

# Public perception and participation towards biogas plants in wastewater treatment facilities: Study cases in southern Spain

Percepción y participación pública en las plantas de biogás de las instalaciones de tratamiento de aguas residuales: Casos de estudio del sur de España

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## Abstract

Biogas stands as one of the most adaptable renewable energy resources, distinguished by its storage capabilities. Its distinctive attributes position it as an exemplary energy source, leveraging waste to generate power. However, beneath this supposedly smart practice of producing electricity, is there real justice for the local community in the biogas planned and sitted? This research delves into the themes of citizen engagement and local perceptions concerning biogas plants development. With this aim a survey was held among residents near two biogas facilities located within wastewater treatment plants in Andalusia. The findings reveal a significant gap in knowledge on biogas development, and a disconnection between the biogas plants and the local community. These insights lead to the conclusion that it is necessary to align the renewable energy facilities' planning with the needs and expectations of the local community, thereby fostering a more inclusive and informed approach to its deployment.

Keywords: planning process; survey; renewable energies; energy transition.

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## Resumen

El biogás se presenta como uno de los recursos de energía renovable más adaptables, distinguido por capacidad de almacenamiento. Sus atributos distintivos lo posicionan como una fuente de energía ejemplar, aprovechando residuos para generar energía. ¿Sin embargo, bajo las apariencias de práctica inteligente, existe una justicia real para la comunidad local en la planificación y emplazamiento de las plantas de biogás? Esta investigación profundiza en los temas de participación ciudadana y percepciones locales respecto al desarrollo de plantas de biogás. Mediante una encuesta realizada entre los residentes cercanos a dos plantas de biogás ubicadas dentro de plantas de tratamiento de aguas residuales en Andalucía. Los resultados revelan una brecha significativa en el conocimiento sobre el desarrollo de biogás y una desconexión entre las plantas de biogás y la comunidad local. Estas percepciones conducen a la conclusión de que es imperativo alinear el desarrollo de instalaciones de energía renovable con las necesidades y expectativas de la comunidad local, fomentando así un enfoque más inclusivo e informado en su implementación.

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Palabras clave: planificación; encuesta; energías renovables; transición energética.

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## 1. Introduction

In order to respond to the challenge of climate change, there is an urgent need to reduce greenhouse gas emissions (Waite, 2017). United Nations Sustainable Development Goal 7 (SDG7) recommends a substantial increase in the proportion of renewable energies (RE), to be able to guarantee access to affordable, reliable and sustainable energy. European Union (EU) climate policies have also set targets for the proportion of energy that should be produced from renewable sources, and member states are required to meet them (Carvalho, 2012; Lucas et al., 2016). Of the various greenhouse gases (GHG), methane is responsible for 25% of global warming. The main sources of anthropic gas emissions are mining, agriculture and waste dumps (landfills). During the 26th United Nations Climate Change Conference held in Glasgow in 2021 (COP26), it was agreed to reduce methane emissions by 30% by the year 2030 in comparison with 2020 levels. Some 103 countries signed this agreement with the exception of some very high emitters such as China, Russia and India. This agreement established the main lines for the policy encouraging the use of biogas as a means of mitigating greenhouse gas emissions (Flotats et al., 2009).

In order to comply with emission reduction targets and with the international commitments assumed under the Paris Agreement, the Spanish government has drafted and approved the Integrated National Plan for Energy and Climate 2021-2030 (PNIEC) setting out the targets for renewable energy development up to 2030. Within Spanish energy planning, biogas is regarded as an important complement to decarbonizing industrial and transport processes in substitution of natural gas, although it treats biogas as a secondary energy source in comparison with other renewable energies. In Royal Decree-Law 6/2022, of the 29th March 2022 passed in a bid to alleviate the high electricity prices caused by the war in Ukraine, the environmental and democratic controls on the construction of renewable installations were weakened, a measure that affected both power plants and auxiliary renewable infrastructures. Within this law, biogas was classified as a renewable gas, and one of its main objectives was to facilitate the transport of renewable gases from their production centres to the places where they are consumed. It also sought to enable the development of isolated networks connecting consumers with producers. Under the new law, gas transport networks were classified as “infrastructures of public utility”, a new status that enables the expropriation of the land required for their construction.

Despite the advantages, bioenergy, in general, also has a number of inherent drawbacks (low-energy density, scattered distribution, direct and indirect land-use change, etc.) (García-Frapolli *et al.*, 2010). Bioenergies induce both direct and indirect land-use changes when farmers decide to change the way they farm their land, switching from food crops to the more intensive forms of agriculture required for biofuel production (Palmer, 2014). In this way, bioenergy transforms pre-existing agricultural landscapes and their related social practices (Gunderson *et al.*, 2016, Frolova *et al.*, 2019b). Energy crops tend to raise public concerns particularly in rural areas where people are worried that they will take the place of traditional food crops (Chodkowska-Miszczuk *et al.*, 2019; Zemo *et al.*, 2019; Martínát *et al.*, 2013). In the specific case of biogas produced from waste, the landscape and land-use impacts are much smaller, because it does not require energy crops planting and the biogas refineries are located in existing agricultural or industrial installations (farms, wastewater treatment plants, solid waste treatment plants or other industrial complexes). This means that the plant itself has a much smaller impact (Ferrario *et al.* 2017). As industries and local councils have a mandatory obligation to treat their waste streams, the digestion, generation, and utilization of biogas obtained from such streams can reduce both the amount of waste and its environmental impact, while producing clean energy (Capodaglio *et al.*, 2016). It can also reduce atmospheric GHG emissions.

Substantial government grants have been made available for the promotion and development of biogas plants in Spain, although according to the industry body (the Spanish Biogas Association, AEBIG), the premiums for biogas energy production have been around 35% lower than the average for other European countries and fewer facilities of this kind have been developed in Spain than in the rest of Europe (Hernández *et al.*, 2016). In 2001, the European Union approved Directive 2018/2001 on the promotion of the use of energy from renewable sources, which in relation to biogas obliged member states to establish a certification system for the gases from renewable sources. In Spain, this legislation is still at the information-gathering stage (April 2023) and its objectives are relatively unambitious in that they do not set a target date for a system to come into force guaranteeing the renewable origin of the gas. Instead, the proposed legislation only mentions some of the milestones that must be reached in relation to the compliance of sustainability criteria and for the reduction of greenhouse gas emissions applicable to bioliquids, biogas and biomass solid fuels.

Spain's National Energy and Climate Plan (PNIEC) classifies biogas within the management of organic waste. This means that biogas also meets the criterion of providing environmental benefits in terms of its use/recycling of waste products. Several studies show that biogas projects involving the construction of new facilities are not always well received by certain residents, although this situation varies within Europe, and even within each country (Capodaglio *et al.*, 2016; Chodkowska-Miszczuk *et al.*, 2021; Martínát *et al.*, 2022). There is an increasing number of studies that analyze the reasons for opposition to these projects (Chodkowska-Miszczuk *et al.*, 2019; Upreti & van den Horst, 2004), in particular once they are up and running (Stober *et al.*, 2021; Kulla *et al.*, 2022). In order to increase public acceptance of biogas facilities, the most critical issues at stake should be investigated, identified, and addressed at a local level (Capodaglio *et al.*, 2016). This can best be achieved by canvassing people's opinions in surveys and by involving a wide range of different stakeholders in the development of biogas projects (Magnani, 2012).

This study seeks to analyse the perception and participation of the local community during the planning phase of biogas plants considered as models of sustainability. The article is divided into five parts. Firstly, a conceptual background on consideration of justice in public participation in

the planning of renewable energy is established. Secondly, the research methodology, study area and case studies are presented. Thirdly, the results are explained, in particular the characteristics of resident's perception of biogas plants and public participation in the process of its planning. Finally, our results are compared them with previous research findings and recommendations for improvement of participation processes for biogas plants are presented.

## 2. Conceptual background

Significant research has been conducted into the public acceptance of renewable energy projects, focusing in particular on the concept of "NIMBY" (Not In My Back Yard). NIMBY opposition to RE developments due to their spatial proximity to peoples' homes or towns is widely viewed either as a rational choice or as an example of individual selfishness, ignorance and irrationality. The latter is often attributed to a lack of public understanding of the relevant science, which results in people only supporting such projects if they are built "somewhere else" (Owens & Drifill, 2008, Batel & Devine-Wright, 2015). However, empirical evidence suggests that NIMBY assumptions are often inaccurate (Van der Host, 2007). For that reason, this paper approach is nearer to the focus on Locally Unwanted Land Uses (LULUs), because wastewater treatment plants can be seen by residents as an unwanted facility (Frantál *et al.*, 2023). One of the alternative theoretical concepts that seems to explain and understand the discrepancy between generally positive attitudes towards renewable energy projects and the opposition to certain siting decisions is justice theory, and within that distributive and procedural justice theory. According to this theory, both the perceived costs and benefits of the facilities, and the relevant characteristics of the planning process must be taken into consideration.

When dealing with local acceptance of renewable energy projects, distributive justice centres on the costs and benefits as local residents perceive them. The benefits include not only monetary benefits, but also for example job creation, tourism, community improvement, and reduced energy costs. It also assesses the costs. In addition to purely economic costs, such as reduced property prices and a decrease in the number of tourists, there are other non-monetary costs such as unpleasant smells, adverse landscape impact, or changes/constraints on the quality of life (including increased local traffic) (Capodaglio *et al.*, 2016). The idea is that all the consequences of the energy system (costs and benefits) must in some way be fairly distributed throughout the whole of society. This includes ensuring that the poorest groups in society have access not only to the energy system, but also to the energy policy decision-making process (Jenkins *et al.*, 2016; Sovacool *et al.*, 2017). Energy justice is distinguished by three main principles: distribution, process and transition (Bielig *et al.*, 2022). The basis of this research is the procedural energy justice that springs from the principle of equality and representativeness within decision-making processes, so as to enable non-discriminatory, inclusive access to participation (Bielig *et al.*, 2022). Procedural justice theory focuses on how these structural aspects of procedure can influence the perception of justice and the behaviour of the authorities towards citizens (Bielig *et al.*, 2022; Capodaglio *et al.*, 2016). Broadly speaking, procedural justice covers transparency and fairness in decision-making processes within the context of participative approaches, while distributive justice deals with fairness in the distribution of costs and benefits between the different actors, such as for example in the siting of infrastructures (Bielig *et al.*, 2022; Goedkoop & Devine-Wright 2016; McCauley *et al.*, 2013). It is hoped that procedural energy justice will strengthen participation and democracy and develop the resilience of local people in the fight against climate change (Van Bommel & Hoffken, 2021).

From this perspective, the way in which the public participation process is carried out is of key importance for the acceptance of biogas plants. In the case of renewable energy, citizen participation consists of involving the general public and local stakeholders in taking decisions that affect them, their community or territory (Reed et al., 2017). Research has shown that public preferences regarding the siting of biogas plants have changed from negative to positive as a result of the holding of public participation processes that residents of the affected areas consider to be fair (Kulla et al., 2022). According to Raven et al. (2009), the sustainable application and the acceptability of renewable energy projects may only be achieved when all the interested parties participate in all the different phases of the project (design, construction, operation and decommissioning). According to different research studies, the key factors affecting attitudes towards biogas plants are the general perception, and in particular the negative views about biogas plants expressed by people in rural areas (Chodkowska-Miszczuk et al., 2019) regarding the real or perceived reduction in the quality of the environment around biogas plants (including the release of bad smells and an increase in traffic) and the damage they may cause in terms of the attractiveness of the area for tourism (Chodkowska-Miszczuk et al., 2020).

There are also various farming-related issues, such as the ethically controversial processing in biogas plants of energy crops cultivated on good-quality arable land, changes in the regional agricultural systems and displacement of food production when biogas plants come into service (Martinát et al., 2017). Another key factor is the impact on the communities situated near the plants and their limited knowledge of the envisaged impacts (Acikgoz, 2011). This hypothesis that proximity to the plant is an important factor in public perceptions has also been tested, with the variable being the distance between the respondent's place of residence and the AD plant. Lastly, it should highlight the factors related with a lack of transparency and clarity when it comes to sharing information about biogas plant projects and the lack of local participation in the planning phase (Martinát et al., 2022; Chodkowska-Miszczuk et al., 2019; Dobers, 2019; Soland et al., 2013).

### 3. Methodology

#### 3.1. Cases studies

For this research, two model cases for the development of a biogas plant in Spain were selected. Biogas plants are normally associated with another business activity which supplies them with the raw material. Two model cases are selected with similar characteristics. The selection criteria were: i) the biogas plant is situated in a larger complex of "biofactories"; ii) there are no conflicts associated with these biofactories; and iii) they were developed as a result of the implementation of a sustainable wastewater treatment plan. The raw material is waste from urban wastewater treatment plants. The biogas plants are part of the process of enhancing the value of this waste. Both plants have won awards for their sustainability strategies and form part of larger complexes known as "biofactories", where the wastewater treatment work is complemented with research and dissemination activities. That research mostly focused on increasing the efficiency of biogas production, while the dissemination activities (e.g. school visits) centred on the water cycle. Biogas in both cases has been promoted as an important means of saving energy at the plant. These plants are the result of private initiative.

They were constructed and operated together with others of a similar kind in Spain by a private company called Hidralia, which is part of the Suez International Group, one of whose specialist business areas is water cycle management. Both plants are managed by public/private companies in which the private manager is Hidralia and its public partners are the various local councils. The companies are known by their initials, i.e. EMASESA in Seville and EMASAGRA in Granada. The biogas plants form part of the sustainability strategies of the two companies in that they were built to enable each complex to become self-sufficient in energy. In the Seville case study, construction of the plant was financed with public funds.

Figure 1: Cases studies location map.



Source: The authors

The power plant in Granada has an installed power of 0.6 MW with an annual production of 4 GWh. It has been in operation since 2015. It is part of a wastewater treatment plant that serves a population of around 425,000 people. It is situated in an agricultural area of great landscape, historic and cultural value known as the Vega of Granada. The land in this area is highly productive due to the fertility of its soil and its ancient irrigation system, which originated in the 11th century (Castillo *et al.*, 2014). According to technical staff from the plant interviewed in 2020, 13,982 tons of sludge, 336 tons of sand and 23 tons of fat were “recycled” by the plant. The biogas plant has four outputs: sands, solid agricultural fertilizer, heat and electricity. The electricity and heat are used to supply the plant’s energy needs, covering 116 % of energy demand with peaks of 140 %. The surplus energy has enabled them to extend the sustainability plan towards the objective of powering a fleet of electric vehicles. The local population near the plant live in medium-sized municipalities (Churriana de la Vega, Cúllar-Vega, Vegas del Genil, Las Gabias and Armilla) with compact town centres (10,000-15,000 inhabitants each), which serve as dormitory towns for workers from the large central city (Granada). Most of the people who live in this area are middle-class. The biogas plant in Seville has an installed power of 2.52 MW and has been in operation since 2003. It supplies 95 % of the plant’s energy requirements. It is located within a wastewater treatment plant that serves a population of 950,000 people. It is situated to the south of the city of Seville near a district known as Fuente del Rey, which belongs to the municipality of Dos Hermanas. This area has a mix of industrial uses, large infrastructures and a military base (El Copero). One of the most interesting characteristics of this biogas plant is the variety of raw

materials that it accepts: apart from the sludge produced by the treatment process, it also handles garden waste and other organic residues. These include, for example, 35 tons of oranges from the 48,000 decorative orange trees in the city, which were previously thrown away (EMASESA, 2021). Most of the people that live in the vicinity of the plant are blue collar workers in nearby districts of the cities of Seville and Dos Hermanas.

### 3.2. Survey: elaboration and application

The questionnaire contained 12 questions which could be subdivided into three blocks (Public perception, attitudes, and participation in the planning process). The interviewees were also asked a series of questions about their gender, age, level of education and current employment status so as to enable us to construct a sociodemographic profile of each person. They were also asked to provide their current address, so permitting us to calculate the distance between their home and the plant. In order to complement the information collected in the review and fill in certain gaps in the questionnaire, we contacted the companies that developed and operate the plants and arranged interviews with the managers.

In the first block of survey, the interviewees were asked about their general attitude to biogas plant and this type of energy. In the second block of survey, we asked for their opinions about the advantages and disadvantages of the biogas plant for the community. For each statement, they were proposed to choose one of five answers on a Likert scale (strongly disagree, disagree, neither agree nor disagree, agree or strongly agree). The advantages of biogas plant can be grouped together in eight categories: (i) it produces clean, renewable energy; (ii) it contributes to environmental protection and helps combat climate change; (iii) it uses materials which otherwise would not be used in any way; (iv) it creates jobs and additional income; (v) it brings economic benefits for the town; (vi) it is a tourist attraction; (vii) it is an attraction that could be used to promote the municipality; and (viii) general development. In a similar way, seven main disadvantages or negative impacts of the biogas plant were identified: i) it would not function without economic incentives; ii) it affects the local environment; (iii) it worsens the quality of life in the municipality (smell, dirt, etc.); iv) it does not bring any economic benefit for the local community; v) it discourages tourists from visiting our town; vi) it causes conflict and divisions within the local community; (vii) the value of real estate in the town has fallen. In the third block, the interviewees were asked on the process of social participation in the planning process.

The study area comprised the territory in a 0-5 km radius around a biogas plant situated within a wastewater treatment complex. This radius was considered suitable for the study area because it includes the main population centres around the AD plants. One of the biogas plants is situated near Seville (population 700,000) and the other is near Granada (population 114,000). The survey was conducted using a standardized questionnaire amongst the inhabitants of the towns and villages situated nearest to the biogas plants. Only adults over 18 years old were allowed to take part. The estimated time for completing the questionnaire was 20 minutes. The interviewees received information about the objectives of this paper. Questionnaires were sent to neighbourhood associations via the social network Facebook. The most active groups focused on sharing neighbourhood-news and representative of local society were selected, thus avoiding sectoral or political groups. The data were collected in an Excel file which was securely stored. The anonymity of the individual answers was guaranteed. The survey was conducted from November 2020 to February 2021. The sampling error of the survey is 9.46% (below the recommended maximum of 10% ) (Gareiou *et al.*, 2021) with a confidence interval of 95%.

### 3.3. Data analysis

For data analysis we first found correlations between different answer options, these correlations were analysed using the bivariate correlation tool in the IBM SPSS Statistics software program. It is important to emphasize that assessing possible dependencies between the variables using the Pearson proof correlation coefficient does not indicate the degree of dependence or independence. Furthermore, in conjunction with the Chi-square significance test and Cramer's test were applied to test the effect size of the relationships between the two variables. The correlations involving individual variables and subgroups within the population, such as gender, socioeconomic status, proximity to the plant and age, among other factors were of particular interest. The final stage of the research was to try to find correlations between the answers to the questionnaire and the socioeconomic data provided by the interviewees in order to find out whether there were certain groups in the community that were particularly opposed to/in favour of the biogas plant and compare these findings with the results of similar studies.

## 4. Results

### 4.1. Sample characteristics

The survey was aimed at local people who live in the vicinity of one of the two biogas plants (Seville or Granada). The nearest urban area to either plant was Fuente del Rey situated at less than 700 m away from the Seville AD plant and the most distant was Granada city, which is 4 km away from the Granada AD plant. 185 responses were received to the questionnaire. Of these, 160 had been living in the area for more than 10 years. 95 responses were received for the Granada case study and 90 for the Seville study. None of those interviewed worked at the biogas plant. The interviewees had an average age of 39 in Granada and 40 in Seville. The average age in Spain as a whole in 2021 was 43.8 years old (National Statistics Institute - INE, 2022).

Figure 2. Characteristics of the interviewed population

Data	Granada	Seville	Total	%
Nº	95	90	185	100
Female	36	56	92	49.7
Male	58	34	92	49.7
Other	3	0	3	1.6
<b>Employment status</b>				
Self-employed	15	7	22	11.89
Employee	66	49	115	62.1
Retired	4	9	13	7.02
Student	7	14	21	11.4
Unemployed	0	9	9	4.8
<b>Distance from plant (km)</b>				
Near: Less than 2	14	41	55	29.7
Medium: 2 to 3	77	56	133	71.9
Far: 3 to 5	1	0	1	0.5
<b>Age (years)</b>				
Young 18-25	13	15	28	15.13
Adult 26-65	80	75	155	83.7
Mature Over 65	2	0	2	1.08



Data	Granada	Seville	Total	%
<b>Level of education</b>				
Primary	0	11	11	5.9
Secondary	28	32	60	32.4
Further	66	34	111	60
<b>Resident in the area (years)</b>				
Less than 5	15	0	15	8.1
From 5 to 10	10	0	10	5.4
Over 10	70	90	160	86.5

Source: The authors

A maximum distance of 5 km was established between the residence of the interviewed person and the biogas plant. Within that, 29.7 % of the interviewed population lived at least three kilometres from the plant (Figure 2). It is also important to note that the plants are located in areas where residential building is not permitted, either because it is protected agricultural land (Granada case study) or because it is a military-industrial area (Seville case study). The socioeconomic data show that 62 % of those interviewed were employed people, followed by self-employed (11.9 %) and students (11.4 %). The group of interviewees had a high percentage of university graduates, particularly in Granada where 60 % met this criterion while in Seville was 40 %.

#### 4.2. Public attitude to the biogas plants

In general, the participants showed a positive attitude to these biogas plants with high acceptability ratings. The Granada biogas plant received a higher rating than the one in Seville. To assess the acceptability of the biogas plant, the interviewees were asked if, hypothetically, they could turn back the clock to a time before the construction of the plant, whether they would give the plant the go-ahead or reject it. The interviewees' answers showed that they would once again allow the plant to be constructed. A positive correlation was observed between the people who live furthest away from the plant and the highest levels of acceptance, with a value of 0.268<sup>1</sup>. At the other extreme, there was also a correlation between rejection of the construction and people who live near the plant (0.456<sup>1</sup>), people with primary education (0.2601<sup>1</sup>) and unemployed people (0.260<sup>\*\*</sup>). The people with further education had a neutral attitude, in other words, they were neither for nor against these plants. Some interviewees preferred not to offer any opinion on this question, namely students (0.246<sup>1</sup>) and young people (0.232<sup>1</sup>).

Lastly, they were asked about their preferences regarding future developments of biogas plants for which they were given three possible answers. 65.76% said that they would accept the construction of other biogas plants. There is a correlation between this answer and the proximity of the interviewee's residence to the plant (0.216<sup>1</sup>). A further 28.26% had no problem with other biogas plants being built, but not in their community. A slight correlation was observed between this answer and the proximity of the interviewee's residence to the plant (0.216<sup>1</sup>). Only 6.52% of the participants answered that no more biogas plants should be built anywhere. There is a slight correlation of 0.2122<sup>1</sup> between this option and unemployed people. As regards acceptability, the results highlight that distance, and in particular proximity to the biogas plant, is an important factor, as manifested by the fact that the most unfavourable opinions about the plant and the

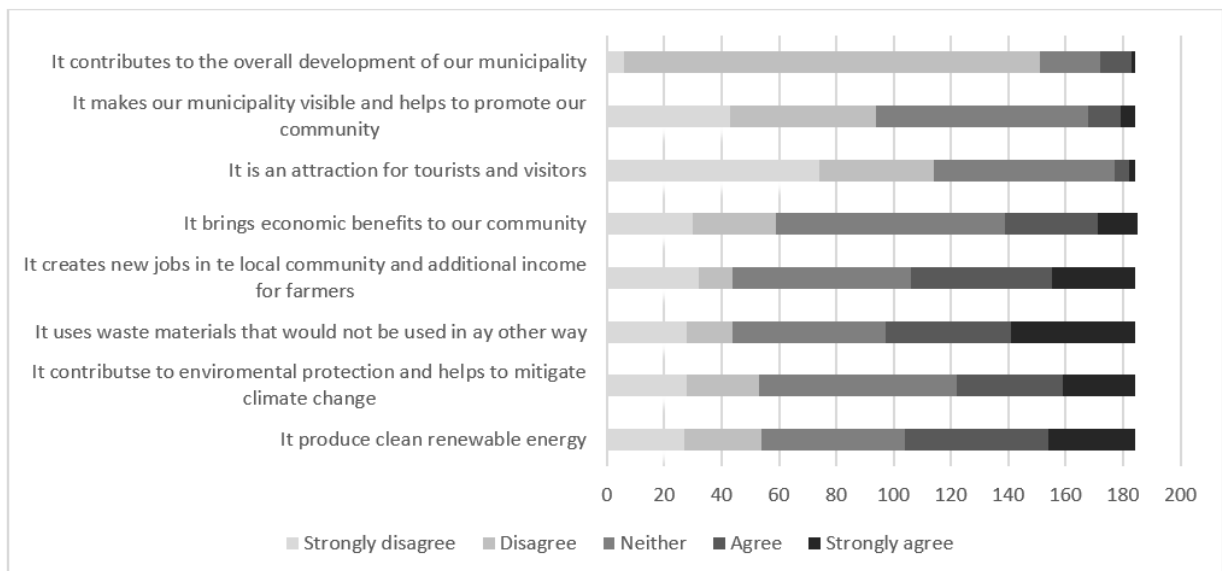
1. A significant correlation at 0.001

construction or development of new plants came from the people that live less than 2 km away from the plant.

### 4.3. Public perception

In the answers to the second block of questions, various interesting trends can be observed in the biogas advantages' perception (Figure 3). When asked if biogas plant "uses materials which would otherwise not be used in any way", 47.02% of the interviewees said they agreed, and there was a correlation between the answer "neither", retired people (0.246\*\*) and those living furthest away (0.215\*\*). There was also a high level of agreement with the statement that "It produces clean, renewable energy", for which a correlation was observed between residents who lived less than 2 Km away from the biogas plant (0,249\*\*) and the answer "agree". When asked about whether "It protects the environment and helps mitigate climate change", 37.29 % replied "neither agree nor disagree", and there was a correlation between unemployed people (0.404\*\*) and "strongly disagree".

Figure 3: Opinions about possible positive impacts of the biogas plant



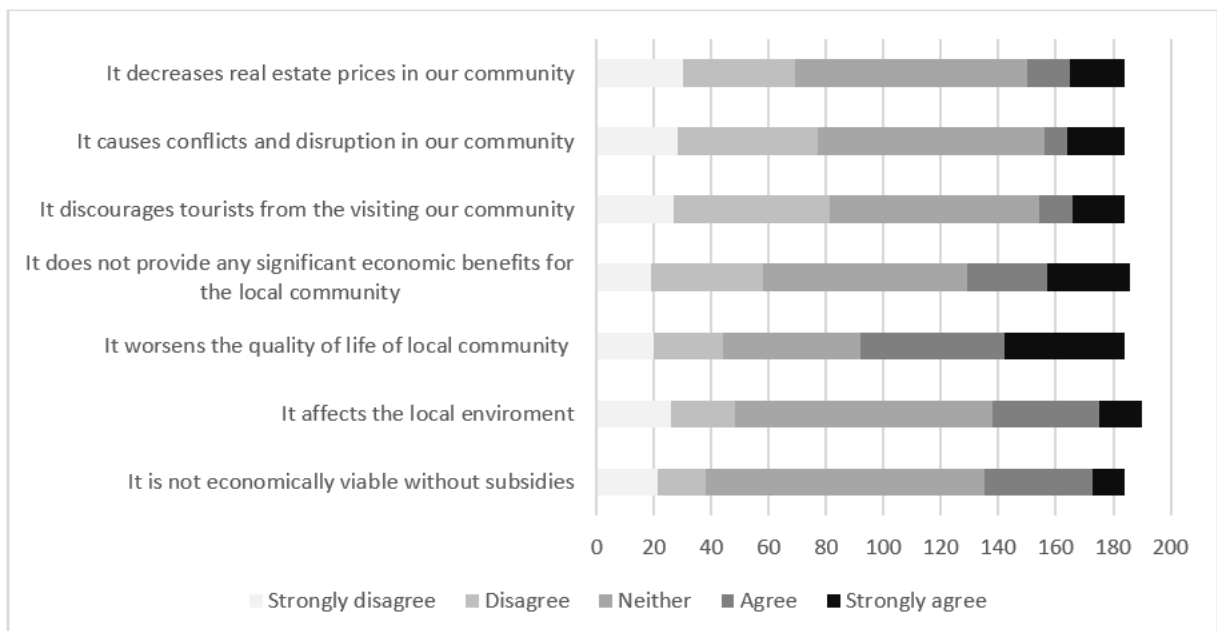
Source: The authors

For the next statement, "It brings economic benefits to community", 43.24% of the interviewees answered "neither". Correlations were observed between "strongly disagree" and older people (0.258\*\*) and residents with primary education (0.261\*\*). The answer "disagree" was associated with those living near the plant (0.266\*\*). For its part, the assertion that the plant makes a "contribution to the general development of our municipality" was rejected by the vast majority of interviewees (78.38%). Correlations were found between "strongly disagree" and people who had been living in the area for less than 5 years (0.251\*\*) and between "disagree" and the people living a medium distance (2-3 km) away from the plant (0.238\*\*). 50.8% disagreed with "It makes our municipality visible and helps to promote our community" and correlations were observed between the "disagree" answer and people living near the plant (0.266\*\*) and people with secondary education (0.356\*\*). For its part, 61.62% of the interviewees disagreed with "It is an attraction for tourists and visitors", for which correlations were observed between the "disagree" answer and

people who had been living in the municipality for the longest period (0.250\*\*), adults (0.302\*\*), and self-employed people (0.212\*\*). Conversely, the “agree” response was correlated with residents living close to the plant (0.224\*\*). “It creates new jobs in the local community and additional income for farmers” garnered support from 42.15% of the respondents. Correlations were observed with the unemployed (0.212\*\*) and with those who had been living in the municipality for a short time (0.223\*\*). For its part, the “neither” response was correlated with the group with secondary education (0.259\*\*) and with retirees (0.207\*\*).

Respondents were asked about their opinions of seven possible negative impacts of the AD plant (Figure 4). They were clearly unsure or indifferent about if “it is not economically viable without subsidies” as 52.43% chose the “neither” option, for which there was a slight correlation with women (0.250\*\*). A correlation was also observed between agreement with this statement and the group with further education (0.249\*\*), employed people (0.229\*\*) and those living nearby (0.261\*\*). The negative impact about which most people agreed was “It worsens the quality of life of the local community (smell, dirt, increased traffic)” with 49.72%. Two groups showed correlations with the “agree” answer, those with further education (0.296\*\*) and those living furthest away (0.225\*\*). In the “strongly agree” answer, correlations were observed with secondary education (0.285\*\*) and residents living nearby (0.497\*\*). This is followed by ‘indifference,’ accounting for 25.95% of the interviewees, with correlations with young people (0.328\*\*), students (0.215\*\*), and the people living further away (0.324\*\*). 23.78% of the interviewees disagreed with this statement.

Figure 4: Opinions about possible negative impacts of the biogas plants.



Source: The authors.

As for the statement that “It affects the local environment”, the most common answer was “neither” at 48.65%, with correlations with women (0.348\*\*), primary education (0.258\*\*), retirees (0.197\*\*), people living 2-3 km away (0.289\*\*), and those living in the municipality for more than 5 years (0.281\*\*). “Neither” was also the most frequent answer to the statement that “It does not provide any significant economic benefits for the local community” at 38.38%, with a slight

correlation with those living furthest away (0.210\*\*). This was followed by options indicating disagreement at 31.24%. A correlation of 0.264\*\* was observed between the “disagree” answer and young people. 30.8% selected options indicating agreement with this statement, for which there were correlations with retirees (0.230\*\*) and the people living closest to the plant (0.266\*\*). 43.78% of the interviewees disagreed with the statement relating to the impact on local tourism “It discourages tourists from visiting our municipality”, for which correlations were observed with older people (0.238\*\*) and those with further education (0.254\*\*). 39.46% had no opinion either way (“neither”), for which correlations were observed with young people (0.258\*\*) and students (0.268\*\*). 16.21% agree with the statement, correlating with the student group (0.268\*\*) and the younger age group (0.258\*\*).

The statement that ‘It caused conflicts and disruption in our community’ was rejected by 41.62% of the respondents, for which a correlation was observed with the people with further education (0.226\*\*). The “indifferent” answer was chosen by 42.7% of interviewees, with a slight correlation with younger people (0.226\*\*). Finally, 15.13% agreed with the statement, for which a correlation was observed with those living nearby (0.348\*\*). When asked whether “It decreases real estate prices in our community”, 43.78% of respondents answered “neither” and 37.29% disagreed with the statement, with slight correlations with older people (0.258\*\*) and people with secondary education (0.258\*\*). 18.38% of the interviewees agreed with this statement, for which a correlation was noted with the people living nearby (0.292\*\*).

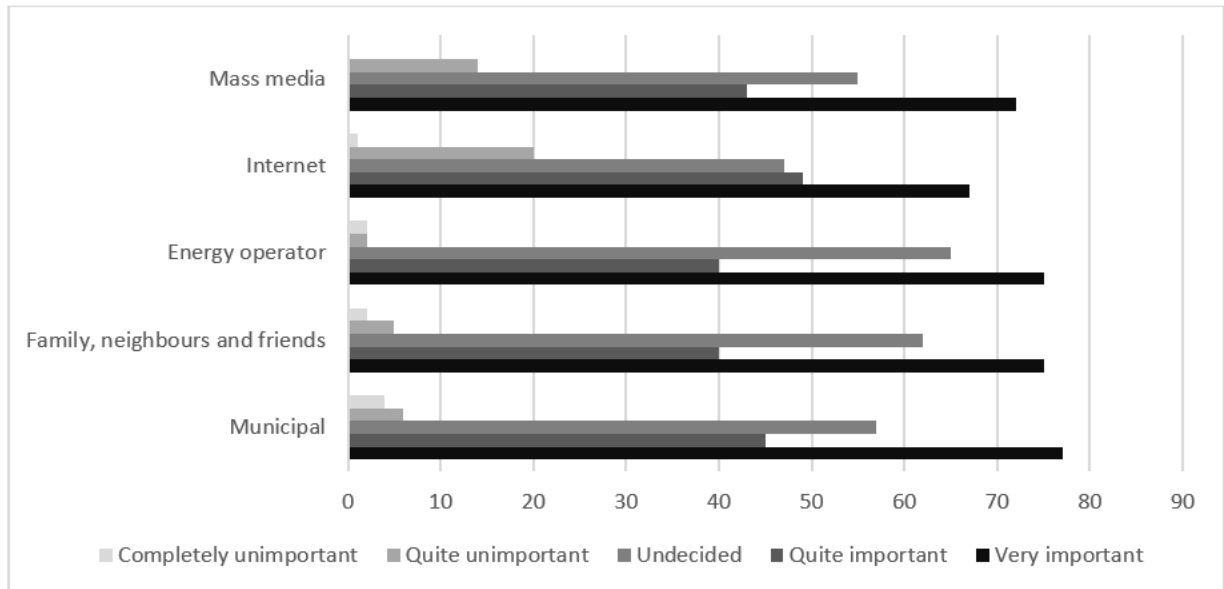
#### 4.4. Public participation

In both cases although the interviewees complained about an almost non-existent participation process, they raised few objections about the plants themselves or about possible future developments. As regards the answers to the question about the quality of the information provided to local people during the planning phase, most of those interviewed believe that the information they received was insufficient and biased. There is a correlation between the retired population (0.3\*\*) and the population who live near the plant (0.263\*\*) and the people who expressed the strongest opinions regarding the insufficiency of the information. By contrast, as regards “the information was sufficient and impartial”, there is a correlation between the answers strongly disagreeing with this statement and the groups of male interviewees (0.212\*\*) and over 65s (0.26\*\*). This level of disagreement is less intense as the level of education rises because the group with further education studies (0.23\*\*) have a greater correlation with more moderate values. There is also a correlation between the people who live at a medium distance (2 to 3 km) from the plant (0.227\*\*) and not being aware of the quality of the information (i.e. those who answered “don’t know”). As for the questions about the available participation tools and those used by the people interviewed, the vast majority, 89 %, did not make use of the opportunity to participate in the process and considered that the possibilities were insufficient. The most common way of participating was by consulting the project documents in the local council offices.

As regards the sources of information about the biogas plant (Figure 5), the interviewees were asked to indicate which sources they had used and how important this source of information had been for them in the process. The available options were local government, family, the developer, Internet and the media. They were asked to assess the importance of these options on a five-point Likert scale: completely unimportant, quite unimportant, undecided, quite important, and very important. Results showed that 64.94% considered the Local Council (announcements, local newspapers, municipality’s websites, Facebook, etc.) as an unimportant information source, for

which a correlation was observed with the people living near the plant (0.292\*\*). Most of the interviewees (62.16%) also considered “Family, neighbours, and friends” as unimportant, for which a correlation was also observed with people living near the plant (0.238\*\*).

Figure 5: Opinions about the sources of information



Source: The authors

The information source “Operator/developer that planned the construction of the AD plant (brochures, lectures, etc.)” was considered important by 62.16% of the population. A correlation was observed between the “important” answer and those who live near the plant (0.262\*\*). The information source ‘Internet (I searched for such information by myself)’ was deemed important by 57.3% and a correlation was observed with women (0.209\*\*) and those living furthest away (0.361\*\*). The interviewees were also asked about the involvement of the developer of the plant in the participation process and about how competently they operated the biogas plant. In both cases over 57,84 % indicated that they did not know the name of the company that developed the project. As regards the question whether the company took the objections of the local population seriously, most of the responses were negative. Strong disagreement was shown by several different groups such as men (0.244\*\*), people who live nearby (0.276\*\*), people who have been living in the area for less than 5 years (0.225\*\*), and people with secondary education (0.281\*\*).

## 5. Discussion

In terms of public opinion, the results show that the Seville plant aroused stronger feelings of rejection than the Granada plant. This rejection was due to two factors, the first of which was proximity, as found in other studies too (Chodkowska-Miszczuk *et al.*, 2020; Shumacher & Schultmann, 2017; Acikgoz, 2011), in that the biogas plant is very close (680 metres) to the nearest urban area, Fuente del Rey, in the province of Seville, where 11.1 % of the interviewees live. In the case of the Granada plant, it is slightly further away (1,560 m) from the nearest urban area (where 19 % of the interviewees live). In the correlations obtained during this research, research shows that the people who live less than 3 km away from the plant have more negative opinions of both

the participative process and the impacts of the plant, so leading to a lower level of acceptance of the project. The second factor behind the greater rejection of the Seville plant is its size. This plant is a very large facility with a power capacity of 2.52 MW, while the Granada plant has a capacity of just 0.6 MW. Our research also shows that the oldest population groups and those with a low level of education (primary education) are the groups most opposed to the construction of biogas plants.

The general acceptance of the biogas plants is high in both Seville and Granada, but the results show that the interviewees were not informed during the design, construction and operation phases. Older people and people with lower levels of education consider themselves most excluded from the participation process. This may be due to the fact that the main source of information about the construction of the plant was through the internet and the media, resources to which older people and people with lower levels of education generally have less access. As other research studies make clear (Navrátil *et al.*, 2021; Chodkowska-Miszczuk *et al.*, 2020; Chodkowska-Miszczuk *et al.*, 2021; Martín *et al.*, 2022), access to information during the design phase of the biogas plant is often limited, and the internet and the media are the preferred channels by which people receive information about biogas plants. In case studies, a similar situation applied, suggesting that digital media have an important role to play as a source of information about biogas plant projects.

Although the cases explored in this paper were mentioned in the local and regional press as positive examples of renewable energy production and sustainability that did not give rise to conflict (Diario de Sevilla, 2023), the results of research show that a suitable social participation process was not carried out. It did not comply with the principles of equality or representativeness of the local community and therefore cannot be viewed as a process with procedural justice. Another result was the absence of any bidirectional relationship between the developer and the local community, confirming the findings of previous studies (Frantál *et al.*, 2023; Kulla *et al.*, 2021). In Spain, there is a long-standing persistent tendency towards a top-down, technocratic, hierarchical planning system inherited from the period when policy-making was highly centralized, before 1978 (Frolova *et al.*, 2019b). National government policy has been keeping grass-roots initiatives at arm's length in the formal decision-making process on Spanish renewable planning. In addition, up until quite recently, the institutionalized power of energy companies has allowed them to influence the rollout of RE facilities (Frolova & Pérez, 2008). Current energy policy is therefore far from complying with the requirements of distributive energy justice.

For the interviewees, the most highly valued positive impact/benefit of the biogas plants is “using materials that would not be used in any other way”. This benefit was especially highly valued by self-employed people and people with a high level of education. The most frequently mentioned reasons for local opposition were odour leakages (Kulla *et al.*, 2022), but in case studies, the public could not distinguish whether the bad smell was coming from the biogas plant or from the water treatment plant in the same facility. The most frequently cited disadvantage was that “it worsens the quality of life”, although there was no correlation between this complaint and any particular group. Older people, retired people and people with the lowest levels of education generally had stronger views regarding the negative impact of the cases studied here.

Lastly, acceptance of the plant was lower amongst people with lower incomes (unemployed) and lower levels of education, and in this case at least, did not increase with the level of education. The increase in the acceptability of the plant is directly correlated with the distance between the plant

and the interviewee's place of residence. The greater the distance between their homes and the biogas plant, the greater their acceptance of the existing plant and of the possible construction of new plants in the future. This paper shows that the most important factor continues to be proximity to the plant. The distance between the interviewee's home and the plant is proportional to the negativity of their attitude towards it; a finding that crops up repeatedly in other research studies (Martinát *et al.*, 2022, Chodkowska-Miszczuk *et al.*, 2020). Rejection is also higher in older people, retired people and those with a lower level of education, who have a more negative opinion of the biogas plants than other people, while younger people and those with further education show higher levels of acceptance. Therefore, our study emphasizes that the groups most opposed to the plant have specific characteristics (old age and lower levels of education). Identifying these groups is useful in that it can help prevent conflicts and increase acceptance.

## 6. Conclusions

Biogas-based energy is an important means of mitigating climate change in that it can be used to decarbonize industrial processes and transport systems as a substitute for natural gas. However, it can generate social conflicts linked to procedural and distributive "injustice", as perceived by the local population. The aim of this study was to enable a better understanding of the acceptability and potential conflicts of projects generally considered as good practice in the rollout of renewable energies, which make use of and recycle residues and wastewater and have a low impact on the landscape or on land uses. While there are numerous studies on the acceptability of biogas plants fed by energy crops (and in particular corn), the study has yet to come across any research about biogas plants in wastewater treatment facilities, despite the fact that in Spain this type of plant is more common in comparison with the rest of the European Union, where biogas plants based on energy crops tend to dominate. In the study, a comprehensive analysis of social participation in projects of biogas plants in wastewater treatment facilities, presented in media as smart practices, have been conducted. This analysis has shown that biogas plants have a high level of acceptability for most interviewees, although there is a group with strongly unfavourable opinions about the cases studied here and regarding the possible future construction of new plants, who may have been excluded from the decision-making processes.

The main results of this paper are as follows:

Firstly, population groups with more negative attitudes towards biogas plants have been detected, namely older people and people with a lower level of education. Another group with a poor opinion of these plants are the residents who live closest to them. This means that the perception of these biogas plants in wastewater treatment facilities is far from uniform, and that some groups in society have a worse opinion of them than others.

Secondly, in the analysis of citizen participation in these cases, it concluded by confirming that the participation of local people was very limited. The participation processes applied in these cases could not be viewed as procedurally just, given that the scenario depicted by the results is one of very low public participation, a negative attitude towards the participation process, poor information, and very little contact with the plant developer/operator.

Thirdly, the advantages and disadvantages of biogas plants were analysed. In the case of the positive impact or advantages, fairly similar ratings were given to three items: reuse of waste materials, production of renewable energy and contribution to climate change mitigation. While in the

disadvantages, the most frequently cited was “it worsens the quality of the environment” as the main perceived negative effect of the gas plant.

The participative process was not fair from the point of view of energy justice. While there is no involvement of the local community in energy policy decision-making, there can be no fair energy transition. The social groups that felt most excluded from these processes were older people, people with lower levels of education and people on low incomes. In this way, research shows that some groups in society could be more vulnerable to procedural and distributive injustice in the energy transition process.

Finally, in terms of gender, the female interviewees showed greater acceptance of the plant and greater involvement in the different participation channels (survey and public hearing). In order to increase acceptance of plants of this kind, the general public must become more involved in energy policy, so as to gain a better understanding of the effects of renewable energy production on their local areas. It is also important to design social participation processes in such a way that the most vulnerable groups in society (such as older people and people with lower levels of education) do not feel excluded and that the information about these projects is accessible to them. It is also important that projects of this kind create positive socioeconomic benefits for the most affected residents due to biogas plants proximity to their homes.

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## Contribución de autorías

Javier Liñán Chacón: Conceptualization, Methodology, Formal analysis, Writing – original draft, review & editing.

Marina Frolova Ignatieva: Supervision, Project administration, Methodology, Writing – review & editing.

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## Conflicto de intereses

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## APPENDIX:

## Questionnaire original (Spanish)

Nos gustaría pedirle que complete este cuestionario para el proyecto de investigación sobre aspectos sociales como la percepción y participación social en las plantas de biogás. Su participación en esta encuesta es anónima. Solo se publicarán los resultados agregados de la encuesta y los resultados se utilizarán únicamente para las necesidades de nuestro proyecto de investigación. Completar el cuestionario no debe llevar más de 10 minutos de su tiempo. Gracias por su colaboración.

## CUESTIONARIO PARA LA POBLACIÓN DE COMUNIDADES CON UNA PLANTA DE BIOGÁS EN FUNCIONAMIENTO

[1] Hay una planta de biogás, en funcionamiento en la área donde reside. Podría usted volver atrás en el tiempo anterior a la construcción y evaluar su actitud hacia ella. Usted estuvo de acuerdo con la construcción de la planta de biogás en su comunidad? Por favor, marque solo una opción.

1 -Definitivamente de acuerdo 2-De acuerdo 3 - No lo sé 4 - En desacuerdo 5 - Absolutamente en desacuerdo

[2] Esta usted de acuerdo con la afirmación siguiente: "La población de la comunidad fue suficientemente informada sobre el plan de construcción de la planta de biogás". Por favor marque solo una opción.

1 -Definitivamente de acuerdo 2-De acuerdo 3 - No lo sé 4 - En desacuerdo 5 - Absolutamente en desacuerdo

[3] Esta usted de acuerdo con la afirmación siguiente: "La información sobre el planteamiento de la planta de biogás fue relevante, imparcial y describe la planta desde una visión realista? Por favor marque solo una opción.

1 -Definitivamente de acuerdo 2- De acuerdo 3 - No lo sé 4 - En desacuerdo 5 - Absolutamente en desacuerdo

[4] ¿Tuvo oportunidad de participar en el proceso de planificación? Si la tuvo, usted utilizó alguna de las formas de participación enumeradas en la tabla siguiente: Por favor, marque las repuestas en cada línea.

Formas de participación	Tuve posibilidad de participar	Utilice la posibilidad y participe
a) Se organizó una excursión para ver una planta de biogás en otra comunidad.	Si / No	Si / No
b) Se llevó a cabo una audiencia pública organizada por la administración de la comunidad o el inversionista de la planta de biogás.	Si / No	Si / No
c) Se expuso en el ayuntamiento local la documentación de proyecto de la planta de biogás.	Si / No	Si / No
d) Se organizó una encuesta centrada en la opinión de la población local sobre la planta de biogás planificada	Si / No	Si / No
e) Se organizó un debate con un experto independiente.	Si / No	Si / No
f) Alguna otra forma de participación? Por favor indíquela		

[5] Considera usted, que las posibilidades para su participación en la planificación de la planta de biogás fueron suficientes: Por favor marque solo una opción.

1 -Definitivamente de acuerdo 2-De acuerdo 3 - No lo sé 4 - En desacuerdo 5 - Absolutamente en desacuerdo

[6] ¿Qué fuentes de información sobre la planificación de la planta de biogás ha utilizado en su comunidad? Por favor, marque el nivel de importancia de la fuente individual de información. Por favor, marque las repuestas en cada línea.

(1= Muy insignificante, 2= insignificante, 3=No lo sé, 4=significante, 5= Muy significativa)

a)	Gobierno local (Anuncios públicos, periódicos locales, páginas web o redes sociales como Facebook, Twitter)	1 2 3 4 5
b)	Familia, vecinos, amigos	1 2 3 4 5
c)	Inversor, quién planteó la construcción de la planta	1 2 3 4 5
d)	Internet ( Con la búsqueda de la información por iniciativa propia)	1 2 3 4 5
e)	Medios de comunicación (TV, radio etc.)	1 2 3 4 5

[7] Está usted de acuerdo con la afirmación siguiente: "El operador de la planta de biogás en su comunidad se toma seriamente las objeciones de la población local hacia la planta de AD y las intenta solucionar" Por favor, marque un opción solo.

1 - Definitivamente de acuerdo 2 - De acuerdo 3 - No lo sé 4 - En desacuerdo 5 - Absolutamente en desacuerdo

[8] Está usted de acuerdo con la afirmación siguiente: "El operador de la planta de biogás en su comunidad es competente y sabe cómo operar su instalación" Por favor, marque un opción solo.

1 - Definitivamente de acuerdo 2 - De acuerdo 3 - No lo sé 4 - En desacuerdo 5 - Absolutamente en desacuerdo

[9] Cuáles son los beneficios de tener una planta de biogás en tu municipio? Por favor, marca tu respuesta en cada línea.

Beneficios de una planta biogás en funcionamiento:	Muy desacuerdo	En desacuerdo	No lo sé	De acuerdo	Muy de acuerdo
a) Produce energía limpia y renovable.	1	2	3	4	5
b) Contribuye a la protección ambiental y ayuda a combatir el cambio climático.	1	2	3	4	5

Beneficios de una planta biogás en funcionamiento:	Muy desacuerdo	En desacuerdo	No lo sé	De acuerdo	Muy de acuerdo
c) Utiliza materiales que no se utilizarían de ninguna forma.	1	2	3	4	5
d) Genera nuevos empleos e ingresos adicionales a los agricultores.	1	2	3	4	5
e) Trae consigo beneficios económicos al municipio (Ej. disminuir el coste de calefacción de los edificios públicos)	1	2	3	4	5
f) Es un atractivo turístico.	1	2	3	4	5
g) Es un elemento de promoción del municipio, haciéndolo visible al exterior.	1	2	3	4	5
h) Contribuye al desarrollo general del municipio.	1	2	3	4	5

[10] Cuáles son los impactos negativos de una planta de biogás en funcionamiento para el municipio? Por favor, marque las respuestas en cada línea.

Impactos negativos de una planta de biogás en funcionamiento	Muy desacuerdo	En desacuerdo	No lo sé	De acuerdo	Muy de acuerdo
a) No funcionaria son incentivos económicos.	1	2	3	4	5
b) Afecta al medio ambiente local.	1	2	3	4	5
c) Perturba visualmente el paisaje local.	1	2	3	4	5
d) It Empeora la calidad de vida del municipio (Olor, suciedad, incremento del tráfico).	1	2	3	4	5
e) No trae un beneficio económico importante al municipio.	1	2	3	4	5
f) Evita que los turistas visiten nuestro municipio.	1	2	3	4	5
g) Causa conflictos y división en la comunidad local.	1	2	3	4	5
h) El valor inmobiliario ha decrecido en el municipio.	1	2	3	4	5

[11] Si volviéramos atrás en el tiempo y tuviera la posibilidad de decidir nuevamente sobre la planta de biogás planificada en tu comunidad, ¿Estarías de acuerdo en construirla? Por favor, marque un opción solo.

1 – Definitivamente de acuerdo 2 – De acuerdo 3 – No lo sé 4 – En desacuerdo 5 – Absolutamente en desacuerdo

[12] ¿Cómo evaluaría usted personalmente el desarrollo de plantas de biogás en su región? Por favor, marque un opción solo.

1 – No se deberían construir plantas AD en ninguna parte.

2 – Se podrían construir algunas plantas, pero no próximas a mi municipio.

3 – No me molestaría si se construyeran otras plantas AD cerca o en mi municipio.

[13] Edad: ..... años Sexo: 1 – Hombre 2 – Mujer

Su grado de educación es: 1 – primaria 2 – secundaria 3 – terciaria

Actividad económica: 1 – Empleado 2 – Autónomo 3 – Dependiente 4 – Jubilado 5 – Desempleado 4 –

Estudiante

A qué distancia vivo de la planta de biogás (estimación) .....metros

Nombre del municipio:..... Cuánto tiempo lleva viviendo en el municipio:.....

Trabajo en la planta de biogás del municipio: 1 – Si 2 – No

Gracias por su tiempo. Su ayuda es muy apreciada.