a potential obstacle.

A local councillor from a municipality in which a large-scale project has been set up explained how the project has been viewed from a broader perspective: “We thought of the project as a whole in terms of its political dimension, in terms of the general interest and the territory, and we told ourselves that we could generate a dynamic that goes beyond the biomethane plant itself” (interview, elected official 5). This integrated approach ties in with the above-mentioned argument, which aims to maximise the benefits for the local population and reinforce positive perceptions of the project. However, as one energy company representative noted, it is vital to communicate these benefits clearly: “It’s important to explain once again that the project will enable the circular economy, create jobs, generate economic spin-offs, ensure the long-term future of the farm, etc. It’s good to be reminded of this because it’s the only way to ensure that the local population will benefit. It’s good to remind people of this because they don’t necessarily have it in their heads. It’s necessary, but not necessarily sufficient. Unfortunately, people don’t necessarily have a strong sense of the general interest” (interview, energy operator 3). Another project developer explained that to increase acceptance of biomethane

projects, it is essential for residents to feel that they are participating in the redistribution of the wealth generated: “People in the area have to feel that they are part of the redistribution of wealth” (interview, energy operator 3).

Another aspect influencing perceptions of the size of biomethane plants is trust in the biomethane project managers. Our analysis of the daily press shows that biomethane plants managed by local project developers tend to enjoy greater acceptance by local communities. This acceptance is often linked to a greater sense of ownership and trust, which can be lacking in projects run by external entities such as large energy companies. For example, when a project is extended to other territories with the involvement of external players, this can often amplify the impression that the project is large in scale. The extension can give rise to concerns about the increased scale of the project and its potential impacts. As one local resident said in a press article (Ouest France, 2024), “We don’t know them, so it doesn’t inspire confidence”. This perception of external appropriation can fuel local resistance, particularly if the benefits of the project do not seem to accrue to the local community but to entities considered “distant” or “impersonal”, especially in the case of projects led by large foreign energy companies.

This situation refers to the role of the project developer’s “indigenous capital” in social acceptability; however, very large-scale projects are rarely carried out by project developers with a high level of indigenous capital. This refers to the advantages and recognition conferred by belonging to well-established networks of relations in each locality. It is a form of social capital rooted in the area, which has intimate knowledge of the local environment, proximity to the community, and a shared history. When a project owner has a strong sense of local identity, he or she is seen as an integral part of the community. This can facilitate communication and trust between residents and the project leader, reducing perceptions of external exploitation of local resources for the benefit of outside interests. Indeed, the fact that the promoter is known locally and has a local network, familiarity with local specificities, and the ability to integrate its local knowledge into the planning and execution of the project can strengthen social acceptance.

Trust between project developers and the local community is crucial, as one project developer put it. This mutual trust ensures that local concerns are considered and that the benefits of the project are fully understood and valued by residents. A biomethane industry professional pointed out that: “The size and nature of projects are not the only criteria influencing their acceptance by the local population. The approach and attitude of project developers when interacting with residents are crucial” (interview, Biogas industry professional 1). This quote

highlights the importance of human interaction and the way in which projects are presented and managed at the local level. Transparent management can significantly improve the perception and acceptability of major projects. Furthermore, as a press article (France 3, 2023) reveals: “The conclusions of the survey highlighted significant opposition from local players, resulting in particular from insufficient consultation on the project”. This information shows that a lack of communication and proper consultation can lead to local resistance, even when large-scale projects are technically well-designed and potentially beneficial for the region. The mayor of a municipality in which a large-scale biomethane plant is located testifies to the importance of involving residents at an early stage: “Local residents were involved very early on” (interview, elected official 3). This early involvement fosters a sense of belonging and contribution and strengthens support for the project.

Table 2 presents the breakdown of findings based on the main types of stakeholders involved in biomethane projects. Our results indicate that perceptions of project size and consequent social acceptability vary significantly among different stakeholder groups. Local elected representatives evaluate quantitative benefits, such as energy autonomy and alignment with regional strategies, alongside qualitative interests, like preserving local agricultural activities. They typically support moderate-sized projects to prevent nuisances and prioritize territorial integration and social acceptance. Energy operators prioritize more tangible measures, such as financial benefits and risk management, favouring large projects for their economic viability. However, these larger-scale projects often encounter difficulties in gaining acceptance. Conversely, residents focus on experiential and emotional impacts, expressing concerns about environmental effects like noise, odors, and road traffic, often leading to strong opposition against perceived negative impacts. Farmers and agricultural cooperatives relate project size to their farming activities, seeking projects that complement their endeavours and provide direct benefits such as self-sufficiency and financial savings. They also consider the need to align with their dual role as farmers and energy producers. Environmental associations concentrate on health and environmental effects, preferring small or medium-sized projects to minimize negative externalities and actively voicing their concerns to promote sustainable agricultural models.

Table 2. Perception of the size of biomethane projects: criteria, approaches and potential impact on acceptability according to stakeholders.

Actors	Criteria guiding the size perception	Approach to size	Potential impact of their approach on acceptability
Local Elected Officials	Mixed: Combine quantitative advantages (contribution to energy autonomy of territories, support for renewable energies, alignment with regional strategy, etc.) with qualitative interests (preservation of local agricultural activities through diversification, valorization of bio-waste, etc.) of the community.	Favor projects that benefit local development and are accepted by residents, prefer moderately sized projects (in general) to avoid nuisances.	• Sensitive to the acceptability by third parties and the impact on local quality of life. • Emphasis on territorial integration and social acceptance. • Favor projects that are accepted by residents, prefer moderately sized projects (in general) to avoid nuisances. • Can position themselves for or against a project based on the project itself or in response to overall rejection from residents (the "no wave" effect).
Energy Operators	Quantitative: Focus on financial metrics and the optimization of technical risk management measures.	Aim for larger projects, concerned with economic viability and large-scale benefits.	• Larger projects may pose acceptability challenges. • Seek to present projects as beneficial and mitigate opposition. • Struggle with how large-scale models fit into the territory.
Residents	Qualitative: Focus on experiential and emotional impacts.	Concerned about direct environmental impacts: living environment, noise, odors, property values, road traffic.	• Strong opposition if perceived impacts are significantly negative, frequent NIMBY phenomenon.
Farmers and Agricultural Cooperatives	Quantitative: Link project size to agricultural operations (proximity to farms, input tonnage, fertilizer tonnage, spreading surfaces, etc.) and direct benefits.	Interested in projects that complement their agricultural activities and offer direct benefits (some autonomy, financial savings).	• Project size adapted to their operations to maximize complementarity with their activities and seek for their projects to be "accepted" by residents. • Issue of explaining the alignment of complementarities between professional identities as farmer and energy producer. • Issue of proximity (local identity vs. large-scale project).
Environmental Associations	Qualitative: Emphasize impacts on health, environment (air quality, digestate quality, etc.).	Prefer small to medium-sized projects to ensure low environmental impact.	• Very sensitive to environmental and social impacts, prefer the least "harmful" projects. • Can voice their opinions publicly by explaining their vision in terms of agricultural model.

4.3. When does size not matter: fertile ground for social acceptability?

Analysis of our data also shows that size is not everything and that there are large-scale projects that are socially accepted. The role of location in the perception of the size of biomethane projects is therefore important.

A biomethane project considered "XXL" or large-scale in each area would not automatically be described in the same way if it were located elsewhere. The perception of size is deeply rooted in the local context, as illustrated by one energy company representative: "We're on the same size site as the one that was planned at Corcoué-sur-Logne and yet it's going to go ahead, so

the question we should perhaps be asking ourselves is why is it being done there and not elsewhere? Why is it being done there and not at Courcoué?" (interview, energy operator 5). This comment highlights the need to understand the specific local dynamics that help or hinder project acceptance.

Among these contextual/territorial factors is the idea that, in some regions, there may be a culture of local protest that can affect perceptions of the scale of projects. In Loire-Atlantique, for example, a culture of struggle, reinforced by movements such as the Notre-Dame-des-Landes airport protest, has influenced the reception of biomethane development projects. A member of an environmental association explained: "More recently, we've had a major militant struggle at Notre-Dame-des-Landes, which in Loire-Atlantique, in particular, brought with it a culture of struggle, a culture of opposition, which has had a big impact" (interview, Head of an environmental association 1). These antecedents militate in favour of the idea that local precedents in terms of mobilisation can play a significant role in the way new projects are received, particularly if they are large enough to affect the immediate environment of residents.

Another element concerns the geographical characteristics of a region. One energy specialist explained that preferences and perceptions vary greatly from one region to another: "It really depends on the region. I know that in the department of La Manche, they're not really in favour of big projects. My colleague told me that in Seine Maritime, they prefer to have a project that centralises everything, and therefore centralises the nuisances to some extent. After all, Seine Maritime is also an area with a history of industry, with the Seine Valley" (interview, energy operator 3). This diversity in local preferences highlights the extent to which territorial context, such as the pre-existence of an industry, can influence social perceptions and lead to movements of opposition or support. The difference in the way large-scale projects are received in the Manche and Seine-Maritime departments can largely be explained by their distinct geographical and historical contexts. The department of La Manche, with its predominantly rural environment and low level of industrialisation, tends to be more reticent about major projects that could disrupt this environment. Residents of these rural areas, who are often more sensitive to visual and environmental impacts, may perceive major projects as a threat to their tranquil landscape and way of life. In contrast, Seine-Maritime, with its industrial Seine Valley, has a long tradition of industrial activity. This history has cultivated a certain habituation to large-scale infrastructure and the associated nuisances, such as heavy traffic and industrial emissions. Residents and local decision-makers in industrialised regions

may therefore be more inclined to accept new, large-scale projects because they are perceived as a continuation of existing industrial activity rather than as a disruptive intrusion.

Finally, the acceptability of a project is not just a question of its size or its objective environmental impact but also depends on the relationships and commitment of local players, particularly elected representatives. “I think that the influence of elected representatives and the road traffic generated by the project are perhaps more decisive factors than the size of the project itself.” (interview, energy operator 4). A project leader added: “I don’t think we can do anything without the mayor, we can’t do anything if the mayor isn’t convinced” (interview, farmer 4). The influence of the local authorities is reinforced by pre-existing commitments to other forms of sustainable development, as another project owner shared: “The mayor told me straight away, I’m interested, we’ve already invested in photovoltaics, in wind power and we also want to invest in biomethane” (interview, farmer 2). Local political support is therefore a decisive factor, particularly when the projects are large in scale and involve numerous players.

5. Discussion: from social acceptability to local ownership

Our results broaden understanding of the dynamics of social acceptability in relation to the sizing of renewable energy projects: size matters, but not necessarily. Cognitive evaluation of the risks and benefits associated with a renewable energy project (Thomas et al., 2019; Prosperi et al., 2019) will play an important role in the perception of size.

In our analysis of the impact of the perceived size of biomethane projects on their social acceptability, we distinguished between objective/tangible perceptions and subjective/intangible perceptions. The former are quantifiable and include factors such as the technical capacity and physical size of the facilities. The latter, on the other hand, encompass less measurable but equally influential factors such as emotional impact and historical and territorial context. From a tangible point of view, the size of a biomethane project is often assessed in terms of energy production (expressed in kWh or cubic metres of biomethane), the surface area occupied, or the number of inputs processed annually. These measures are essential because they determine not only the scale of the infrastructure required but also the extent of the direct environmental impact. However, our results show that subjective perception of the size of a project cannot be reduced to these measurable elements. It is strongly influenced by the emotional impact that the project may have on residents. For example, a technically small project may be perceived as intrusive and disproportionate if

located too close to a residential area, provoking negative reactions because of the radical change in the daily environment of the inhabitants. In addition, the historical and territorial context plays a significant role. In regions with a history of resistance to large-scale projects, even a modest project may be perceived as a precursor to larger, more invasive changes, exacerbating local fears and resistance.

Following the example of Wüstenhagen et al. (2007), who showed that there were differences in perceptions of social acceptability depending on the stakeholder, we show that the perception of the size of a project also varies depending on the stakeholder. This divergence between these two types of perception can lead to significant misunderstandings between project developers and local communities. On the one hand, developers, armed with objective data, may feel that their projects are perfectly acceptable and comply with standards. On the other hand, communities, guided by their experiences and emotions, may interpret the same size of project as a threat to their quality of life or to the integrity of their local environment.

In assessing the social acceptability of biomethane projects, it is also essential to understand the local dynamics that influence the perceptions of the local population. Our results indicate that, although large-scale biomethane plants can often generate opposition, there are cases where they have been well received. These successful cases highlight the importance of both a project's territorial integration and effective communication with the local population. This confirms the findings of several authors (Prosperi et al., 2019; Bourdin et al., 2020a, Niang et al., 2022b) on the role of a project's local roots and communication with residents very early on in the project.

Our results confirm previous studies indicating that the perception of environmental impact plays a crucial role in the acceptability of biomethane projects. As suggested by Batellier (2015), projects that are perceived as having an impact on their environment tend to generate greater resistance. This idea is reinforced by our observation that large installations require careful management of visual impact and respectful integration into the local landscape to be accepted. In the opposite case, attachment to place will be an argument put forward by local opponents (Devine-Wright, 2009).

Our study shows that successful integration of a large-scale biomethane project depends on the project's ability to align itself with the values and needs of the local population. For example, in areas where the energy transition is perceived as a priority, large-scale projects have been favourably received when they have clearly aligned their development with the area's sustainability objectives. This is in line with the idea developed by Lyytimäki et al. (2021).

In the Alsace region, for example, a major biomethane project was accepted because of its direct association with support for local agriculture, local energy self-sufficiency and the reduction of carbon emissions, thus aligning the project's objectives with local ecological priorities.

Another aspect of our results is that show that if a project is large in scale, it is more likely to generate negative externalities (visual impact, more traffic). At the same time, they also show that it is this type of large-scale project that is most likely to generate, according to the project promoters, positive externalities in terms of job creation, energy autonomy, contribution to the local ecological transition, or even dividends for local shareholders where local energy communities are created. In this context, we also show that the perception of size depends on the distribution of externalities. This ties in with the idea developed by Schumacher and Schultmann (2017) on the need to put environmental justice at the heart of thinking in project design.

Finally, a final contribution of our analysis is to demonstrate that the level of local ownership plays a crucial role in mitigating the negative effects associated with a biomethane plant, whether perceived or real. This ownership, defined by an active commitment reflecting a sense of belonging to the areas hosting biomethane projects, leads to a transformation in the perception of the project. It adds an inclusive dimension by encouraging the integration of local concerns, which contributes to a shared vision among stakeholders. Our results show that local ownership can overcome reluctance linked to the size of the project. Indeed, there are large-scale projects that are socially acceptable to citizens, thanks to a relational proximity between stakeholders, the territorial roots of local economic players, and the principle of distributive justice (Evensen et al., 2018; Kulla et al., 2022). These elements encourage ownership of the project and recognition of its added value for the area, particularly by anticipating the benefits brought about by biomethane (Faulques et al., 2022). In addition, local ownership makes it possible to project stakeholders into the energy transition, thereby strengthening their support for the project (Kabeyi & Olanrewaju, 2022). Regarding local ownership, it is crucial to note that various stakeholders have differing views on the matter. Farmers and local elected officials generally see local ownership as essential for the projects' success and acceptance. They emphasize the direct benefits and alignment with local interests. On the other hand, energy operators prioritize larger projects for their economic returns. However, they often encounter obstacles in gaining social acceptance due to the perceived lack of local control. Residents and environmental associations prioritize projects that provide tangible local benefits and have

minimal environmental impact. Consequently, they emphasize the necessity of robust local ownership and engagement to improve acceptability.

Table 3 provides context for our findings. The difference in perception among stakeholders (as shown in table 2) emphasizes the importance of targeted communication strategies to bridge the gap between concerns of residents regarding direct negative impacts and the emphasis placed by public authorities on local benefits. Additionally, it is crucial to understand the historical dynamics of the local area, including territorial contexts and previous instances of mobilization, to tailor projects to local experiences and gauge the level of support for this type of initiative. Moreover, addressing perceived negative consequences, such as increased traffic, through specific action plans and technical solutions is vital to minimize social resistance. Lastly, clarifying the roles and responsibilities of the various parties involved in large-scale projects can simplify governance and improve communication coherence.

Table 3. Key Challenges in the Social Acceptability of Biomethane Projects: Divergent Perceptions, Local Dynamics, Externalities, and Governance

Key points	Description	Insights	Recommendations
Divergence of perception	The perceptions of methanation projects vary considerably among different actors, influencing social acceptability.	Local residents may fear direct negative impacts, while public authorities focus on local benefits.	• Implement targeted communication initiatives to address the specific concerns of different actors, ensuring to communicate differently about the scale of the project depending on the target audience.
Past local dynamics... the existence of fertile grounds for large-scale projects	Territorial contexts and specific past local dynamics (path dependency) play a determining role in the acceptability of projects.	Mobilization precedents, the existing density of renewable energies already in the territory, and geographical characteristics influence local perceptions.	• Adapt projects to past local dynamics and experiences and test the "territorial appetite".
Externalities	Perceived negative externalities, in the context of "large" projects, affect social acceptability.	Concerns about increased traffic are frequent obstacles.	• Evaluate and minimize negative externalities through specific action plans and appropriate technical solutions. • Explain the implications of increased road traffic.
Defining roles	Large-scale projects are characterized by increased participation of diverse actors, which can complicate governance by making it more opaque and blurring communications.	The diversity of governance can lead to perceived incoherent communication, causing confusion about the project's objectives, advantages, and beneficiaries.	• Clarify the roles and responsibilities of each involved actor. • Implement transparent governance with clearly defined leaders to improve coordination.

6. Conclusion and policy implications

Our article analysed how the size of renewable energy projects was perceived and how this perception influenced the social acceptability of projects. We drew on a qualitative study of biomethane in France. Our results provide a broader understanding of the dynamics of social acceptability in relation to the size of renewable energy projects. Our main conclusion is that size does matter, but not necessarily. It is not necessarily an obstacle to the implementation of larger projects, but it can still be at the heart of social concerns that can generate issues relating to acceptability.

We contribute to the literature by emphasizing the importance of both tangible and subjective factors in shaping the perception of project size. Tangible factors include measurable aspects such as energy production capacity and physical footprint, which can significantly impact public perception. However, subjective factors, including emotional responses and historical context, also play a crucial role. This dual focus enriches the theoretical framework of social acceptability by integrating cognitive and sociopolitical perspectives (Evensen et al., 2018; Wolsink, 2018). Our empirical data further emphasize the significance of local context and territorial governance. Regions with a history of industrial activity may be more inclined to accept large-scale projects, while rural areas with strong place attachment may resist even modest-sized initiatives (Devine-Wright, 2009; Dobers, 2019). This aligns with the findings of Lyytimäki et al. (2021) regarding the importance of aligning projects with local values and needs. Additionally, our study underscores the role of local ownership in alleviating negative perceptions. Projects perceived as community-led, with clear economic benefits for residents, tend to garner higher acceptance (Azarova et al., 2019; Bourdin et al., 2020). This highlights the necessity of incorporating mechanisms for local stakeholder involvement and benefit-sharing in policy frameworks to enhance the social acceptability of biomethane projects.

The urgent need to develop large-scale biomethane infrastructure to meet ambitious environmental and energy targets despite local preferences for smaller, more integrated projects highlights a fundamental tension in energy transition planning. On the one hand, national and international directives encourage large-scale projects to maximise biomethane production and thus reduce greenhouse gas emissions. On the other, these large-scale projects can come up against significant resistance from local communities, which prefer small-scale facilities that are perceived to be better suited to their living environment and surroundings.

This divergence highlights the importance of strategies that not only respect large-scale ecological and economic imperatives but also consider the values, needs, and expectations of local populations, as well as the benefits they may derive from these facilities. Such an approach requires in-depth consultation, mechanisms for redistributing added value locally, and genuine co-construction of projects with the populations that could be directly affected, to harmonise the global objectives of sustainable development with local well-being (Atchike et al., 2022).

In addition, to increase the acceptability and integration of biomethane projects, it is essential to improve the degree of local ownership. This can be achieved by promoting management that is firmly rooted in the local community. This means involving local leaders and key stakeholders from the earliest planning stages and throughout project implementation. By involving local authorities, residents' associations, and interest groups in day-to-day management, biomethane projects can reinforce a sense of collective ownership and community involvement. This can be achieved by setting up monitoring committees, such as "territorial assemblies" made up of residents and others, which would actively participate in monitoring environmental and social impacts throughout the project (from conception to actual operation).

Our results show that it is also important to develop models that ensure that the economic benefits of biomethane plants return to local communities. From this point of view, enhancing the degree of local ownership can also include offering ownership shares in the project, where residents could invest and thus benefit directly from the profits generated. Another approach would be to link the project's revenues to community development funds that would finance local initiatives, such as improving public infrastructure or educational programmes on the ecological transition. These economic models should be transparent and adapted to the specific characteristics and needs of each community to maximise their positive impact.

The policy implications of our study complement and build upon existing national and international policies that aim to promote the energy transition and enhance social acceptance of renewable energy projects. At the national level, our findings align with the French Pluriannual Energy Programme (PPE), which emphasizes the importance of increasing renewable energy capacity while ensuring the engagement and benefits for local communities, to achieve a balanced and inclusive energy transition. Similarly, our policy implications align with the European Union's Green Deal, which aims to achieve carbon neutrality by 2050. The Green Deal highlights the importance of integrating renewable energy projects into local communities through participatory processes and fair distribution of benefits. Our findings

underscore the significance of such participatory processes and propose practical mechanisms, such as local ownership models and stakeholder engagement, that can be implemented to improve the social acceptability of large-scale biomethane projects. Additionally, our study reflects the principles outlined in the United Nations Sustainable Development Goals (SDGs), particularly Goal 7 (affordable and clean energy) and Goal 13 (climate action). The objective is to develop policies that encourage the involvement of local stakeholders and promote equitable distribution of economic benefits.

Although the interviews and press analysis provided valuable insights, they represent qualitative perspectives. This leaves open quantitative questions that could be explored to better understand the correlation between the size of projects and their acceptability, for example by mobilising surveys. In addition, a more longitudinal perspective on the perception of size could identify any changes in the perception of size. This could be done in the context of in-depth case studies in which we would gather information at different points in the project on how the perception of size is perceived by the various stakeholders.

Finally, our results highlight the existence of potential 'fertile ground' for the perception of size by stakeholders. There are territorial contexts that are conducive to the integration of energy transition projects, whatever the size of the project. It would therefore be relevant to explore the notion of 'fertile ground' in future research by exploring the extent to which territorial variables influence the perception of size and, more generally, the social acceptability of renewable energy projects. To explore this idea further, future research could, for example, use the theory of regional path dependency to shed light on this issue (Boschma & Martin, 2007).

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