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Summary:

Despite the potential benefits of anaerobic digestion in the context of climate change and the need to move towards energy transition, there is a lot of resistance to biogas projects. Using a contingent valuation method, we test the extent to which the socio-economic characteristics of populations influence the environmental effort that people are willing to make for the deployment of biogas in a French region. Our results show that young people and people familiar with the biogas process are more inclined to develop biogas. We also highlight that the educational and location aspects should not be neglected in order to increase environmental effort and promote the adoption and development of biogas.

Keywords:

Biogas, anaerobic digestion, socio-economic characteristics, environmental effort, contingent valuation, social acceptability

1. Introduction

The public's growing interest in fighting environmental degradation and the pressure on governments to set ambitious targets to combat global warming are at the heart of the matter. In addition, new issues are being raised concerning (i) the reliability of supply, (ii) the energy autonomy of territories and (iii) the rising prices of fossil fuels (oil, coal and natural gas). The recent crisis in Ukraine is a good example of how the dependence of states on one supplier can pose great difficulties from a geopolitical, energy and economic point of view. In view of the climate emergency (UN, 2022; IPCC, 2022), the European Union has taken up these challenges and has put in place a number of policies such as the Green Deal¹, which aims to achieve carbon neutrality by 2050, to ensure economic growth that is decoupled from resource use. More recently, the Commission has presented a new plan, called REPowerEU², to rapidly reduce the EU's dependence on Russian fossil fuels, especially gas, and to fight the climate crisis. The plan proposes a specific action plan for biomethane³ which sets out tools such as a new industrial partnership for biomethane and financial incentives to increase production to 35 billion m³ by 2030. In France, biogas represents 1,1% of renewable energy consumption in 2018 and its development potential is very high⁴.

However, these alternative energies to fossil fuels are not without challenges that need to be addressed, even though there is increasing policy support (Bourdin and Nadou, 2020; Robyns et al., 2021). For biogas, Brémond et al. (2021) identified technological issues (such as the use of waste and crops in production) but also environmental (such as CO₂ recovery) or economic challenges (such as reducing production costs). Another challenge concerns the problems of social acceptability (Schumacher et al., 2019). The question of their appropriation and the cooperation of the public is indispensable. Therefore, it is necessary to improve the social acceptability of these energies if the energy transition is to be successful.

Social acceptability can be defined as the public's approval of a certain policy (Fournis and Fortin, 2017). Wüstenhagen et al. (2007) distinguished between global or general acceptability and local acceptability. Applied to the energy transition, the public may be generally in favour of its deployment but refuse to allow it to take place close to their homes. For example, in France, a recent French Institute of Opinion survey⁵ shows that the French are very much in favour of the energy transition, and six out of ten even think that it is not going fast enough in our country. However, even if it is popular at the national level, it can be the subject of very strong opposition when it comes to setting up a renewable energy project near the inhabitants. The literature on "not in my backyard" (NIMBYism)⁶ is extensive on this subject, but

¹ https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

² https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowerEU-affordable-secure-and-sustainable-energy-europe_en

³ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A230%3AFIN&qid=1653033922121>

⁴ https://www.senat.fr/fileadmin/Fichiers/Images/redaction_multimedia/2021/2021-Documents_PDF/20211005_MI_Methanisation_dossier_de_presse.pdf

⁵ <https://www.ifop.com/publication/les-francais-et-les-energies-renouvelables-3/>

⁶ The principle of NIMBY can be defined according to Lake (1996) as a syndrome in which people oppose facilities with negative externalities only because they are built in their immediate vicinity. These nimbysites are then

researchers have also shown the limits of this approach by highlighting that other factors could explain this reticence (or even resistance) to renewable energy projects at the local level (i.e. Devine-Wright, 2005; Bourdin et al., 2020).

Several theories have traditionally been mobilised to explain greater or lesser local acceptability. Among them are those relating to environmental justice (Gross, 2007; Upham et al., 2015; Devine-Wright et al., 2017; Gaede and Rowlands, 2018) or contextual and territorial effects (Devine-Wright, 2009; Fournis and Fortin, 2017; Bourdin et al., 2020). However, to our knowledge, the theory of environmental effort developed in sociology has not been mobilised, even though it is useful for analysing these issues of social acceptability. Environmental effort can be defined as a voluntary or spontaneous contribution to the protection of the environment, the consequences of which (limitation of access to the resource, changes in practices, negative externalities, financial costs, etc.) are unequal depending on the population or social group (Deldrève and Candau, 2014). However, one of the aims of the energy transition is to protect the environment, and it generates consequences (particularly in terms of negative externalities) that are not equally distributed in space. In particular, people located nearby tend to suffer more externalities than people living far away from renewable energy installations (Fast, 2013); therefore, they do not want such infrastructures close to their homes (Faulques et al., 2022). Thus, it is possible to link issues of local social acceptability to an environmental effort that people are willing to make to protect the environment. Consequently, this environmental effort will be all the more important the more people consider that the installation of renewable energy is worthwhile.

In this context, the objective of our article is to mobilise the theory of environmental effort to analyse the social acceptability of renewable energy projects. [More specifically, we take the example of biogas because recent studies have shown that local opposition can explain limited development in the territory \(Kim et al., 2016; Lee et al., 2017; Thapa et al., 2021; Bourdin et al., 2020\).](#) In the literature, only a few studies have attempted to estimate the acceptance of biogas units by local populations. In this context, we contribute to the literature by assessing the level of acceptance of biogas, as measured by the contingent valuation method. These estimates allow us to evaluate the extent to which the socio-economic characteristics of the population explain their environmental effort. Our study is based on a sample of 394 people surveyed in a French region.

The remainder of this document is structured as follows. Section 2 reviews the previous literature on the social acceptability of biogas and the environmental effort framework. The third part presents the methodology of the study, and the results are presented in Section 4. Finally, the last section concludes with a discussion of the policy implications of this study.

2. Literature review

labelled as selfish (do not take into account the common good and general interest), irrational (react emotionally and not rationally), ignorant (are not able to understand the need to build such facilities).

After presenting the approaches applied to analyse barriers and drivers for the deployment of biogas technology from a theoretical point of view, we propose a review of the empirical studies that have examined the question of the perception of biogas projects.

2.1. Explaining the greater or lesser acceptance of the biogas deployment

Several studies have highlighted that anaerobic digestion is generally considered a virtuous energy production technology from an environmental point of view (Hijazi et al., 2016). It is an activity based on the reuse of biomass waste in the broadest sense, including agro-industrial waste (e.g. manure, green waste, food residues, etc.) and/or wastewater treatment plants (industrial and municipal wastewater). Thus, waste becomes a resource for producing energy (in co-generation [electricity + heat] or gas). In addition, part of the digestate (the residue from anaerobic digestion) can be used to fertilise agricultural soils. Recent studies also show that biogas technology has environmental benefits related to the reduction of nitrogen leaching from manure to local water bodies (Nayal et al., 2016; Wang et al., 2021). Biogas also creates new value and maintains agricultural activity through the income it can provide to farmers (Berthe et al., 2018). Niang et al. (2022a & b) highlighted the dynamics of territorial anchoring that biogas can generate. Indeed, it is an energy that intrinsically uses local resources (material and immaterial) to be produced. With biogas, we move from centralised energy production to decentralised energy production. From this point of view, it can also be conceived of as a means of achieving autonomy and energy security in the territories where it is implemented. In this way, biogas produces positive externalities and can generate new opportunities, particularly for rural areas.

Despite these positive elements and the role of biogas in climate change mitigation strategies, it can give rise to protests due to negative externalities (real or perceived) (Bourdin et al., 2020). Based on a lexicometric analysis of press articles, Bourdin et al. (2020) highlighted the main elements claimed by opponents. Among the costs mentioned are odour emissions, the increase in truck traffic (linked to the regular supply of biomass to the biogas plant) and, to a lesser extent, visual pollution, noise pollution and industrial risk. These authors mobilise theories related to environmental justice to explain what they observe. More specifically, some authors have also mobilised theories of procedural justice to show that, in certain projects, the transparency and quality of the information received during public meetings and the very organisation of the consultation process could be the source of tensions (Martin, 2013; Capodaglio et al., 2016; Schumacher and Schultmann, 2017; Bourdin, 2020a). Finally, based on the theoretical framework of distributive justice, it has also been pointed out that local populations could be resistant to the implementation of a biogas unit because the distribution of benefits (positive externalities) and costs (negative externalities) is not fair/equitable (Soland et al., 2013; Damgaard et al., 2017; Bourdin, 2020a). These authors concluded that in the presence of significant negative impacts on local populations, it is desirable to avoid (or at least reduce) costs. If this step is insufficient, it is possible to design incentives to compensate for the inhabitants directly affected by negative externalities.

However, these factors alone do not explain why biogas projects are sometimes rejected at the local level. Other socio-cultural and psychological factors have been identified that are identical to those observed for other renewable energies, such as wind power (Wolsink, 2007; Devine-

Wright, 2011; Soland et al., 2013; Bourdin, 2020b). In this case, beyond the NIMBYist (selfish) attitude that some local residents may have, several authors have highlighted that attachment to the place (Soland et al., 2013; Dobers, 2019; Bourdin, 2020a; Bourdin et al., 2020) could explain the disputes.

Finally, since we observe a global acceptability of the energy transition but problems of local acceptability, it is possible to mobilise the theory of environmental effort to explain why some citizens are more inclined than others to accept the deployment of renewable energy. Several factors have been put forward in the literature on this issue, such as knowledge of the issues involved in the ecological transition in general, as well as knowledge of the green technology in question (Robyns et al., 2021; Faulques et al., 2022), the calculation of economic benefits and costs (Sidhu et al., 2018), the level of education and income or demographic factors (Haller and Hadler, 2011; Gingrich et al., 2018). Generally speaking, these studies show that environmental effort is lower among people with fewer diplomas and no knowledge of the issues involved in the ecological transition, as well as among people with lower incomes. These people are also less inclined because they believe that their lifestyle is less “greedy” than that of richer people and that, therefore, it is they who should pay. From an environmental justice perspective on energy transition issues at the local level, it is plausible that citizens with less education and lower incomes are more opposed to the possible environmental efforts that they would have to make. This is because their economic cost–benefit calculation would be to their disadvantage, and they cannot afford any possible increase in energy costs resulting from the greater use of renewable energy (Marquart-Pyatt et al., 2019).

2.2. Empirical studies on the perception of biogas projects by the population

Here, we return in more detail to empirical studies based on surveys of the population concerning biogas projects. To our knowledge, the literature has partially covered the social acceptability of issues related to the implementation of units (Dobers, 2019) and does not highlight which types of populations are more inclined to favour biogas deployment.

Based on a survey of 502 residents of biogas plants in Switzerland, Soland et al. (2013) measured the perceived benefits and costs of biogas production. They estimated a structural equation and showed that odour perception increases perceived costs and reduces perceived benefits and trust. These perceived negative externalities can be counterbalanced by good project information. On the other hand, they showed that the participation of citizens (consultation workshops) in the development of the project did not have a significant effect.

In a more recent study, but using the same method, Dobers (2019) conducted an online survey in Germany, interviewing 942 people, and found that spatial variables (distance from the unit to the first houses and density of units) influenced social acceptability. In his paper, Dobers (2019) also showed that the level of acceptability remains lower compared to other renewable energy sources, such as wind turbines or photovoltaics. Kortsch et al. (2015) investigated social acceptability in a sample of 423 people interviewed between 2009 and 2011 (longitudinal study) in the Altmark region of Germany. The particularity of this region is that it has concentrated a large number of units for several years. Kortsch et al. (2015) observed that acceptability remained constant and high over time. This refers to the local context and the

positive past experiences that citizens have had with the implementation of units. Similar to the findings of Soland et al. (2013), the results presented the role of the quality of information and knowledge as positive drivers influencing the social acceptance of biogas projects.

In the above-mentioned studies, the authors did not look at socio-economic characteristics as an explanatory factor for greater or lesser social acceptability. These studies provide useful elements for a better understanding of the greater or lesser social acceptability of biogas. However, a comparison of the studies shows that the factors influencing acceptability can vary, and some are not always significant. Some researchers have attempted to estimate social acceptability in monetary terms (Kim et al., 2016; Lee et al., 2017; Thapa et al., 2021). This is known as WTP.

In their study of 1000 Koreans, Kim et al. (2016) concluded that gas consumers are willing to take on a financial share of the expansion of biogas use. An important contribution was made by Lee et al. (2017), who estimated the degree of support and opposition of local people to the construction of a biofuel plant in Michigan, USA. Their contingent valuation study, based on a sample of 1,013 residents surveyed, showed that, on average, a supporter of biodiesel would be willing to pay \$59.16 to support the establishment of a plant in his or her area, whereas an opponent of biodiesel would be willing to pay \$95.74 to prevent such a plant from being established in his or her neighbourhood. The most recent work on the subject is that of Thapa et al. (2021), who used a contingent model based on a sample of 800 rural Nepalese households.

They show that households are willing to pay an average of US\$361.54 for a micro biogas digester, which is lower than the full market price of US\$433.79 but higher than the current market price net of government subsidy (environmental income provision). In these different works, the authors do not distinguish how WTP varies with the socio-economic characteristics of local populations.

Given the small number of publications studying the economic evaluation of local residents' support or opposition to biogas plants and the divergent results, there is a need for more empirical evidence on the social acceptability of projects and, in particular, to identify the extent to which certain types of population are more likely than others to approve biogas projects.

3. Methodology

Our study is based on the contingent valuation method. Within the framework of our analysis, it consists of making the citizens of [a French region \(Upper-Normandy\)](#) reason about their preferences in terms of renewable energies and, more precisely, concerning photovoltaic panels, wind turbines and biogas. More specifically, it is a question of proposing an empirical framework that makes it possible to justify the merits or otherwise the use of biogas as a public good in the energy transition.

3.1. Contingent valuation method

Our investigation is based on the implementation of a contingent evaluation method (CEM). It is based on a cost-benefit analysis (CBA), which measures, according to utilitarian criteria, the

monetary value of a non-market public good. The method was developed by economists with the main objective of a CBA of natural resources. The US government⁷ has strongly developed environmental assessment methods, especially the CEM. The first application of contingent valuation can be attributed to Siegfried Von Ciriacy-Wantrup (1947), who investigated the measurement of the benefits of soil protection against erosion. The first real contingent valuation study is attributed to Robert Davis (1963), which concerned the recreational value of forests in Maine (USA). As Sébastien Terra (2005) pointed out, the method was first developed 'to measure the recreational benefits of using a natural area' (p. 3). As early as the 1960s, environmental activists applied the CEM and gave it visibility and even credibility (Claeys-Mekdade et al., 1995). Later, it was used to assess environmental risks and damages (Venkatachalam, 2004; Kim et al., 2016; Koto and Yiridoe, 2019). It also led to its use in the 1980s in the US courts in the context of the *Comprehensive Environmental Response, Compensation and Liability Act*.

Through it, we seek to calculate how much individual citizens are prepared to pay *ex ante* (the WTP⁸) for a given (hypothetical) modification of a public good under income constraints. The approach adopts the Hicksian concept of constant utility: the reference utility levels are defined on the basis of (U_0) and (U_1).

This gives the case of an environmental quality improvement:

- the (compensatory) WTP is the monetary equivalent that makes the individual indifferent (to his initial situation) to the idea of accepting the improvement of Z_0 in Z_1 : $U_0(R - WTP, Z_1) = U_0(R, Z_0)$;
- the consent to receive (CtR) (equivalent) is the monetary equivalent that makes the individual indifferent (in his final situation) to the idea of not benefiting from the improvement Z_0 in Z_1 : $U_0(R + CtR, Z_0) = U_1(R, Z_1)$.

This gives the case of a deterioration of an environmental quality:

- the (compensatory) WTP is the monetary equivalent that makes the individual indifferent (to his initial situation) to the idea of accepting the deterioration of Z_1 in Z_0 : $U_0(R - WTP, Z_1) = U_0(R, Z_0)$;
- the CAR (equivalent) is the monetary equivalent that makes the individual indifferent (in his final situation) to the idea of not benefiting from the deterioration of Z_1 in Z_0 : $U_0(R + CtR, Z_0) = U_1(R, Z_1)$.

The correct measures of the change in utility are the compensating WTP or CtR, whether for improvement or deterioration. The advantage of this interpretation is that it shows that WTP is based on the analysis of substitution relationships between income and the quality of a non-market good. Thus, in the CEM, the utility (U) of an individual depends on two types of goods, market goods represented by $X = (x_1, x_2, x_3, \dots, x_k)$ and Z , which represents the quality of an environmental good. [This relationship has been developed in the environmental field, but it](#)

⁷ The federal Environment Protection Agency was involved in the development of the CEM.

⁸ Equivalently, we can also speak of the *Consent to Receive* (CAR): "Willingness to accept", how much would the individual have to give to compensate for the decrease of a good?

can be applied in other fields. For example (Rizzi and Ortúzar, 2006) analyzed the quality of safety on a road is a public good. The public decision-maker may wish to upgrade road facilities to save human lives. In the case of improving the quality of road services offered. In that case, WTP can therefore be defined as the decrease in revenue to obtain an improvement in the quality of road services.

The method is described as 'contingent' since it proposes a hypothetical scenario, 'a fictitious market'. The latter must correctly describe the good to be evaluated in order to gather the respondents' preferences. Using a questionnaire, a sample of individuals is asked a hypothetical question that allows them to decide whether or not to accept paying for the good being valued. The success of a contingent survey depends on respect for certain rules. For the relevance of the questionnaire, it is essential to define the context of the study so that the monetary measures of the contingent survey are valid: the characteristics of the good being valued, the scope chosen and the type of population surveyed.

Despite the recommendations of the National Oceanic and Atmospheric Administration (NOAA) Panel,⁹ the method suffers from numerous biases and methodological limitations that reduce the reliability of the results. The main criticisms relate to the collection and interpretation of the data and, in particular, the difficulty of placing individuals in a hypothetical situation that accurately reflects what the individual is thinking (Venkatachalam, 2004). Despite the criticism, proponents of the CEM recommend its use as a tool to support public decision-making (Cuccia, 2020). The hypothetical situation requires methodological *devices* that allow people to express themselves in a market context. Moreover, each step must be conducted rigorously to ensure the validity of the results. This method relies on the quality of the questionnaire. The construction of this survey instrument is the central stage of the approach. It must formulate, around a series of clearly defined questions, all the information on the public good whose monetary value is to be defined (Chassy, 2015). The estimation of the value is based on a survey of opinions (or preferences) using a representative sample of the population (individuals or households) who are asked to answer the questionnaire. After explaining and valuing the changes that would affect the good, the scope of the study and the reference population must be determined.

Next, a questionnaire should be developed, first setting out the context and objectives of the study. Next, it should describe the hypothetical scenarios and payment conditions that constitute preference revelation. The preference-revealing technique can then vary: tax surcharge, local tax surcharge, entrance fee, parking fee, water bill (electricity, ...), transport cost surcharge and donation to a specific fund (Adamowicz et al., 1994).

3.2 Study area, survey data and proposed scenarios

For our study, we focused on the Upper-Normandy region. This region is representative of the French energy mix as it includes nuclear power plants as well as renewable energies such as

⁹ The Report of the NOAA Panel on Contingent Valuation was published in January 1993 in Federal Register 4601 (15 January 1993). The experts in charge of this expert work on the validity of the CME are: Kenneth Arrow, Robert Solow, Paul Portney, Edward Leamer, Roy Radner (economists) and Howard Schuman (sociologist) (all advocates of the method).

solar, hydrogen, onshore and offshore wind and biogas. It is also a region that is very committed to the energy transition (Dialga, 2021). From this study area, the aim was to evaluate the influence of renewable energy installations (and specifically the biogas) on citizen consumers in Upper-Normandy. The questionnaire was administered on a door-to-door (face-to-face) basis to 396 people. It took on average 30 minutes to answer the survey. The initial objective was to target 500 individuals. We had a reply of 402 people. Due to incomplete responses, this figure was eventually lowered to 396 questionnaires. To be sure that our sample is representative of the population, we compared the official population to the one of our sample. The representativeness rates of our sample are as follows (table 1): Female 1 and Male 1.01; Age: 20–64 and 1.10; 65 and over 1.03. For the socio-professional category: Employee, 1,05; Middle management, 0.93; Worker, 0.93; Craftsman, 1; Retired, 0.98). The rate for farmers could not be calculated, as no farmers responded to the survey. Overall, our sample is very close to the parent population determined by the National Institute of Statistics and Economic Studies (INSEE) in 2019. Nevertheless, we note that the occupational category "workers" is under-represented in our sample. To correct our sample according to the real characteristics of the population, we applied the quota method to the following three variables: gender, age and professions and socio-professional categories. The calculation method is based on the representativeness rate $(T) = (1 + \text{Survey rate}) / (1 + \text{INSEE rate})$ and states that if $T > 1.10$, there is over-representation in the sample, and if $T < 0.95$, there is under-representation. This method has traditionally been used to analyse the characteristics of respondents in relation to a parent population. Thus, the sample was corrected so that the structure of the parent population and the study sample were exactly the same.

Table 1 : Representativeness of the two samples in reference to the total population

Upper-Normandy - 2019 - Sample of 396 people						
			2019	2019	Mean	
		Sample	INSEE SM	INSEE Eure	INSEE	RESULTS
Gender	Woman	51,26%	51,90%	51,40%	52%	1,00
	Man	48,74%	48,10%	48,6%	48%	1,01
CSP						
Farmer	CSPA	0,00%	0,8%	0,6%	0,7%	0,00
Employee	CSPB	22,2%	16,5%	16,9%	16%	1,05
Middle management	CSPC	15,90%	20,3%	20,3%	20%	0,97
Worker	CSPD	7,30%	18,3%	14,70%	16%	0,93
Craftsman	CSPE	2,53%	3,4%	2,60%	3%	1,00
Retired	CSPF	24,24%	26,10%	27,60%	27%	0,98
Age						
	20-64 yo	74,24%	58,6%	57,8%	58,0%	1,10
	+65 yo	25,76%	22,9%	21,8%	22,0%	1,03

>1,10 Over-representation - <0,95 Under-representation

(INSEE is a statistic institute in France. SM and Eure are two departments of the Normandy. The numbers of these two departments represent the territorial population of the Normandy. Mean represent the national population in France).

The population sample collected in our survey has socio-economic and demographic characteristics that allow the contingent valuation questionnaire to be administered as the first step. The questionnaire consists of 81 questions and is divided into four parts: the individual's living conditions and geographical environment, the individual's level of knowledge of the energy transition, the choice of scenarios and finally the individual's socio-economic characteristics. The questionnaire must specify the "payment vector" which specifies in which form the payment will be made; here the payment vector is the increase of a few euros on the electricity bill depending on the amount of the bill. It indicates whether or not the citizen-consumers surveyed would be willing to increase the amount of their electricity bill in order to increase the share of renewable energy in the four hypothetical scenarios: three non-monetary and one monetary. The individual is asked to choose which of the four proposed scenarios best suits them. Thus, in our study, the following hypothetical question was asked: Choose the scenario that best suits you. Each is composed as follows: % share of wind power in electricity, % share of photovoltaics, % share of biogas and increase in kWh (in euro cents):

Box: Energy transition scenarios

For a better understanding, these scenarios are defined according to four attributes or characteristics regarding an energy mix in France. An attribute corresponds to the additional cost associated with each proposed scenario; this additional cost corresponds to an increase in the price of the kWh charged monthly. This increase in the price per kWh that was virtually charged to the interviewee corresponded to an automatically calculated increase in the price per kWh supplied by Edf (*Électricité de France* is a French electricity generating and supply company, more than 80% owned by the state). The different energy transition scenarios presented to the interviewees are derived from projections made by the *Réseau de transport d'électricité* in 2050 (French transmission system operator responsible for the public high-voltage electricity transmission network in France). Each scenario presented a possible energy mix including nuclear power, fossil fuel (natural gas, oil or coal), hydro, wind, solar and biogas. For our study, we only focused on the answers given by the interviewees on the share they were willing to allocate to biogas. In other words, we focus on the four scenarios proposed to the respondents corresponding to the share of electricity supplied from the biogas in the electricity they will consume. The first scenario corresponds to the status quo, *i.e.* the current situation without any increase in the price of the kWh (with a share of wind energy equal to 4.6%, photovoltaic equal to 0.5% and 1.1% for biogas). The second scenario corresponds to an increase from 1,1% to 4% in the energy mix; The third scenario corresponds to an increase from 1,1% to 10% in the energy mix; The fourth scenario corresponds to an increase from 1,1% to 12% in the energy mix. The last two scenarios are those that are the most favorable to biogas.

At the time of the interviews, the price of the kWh was 17.65-euro cents at peak hours. To make it easy for people to project their own electricity bill, we asked them how much money they were paying per month for electricity, and then automatically calculated bill increases according to the scenarios they chose. Thus, with this method, it was possible to calculate the environmental effort that people were willing to undertake to promote the increase of biogas in the French energy mix.

**The French energy mix consists of nuclear power (= 68%); fossil fuel power plants (natural gas, oil or coal = 8.5%); hydro (=13%); wind (7.9%); solar (=2.5%); biogas (1.1%).*

The final stage consists of identifying these preferences through an econometric analysis of the results. This data processing makes it possible to highlight the determining role of the responses made, particularly in the citizens' concerns regarding energy matters.

The econometric treatment was based on a probit model¹⁰ using closed questions. The model explains the probability of an event (qualitative dependent variable) based on a binary choice with two modalities (in real numbers)—yes or rather yes = 1 if agent *i* accepts and 0 in the case of refusal—as a function of explanatory variables. Non-responses were treated as missing data. This gives $\Pr(\text{choice } ij = 1) = f(X_{ij} \beta_j)$. It should be noted that function $f(\cdot)$, known as the “link function” in the context of generalised linear models, is the distribution function of a standard normal distribution (i.e. with mean zero and variance 1); its formula is as follows:

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{t^2}{2}} dt$$

The variables were grouped into three distinct blocks. These variables are traditionally used in the literature in the analysis of people’s WTP for renewable energies (see the literature review above). We thus distinguish (i) socio-demographic variables (gender, age, socio-professional category, income and level of education¹¹), (ii) living conditions and location (house, flat, homeowner, urban, peri-urban and rural) and (iii) cognitive variables (energy transition and gas production through biogas).

The coding consisted, within the framework of a probit-type methodology, of classifying the modalities of explanatory variables by choosing an omitted reference modality (ref). If we have a qualitative variable in two or three classes, one of its modalities must be omitted and the interpretation is always made in relation to this modality (table 2).

Table 2: Coding of explanatory variables

Variables	Meaning
<i>Socio-economic data of households</i>	
<i>Gender</i>	1 if individual <i>i</i> is female; 0 otherwise – Man (Ref)
<i>Urban</i>	1 if individual <i>i</i> lives in an urban area; 0 otherwise – Rural (Ref)
Aged 18–30	1 if individual <i>i</i> is aged between 18 and 30; 0 otherwise
Aged 45–60	1 if individual <i>i</i> is aged between 45 and 60; 0 otherwise
Aged 60 and over	1 if individual <i>i</i> is aged between 60 and +; 0 otherwise
Aged 30–45	(ref)
KnowlTransition	1 if individual has a good knowledge of energy transition <i>i</i> says Yes; 0 otherwise
KnowlBiogas	1 if individual has a good knowledge of biogas energy <i>i</i> says Yes; 0 otherwise

¹⁰ For the Probit: $P(Y=1 | X) = F(X'b)$, $F(\cdot)$ is the distribution function of a standard normal distribution. In the regression calculation, we voluntarily omitted the following two variables due to lack of observations: CSP (Farmer), (Suburban).

¹¹ For the level of education, see: https://publication.enseignementsup-recherche.gouv.fr/eesr/10EN/EESR10EN_Annexe_8-levels_of_educational_attainment.php

Owner	1 if individual <i>i</i> says Yes; 0 otherwise
Commercial	1 if individual <i>i</i> says Yes; 0 otherwise
Employee	1 if individual <i>i</i> says Yes; 0 otherwise
Intermediate	1 if individual <i>i</i> says Yes; 0 otherwise
Worker	1 if individual <i>i</i> says Yes; 0 otherwise
Framework	1 if individual <i>i</i> says Yes; 0 otherwise
Other	1 if individual <i>i</i> says Yes; 0 otherwise
No Activity	(ref)
Degree VIV	1 if individual <i>i</i> says Yes; 0 otherwise
Degree III	1 if individual <i>i</i> says Yes; 0 otherwise
Degree II and above	(ref)
Low Income	1 if individual <i>i</i> says Yes; 0 otherwise
Average Income	1 if individual <i>i</i> says Yes; 0 otherwise
High Income	(ref)

To estimate our four probit model equations, we proceeded in three steps (see Table 3): the use of the “Stepwise regression” method. In the first step, we integrated all the explanatory variables (x_1, x_2, \dots, x_k) (column 1) and in the second step, we eliminated one by one the least relevant explanatory variables (i.e. those whose significance was greater than 10% and the least significant of all). The stopping criterion is that the variables retained are all significant at the 10% threshold (column 2). To validate the models selected, we carried out an additional test for each dependent variable in the model. We then used the following two criteria: the Akaike information criterion (AIC) (Akaike, 1973) and the Bayesian information criterion (BIC) (Schwarz, 1978). The ‘best’ model is the one with the lowest AIC and BIC. When the addition of variables test was not significant at the 10% level, we kept the reduced model, as the eliminated explanatory variables were not significant overall at the 10% level. Finally, the marginal effects (ME - column 1 & 2) calculations of our global/initial and final probit models measure the effect of a change in one of the ‘regressors’ on the conditional mean of the variable to be explained (y).

This indicates whether the explanatory variables influence the probability of the event $y_i = 1$ upwards or downwards. This gives a good approximation of the amount of change in the probability following this change. When the explanatory variables are qualitative, the marginal effect is calculated as follows:

$$effet_k = \Phi(\bar{X}_1 \hat{\beta}_1 + \dots + \hat{\beta}_k + \dots + \bar{X}_k \hat{\beta}_k) - \Phi(\bar{X}_1 \hat{\beta}_1 + \dots + 0 + \dots + \bar{X}_k \hat{\beta}_k)$$

We find that, for the four scenarios, the different global/initial models (column [1]) the final models (column [2]) are globally significant and can be effectively retained following the elimination of the explanatory variables by “stepwise regression”.

In our study, we were unable to address the methodological biases debated in the literature, particularly hypothetical biases. This is a limitation. In this case, we followed Hensher’s (2010) recommendations: the results should be compared with previous studies that used a similar theoretical framework.

4. Results

4.1. An analysis of the one who are willing to make an environmental effort to promote biogas

The results of the four scenarios are shown in Table 3. The interpretation of the results is based on column 2 of each scenario, representing the highest significance level. First, we focus on the most favorable scenarios to biogas (scenario 3 and 4). In Scenario 3 (10%), we observe a positive and significant influence of the variable relating to people aged 18 to 30 years for an energy mix based on biogas (10% or more). Young people are ready to make an environmental effort by being prepared to pay 10% of the biogas share of their electricity bills. Our results corroborate, to a large extent, previous work on social acceptability and environmental effort. For example, as in the work of Karasmanaki (2021) or Faulques et al. (2022), we find a very strong generational effect. Young people are more in favour of the energy transition and are prepared to pay an increase in their electricity bills to promote the deployment of biogas. Awareness of the need to accelerate the transition is very strong in this age group, if the latest results of the Eurobarometer on citizen support for climate action¹² are to be believed.

For the scenario 3 (10%), we found that those who have already heard of the energy transition and those who say they know what energy production via biogas is tend to want to pay more on their energy bill to see this energy developed. This is in line with the work of Robyns et al. (2021) on the importance of knowledge of renewable energy in willingness to pay. These results also support those of previous studies on the social acceptability of biogas projects, such as those of Soland et al. (2013), according to which good knowledge of biogas has a positive effect on the feeling of environmental justice and, therefore, of social approval of this type of energy.

For Scenario 4 (12%) – which is the most oriented towards the deployment of biogas – people living in urban areas seem to be less in favour of a larger share of biogas in their electricity bill. It is in line with what has been demonstrated in the literature, namely that urban dwellers tend to promote the energy transition more, but not in their immediate environment (Batel, 2020). As in the previous scenario, the choice of this scenario reflects the importance of knowledge of energy transition and biogas production. Our results confirm the study by Faulques et al. (2022) according to which the level of knowledge of the energy transition and biogas determined the degree of social acceptance of renewable energies.

In our analysis, we also show that urban dwellers tend to favour the development of renewable energies, particularly biogas. Given that a large proportion of biogas plants are located in rural areas, it can be assumed that urban dwellers are less likely to have a NIMBYist attitude.¹³ Indeed, since they are located far away from the facilities and their potential negative externalities, they see fewer disadvantages in supporting a greater energy transition based on biogas. To our knowledge, no study has compared the differentiated preferences of urban versus rural dwellers regarding the deployment of biogas. From this point of view, this result

¹² https://ec.europa.eu/clima/citizens/citizen-support-climate-action_en

¹³ It should be noted that, to our knowledge, there is no article that has evaluated the rural/urban differences in terms of the NIMBY phenomenon.

discusses the literature on the importance of territorial characteristics in promoting social acceptability (Bourdin et al., 2020).

4.2. An analysis of the less favorable to the biogas deployment

We now focus on the most unfavourable to biogas in the energy mix, (scenario 1 and 2). First of all, the scenario 1 (1,1% – the status quo scenario – i.e.) is chosen very little by the interviewees (15% of our sample), indicating that most of the respondents wish to make an environmental effort and move towards an energy transition. For this scenario, we observe that homeowners, are not ready to pay for the energy transition and prefer to maintain the status quo. It can be assumed that the environmental effort required of them could affect the price of their property (if a renewable energy installation were to be installed close to their home) and that, consequently, they do not wish to make this effort. Finally, our results show that preferred owners are not ready to make an environmental effort. This supports the idea of the NIMBY phenomenon. As Bourdin et al. (2020) explain by mobilising the theory of proximity (Torre and Zuideau, 2009), on the one hand, and Hirschmann's model (1970), on the other, in a context where a landowner sees a project being set up close to his home, he will consider that he is subjected to this installation (subjugated geographical proximity) (he never asked to live next door). From then on, the owner has several options for action (exit, voice or loyalty). Since spatial exit is not possible (because it would mean selling his house at risk of selling it for less because of its proximity to the biogas unit (see Zemo et al., 2019), he has the choice between voice (confrontation) and loyalty (social acceptance). However, previous studies have shown that voice often prevails and materialises in local conflicts. Therefore, in a context where this potential proximity to a renewable energy installation is experienced, the people concerned consider it an environmental injustice and will not be willing to make an environmental effort

Our results also show that people with a low level of education tend to favour the status quo rather than the deployment of biogas. We can assume that these people are less sensitive to issues of climate change and ecological transition. For those with a low level of education, it is probably their lack of knowledge of the issues involved in the ecological transition that may explain why they are more reluctant to make an environmental effort. This is what Almulhim and Abubakar (2021) recently highlighted in their study on public environmental awareness. In fact, the environmental efforts of people who are unaware of ecological transition issues are low (Sidhu et al., 2018).

However, we observe a negative and significant effect of young people. We can interpret this result by the fact that youth reject this scenario of status quo because they want to accelerate the energy transition (Faulques et al., 2022). We also observe a negative and significant effect for blue-collar workers. In that case, the interpretation is different. These people are unfavourable to the status quo and generally do not want to pay for the energy transition (given their low income). This is also noted by Schlör et al (2013) in their study on blue-collar energy consumption.

In Scenario 2 (4%), only the variable relating to owners is negative and significant. As already shown in the literature on social acceptance of renewable energies, the homeowners are more

sensible to the NIMBY effect than tenants (Lake, 1996). The sign is then negative because they reject a scenario of (even a small) increase of the energy mix by biogas, fearing the negative externalities it could generate (Zemo et al., 2019; Faulques et al., 2022).

Table 3: Results of the estimation procedure for the three probit models

Variables	Scenario 1 – 1,1%				Scenario 2 – 4%				Scenario 3 – 10%				Scenario 4 – 12%			
	(1)		(2)		(1)		(2)		(1)		(2)		(1)		(2)	
		ME		ME		ME		ME		ME		ME		ME		ME
Home	-0,355	-0,056	-0,365*	-0,059*	0,179	0,07	-	-	0,177	0,029	-	-	-0,135	-0,047	-	-
Apartment	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
Urban	0,264	0,038	-	-	0,246	0,094	-	-	0,055	0,008	-	-	-0,330*	-0,121*	-0,300*	-0,11
Rural	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
Woman	0,164	0,026	-	-	0,1	0,039	-	-	-0,274	-0,044	-	-	-0,082	-0,029	-	-
Man	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
Age 18–30	-0,652**	-0,094	-0,782***	-0,114***	0,008	0,003	-	-	0,388	0,067	0,580**	0,112**	0,129	0,045	-	-
Age 45–60	0,034	0,056	-	-	-0,26	-0,099	-	-	-0,136	-0,02	-	-	0,282	0,102	-	-
Age 60+	0,226	0,039	-	-	-0,15	-0,058	-	-	-0,221	-0,032	-	-	0,032	0,011	-	-
Age 30–45	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
KnowlTransition	0,056	0,009	-	-	0,002	0,009	-	-	0,03	0,046	0,492**	0,076**	-0,153	-0,054	-	-
KnowlBiogas	-0,824**	-0,104	-0,843***	-0,110***	-0,057	-0,022	-	-	0,148	0,024	-	-	0,347**	0,126**	0,299**	0,108**
Owner	0,440**	0,076	0,470**	0,084**	-0,427**	-0,164	-0,408**	-0,158**	0,304	0,05	0,388**	0,070**	0,121	0,042	-	-
Commercial	0,401	0,083	-	-	-0,085	-0,033	-	-	-0,254	-0,034	-	-	-0,109	-0,037	-	-
Employee	-0,22	-0,033	-	-	0,047	0,018	-	-	-0,159	-0,023	-	-	0,161	0,057	-	-
Intermediate	0,34	0,066	-	-	0,16	0,063	-	-	-0,403	-0,05	-	-	-0,085	-0,029	-	-
Worker	-0,482	-0,059	-0,611*	-0,072*	0,243	0,096	-	-	-0,275	-0,037	-	-	0,14	0,05	-	-
Executive	-0,166	-0,024	-	-	0,407	0,161	-	-	-0,649	-0,07	-	-	0,101	0,036	-	-
No Activity	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
Degree VIV	0,598	0,089	0,798***	0,121***	0,124	0,048	-	-	-0,581	-0,102	-	-	0,164	0,057	-	-
Degree III	-0,194	-0,03	-	-	0,119	0,047	-	-	-0,382	-0,054	-	-	0,359	0,13	-	-
Degree II and above	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
Low Income	0,32	0,054	-	-	0,106	0,041	-	-	-0,38	-0,058	-	-	-0,134	-0,046	-	-
Average Income	0,382	0,064	-	-	0,131	0,051	-	-	-0,37	-0,057	-	-	-0,169	-0,058	-	-
High Income	(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)		(ref)	
Number of explanatory variables (k)																
(k)	20		6		20		1		20		3		20		2	
Number of observations (N)																
(N)	394		394		394		394		394		394		394		394	
Chi2	58,38%		47,70%		18,60%		9,71%		35,93%		15,73%		14,71%		7,28%	
AIC	307,05		289,56		560,47		532,38		288,94		268,83		513,02		486,32	
BIC	382,6		317,39		639,99		540,33		368,46		284,74		592,55		498,24	
Addition of variables test (Lr test H₀: Final model)																
Prob > chi2	88,86%				97,99%				75,10%				97,94%			
Chi2(k2-k1)	6,50%				7,91%				11,90%				7,30%			

5. Conclusion and recommendations

In a context where one of the main obstacles to the deployment of biogas is local opposition to biogas units, it is important to better understand the causes of these social acceptability problems. Until now, previous studies have focused on analysing local conflicts and the territorial governance of biogas projects without necessarily highlighting the extent to which the socio-economic characteristics of the population influence their level of acceptance for a greater energy transition based on biogas. It is in this context that our study focused, using the contingent valuation method, on a sample of 394 people interviewed in the Upper-Normandy region.

Our results show a strong generational effect, with young people being more favourable to making an environmental effort, thus confirming the recent work of Faulques et al. (2022). Similarly, the willingness to pay is higher for respondents who already know what biogas is. We also note that homeowners tend to favour a status quo scenario, which leaves little room for the deployment of renewable energy. The same is true for people with a low level of education, suggesting that these citizens are less inclined to favour biogas.

In light of our results, the question arises as to the importance of pedagogy in encouraging greater environmental effort. Indeed, in previous analyses of conflicts related to energy transition projects, the problem of informational justice and a lack of knowledge about renewable energies are major issues. Consequently, it would be useful for both project developers and political decision-makers to promote and raise awareness of (i) the issues related to climate change, (ii) the place of renewable energies in this context and (iii) the role of biogas in particular. This can be done through communication campaigns via social networks and various media but also by organising visits to biogas demonstration units, both in rural and urban areas. This will improve knowledge of biogas and awareness of its benefits, and increase the environmental efforts that people are willing to make.

As proposed by Batel (2020), future research on social acceptability and environmental effort could focus on analysing the discourse of stakeholders of different renewable energies (companies, citizens, local authorities, etc.) on social networks (Facebook, Twitter, etc.). To go further, one could test the extent to which social networks can influence environmental efforts via an analysis of inhabitants' WTP. Finally, the theory of environmental effort offers stimulating prospects, particularly through the mobilisation of the contingent valuation method.

The latter would make it possible to better understand the tension that exists between global social acceptability (people are willing to make an effort) and local opposition (people are not necessarily willing to make an effort, especially if they feel that they are victims of environmental injustice).

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