CEntre for Research on Circular economy, Innovation and SMEs

Working Paper Series

The Biogas dilemma: an analysis on the Social Approval of large new plants

by

M. Mazzanti, M. Modica, and A. Rampa

The CEntre for Research on Circular economy, Innovation and SMEs (CERCIS) is part of the Department of Economics and Management at University of Ferrara and, in particular, of the departmental development program funded by the Italian Ministry of Education, University and Research (MIUR) on a competitive basis for the period 2018–2022 to promote excellence in education and research ("Dipartimenti di Eccellenza"). The Department of Economics and Management is one of the 18 Departments funded in the Scientific Domain of Economics and Statistics at a national level.

Papers can be downloaded free of charge from the following websites:
http://eco.unife.it/it/ricerca-imprese-territorio/centri-di-ricerca/cercis/working-papers

Enquiries: cercis@unife.it

CERCIS Working Paper
03/2021
By M. Mazzanti, M. Modica, and A. Rampa

The Biogas dilemma:

an analysis on the Social Approval of large new plants

Massimiliano Mazzanti Marco Modica Andrea Rampa

This paper has promoted by Institute on Sustainable Economic Growth (IRCrES-CNR) on behalf of Increasing Social Awareness an Acceptance of biomass project (ISSAC project), an European project financed by Horizon 2020 Programme.

Massimiliano Mazzanti. University of Ferrara; Sustainability Environmental Economics and Dynamics Studies (SEEDS) - Research Centre, Ferrara (Italy).

Marco Modica. Gran Sasso Science Institute, Social Sciences Area, Via Iacobucci 2, 67100, L'Aquila (Italy).

Andrea Rampa. Ministry of Economy and Finance – Directorate of Economic and Fiscal Studies, Via dei Normanni, 5, 00184 Rome (Italy); Sustainability Environmental Economics and Dynamics Studies (SEEDS) - Research Centre, Ferrara (Italy). andrea.rampa@mef.gov.it. – ***The views expressed in this paper are those of the authors and do not necessarily reflect those of the Ministry of Economy and Finance and the Department of Finance.***

Abstract. The degree of social acceptance of biogas as a renewable green energy source is still somewhat disregarded. Although many initiatives have focused on the construction of new biogas plants around the world, with Italy as a relevant actor in the field, local protests on the construction of new plants are frequent in some areas. This study aims to analyse the determinants of citizens' perceptions regarding the construction of new biomass plants in their neighbouring areas. In particular, the focus is on prior knowledge of the production process of biogas as well as on other individual characteristics. The investigation is based on two repeated surveys administered to citizens living in proximity to two Italian local areas in which the construction of new large biogas plants is planned: the provinces of Oristano in Sardinia and Andria in Apulia. The first survey analyses the main variables correlated with the degree of biogas acceptability with a focus on the role played by biogas knowledge. The second set of surveys focuses on the role of participatory processes and information campaigns undertaken by policy makers and environmental associations to increase the social acceptance of communities regarding the construction of new biogas plants.

Keywords: Biomass, Local Acceptance, Local public goods, waste management, renewable energy, Circularity

JEL Classification: Q42, H49

1. Introduction

The transition to a circular and decarbonized economy (EMF, 2019, EEA, 2019) is driven by the co-evolution of different transitions occurring in different geographical and impact dimensions (EEA, 2020). States, macro regions, socio-economic and innovation systems, and districts are the socio-economic-technological spaces in which new business models and innovations emerge and develop. To create the most favourable conditions to ensure that the green and circular economy (CE) is the dominant paradigm, governments are required to implement policies for correcting market imperfections and provide adequate economic incentives to producers and consumers while pursuing sustainable production for the former and a sustainable lifestyle for the latter. Regions and territories are social and economic institutions where a large portion of the transitions develop and exert their impacts due to the decentralization of policies, especially in areas such as environmental protection and innovation. In addition, the management of resources occurs mainly at the local level, where negative externalities also occur and sustainability policies are implemented. For the design of systemic policies that encourage a CE, it is therefore necessary to learn more about the local driving factors of CE-oriented consumption and production behaviour (Cainelli et al 2020). Following a Nexus approach, circular, low carbon and Bioeconomy trajectories are integrated, as shown in Figure 1.

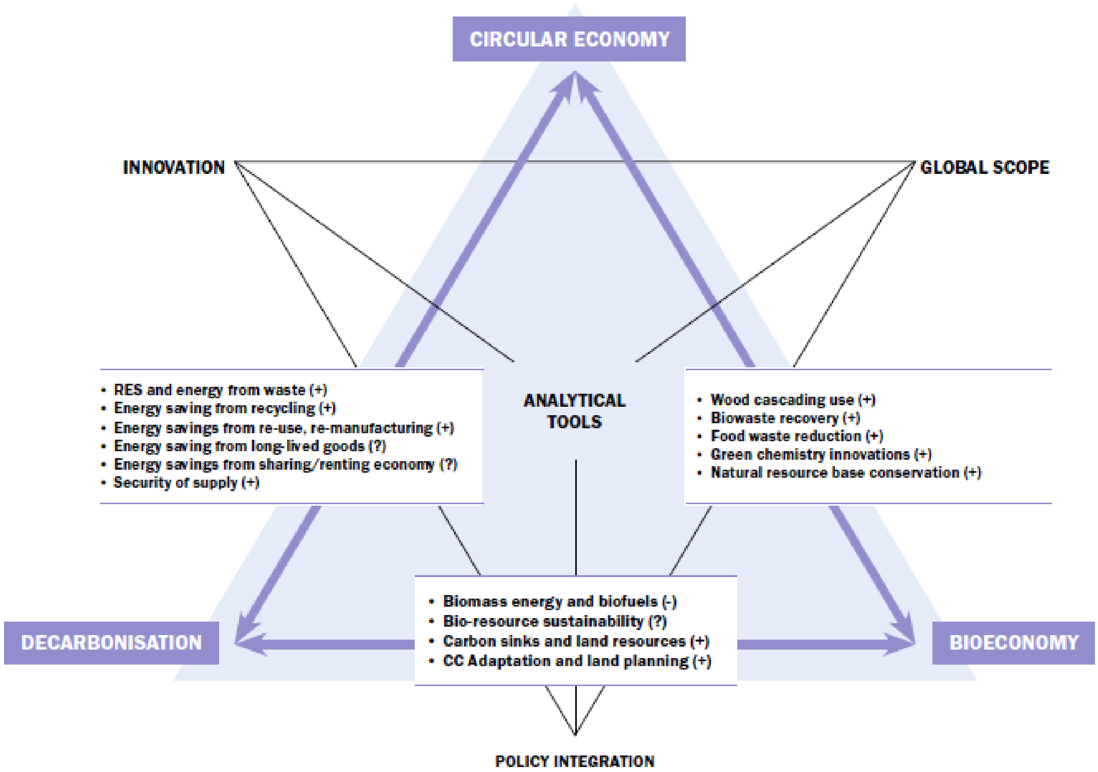

Figure 1. Analytical tool of circular economy (source: Zoboli et al., 2019)

Renewable energies and circular Bioeconomy connections are relevant in terms of the innovation and policy integration realms.

Notwithstanding their role in climate change mitigation strategies, the social acceptance of the construction of new renewable energy infrastructures, especially those that highly impact the local socio-economic and natural environment, appears difficult to achieve because of the so-called NIMBY effect (e.g., Bell et al., 2005, Dan van der Horst, 2007, Warren et al., 2005).

The construction of new plants for the production of biogas is emblematic of this issue because even if biogas is generally considered an environmentally friendly technique for the production of energy, such construction leads to protests based on public opinion (Modica, 2017). In fact, a plant for the production of biogas promotes a series of complex and varied activities mainly derived from the reuse of waste, especially waste from agro-industry (e.g., manure, sewage from farms, vegetables and food residues) and/or industrial and municipal wastewater treatment plants. Furthermore, the biogas industry is able to use agricultural lands that are difficult to exploit economically to produce materials that can be used for the operation of plants in a profitable way. Thus, the production of biogas promotes a series of new opportunities, especially for rural and inner areas, thereby producing positive externalities for the associated areas.

Despite these positive elements, biogas production might produce protests in local communities because of the (real or perceived) negative elements or social-environmental costs of biogas production activities. These negative elements are typically summarized according to three main recurrent issues: soil erosion due to increased exploitation of agricultural land (Abbasi and Abbasi, 2000); potential groundwater pollution due to sewage production and air pollution due to the combustion of biomass (Abbasi and Abbasi, 2000); and the negative impacts of waste combustion (Skøtt, 2006; Soland et al., 2013).

The study of biogas social acceptance is thus relevant for the development of the biogas industry and essential for promoting the construction of new biogas plants. Indeed, the absence or presence of significant negative impacts on the involved actors (citizens, local associations and institutions) certainly plays an important role in avoiding/reducing the need to design incentives for compensating households in relation to negative externalities.

This paradigm is particularly true for Italy, which is one of the largest producers of biogas energy and where frequent demonstrations and public disagreements occurred regarding the construction of new plants (here: 1, 2, 3, some Italian newspaper articles, on demonstrations in opposition of new Biogas plants [accessed on 12th December 2020]). However, it is important to stress that local acceptance do not represent an additional assessment for improving energy production linked to proper waste management. Rather, citizens' engagement is needed to implement a shift from centralized to decentralized energy production, which contrasts with previous energy production-distribution systems. Corsini et al. (2019) focused on the role of social engagement in the energy production decision as well as the knowledge of the biogas production process, which few research studies have investigated. Dobers (2019) indicated that biogas acceptability might depend on several spatial and local factors, such as place attachment and attitudes. Overall, public involvement might be a key point for the successful investment in biomass, such as in the case of the Energy Cooperative Company of Karditsa, a Greek prefecture where a partnership has been made among all residents for the production of energy and heat from biogas (Corsini et al., 2019).

To the best of our knowledge, the socio-economic literature has partially covered the social acceptability of biogas plant issues (Dobers, 2019; Radics et al., 2015). At the country level, Soland et al. (2013) measured the perceived social costs and benefits of biomass energy production via structural equation modelling based on a survey of 502 citizens living near 19 biogas plants in Switzerland, and they found that two characteristics played a relevant role in individual biogas acceptance, namely, invasive scent detection and the amount of information received. In contrast, participation options such as workshops and group discussions did not have a significant effect. Similarly, Emmann et al. (2013) used a structural equation to investigate the local acceptance of biogas. However, they focused on a more rural context and investigated farmers and their willingness to adopt biogas production. Moreover, personal attitudes and personal innovativeness are the strongest determinants of biogas investment, even with respect to legislative incentives, thus highlighting the more relevant role of individual characteristics rather than institutional characteristics. In a more recent study, Dobers (2019) conducted an online survey using a sample of 942 interviewees and found that spatial variables in addition to individual attitudes have a significant influence on the acceptance of biogas plants. The paper also showed that the level of acceptance remains lower with respect to other renewable sources of energy, such as wind and solar energy plants. Although spatial variables play an important role in community acceptability, differences are not observed between rural and urban populations.

Scaling down the level of analysis, Schumacher and Schultmann (2017) identified the importance of political and cultural context in the acceptability of renewable energy projects. Their analysis was based on the supranational Upper Rhine region covering three different countries (Switzerland, Germany and France). The authors showed different dynamics in the acceptance of biogas because of the stringency of environmental protection laws (for example, regarding manure to involve) and trust in institutions; thus, they found that procedural and distributive justice matter. At the regional and local levels, Kortsch et al. (2015) studied biogas acceptance in a region where biogas plants already exist (Altmark, in Germany) and observed that public acceptance remained constant over time, which is mainly based on context and past experiences. The results again show that the knowledge and quality of information positively influence the social approval of biogas.

All these studies also provide indications regarding possible limitations in the social acceptability of the use and production of biogas as a green source of energy. However, this evidence is not as clear in more recent studies that analyse the effect of the presence of biogas plants on the surrounding housing property values. In some sense, these results might be interpreted as a proxy of the potential costs suffered by people living next to biogas plants, thus providing a method of indirectly measuring the (perceived) acceptability of this source of energy production. In fact, these studies provide mixed evidence. Modica (2017) showed that the construction of new biogas plants had no significant impacts on local housing values since the project is public knowledge. In this context, the NIMBY phenomenon does not occur. In contrast, Zemo et al. (2019) showed that the NIMBY and PHIMBY phenomena do not play a clear role while Dobers (2019) asserted that the NIMBY explanation is too simplistic. Indeed, Zemo et al. (2019) observed both positive and negative impacts on rural residential property values if new farm-scale or large biogas plants are built, respectively. Schumacher and

Schultmann (2017) argued that the “fault” of local non-acceptance associated with NIMBY is often a non-in-depth conclusion that does not sufficiently consider conflicting parties and political issues.

After reviewing the social acceptability of biogas energy production, the main drivers of social biogas acceptability are the amount of information received and several spatial and local factors, such as place attachment, attitudes and institutional quality. Public involvement and participation options show mixed evidence. Against this background, this paper aims to analyse the social acceptability of the construction of new biogas plants and primarily focuses on the role played by the participatory process and the quality of information received. To do this, we focus on two Italian provinces, namely, Barletta-Andria-Trani in Apulia and Oristano in Sardinia, where two large biogas plants are in construction and the community has largely been included in the decision-making process through participatory processes.

Consequential sets of citizen surveys (three in total) were implemented within a multistep integrated empirical process: a first survey questionnaire was administered in April 2017 (first step), while the second step (namely, a set of two surveys) was repeated twice, before and after the participatory process in springtime 2018. In specific terms, the first survey of the second step was carried out in January 2018, and the second survey was carried out in June 2018.

The results show that the higher the level of knowledge regarding biogas production activities, the higher the degree of acceptability. However, when differentiating between collective and individual impacts, this evidence is not that straightforward. First, more biogas-related knowledge implies i) a higher likelihood of the respondents believing that biogas production has positive impacts on society and ii) a lower probability of believing that biogas has negative impacts on society. Nonetheless, prior beliefs on the negative impact of the opening of new biogas plants on individuals living next to the plants are not reduced by higher biogas knowledge or by participatory processes and informative campaigns. The paper is organized as follows: the next section introduces the case study, the survey and the method; Section 3 presents and discusses the results; and Section 4 provides the conclusions.

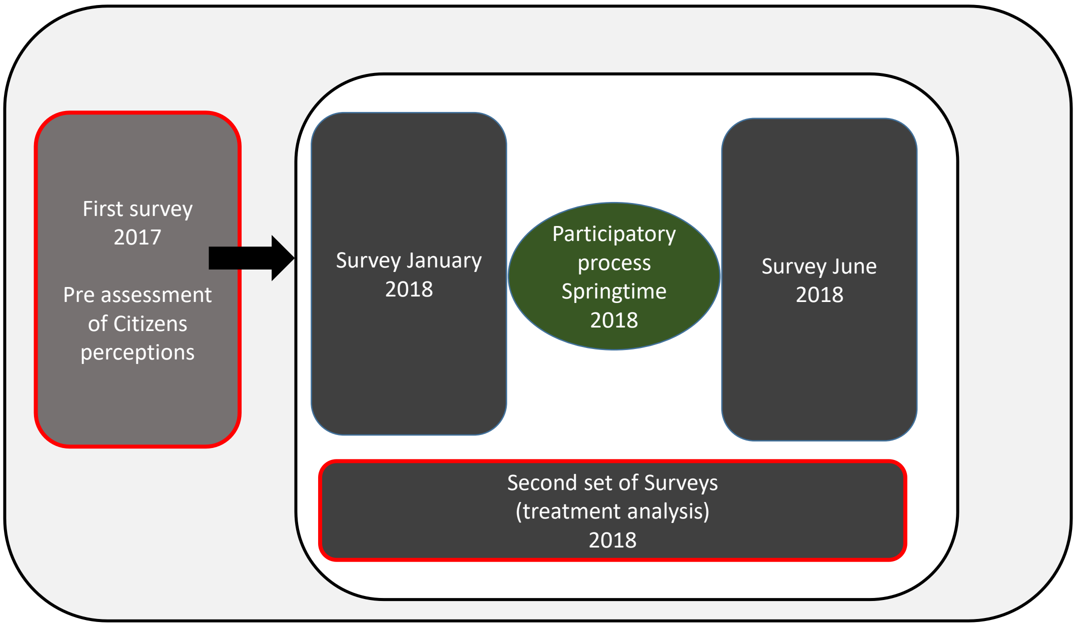

Figure 2. The two steps three surveys empirical process

2 Material and Methods: Case Study

2.1 Empirical analyses: surveys and case studies

The acceptance of a community regarding a new public intervention that implies consequences for the territory or the local environment is usually studied through different tools that can evaluate market and non-market goods (Ozderimoglu and Hails, 2016). This paper presents the results of two surveys on citizens. Thus, the setting of this study is divided into two steps. The first survey is aimed at analysing the determinants of people's biogas perception regarding the construction of new biogas plants near their city or area before conducting any participatory process. In this first survey, we mainly focus on the role that biogas knowledge plays in individual acceptability differentiation by collective and individual positive or negative influences. We also controlled for other socio-demographic and economic characteristics such as age, sex, family size and so on.

The second survey is aimed at studying the influence of participatory processes and information campaigns undertaken by policy makers and other relevant actors (such as Legambiente, one of the main Italian pro-environment NGOs) to inform communities regarding the costs and benefits of investment in the construction of new biogas plants. This second survey was repeated twice, with the first on 2018 January and the last on 2018 June. Between these two waves, a participatory process was organized by Legambiente in the municipalities of Andria (Barletta-Andria-Trani NUTS3 province in the Apulia NUTS2 region) and Arborea (Oristano NUTS3 province in the Sardinina NUTS2 region). These initiatives were performed inform the local population regarding biomass technology adopted in the construction of two new biogas plants in the two mentioned municipalities and the costs and benefits entailed in this type of renewable energy. We then assessed the drivers of probable changes between the two surveys. Based on the results of the first survey, our main hypothesis is that a participatory process that provides biogas information should increase the degree of social local acceptability of the two new biogas plants.

This first survey (pre-assessment, 2017) focuses on the two different case studies. In particular, 811 residents in the province of Barletta-Andria-Trani, which is part of the Apulia Region, and 803 residents in the province of Oristano, Sardinia Region, were interviewed between April and August 2017 through CATI (computer-assisted telephone interviewing). The samples are representative of the population of the provinces of Andria and Oristano, according to age classes and gender. The survey is composed of three sections: the first examines the current knowledge regarding biogas production options, the second investigates the perceived benefits and costs, and the third elicits socio-demographic data. The questionnaire is presented in Appendix. Arborea is a small town with

3,900 habitants; therefore, to avoid sample bias, this survey covers the territory of the entire province of Oristano, with approximately 160,000 residents, making the sampling region closer to the case of Andria, a large municipality of approximately 100,000 residents.

The second set of surveys (treatment analysis, 2018) was performed before and after a ‘treatment’, namely, the occurrence of a participatory process that involves the local population, and it assessed whether the process changes biogas preferences and perceptions. In fact, we conducted the same repeated survey in two different areas where the construction of new biogas plants is already planned in two Italian regions, Arborea, Sardina and Andria, Apulia. The interviews were conducted for the two regions with a questionnaire of 821 respondents, 401 in Andria and 420 in the area near Arborea by CATI (computer-assisted telephone interviewing). The samples are representative of the Andria and Arborea populations, according to age classes and gender. The same interviews were repeated after a few months (1.605 respondents, 800 in Andria and 805 in the area near Arborea).

Our work is generally consistent with the analysis of Soland et al. (2013), which focuses on the social acceptance of agricultural biogas plants by citizens living in their proximity. However, contrary to Soland et al. (2013), our work aims to highlight the shifting of social acceptance for the construction of biogas plants driven by participatory processes conducted by environmental associations from an ex ante perspective.

2.2 Empirical model: dependant and independent variables of the econometric regression

2.2.1 Dependant variables

For both rounds of surveys, a variable that measures the degree of biogas acceptability of individuals is set, which represents the dependent variable in the investigation (see Tables 3 and 4).

For the first survey (first step), the acceptability variable was defined as a composite indicator that resulted from three different questions. In detail, we sought to determine the i) potential positive effects on society, ii) negative effects on society and iii) individual impacts. In particular, we ask the following three questions: "*Do you believe that a biogas plant could have positive impacts on the community?*"; "*Do you believe that a biogas plant could have negative impacts on the community?*" and finally, "*Do you believe that citizens who live in the vicinity of a plant must be compensated?"*

In particular, the composite indicator is defined as follows: we assign a value of 1 if respondents answer *Yes* to the first question, namely, respondents believe that biogas plants do have positive impacts on the community and 0 otherwise; we assign a value of 1 if respondents answer *No* to the second question: namely, they believe that biogas plants have a negative impact on the community and 0 otherwise; and we assign a value of 1 if respondents answer *No* to the third question, namely, they believe that citizens who live in the proximity of a plant do not need any compensation and 0 otherwise. In this way, this variable can assume a value from 0 for the minimum level of acceptability to 3 for the maximum.

Instead, in the second set of surveys (second step), we refine the above questions to consider impacts that can be identified as more "concrete"; in fact, we ask about the reaction of individuals to the opening of new biogas plants in their surrounding areas. In detail, we ask the following two nested questions: *"Would your reaction be positive or negative to the news regarding the construction of a Biogas plant in your* territory?". If the answer to the first question is negative, then we ask the following: "*Do you believe that citizens who live in the vicinity of a plant must be compensated?"*

Then, we assign a score of 2 for a positive answer to the first question and 1 if the answer is no to the second question, thus indicating the degree of biogas acceptability. Again, the range of this variable varies between 0 and 2.

2.2.2 Independent variables

The main independent variables defined based on the first survey are the i) self-assessment level of awareness and knowledge of the biogas energy production process (*biogas knowledge);* ii) knowledge about the construction of a plant in the next future and in the surrounding area of the respondents (*plant project*); and iii) participation in biogas informative meetings (*participation*). In detail, we ask the following 6 questions: "*Do you know how biogas is produced*?", "*Are you familiar with the biogas/bio-methane supply chain*?", "*Do you know that bio-methane can be produced from biogas*?", "*Do you know that with biogas it is possible to produce electricity*?", "*Do you know that with biogas it is possible to produce thermal energy*?", and "*Have you ever visited biogas plants*?" Then, we assign a score from 1 (all NO) to 7 (all YES). Finally, we also add a variable that considers the individual knowledge of the realization of projects for the construction of biogas plants next to the person (*plant project*). This is a dummy variable with a value of 1 if the person knows about a new biogas plant project and 0 otherwise. Similarly, *participation* takes a value of 1 if the respondent already participates in previous informative meetings and 0 otherwise.

The second survey, which was implemented in June 2018, follows and focuses on the participatory process that is held between January and May 2018. However, a huge public campaign (A local newspaper article's link about dissemination activity [accessed on 12th December 2020]) occurred in the territories under analysis.

The key independent variable is therefore a dummy variable that has a value of 1 if the respondents participate in the first or second wave of questions during the second survey. If the variable has a value of 1, we could infer that the level of knowledge of the biogas production process should be higher because of the informative public campaign in that territory.

We also add several controls that consider socio-economic, demographic and spatial characteristics of the people interviewed. The control variables are presented below. The socio-economic characteristics include *human capital* and *employed*, which are dummy variables that assume a value of 1 if the respondent is a graduate and employed, respectively, and 0 otherwise; and *environment* and *party*, which are dummy variables that take a value 1 if the respondents are part of any environmental association or political party, respectively, and 0 otherwise. The demographic characteristics include *age*, *sex* and *family size*. Finally, the spatial characteristic is *rurality*, which assumes a value of 1 if the person lives in an urban centre and 3 if the person lives in a semi-rural and rural area. We also include provincial fixed effects, and in the second sets of surveys (2018 data), we ran a pooled OLS with robust standard errors.

We then run the following OLS model with robust standard errors:

$$Y = \alpha + \beta_{Knowledge} Knowledge + \beta_{Plant} PlantProject + \beta_{Participation} ParticipatoryProcess + \beta_{Rurality} Rurality + \beta_{Family} FamilySize + \beta_{Knowledge} Knowledge + \beta_{Gender} Female + \beta_{Age} Age + \beta_{Human} HumanCapital + \beta_{Job} Employed + \beta_{EnvAss} EnvironmentalAssociation + \beta_{pp} PoliticalParty$$

List of independent variables:

Knowledge: Awareness and knowledge of the biogas energy production process.

Plant Project: Knowledge about the construction of a plant in the next future and in the surrounding area of respondents.

Participatory Process: Participation in biogas informative meetings. This is a dummy variable taking a value of 1 if the respondent has participated in an initiative and 0 otherwise.

Rurality: Grade of rurality of the respondent. This variable takes a value of 1 if the interviewee lives in the urban centre and 3 if the interviewee lives in a rural area.

Family Size: Number of family members.

Female: Gender variable, which is a dummy variable with a value of 1 if respondent is female.

Human Capital: Dummy variable that assumes a value of 1 if the respondent is a graduate and 0 otherwise.

Employed: Dummy variable that assumes a value of 1 if the respondent is employed and 0 otherwise.

Environmental Association: Dummy variable that assumes a value of 1 if the respondent is enrolled in an environmental association and 0 otherwise.

Political Party: Dummy variable that assumes a value of 1 if the respondent is enrolled in a political party and 0 otherwise.

3 Results and Discussion

3.1 First survey: pre assessment

Table 1 provides an overview of the variables employed in the analysis with a set of descriptive statistics. The correlation among the variables is reported in Table 2. No severe collinearity issues were identified.

Table 3 provides the results of the analysis on the first step (first survey) carried out in 2017. The aim of this first step is to analyse the link between biogas production knowledge and the level of acceptability of this potentially green energy resource. From column 1 to column 3, the results are shown for the variable representing acceptability over different dimensions, namely, if the biogas plant's impact on society is positive (1) or negative (2) and the biogas plant's impact on residents living in proximity (3). Finally, column 4 shows the results for the composite indicator of acceptability.

Table 1. Descriptive statistics

	# Obs.	Mean	Standard Deviation	Min	Max
		First Survey			
Positive Impact	959	.79	.41	0	1
Negative Impact	959	.78	.42	0	1
Individual Impact	959	.38	.49	0	1
Acceptance	959	1.95	.78	0	3
Biogas knowledge	959	2.44	1.61	0	6
Plant project	959	.177	.382	0	1
Participation	959	.032	.177	0	1
Rurality	959	2.14	.830	1	3
Family size	932	3.04	1.19	1	5
Female	959	.487	.500	0	1
Age	959	50.81	17.34	17	89
Human capital	959	.259	.438	0	1
Employed	959	.415	.493	0	1
Environmental assoc.	959	.073	.260	0	1
Political party	959	.032	.177	0	1
		Second Survey			
	# Obs.	Mean	Standard Deviation	Min	Max
Collectivity Impact	1,639	.653	.476	0	1
Individual Impact	453	.305	.460	0	1
Acceptability	1,639	1.39	.873	0	2
Biogas awareness	1,639	1.99	1.14	0	3
Participatory process	1,639	.600	.490	0	1
Rurality	1,639	2.03	.900	1	3
Family size	1,561	2.96	1.17	1	5
Female	1,639	.526	.499	0	1
Age	1,639	54.59	16.02	19	98
Human capital	1,606	.230	.421	0	1
Employed	1,639	.470	.499	0	1
Environmental assoc.	1,639	.065	.247	0	1
Political party	1,639	.034	.182	0	1

Knowledge of biogas production activity is significantly positively correlated with the possibility of believing that biogas plants have positive impacts on collectivity (column 1), while the coefficient is not significant in relation to the negative impacts of biogas plants on society. Nonetheless, higher knowledge of biogas production is negatively correlated with the belief that biogas plants have negative impacts on the people living in the surroundings of the plant; thus, incentives that compensate for these negative impacts are required. Overall, however, it is possible to recognize a positive correlation between knowledge and the degree of acceptability of the biogas plant, as shown in column 4.

When looking at the other two variables that identify ‘biogas awareness’, namely, knowledge about the construction of a biogas plant and prior participation in biogas informative meetings, the results are almost consistent with the findings presented above. In the first case, being aware of the construction of new biogas plants in the surrounding areas reduces the acceptability of biogas. In particular, estimates show a significantly negative correlation between this variable and the beliefs that biogas plants have negative impacts on society (3) and an overall reduction in the acceptability degree (4). In contrast, participation in prior biogas informative meetings does not have any significant impact on the degree of acceptability. However, it is important to note that this result might be influenced by the very few positive answers to this question; in fact, only 9 people over the entire sample have participated to this kind of meeting.

The other control variables that might be correlated with the degree of biogas acceptability include living in rural areas, which has a significant positive effect on the likelihood of accepting the construction of a biogas plant and corresponds to reduced incentives required for people who live in the area surrounding a plant. This result that differs from that of Dobers (2019), who found no difference in biogas plants between urban and rural populations. Finally, only human capital and political party membership seem to have significant impacts on the degree of biogas acceptability. These are signals that investments in human and social capital are levers of information and awareness; thus, they are crucial for broader investigations of the role of information and knowledge to support public actions that are characterised by conflicts. The COVID-19 case study is another example, where information and knowledge developed through investments in education and networking can improve the decision-making systems (e.g., social acceptance of vaccine, which is a typical mixed public good that conveys public and private benefits).

Table 2. Correlation matrix among the controls (Controls)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
						First Survey					
(1) Biogas knowledge	1.0000										
(2) Plant project	0.2491	1.0000									
(3) Participation	0.1554	0.1805	1.0000								
(4) Rurality	-0.0475	0.0225	-0.0059	1.0000							
(5) Family size	-0.0527	-0.0064	-0.0013	0.0958	1.0000						
(6) Female	-0.2423	-0.1024	-0.0726	0.0416	0.0208	1.0000					
(7) Age	0.1088	0.0551	-0.0749	-0.0216	-0.4143	-0.0295	1.0000				
(8) Human capital	0.1366	-0.0096	0.0139	-0.0698	-0.0037	0.0410	-0.0406	1.0000			
(9) Employed	0.1213	0.0582	0.0518	0.0019	0.1014	-0.2189	-0.2237	0.1914	1.0000		
(10) Environmental assoc.	0.0854	0.0084	0.0390	-0.0617	-0.0441	-0.0454	0.0140	0.0678	0.0553	1.0000	
(11) Political party	0.0184	0.0140	0.0701	0.0180	-0.0009	-0.0877	-0.0233	0.0075	0.0262	0.1145	1.0000
						Second Survey					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
(1) Biogas awareness	1.0000										
(2) Participatory process	0.0059	1.0000									
(3) Rurality	-0.0437	0.0302	1.0000								
(4) Family size	-0.0249	0.0252	-0.0014	1.0000							
(5) Female	-0.1069	0.0142	0.0002	0.0392	1.0000						
(6) Age	-0.1052	0.0378	-0.0075	-0.0699	0.0256	1.0000					
(7) Human capital	0.1407	-0.0536	-0.1197	-0.0348	0.0322	-0.1085	1.0000				
(8) Employed	0.1286	-0.0511	-0.0566	0.0419	-0.1609	-0.4374	0.1850	1.0000			
(9) Environmental assoc.	0.0653	-0.0024	0.0151	-0.0293	-0.0345	-0.0584	0.1436	0.0934	1.0000		
(10) Political party	-0.0019	0.0054	-0.0285	-0.0185	-0.0810	-0.0251	0.0107	0.0553	0.0739	1.0000	-

The aforementioned results provide at least four important pieces of evidence. First, defining biogas acceptability is pivotal to discriminating between the effects on the community and individuals. In fact, even if it is possible to recognize benefits for society as a whole, negative effects on the people living in the surrounding areas are critical. Second, the higher the degree of biogas knowledge, the higher the degree of acceptability of biogas production. Thus, according to this evidence, an informative campaign on the biogas production process would be relevant for increasing the acceptability of the construction of new biogas plants and for reducing potential protests in areas of interest. Third, the acceptability of biogas does not heavily depend on other socio-economic and demographic variables; rather, it is primarily based on prior knowledge of the production process. Fourth, people who live in rural areas are more likely to accept the biogas plant, which is associated with the closest proximity to the biogas plant (which are typically built in rural areas and next to other agricultural activities) but also on a better knowledge of the pros and cons of biogas plants, and it is a vital component of many farms.

Overall, this evidence highlights how informed people might be more aware of the potential negative and positive impacts of biogas energy production, which is even more important when discriminating between collective and individual effects. Thus, these preliminary results highlight the need to spread knowledge on biogas to improve the degree of acceptability. The participatory process might be essential for increasing the amount of knowledge for the involved communities, which is why two different waves (the first in January 2018 and the second in June 2018) were implemented in the second step of the empirical process.

3.2 Second set of surveys: assessment of participatory processes

Table 4 shows the results of a pooled OLS that considers whether the respondents are from the first or second waves by including the dummy *Participatory process*, which assumes a value of 1 if the respondents are those of the second wave. This process allows for the consideration of the role played by the public participatory process and the public campaigns on the construction of two large biogas plants in Arborea (Sardinia) and Andria (Apulia), with the aim of analysing the potential impact of this informative campaign on local actor perceptions and decisions.

Three biogas ‘acceptability indicators’ are set: the collectivity impact, which assumes a value of 1 if the respondents answer that they believe that biogas plants have positive impact on the society and 0 otherwise (column 1); need for incentivization impact among individuals living next to a plant who negatively answered the first question, which assumes a value of 1 if the answer is no (column 2); and a biogas acceptability composite indicator, which is set analogously to that in Section 2.

Biogas awareness shows similar results to that in Table 3. In detail, it is interesting to note that biogas awareness is significantly positively correlated with the belief that biogas plants have positive impacts on collectivity, and this result is robust after specifically including a local specification for the construction of a hypothetical new plant in the local area of the respondents in the second survey. Nonetheless, higher awareness of biogas production is still negatively correlated with the need to compensate individuals living next to biogas plants. However, it is possible to recognize a positive correlation between awareness and degree of acceptability of the biogas plant, as shown in Column 3.

An analysis of the role of the participatory process shows that people who have participated in the second wave of the second survey, which occurred after the public informative campaign on the biogas production process, indicated that individuals living in the area around biogas plants need to be compensated. This result is thus in line with the results of the first survey, where knowledge of the construction of new plants was at stake. Thus, the informative campaign and participatory process do not appear to change the beliefs of the involved people. Regarding the other control variables, the degree of rurality does not show significant results as observed in the former survey, while being female and employed are negatively correlated with the level of biogas acceptability.

Overall, the results of the integrated surveys in this second step indicate that when assessing biogas acceptability in a given territory, it is pivotal to discriminate between effects on the community and effects on individuals. After informative campaigns, individuals still recognize the benefits for society, even if we do not show any significant impact on the increase in biogas acceptability when we consider the impact on individuals living close to these plants.

Therefore, economic incentives, such as compensatory measures and information provisioning, are levers that can increase awareness and support by local communities. These are marginal investments and measures that may increase the role of stocks of knowledge, such as the existing knowledge (human capital) a territory possesses based on the historical accumulation of capital.

Table 3. Results of the OLS estimation for the first survey

	(1)	(2)	(3)	(4)
	Positive Impact	Negative Impact	Individual Impact	Acceptance
Biogas knowledge	0.0690***	-0.00882	-0.0258**	0.0344*
	(0.00967)	(0.00963)	(0.0113)	(0.0179)
Plant project	0.00307	-0.115***	-0.0357	-0.148**
	(0.0316)	(0.0416)	(0.0424)	(0.0702)
Participation	-0.0625	-0.0654	0.0694	-0.0585
	(0.0717)	(0.0881)	(0.0945)	(0.174)
Rurality	-0.00847	0.0202	0.0457**	0.0574*
	(0.0154)	(0.0167)	(0.0190)	(0.0307)
Family size	0.00976	0.0155	-0.0161	0.00921
	(0.0124)	(0.0128)	(0.0148)	(0.0234)
Female	0.00360	0.0254	-0.0108	0.0182
	(0.0271)	(0.0284)	(0.0334)	(0.0539)
Age	-0.00103	0.000696	0.000593	0.000258
	(0.000797)	(0.000874)	(0.00106)	(0.00159)
Human capital	0.0526*	0.00546	-0.0418	0.0162
	(0.0277)	(0.0322)	(0.0370)	(0.0622)
Employed	0.00587	0.0136	-0.00636	0.0131
	(0.0276)	(0.0298)	(0.0350)	(0.0574)
Environmental assoc.	-0.00140	-0.0129	0.00475	-0.00960
	(0.0478)	(0.0552)	(0.0603)	(0.108)
Political party	-0.00811	-0.00274	-0.142*	-0.153
	(0.0794)	(0.0820)	(0.0782)	(0.174)
Constant	0.670***	0.648***	0.426***	2.744***
	(0.0789)	(0.0894)	(0.104)	(0.157)
Andria Dummy	-0.0434	0.0587**	-0.0758**	-0.0604
	(0.0270)	(0.0291)	(0.0334)	(0.0540)
R^2	0.0156	0.0932	0.0302	0.0258
F	1.103	7.450	2.077	2.341
N	932	932	932	932

*, **, *** significance at 10%, 5% e 1%. Robust S.E. in parenthesis

Table 4. Results of the OLS estimation for the second survey

	(1)	(2)	(3)
	Collectivity Impact	Individual Impact	Acceptability
Biogas awareness	0.159***	-0.0623***	0.264***
	(0.0103)	(0.0194)	(0.0193)
Participatory Process	0.00970	-0.0770*	-0.0182
	(0.0229)	(0.0448)	(0.0423)
Rurality	0.0190	-0.0367	0.0239
	(0.0126)	(0.0249)	(0.0236)
Family size	-0.0124	-0.00649	-0.0255
	(0.0102)	(0.0199)	(0.0190)
Female	-0.0592***	0.0266	-0.0966**
	(0.0228)	(0.0449)	(0.0427)
Age	0.000574	0.00130	0.000867
	(0.000823)	(0.00166)	(0.00155)
Human capital	0.0129	-0.0223	0.0171
	(0.0267)	(0.0548)	(0.0506)
Employed	-0.0355	-0.108**	-0.0947**
	(0.0252)	(0.0500)	(0.0476)
Environmental assoc.	-0.0465	0.0281	-0.0761
	(0.0436)	(0.0924)	(0.0819)
Political party	0.0237	-0.00931	0.0413
	(0.0564)	(0.131)	(0.108)
Constant	0.305***	0.482***	0.871***
	(0.0784)	(0.149)	(0.148)
Andria Dummy	0.0793***	0.0356	0.156***
	(0.0228)	(0.0468)	(0.0422)
R^2	0.154	0.0676	0.127
F	26.70	2.596	21.51
N	1553	426	1553

*, **, *** significance at 10%, 5% e 1%. Robust S.E. in parenthesis

4 Conclusions

The paper provides some insights into the social acceptability of biogas plants and renewable energy processes that present general costs and benefits. A survey-based multistep empirical framework is proposed as a tool to analyse knowledge and awareness. The surveys can be integrated within the citizen engagement process that shares and discusses the costs and benefits with the population and stakeholders. In this case, we propose embedding the participatory process and information campaign within a set of surveys to assess the ‘value of information’. The surveys themselves act as part of the participatory process, and they are strongly interrelated with information campaigns and bottom-up democratic participation and citizen engagement. These surveys can also complement contingent valuation or choice modelling exercises that estimate willingness to pay and accept in broad multi-disciplinary frameworks. First, the analysis confirms the value of information and knowledge, although more details are offered by the rich dataset and the multivariate analysis. A fair outcome is that the higher the degree of biogas knowledge, the higher the degree of acceptability of biogas production. The acceptability of biogas does not heavily depend on other socio-economic and demographic variables but mainly relies on prior knowledge of the production process. Moreover, assessing biogas acceptability is pivotal to discriminating between the effects on the community and effects on individuals.

Other main results of the empirical exercise are that people who participate in multistep surveys integrated with public informative campaigns on the biogas production process tend to support compensation for individuals living in the area around biogas plants. At least in this case, informative campaigns and participatory processes seem to have no impact on changing the beliefs of the people involved. Taking stock from the evidence, it may be appropriate to implement a system to incentivize the social acceptability of biogas plants by households through better institutional communication or through the provision of discounted prices for energy and heat through a system of coupons and/or discounts on electricity bills.

In this pandemic crisis period, a broader message is related to the value of information provision and citizen engagement, especially for public goods whose costs and benefits are not fully clear to the population based on standard media information. The message is reinforced for those environmentally and health-related public goods that are managed at decentralized levels.

References

[1] Akerlof, G.A. and W.T. Dickens (1982): “The economic consequences of cognitive dissonance”, The *American Economic Review*, 72(3), 307-319.

[2] Bell, D., Gray, T., & Haggett, C. (2005). The ‘social gap’in wind farm siting decisions: explanations and policy responses. *Environmental politics*, 14(4), 460-477.

[3] Cainelli, G., D’Amato, A., Mazzanti, M. (2020). Resource efficient eco-innovations for a circular economy: Evidence from EU firms. *Research Policy*, 49(1), 103827.

[4] Cheng, S., Li, Z., Shih, J., Du, X., Xing, J. (2011). A field study on acceptability of 4-in-1 biogas systems in Liaoning Province, *China. Energy Procedia*, 5, 1382-1387.

[5] Clinch, J., Murphy, A. (2001). Modelling winners and losers in contingent valuation of public goods: appropriate welfare measures and econometric analysis. *The Economic Journal*, 111(470), 420-443.

[6] Corsini, F., Certomà, C., Dyer, M., & Frey, M. (2019). Participatory energy: Research, imaginaries and practices on people' contribute to energy systems in the smart city. *Technological Forecasting and Social Change*, *142*, 322-332., Vol. 142, pp. 322-332.

[7] Dobers, G. M. (2019). “Acceptance of biogas plants taking into account space and place”. Energy Policy,135, 110987.

[8] EEA, (2019). Paving the way for a circular economy: insights on status and potentials. European Environment Agency. EEA Report n. 11/2019, retrieved on 31/12/2020 at https://www.eea.europa.eu/publications/circular-economy-in-europe-insights

[9] EEA, (2020). Sustainability transition in Europe in the age of demographic and technological change. European Environment Agency. EEA Report n. 23/2020, retrieved on 31/12/2020 at: https://www.eea.europa.eu/publications/sustainability-transition-in-europe

[10] EMF, (2019). Completing the Picture: How the Circular Economy Tackles Climate Change. Ellen MacArthur Foundation (2019), retrieved on 31/12/2020 at: https://www.ellenmacarthurfoundation.org/publications/completing-the-picture-climate-change

[11] Emmann, C. H., Arens, L., Theuvsen, L. (2013). Individual acceptance of the biogas innovation: A structural equation model. *Energy Policy*, 62, 372-378.

[12] Kim, H. Y., Park, S. Y., Yoo, S. H. (2016). "Public acceptability of introducing a biogas mandate in Korea: A contingent valuation study". *Sustainability*, 8(11), 1087.

[13] Kortsch, T., Hildebrand, J., Schweizer-Ries, P. (2015). Acceptance of biomass plants–Results of a longitudinal study in the bioenergy-region Altmark. *Renewable energy*, 83, 690-697.

[14] Modica, M. (2017). Does the construction of biogas plants affect local property values?. *Economics Letters*, 159, 169-172.

[15] Ozdemiroglu, E., Hails, R. (2016), Demystifying Economic Valuation, Ozdemiroglu, E., Hails, R. (eds), 2016. Valuing Nature Paper VNP04.

[16] Radics, R. I., Dasmohapatra, S., Kelley, S. (2015). Systematic review of bioenergy perception studies. *BioResources,* 10(4), 8770-8794.

[17] Santagata, W., Signorello, G. (2000). Contingent valuation of a cultural public good and policy design: The case of``Napoli musei aperti". *Journal of cultural economics*, 24(3), 181-204.

[18] Schumacher, K., Schultmann, F. (2017). Local acceptance of biogas plants: a comparative study in the Trinational Upper Rhine Region. *Waste and biomass valorization*, 8(7), 2393-2412.

[19] Soland, M., Steimer, N., Walter, G. (2013). Local acceptance of existing biogas plants in Switzerland. *Energy Policy*, *61*, 802-810.

[20] Van der Horst, D. (2007). NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies. *Energy policy*, *35*(5), 2705-2714.

[21] Warren, C. R., Lumsden, C., O'Dowd, S., Birnie, R. V. (2005). 'Green on green': public perceptions of wind power in Scotland and Ireland. *Journal of environmental planning and management*, 48(6), 853-875.

[22] Zemo, K. H., Panduro, T. E., Termansen, M. (2019). Impact of biogas plants on rural residential property values and implications for local acceptance. *Energy policy*, *129*, 1121-1131.

[23] Zoboli, R., Nicolò, B., Ghisetti, C., Giovanni, M., Paleari, S. (2019). Towards an Innovation-Intensive Circular Economy. Integrating Research, Industry and Policies available at

https://www.feem.it/it/pubblicazioni/reports/towards-an-innovation-intensive-circular-economy-integrating-research-industry-e-policies/