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METHODOLOGICAL REPORT ON THE SOCIO-ECONOMIC ANALYSIS

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1. Introduction

This report presents the elements needed to carry out socio-economic analyses of biogas and biomethane investments. The aim is to select instruments to be used in the empirical applications to the test area of the ISAAC project. We address the framing of the analysis by selecting the most relevant approaches and tools. In general, these approaches and tools are based on Cost-Benefit Analysis (CBA) in its 'socio-economic' version, which includes non-market, social and environmental effects, all translated into a monetary metrics, in the assessment of investment projects.

The analysis carried out in this report is needed because biogas and biomethane plants represent an area in which the state of 'social CBA' is still poor at present, with few studies going beyond project appraisal in purely financial terms (industrial private costs and benefits only). Therefore, the starting state of knowledge of social effects of biogas provides a poor guidance for the work to be carried out in the test area of the ISAAC project.

In the report, we start by defining the difference between 'financial' and 'social' CBA and the need for information and direct monetary estimates associated to the latter. We then explain the need and the use of original social CBA in the case of biogas/biomethane plants in Italy by examining the results of the few 'social CBA' studies available at the international level (Section 2).

The available techniques for monetary estimates of social and environmental values of a project, in a CBA framework, are briefly presented from a methodological point of view (Section 3) and are then developed in more details in two cases:

- (i) the possible external cost of biogas plants in terms of effects on housing values in areas surrounding the plants (Section 4); in this case we present the first results of an original econometric analysis (the first one for Italy) carried out on the biogas plants of the Piemonte region; a diff-in-diff estimate is made on the effects of biogas plant approval and establishment on the market values of houses located in close areas;
- (ii) a review of the available estimates of external (monetary) costs of air pollutants and CO₂ to be used, possibly through 'value transfer' techniques, in the applications to the test areas of the ISAAC project (Section 5).

With respect to direct environmental pressure factors and parameters, LCA (Life Cycle Analysis) can provide a more satisfactory approach to measure the resource use and environmental effects of projects, including biogas/biomethane projects, for example in the case energy balances and air pollution. However, LCA approaches are rarely integrated into CBA. We therefore explore the LCA approach as possibly useful for improving social CBA and to identify the need of information that can make this integration possible and feasible (Section 6).

We address the state of knowledge on social acceptance issues for biogas/biomethane investments in Section 7. Differently from other areas, in which the NIMBY syndrome has been extensively explored, the available literature on social acceptance of biogas plants is poor, and not referred to Italy. Therefore, the results of this analysis and those of the direct surveys to citizens shaped for the designated areas of the ISAAC project (under definition), which is the work of Task 1 of WP6, will help to shape the detailed overall project's socio-economic assessment report. This analysis is relevant also for the integration between 'social CBA' carried out in WP6 and participatory processes to be developed in WP 3 and 4.

We finally extract the main conclusions and the directions for the development of applied case studies in the tests area of the ISAAC project (Section 8).

2. A cost benefit framework for biogas projects

2.1 From 'financial' to 'social' appraisal of projects

CBA is a tool to appraise investment decisions in order to secure the most efficient allocation of resources. It entails assessment of a project with respect to alternative projects according to specific criteria based on 'welfare economics' concepts (see Drèze and Stern 1987 for a theoretical treatment).

The comparison of costs and benefits is ubiquitous in economic and social reasoning whenever there are problem of choice regarding alternative course of action or decisions about the optimal (efficient) allocation of scarce resources that raises trade-offs. A CBA approach is commonly proposed also in the debate on the overall validity of major policies, like global climate change policy (see Stern et al., 2006). However, CBA has been progressively codified as a technique for appraisal of specific projects that is grounded in microeconomic principles and is structured as a practical decision tool for both private and public investment decisions.

CBA is extensively used in some countries, especially in the US and the UK, under specific regulatory requirements on the assessment (ex ante) of public investments and the introduction of new regulations, which can be seen as 'projects' that have a set of costs and benefits distributed over the society. In the EU, CBA is a requirement for getting co-financing on structural funds 'major projects', in particular Cohesion Fund for project of a size higher than 50-75 million/€ (see EC, 2015).

The common elements of any CBA (ex ante) are (see EC, 2015):

- The definition of the 'project' or projects, which must be represented by well-defined actions of change;
- The assessment of the project with respect to alternative projects, which can include the status quo (no action or 'do nothing'), or with respect to a counterfactual;
- The identification of costs and benefits of the project(s), which should be framed within an 'opportunity cost' approach (the value of the best foregone alternative in the use of resources);
- The use of a monetary metrics for all costs and benefits (including, in social CBA, those without reference markets, e.g. environmental pressures, which entails the use of monetary evaluation techniques);
- Discounting of future flows of costs and benefits and then the use of discount rates to translate future values into present values;
- The cash-flow approach in accounting the different costs and benefits;
- The use of performance indicators, in particular Net present value (NPV), the Internal rate of return (IRR), the benefit-cost ration (B/C) than can summarise the net benefits of a project in one single

number; among the three performance indicators, only NPV also gives the absolute size of the net value created by the project.

'Financial' CBA is a standard investment decision procedure that includes the above elements but considers just the 'private' CBs of the project owner and delivers the purely financial/economic net return of the project itself. Even in CBA of public investment, like those considered in EC (2015) that includes a number of indirect effects on the markets affected by the project, financial analysis is the first step in that it can indicate the financial/economic viability and self-sustainability of a project 'on the market' before any considerations of social values of the project itself (e.g. risk to people, environmental effects) not captured by financial appraisal. The 'social' (sometimes defined as 'economic') CBA, which is the relevant approach for the assessment of public projects or private projects causing significant social effects, entails a significant extension of the elements to be taken into account in a CBA exercise and, what is more, a change in the evaluation criteria of some key elements already included in 'financial' CBA. The main changes to be considered in passing from 'financial' to 'social' CBA are the following:

- conversion of market to 'accounting prices'; it entails the reference to 'shadow prices', instead of market prices, as able to measure the true scarcity of the input and/or the output of the project; conceptually derived from constrained optimisation and general equilibrium approaches, shadow pricing should be used when market prices do not represent true scarcity because of, for example, monopolistic market power in some input or output market, or subsidisation, or prices not reflecting idle resources, for example salaries not reflecting unemployment in the local labour market;
- monetisation of 'non-market impacts'; for example, the project can involve effects on the environment that represent external costs to the society or to other economic activities for which there are not specific prices, or it can create risk to people for which there are not transactions and reliable monetary values; to have a social CBA these effects can be accounted for by using specific evaluation techniques to assign these effects a monetary value to be included among the CB flows;
- inclusion of additional indirect effects (if relevant); when exiting the boundaries of the private investor, (financial analysis), there can be an enlargement of the relevant effects (indirect) as, for example, the deviation of transport flows from one site to another, which can involve a set of CBs outside the specific location of the project;
- use of a 'social discount rate', instead of financial discount rate; while in financial analysis the market interest rate can be used for discounting, in social CBA a social discount rate should be used that can differ from the financial market rate, the former depending on factors like the time preference factor and the marginal utility of income;
- distribution of costs and benefits across different stakeholders, social groups, and individuals; while private project CBA ignores the distribution of costs and benefits outside the project ownership boundaries, in social CBA many different social actors can be affected by the project even from a purely economic (e.g. income) point of view and this must be taken into account; this can be

particularly relevant when a combination of external costs and private benefits (or vice versa) can arise from the project.

The suggested path of financial and economic (social) CBA is presented in Figure 2.1 for the projects supported by EC funding within structural funds.

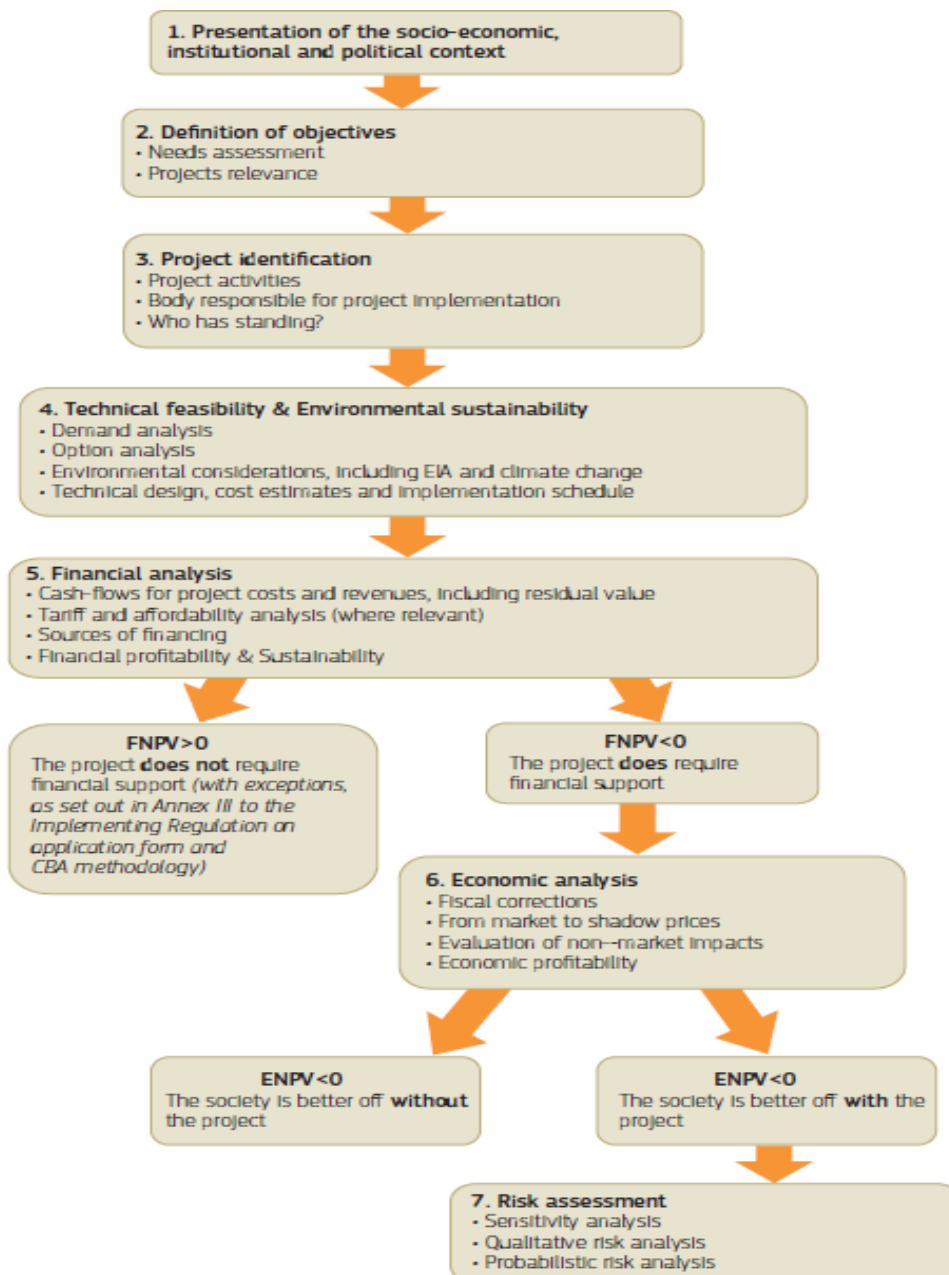


Figure 2.1. The steps of the appraisal (Source: EC, 2015, Figure 2.1, p. 28).

All the extensions and changes reframing the CBA from financial to social can present serious problems on both methodological and empirical grounds, and may face challenging issues in application. For example, the choice of a social discount rate is subject to endless debates and any choice can be criticised. The same applies to the estimation of shadow prices or the reliability external cost monetary estimates. These difficulties will be taken into account in the analyses presented in this report and, to some extent, they may impose a limit to the possibility of carrying out a complete social CBA for biogas and biomethane.

Biogas and biomethane projects can be appraised from a purely private perspective as any other industrial investment that can deliver a net positive or negative financial/economic return to the project owner. However, these projects clearly present a 'public' dimension in that they are generally deemed to positively contribute to reduce waste, to generate energy from renewable sources, and to have a range of public benefits. As a consequence, they are subject to public subsidies within almost all RES policy schemes adopted in Europe and many other regions. At the same time, these projects are alleged to have external negative costs to the local communities and are then subject to oppositions of the type generally known as 'NIMBY syndrome'. Biogas and biomethane projects are therefore best appraised in a combination of 'financial' and 'social' or socially extended CBA.

2.2 Biogas and biomethane projects from a 'financial' and 'social' CBA perspective

2.2.1 Cost and benefits in general

The production of biogas is a complex and differentiated industrial activity based on the exploitation of waste from livestock (e.g. manure), food production (e.g. waste fruit, vegetable), industrial and municipal wastewater treatment plants (e.g. sewage sludge), and biomass from agricultural residuals and dedicated crops. Biogas is produced by organic substances in special fermenters and it is a mixture consisting mainly of methane and carbon dioxide. The organic feedstock is converted into biogas by means of anaerobic digestion processes that can be differentiated according to several variables (e.g. kind of waste, temperature and so on, for a review see Brown et al., 2013; Møller and Martinsen, 2013 and Poeschl et al., 2012). The transformation of biogas into energy can occur by direct combustion with production of heat only or by combustion in co-generators producing in this way both electricity and heat. Biogas could also be purified into methane, thus becoming bio-methane and it can be used as fuel for other vehicles.

Biogas plants can generate a range of environmental advantages that can be summarised as follows:

- lower (or equal) CO₂ emissions than the amount absorbed by the plants for growth with zero or positive effect (Boldrin et al., 2016);
- re-use of agricultural waste and production of high-quality fertilizer (Robinson et al., 2001);

- the digestate from biogas production as fertilizer minimizes the use of energy intensive chemical fertilizers and further alleviate GHG emissions (Poeschl et al., 2012);
- small local plants do not have high production and transport costs (Raven and Gregersen, 2007);
- no risks of extraction and transport and low risk of severe accidents (Burgherr et al., 2014).

Because of all these possible advantages biogas plants can play an important contribution in producing energy from renewable sources and in the disposal of organic waste. For these reasons, in several countries (especially within European Union Member States) energy production through biogas has been encouraged. For instance, the Directive 2009/28/CE set the overall 20% share of energy from renewable sources to be achieved by 2020 for any EU Member States and 10% as share of renewable energy for all mode of transport. In line with the EU directive, Italy has then introduced a number of subsidies aimed at favouring the energy production through renewable resources.

However, the social acceptability of biogas plants, also in comparison to other renewable sources, is low because of the resistance from local communities that are afraid of potential local negative externalities (ARPAT, 2015). The perceived environmental disadvantages can be summarised as follows:

- intensification of soil erosion problems and nutrient loss by the harvesting of crop residues (Abbasi and Abbasi, 2000; Magnani, 2012);
- air and water pollution due to possible emissions of particulates and oxides (Abbasi and Abbasi, 2000);
- biogas burning (from biomass conversion) for the production of energy may be associated with the combustion of waste (ARPAT, 2015; Skøtt, 2006; Soland et al., 2013; Upham and Shackley, 2006);
- oversizing of the plants with respect to the availability of the raw material that leads to an increase of heavy vehicle traffic (ARPAT, 2015; Upham and Shackley, 2006);
- smell (Skøtt, 2006; Soland et al., 2013);
- distributive justice (Gross, 2007; Magnani, 2012) in the case of large centralised biogas plants that would generate benefits to a few actors;
- reduced property values or loss of customers in tourist areas (Skøtt, 2006; Soland et al., 2013);
- visual disamenities because plants could alter the natural landscape (Soland et al., 2013).

Although several studies have provided evidence of limitations in the social acceptability of biogas, only very few studies have directly investigated the possibility of economic (direct and indirect) losses of households next to biogas plants. For instance a survey provided by Soland et al. (2013) reports low score (1.91 over 6) regarding the possibility to get a loss (e.g. reduced property values) due to the proximity of biogas plants. As denoted by the authors, the survey has been made among Swiss citizens living near biogas plants where no strong protests take place.

2.2.2 Examples of full social CBA

2.2.2.1 Premise

The major example of analyses of biogas plants in a 'welfare' perspective, i.e. in a 'social CBA' perspective, is the work by Moeller and Martinsen (2013) for Denmark. The examples Moeller and Martinsen (2013) in this paragraph are described only to evaluate the methodology applied; the data used and reported in the tables are actually not factual and not related to any existing plant, but based on scenario descriptions defined jointly by the participants in the BIOMAN project.

The examples discussed afterward have several assumptions and not all of them could be applied to biogas plants in Italy:

- Costs and currency: the estimations of costs were made in 2009 and are reported in Danish local currency (DKK);
- Use of biogas: part of the produced biogas is sold to external combined heat and power (CHP) plants;
- Biogas users: biogas is transported from producer to user through pipelines established specifically for this purpose, and the costs associated with establishing this distribution network implies that it is not straightforward to establish new customer relations with very little market flexibility

As stated by the authors, Moeller and Martinsen (2013): *"This result (of the study) is of course highly dependent on the assumptions underlying the analyses in terms of opportunity costs of inputs, transport costs, dry matter content of input and thereby amount of biogas produced and price of natural gas and GHG emissions. Hence, if the assumptions are changed the results will also change. However, it appears that prices, costs and biogas productivity have to change significantly in favour of biogas production to make it welfare economically profitable. In relation to the interpretation of the results it is important to emphasise that the results are inextricably linked to the underlying assumptions. Consequently the results cannot be used as the base for drawing more general level conclusions regarding the welfare economic desirability of biogas production"*.

2.2.2.1 Evaluation of the examples

Moeller and Martinsen (2013) cover a set of 15 different plant configurations ('scenarios') in terms of size and feedstock combinations (from pig slurry and cattle slurry to organic grass clover), in particular:

- Biogas production from 100% conventional pig slurry at 800, 500, and 50 tonnes per day plant;
- Biogas production from 75% conventional pig slurry and 25% maize at 800, 500, and 50 tonnes per day plant;
- Biogas production from 100% organic cattle slurry at 800, 500, 50 tonnes per day plant;

- Biogas production from 50% organic cattle slurry and 50 % organic grass clover at 800, 500, 50 tonnes per day plant;
- Biogas production from 100% organic grass clover at 800, 500, 50 tonnes per day plant.

The 50 tonnes/day capacity plant corresponds, in the study, to a decentralised production facility (i.e. farm biogas plant), the other two sizes (500 and 800 tons/day) corresponds to centralised plants fed by different inputs. The technological configuration is in any case one of CHP, which corresponds to situation in Denmark: part of the produced biogas is used on-site for the production of heat; electricity is sold, and the rest of the biogas is sold to local CHP plants. The biomethane option is not considered because in Denmark when biomethane is fed into the natural gas distribution network is taxed equally to natural gas irrespective of the CO₂ neutrality of biogas, and “*the tax system does not take account of the lower level of externalities associated with biogas compared to natural gas*” (p. 14).

From a methodological point of view the study seems to presents some open issues¹.

The study is framed in standard CBA but the use of ‘financial analysis’, as defined in the study, is different from the one adopted by the European Commission (see above and EC 2015) even for public investments: the ‘financial analysis’ includes here a set of indirect effects and income distribution effects, instead of a privately financial viability of the project before considering the societal effects of the project. In the case of biogas plants, which are generally private investments, although subsidised within the renewable energy policies, the distinction between financial and social (‘welfare’) analysis must be clear. This unclear distinction between financial and social analysis can have influenced the results.

Another critical element is that, among the consequences of the biogas plants, while the study considers the substitution of natural gas (output side), there is not a clear consideration of the alternative destination of the feedstock, e.g. pig slurry, when it is a waste to be managed generally at a cost (input side). In addition, external effects are restricted to environmental effects, in particular CO₂ emission, as the study primarily aims at evaluating the cost of reducing GHG emissions through energy from biogas. Actually, in the study, it is interesting the approach to ‘social’ evaluation of biogas, which is reported as follows “*For the part of the biogas which is sold, it is assumed that the biogas replaces natural gas as fuel in a local gas-fired CHP plant. Therefore the value to society of biogas is equal to the value of the amount of natural gas which is assumed to be replaced. As natural gas is a fossil fuel substituting this with biogas, which by definition is considered to be CO₂ neutral, also means a decrease in CO₂ emissions which also has a value to society. The electricity from the biogas plant has a value to society because it replaces other electricity production or import. Depending on how the replaced electricity is assumed to be produced, there might also be a CO₂ gain related to the produced electricity. For the farm biogas plants heat is produced in excess of the requirements for process heat, and this implies that farm biogas plants will produce an amount of heat for sale. In many*

¹ The study is carried out by an environmental research department seemingly without the involvement of economists.

cases, however, it may be difficult to find interested buyers, and consequently, the value of a significant share of the produced heat may in many cases turn out to be zero. In the present analysis it is assumed that 30% of the excess heat production is used, while the remaining 70% is lost". (p. 27)

About taxes and subsidies in the Danish framework, biogas based power production is subsidized with 0.414 DKK per kWh (2009), and biogas based power production is exempt from CO₂ tax which means a tax exemption of 0.351 DKK per Nm³ (2010) replaced. Given this structure of taxes and subsidies, the social price of gas is adjusted in the following way:

- When biogas substitutes for natural gas: the market price of 1.77 DKK / Nm³ is augmented by the a net tax factor of 1.17 to arrive to an economic accounting price of natural gas of 2.07 DKK per Nm³
- When used to produce electricity, using the same net tax factor of 1.17, the price passes from 0.301 DKK per kWh, including the cost of CO₂ quotas, to 0.352 DKK per kWh;
- When biogas replaces natural gas at a local CPH plant the calculation is as follows: "more expenditure in form of subsidies from the State and loss of tax income to the State. The value of subsidies is calculated as the produced amount of electricity multiplied with 0.414 DKK per kWh (2009). The value of CO₂ tax exemption is calculated as 0.351 DKK per Nm³ (2010) multiplied with the amount of natural gas replaced. Furthermore the CHP plant avoids paying natural gas tax for heat production equal to 0.742 DKK per Nm³ multiplied with the amount of natural gas replaced. The sum of subsidies and loss of tax income is finally multiplied with the dead weight factor equal to 1.2 to get the value of total welfare loss to society of the increased expenditures and lost tax incomes for the State" (p. 28).

With this elements, shortcomings, and assumptions in mind, for our aims it is useful to look into the structure of 'social' (welfare) and 'financial' CBA used in the study in two cases of farm level small plants. **We are mainly interested in the elements included/excluded and the methodology.**

Table 2.1 reports the 'consequences' of a scenario for a small plant (50 tons/day) fed with 100% pig slurry. It can be noted that most of the consequences are about net emissions and substituting synthetic fertilisers, but the set of consequences does not include the avoided waste of pig slurry with respect to the non-plant scenario. Furthermore, all the consequences are measured as direct effects and not in an LCA perspective (see Section 6).

Table 2.1. Scenario for a small plant (50 tons/day) fed with 100% pig slurry

Economic consequences				Consequences per year
<i>Agriculture</i>				
- reduced demand for synthetic fertilizer				7.2 tonnes
<i>Biogas plant</i>				
- electricity production for sale (total production)				760,003 kWh
- heat production – displaced gasoil				778,078 MJ = 21,692 litre
- investment costs				8.1 M DKK
- labour				365 hours
- electricity consumption				100,375 kWh
- water consumption				300 m ³
- chemicals				2,500 DKK
- service and maintenance				270,000 DKK
Emissions consequences	Total tonnes	Agricultural tonnes	Biogas tonnes	Transport tonnes
CO ₂ emissions	-353.751		-353.751	0
N ₂ O emissions	-0.557	-0.563	0.006	0
CH ₄ emissions	-13.586	-16.425	2.839	0
C content of soil	-36.956	-36.956		
Particle emissions	0.004		0.004	0
NO _x emissions	1.094		1.094	0
SO ₂ emissions	0.051		0.051	0
CO emissions	1.995		1.995	0
NM VOC emissions	0.030		0.030	0
N-leaching	-2.306	-2.306		
Taxes and subsidies				
<i>On site CHP plant</i>				
- reduced demand for gas oil-energy tax				53,744 DKK
- reduced demand for gas oil- CO ₂ tax				9,111 DKK

Source: Moeller and Martinsen (2013)

The results of the 'welfare economic' analysis (social CBA) are presented in Table 2.2. The net welfare results is negative by 0,43 million/DKK, with an 'economic loss' of 0,49 MDKK, a public loss (net subsidies) of 0,1 MDKK, and a net gain in monetary value of avoided emissions of 0,7 MDKK. The result is surprising and it can depend from the methodology (see below for a discussion). It can be noted that the 'economic loss', 0,49 MDKK, is almost equal to the value of the investment, (0,50 DKK), which can be difficult to understand given that the feedstock (pig slurry) is not to be procured on the market at a positive market price. It can be also noted that all the output and input (excluding some emissions) are corrected for the same factor of 1.7 to get the 'accounting prices'. While in the case of the social price of biogas this has been justified (see above), the uniform application of such a factor to (almost) all inputs and output is difficult to

justify because the accounting price should reflect the scarcity of the specific factor according to local conditions for the project and not reflected in market prices (shadow pricing). This can be particularly relevant in the case of labour costs, especially in the case of a farm using internal labour for running the plant.

Table 2.2. Welfare economic analysis for a farm biogas plant with 50 tons/day capacity fed by 100% pig slurry

	Consequence per year	Accounting price	Welfare economic value
Economic consequences			-0.49
Agriculture			
- reduced demand for synthetic	7.2 tonnes	7.500 DKK pr tonne 1,17	0.06
Biogas plant			
- electricity production for sale	760.003 kWh	0.46 DKK pr kWh 1.17	0.41
- heat production – displaced gasoil	778.078 MJ = 21,692 litre	110 DKK pr GJ 1.17	0.10
- investment costs	0.5 M DKK	0.5 M DKK 1.17	-0.59
- labour	365 hours	200DKK 1.17	-0.09
- electricity consumption	100,375 kWh	0.46 DKK pr kWh 1.17	-0.05
- water consumption	300m ³	25 DKK pr m ³ 1.17	-0.01
- chemicals	2.500 DKK	2.500 DKK 1.17	-0.00
- service and maintenance	270,000 DKK	270,000 DKK 1.17	-0.32
Emission consequences			
- CO ₂ emissions	-353.751+296.173	105 DKK pr tonne 1.17	0.01
- N ₂ O emissions	-0.557 tonnes	105 DKK pr tonne 310 1.17	0.02
- CH ₄ emissions	-13.586 tonnes	105 DKK pr tonne 21 1.17	0.03
- C content of soil	-36.956 tonnes	105 DKK pr tonne 3,67 1.17	0.03
- Particle emissions	0.004 tonnes		
- NO _x emissions	1.094 tonnes	55,000 DKK pr tonne	-0.06
- SO ₂ emissions	0.051 tonnes	85,000 DKK pr tonne	-0.00
- CO emissions	1.995 tonnes		
- NMVOC emissions	0.030 tonnes		
- N-leaching	-2.306 tonnes	40,000 DKK pr tonne	0.09
Public income	-62.885 DKK	-62,885 DKK 0,2	-0.01
Total			-0.43

Source: Moeller and Martinsen (2013)

The results of the financial analysis are presented in Table 2.3. In this case, without the social accounting correction and without the emissions monetary evaluation, which is the only external cost/benefit considered in the study, the loss is lower for the plant, 0,28 MDKK, which is any case a big loss compared to the investment. The State (nets subsidies) has a loss of 0,6 MDKK, but it should not be accounted here because

it is part of the welfare (social) analysis, whereas in the financial perspective only the net tax/subsidies of the plants should be considered (see below for a discussion).

Table 2.3. Financial analysis for a farm biogas plant with 50 tons/day capacity fed by 100% pig slurry

	Consequence per year	Price	Income and expenditures
Agriculture			0.05 M DKK
- reduced demand for synthetic fertilizer	7.2 tonnes	7,500 DKK pr tonne	0.05 M DKK
Biogas plant			-0.28 M DKK
- electricity production for sale	760,003 kWh	0.772 DKK pr kWh	0.59 M DKK
- heat production – displaced gasoil	778,078 MJ = 21,692	6.845 DKK pr litre	0.15 M DKK
- investment costs	0.598 M DKK	-	-0.60 M DKK
- labour	365 hours	200DKK pr hour	-0.07 M DKK
- electricity consumption	100,375 kWh	0.65 DKK pr kWh	-0.07 M DKK
- water consumption	300m ³	25 DKK pr m ³	-0.01 M DKK
- chemicals	2.500 DKK	2.500 DKK	0.00 M DKK
- service and maintenance	270,000 DKK	270,000 DKK	-0.27 M DKK
The State			-0.06 M DKK
- reduced demand for gas oil-energy tax	53,744 DKK		-0.05 M DKK
- reduced demand for gas oil- CO ₂ tax	9,111 DKK		-0.01 MDK

Source: Moeller and Martinsen (2013)

The second example from the Moeller and Martinsen (2013) study is for a plant having the same capacity, but feed 100% with biomass from grass clover.

Table 2.4 Welfare economic analysis for a farm biogas plant with 50 tons/day capacity fed by 100% grass clover

	Consequence per year	Accounting price	Welfare economic value
Economic consequences			-1.5 M DKK
Agriculture -production			
- grass clover production for fodder	-1,901,041 FE = -9,125 tonnes	1.30 DKK pr FE 1.17	-2.89 M DKK
- barley production	-455,729 kg	1.5 DKK pr kg 1.17	-0.80 M DKK
- triticale production	-585,938 kg	1.6 DKK pr kg 1.17	-1.10 M DKK
- grass clover production for biogas production	3,802,083 FE = 18,250 tonnes		
Agriculture –resource use			
- grass clover seed for fodder production	-2,258 kg	40 DKK pr kg 1.17	0.11 M DKK
- barley seed	-22,135 kg	3.6 DKK pr kg 1.17	0.09 M DKK
- triticale seed	-22,135 kg	3.8 DKK pr kg 1.17	0.10 M DKK
- grass clover seed for biogas production	4,516 kg	40 DKK pr kg 1.17	-0.21 M DKK
- labour	-22 hours	150 DKK pr hour 1.17	0.00 M DKK
- fuel consumption (diesel)	-281 litre	3.82 DKK pr liter 1.17	0.00 M DKK
- electricity consumption (watering)	68,148 kWh	0.46 DKK pr kWh 1.17	-0.04 M DKK
- machine services and labour watering	23,438 DKK	23,438 DKK 1.17	-0.03 M DKK
- maintenance of machines (incl. watering)	40,620 DKK	40,620 DKK 1.17	-0.05 M DKK
Agriculture –yield increase			
- barley – increased N-application	920 hkg	1.5 DKK pr kg 1.17	0.16 M DKK
- triticale – increased N-application	920 hkg	1.6 DKK pr kg 1.17	0.17 M DKK
- grass clover production–increased N-application	188,902 FE	1.30 DKK pr FE 1.17	0.29 M DKK
Agriculture –treated grass clover increase			
- reduced demand for synthetic fertilizer	79 tonnes	7,500 DKK pr tonne 1.17	0.69 M DKK
Transport			
- import of grass clover, barley and triticale	7,504 km	15,22 DKK pr km	-0.11 M DKK
Biogas Plant			
- electricity production for sale	5,705,482 kWh	0.46 DKK pr kWh 1.17	3.07 M DKK
- heat production – displaced gasoil	7,454,475 MJ = 207,819 litre gasoil	110 DKK pr GJ 1.17	0.96 M DKK
- investment costs	0.97 M DKK	0.97 M DKK 1.17	-1.14 M DKK
- labour	365 hours	200 DKK 1.17	-0.09 M DKK
- electricity consumption	119,795 kWh	0.46 DKK pr kWh 1.17	-0.06 M DKK
- water consumption	300m ³	25 DKK pr m ³ 1.17	-0.01 M DKK
- chemicals	2,500 DKK	2,500 DKK 1.17	-0.00 M DKK

-service and maintenance	525,000 DKK	525,000 DKK 1.17	-0.61 M DKK
Emission consequences (tonne)			
- CO ₂ emissions	-3,024.31+2,508.499	105 DKK pr tonne 1.17	0.06 M DKK
- N ₂ O emissions	5.75	105 DKK pr tonne 310 1.17	-0.22 M DKK
- CH ₄ emissions	30.53	105 DKK pr tonne 21 1.17	-0.08 M DKK
- C content of soil	130.6	105 DKK pr tonne 3,67 1.17	0.06 M DKK
- Particle emissions	0.02		
- NO _x emissions	7.95	55,000 DKK pr tonne	-0.44 M DKK
- SO ₂ emissions	0.29	85,000 DKK pr tonne	-0.02 M DKK
- CO emissions	14.83		
- NMVOC emissions	0.18		0.17 M DKK
- N-leaching	-4.26	40,000 DKK pr tonne	
Public income	-602,467 DKK	-602,467 DKK 0,2	-0.12 M DKK
Total			-2.09 M DKK

In this case, all the costs for producing the biomass feedstock are considered in the analysis, including transports. The welfare economic consequences of this scenario are reported in Table 2.4. Compared with the 100% pig slurry scenario, the net loss is higher, of course, given the additional costs and consequences from producing the feedstock, considered as a dedicated crop. The total loss is 2,09 MDKK, of which an 'economic' loss of 1,6 MDKK, a loss for the state (net subsidies) of 0,12 MDKK, and in this case even a net loss for the monetary value of emissions of 0,47 MDKK. The observations of this results, in particular about the possible drawbacks, are similar to those of the scenario with 100% pig slurry. We do not report the financial analysis in details, but even in this case, the biogas plant is at a loss (0,98 MDKK over an investment of 1,17 MDKK) but the agricultural production gains 1,86 MDKK, thus making the overall balance less negative.

In general, all the scenarios elaborated by Moeller and Martinsen (2013) have negative outcomes from both the social and financial perspective. Table 2.5 reports the results of the financial analysis for all the scenarios, which actually, given the approach of the study includes also a cost-benefits distribution and social analysis components (excluding the environmental effects). In general agriculture gains, the biogas plant is at a loss (except is few scenarios), the local CHP plant gains, and the State (net subsidies) is at a loss. In general, the loss to the state is higher than the *combined gains* of the other actors which suggests that the study emphasises the welfare loss to the consumers and/or does not take into account the redistributive features of the state subsidies (see below)

Table 2.5 Result of the 'financial analysis' for all the scenarios (M DKK)

Scenario	Agriculture	Biogas Plant	Local CHP plant	The state
1A	0.86	-1.77	0.38	-4.94
1B	0.54	-0.96	0.24	-3.21
1C	0.05	-0.28	0	-0.06
2A	7.31	-1.03	1.85	-20.19
2B	4.55	-0.47	1.15	-12.75
2C	0.45	-0.15	0	-0.23
3A	1.72	0.28	0.51	-6.28
3B	1.07	0.33	0.3	-4.04
3C	0.1	-0.05	0	-0.2
4A	13.91	-9.46	2.74	-29.53
4B	8.69	-5.52	1.71	-18.6
4C	0.86	-0.4	0	-0.52
5A	29.76	-20.76	4.96	-50.84
5B	18.59	-12.61	3.1	-31.78
5C	1.86	-0.98	0	-0.61

Moeller and Martinsen (2013)

Although very extensive and detailed, the Moeller and Martinsen (2013) study presents some elements that can raise issues about the validity of results, especially outside the country of reference (Denmark):

- there is not a clear-cut distinction between the purely 'financial' CBA and the 'social' CBA phase of the analysis, differently from what suggested by the guidelines from the European Commission (see EC 2015), which are for public investments but keep this distinction very clear; in addition, the biogas plant investment is a purely private investments (in Italy) that should be first analysed as a private industrial investment (only costs and benefits to the project owner) then enlarging the perspective to the indirect and external effect of the investments (social analysis); this social analysis is justified in general (when there are indirect/external affects from private investments) and in particular when there are public incentives to biogas production based on alleged external benefit of this activity (energy and emission advantages); an imprecise distinction between the private financial dimension of biogas investments and their public dimension, can confuse the distributional aspects (the investor vs the local economy and community) of the investments themselves;
- the main external costs and benefits considered are those associated to CO₂ and polluting emissions, which reflect the approach of the study to consider biogas as strategy to reduce CO₂ and emissions to be compared to other options that can contribute to national emission strategies; the set of relevant indirect and external effects of biogas investments is larger (see above at the beginning of the section);
- the treatment of net public subsidies to biogas is unclear and it is critical to net losses attribute to these investments: without considering net public subsidies, most of the scenarios deliver a *net positive financial outcome* for the system made of agricultural producers, the biogas plant, the CHP plant (and then positive public outcome, given the way 'financial' is defined in the study and given

that the only external effects considered are saved emission, which are generally of positive monetary value) (see Table 2.5); in the case of 'vertically integrated' production systems (same enterprise with agricultural inputs, biogas production, and CHP) this means an economic viability of the project; then the calculation of the public net subsidies is critical for the social viability and, while the study correctly place emphasis on consumer surplus as a guide for 'public' or social assessment (in theory), it should be better take into account that net public subsidies are a distributional transfer internal to the system of actors involved in the project scope and, while the subsidy is a cost to the public actor (outlay) it is a benefits to the plant/project owner (revenue) and then neutral in a social analysis²; it is therefore the justification of this subsidies on social grounds (e.g. energy import saving, emission reduction) that is interesting in a social analysis perspective, and the study is not complete in this respect;

- the study never considers the feedstocks of biogas plants as potential waste, thus implicitly assuming they are always commodities having a positive market value, which is not always the case for agricultural inputs of biogas and even less the case with biogas plants fed by biowaste;
- the treatment of the time frame of the projects and the corresponding use of social discount rate in the welfare assessment is not fully clear; the applied social discount rate of 4% seems to be very high with respect to social discount rates prevailing in many social CBAs.

Therefore, while part of the CBA framework proposed by Moeller and Martinsen (2013) is acceptable, other elements suggest adopting a framework closer to the one proposed by EC (2015) in the applied analysis of the ISAAC case studies.

² About the fiscal corrections in social CBA, the European Commission handbook (EC 2015) says: "Taxes and subsidies are transfer payments that do not represent real economic costs or benefits for society as they involve merely a transfer of control over certain resources from one group in society to another. Some general rules can be established to correct such distortions: prices for input and output must be considered net of VAT; prices for input should be considered net of direct⁵¹ and indirect taxes; prices (e.g. tariffs) used as a proxy for the value of outputs should be considered net of any subsidy and other transfer granted by a public entity. As concerns the methods of eliminating transfer payments, if it is possible to determine their exact value, they should be directly eliminated from the cash flows. For example, VAT payments on construction costs can be simply dropped off in the economic analysis. If it is not possible to determine their exact value, they should be eliminated from the project cash flows using conversion factors (see section 2.8.4). In some projects the fiscal impact can be significant because, for example, the revenues generated by the project may decrease the need to finance budgetary deficits by public debt or taxation. Despite the general rule, in some cases indirect taxes (or subsidies) are intended as a correction for externalities. For example, taxes on NO_x emissions to discourage negative environmental externalities. In this and in similar cases, it is justified to include these taxes (subsidies) in project costs (benefits), provided that they adequately reflect the underlying marginal cost (Willingness-To-Pay (WTP)), but the appraisal should avoid double counting (e.g. including both energy taxes and estimates of full external environmental costs)".(p. 55)

3. Evaluation of social and non-market costs and benefits

The limited socio-economic analysis available for biogas investments, in particular on public/non-market costs and benefits, derives from at least three factors:

1. The lack of integration between environmental sciences/engineering studies and public/environmental economics studies in this specific area, which is instead more frequent in the broad waste disposal/management realm (e.g. Dijkgraaf and Vollebergh, 2004, who assess landfills and incineration options through social CBA);
2. More generally, the intrinsic ex ante nature of many economic valuation analyses, which is less frequent in certain institutional environments (e.g. Italy), where ex post socio-economic assessments prevail (e.g. calculating ex ante the benefits and costs of prevention and risk reduction vs the ex post damages after environmentally negative effects);
3. The technological and site specific orientation of most studies, which have thus a circumscribed focus to the 'site', not the entire 'economic jurisdiction', namely the area – not necessarily the administrative one – where costs and benefits are 'diffused'.

It is worth noting that avenues of integration are possible when looking at some techno-energy-economic or thermo-economic studies (Bettocchi et al. 2010; Gonzalez-Salazar et al. 2016; among others): the integration of externalities values, non-market indicators and money values, etc. is definitely worth pursuing in future works to represent the whole set of private and public values. The main implication and usefulness is that a comprehensive CBA of the site in the territory better highlights the set of winners and losers and allows reasoning on forms of funding and compensations of energy projects in a given territory.

Among the various sets of economic valuation techniques that might be used to quantify extra market values such as air quality, amenity values, etc. (Pearce et al. 2006; Atkinson and Mourato, 2015³) there are three specific techniques that can support social CBA in the context of renewable energy projects/biogas projects.

On the side of revealed preferences, namely techniques that rely on the observation of behavioural tracks and are thus mainly ex post, we highlight Hedonic pricing. This method of economic valuation is useful for two main reasons. It captures the values related to public goods/bads variation through the observation and analysis of housing markets. Then, it is able to decompose the value of a good in its characteristics. Briefly, housing market exchanges are based on and driven by the set of private and public goods that are close (or distant) to a location. The closer the positive feature, the higher the exchange price and vice versa. Having information on market exchanges in a given community, and through multivariate analysis, it is possible to

³ For a non-technical description of what economic valuation is and the various techniques are about, see EFTEC – Ozderimoglu and Hails (2016) - http://assets.worldwildlife.org/publications/921/files/original/VNN-Demystifying_Economic_Valuation-Paper.pdf?1470335837 (Valuing Nature paper by EFTEC London).

infer how society values the various components of welfare. It is thus possible to analyse the impact of biogas site (different biogas sites) on housing market prices. The real difficulty is empirical, that is the availability of micro-data. The more refined and less aggregated the dataset, the more robust and specific the analysis.

Even if the technique is using real data and is then ex post in nature, one might use historical data to infer value changes regarding future similar situations. The key hypothesis of interest for the project at stake is whether a new biogas site significantly impacts on housing market prices, and if so to what extent (the magnitude), with which sign (negative or positive effects), and finally within which boundary in the territory (the economic jurisdiction defined by significant economic effects).

On the side of stated preference techniques, contingent valuation (CVM) and choice experiments (CE)⁴ are tools that provide values for market and non-market components of welfare. Those tools are typical ex ante methods that analyse whether a project is worthwhile by monetising those features that are usually left with no money flags. The implication is that market and/or thermo-economic analyses and other qualitative and quantitative techniques under represent the public good side of the cost-benefit narrative⁵.

The difference between CVM and CE is that the first is holistic in the way it approaches and values the 'good', while the second is able to estimate the different features by which a good (e.g. a biogas site) is defined. The conceptual basis is microeconomics, welfare economics and consumers theory. The notion of value is that of economic surpluses, namely the willingness to pay society and individuals express for 'buying' variations of private and public goods. Theory also defines the concept of willingness to accept, facing a decrease in welfare (dis-amenity, lower air quality, etc.)

Contingent means that the way one elicits the value is project and site specific: the boundary of the system (the population of reference, the administrative / fiscal territory) are perfectly defined. Then, the maximum willingness to pay (WTP)/accept of consumers/citizens is linked to the increase/decrease of welfare they perceive/experiment.

The money values are estimated through a structured questionnaire, which is administered to a statistically representative sample of the population, usually between 300 and 1.500 interviews). A key historical example is the CVM that was implemented to monetise the value of reducing the risk of future oil spills, by a defined project, after the Exxon oil spill in the Valdez bay in 1989 in Alaska. The average WTP of the US

⁴ Or choice modelling. "A number of choice modelling methods are consistent with consumer theory, and its focus on an attribute-based theory of value permits a superior representation of many environmental management contexts" (Hanley et al., 2001).

⁵ Multi criteria analysis is another complement method that is able to treat and analyses social tradeoffs (e.g. higher economic performances vs lower environmental ones, or vice versa). In our view, it is not a decision making scheme and is not fully relevant for analyzing project based frameworks where non-market and private values are jointly at stake. It is more useful for macroeconomic analysis of social tradeoffs.

population was estimated by a nationwide CVM. The boundary of CVM studies is often more circumscribed: local public goods and investments are the appropriate framework to apply it.

The average WTP is multiplied by the number of involved people to provide the social benefit figure that must be compared with the costs of the project: the inclusion of non market values in CBA gives the opportunity to compare the full set of project values with its costs, pointing to its eventual social desirability⁶.

In other words, CVM and CE (as well as hedonic pricing to some extent) enlarge the boundary of considerable and includable values. The assessment and ranking of project options (e.g. fossil fuel energy vs renewable options, different renewable energy projects confronted to each other) is performed on an extended socio-economic analysis.

With respect to biogas sites, CVM and CE are able to quantify in money values the WTP payments or WTA compensations that are related to the characteristics of the site and its effects in the territory. CE is theoretically able to decompose various characteristics, pointing to negative and positive welfare effects, while CVM holistically integrates all features in one 'good' (e.g. the new plant/site).

⁶ We here link the discourse on non-market valuation to CBA, which is its natural framework. We note that CBA, given that it compares and ranks projects by calculating their net present values, is a tool that fully accounts for the dynamic nature of the benefit-cost flows, differently from often used decision making procedures such as benefit cost ratios and break even (Nutti, 2002). CBA requires a careful analysis of which discount factor to include (social, market based). Even if the future benefits are penalised by discounting, we note that economic theory has recently justified the use of declining with time discount rates; Weitzman, 2001; UK Treasury, 2003).

4. Empirical evaluation of social indirect effects: Do biogas plants affect housing values?

4.1 Introduction

Italy is one of the countries with larger energy production from biogas plants in the world. In 2015, Italy accounts for 1,555 biogas plants for around 1,160 MWeI installed power and 9,3568 TWh of electricity production (CIB elaboration based on GSE report, 2015). The number of biogas plants has been increasing in the last years (e.g. the number of biogas plants in 2010 was 313 according to GSE, 2010) and this is also underlined by the fact that substantial investments were made for an amount of 4.5 billion euro in the last five years. It has been estimated that the number of biogas plants could be double before 2030 (Althesys, 2015).

Despite the positive effect due to reduction of pollution and emission of CO₂, the social acceptability of biogas plants is controversial due to resistance from local communities who are afraid of potential local negative externalities including smell, heavy traffic and congestion, noise and visual disamenities. Then, one of the biggest challenges for policy makers and private actors in establishing new biogas plants is the resistance of local communities.

To evaluate these claims this section uses evidence from housing market values. Indeed the price of real estate incorporates both intrinsic quantitative and qualitative attributes and 'external' attributes. The external attributes arise from the location, and they are referred to the amenities of the reference areas, including the surrounding housing characteristics. It follows that if households evaluate the presence of a biogas plants such as a disamenity, this should be incorporated in the housing values, producing a decreasing in the price of housing in the nearby of plants after the opening of a biogas plant.

This section tests this possibility by using 167 biogas plants opened in Piedmont between 2006 and 2015 by means of a diff-in-diff econometric model. It also differentiates between authorization date and opening date. Advantages of a diff-in-diff model are summarized in Hallstrom and Smith (2005) and Modica et al. (2016): first, it accounts for possible fluctuations of the market, second, it isolates the effects of new information brought by the opening of a biogas plant.

The results show that the average level of the housing prices in the area where biogas plants localize is not significant different from the other parts of the region, unless the plant owns a CHP (combined heat and power) unit. In this case the housing values of a particular kind of residential unit (low-quality housing) is 1% lower in a 2km radius from the biogas plant than in the other part of the region. A possible explanation is that households perceive a biogas plant with CHP at the same way as a waste-to-energy plant (which is one of the principal concerns according to ARPAT, 2015). However, there is not enough data to confirm this hypothesis and further analysis are necessary and they will be developed in future developments of this analysis.

To the best of our knowledge this is the first work aiming at evaluating the impact of the opening of biogas plants on housing values. Even though, it should be noted that dozens of studies have used residential housing market data to estimate the impact of locally undesirable facilities and or environmental quality on housing prices (Davis, 2011). While most of the papers focuses on evaluating the impact of hazardous waste sites (Gamper-Rabindran and Timmins, 2013; Gayer et al., 2000; Greenstone and Gallagher, 2008; Ham et al., 2013; Kiel and Williams, 2007; McCluskey and Rausser, 2003), few others focus on specific type of plants, for instance hazardous industrial plants (Grislain-Letrémy and Katosky, 2014); nuclear power plants (Ando, 2015); power plants (Davis, 2011); toxic plants (Currie at al., 2013; Sanders, 2011); waste incinerators (Kiel & McClain, 1995) and wind turbines (Lang et al., 2014)⁷. The analysis is organised as follows: Section 4.2 describes the general framework, the main characteristics of biogas plants, the subsidies and potential positive and negative externalities. Section 4.3 describes data and method. Section 4.4 provides the results of the analysis. Section 4.5 proposes some conclusions and policy implications.

4.2 Biogas plants location, housing market data, and evaluation model

The data on the localization of the biogas plants in Piedmont are provided by the Regional Agency for Environmental Protection of Piedmont (ARPA – Piemonte). The database provides information over 167 biogas plants and their localization. The available information includes address, installed power, presence of CHP (combined heat and power) unit; authorization date and effective opening date. Descriptive statistics are provided in Table 4.1.

Table 4.1 – Descriptive Statistics on biogas plants

<i>Biogas plant characteristics</i>	<i>No. observations</i>	<i>Average value</i>	<i>Standard deviation</i>	<i>Min</i>	<i>Max</i>
Installed power (KW)	167	700.61	711.48	50	8000
CHP unit	84	-	-	-	-
Authorization date	157	2010	2.2	1995	2014
Opening date	149	2011	2.2	1995	2014

The housing values are provided by the 'Italian Tax and Revenue Service' (Agenzia delle Entrate) through the OMI (Osservatorio Mercato Immobiliare) database. This database makes available average prices of

⁷ Readers can consult Farber (1998) for a review of the literature of older studies.

houses for specific sub-municipal areas derived from the actual transactions that take place in the housing market. The data are grouped by type and current quality status of the house at sub-municipal level. Even though, there is the possibility to select different types of building units, for the aim of this work, we focus only on residential buildings. These can be classified as ‘high-quality’ residential unit, which shows good general characteristics and value; ‘low-quality’ residential unit, which shows low general characteristics and value and ‘villa’ that is single-family residential unit with superior construction characteristics.

The spatial scale is very detailed and it is possible to focus on sub-municipal areas, namely homogeneous segments of the local real estate market that own uniform economic and socio-environmental conditions. The data cover the period 2006 - 2015 and are semi-annual. Table 4.2 provides main distributional statistics for sub-municipal areas of Piedmont in comparison to the overall number of municipalities of Piedmont.

Table 4.2 – Distribution of sub-municipal areas

Biogas plant characteristics	No. observations
Municipalities	1,210
Sub-municipal areas	3,854
Central sub-municipal areas	1,315
Semi-central sub-municipal areas	225
Sub-urban sub-municipal areas g date	1,434
Rural sub-municipal areas g date	1,749

The main empirical challenge in such a study is constructing an appropriate ‘treated group’ (e.g. areas with an opening of a biogas plant at a given distance) and a suitable counterfactual for the locations where biogas plants were opened. The adopted strategy is then the following: first, the analysis focuses on cross-sectional comparisons between locations with and without biogas plant. With the aim of selecting appropriate treated areas we focus on sub-municipal areas that have a biogas plant within a distance of 2 km from their centroid. This distance has been considered because odour nuisances (here used as a proxy for disturbance due to biogas plant) can reach 2 km (see Skøtt, 2006). However, we do not consider rural areas because typically all the surrounding area of a municipality is considered as a single homogenous housing market area in the housing market database and this can lead to bias our analysis. Finally, we consider as control group all the

other homogenous market areas that have no biogas plants nearby. Figure 4.1 shows a map of treated and control areas.

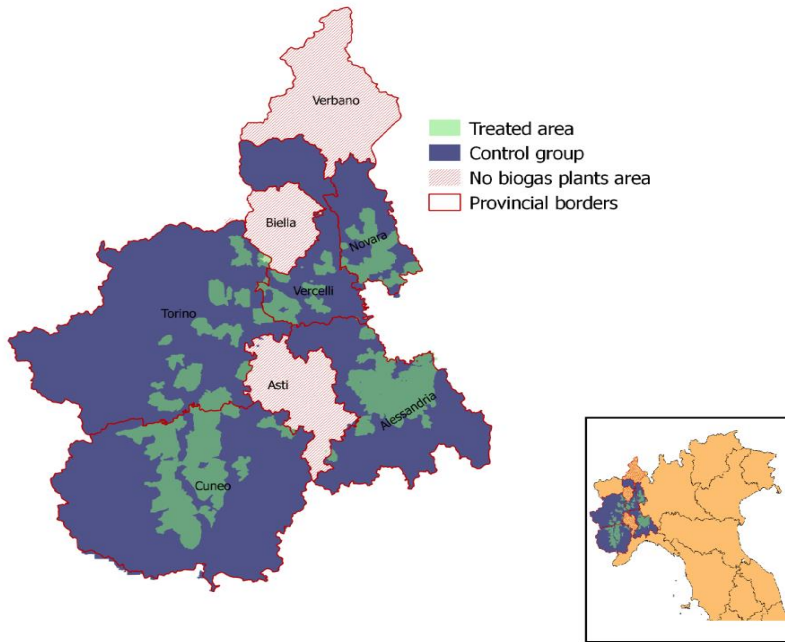


Figure 4.1 Study area

Table 4.3 shows descriptive statistics of the housing values in reference to the treated and non-treated. Moreover, we also show detail for type of housing (e.g. ‘high-quality’ housing, ‘low-quality’ housing, and ‘villa’). To evaluate the market response to the opening of biogas plant we use a standard diff-in-diff model as follow:

$$\log(\text{Price}_{i,j,t}) = \alpha_{i,j} + \beta_1 D_j + \beta_2 D_j * \text{Post}_t + \text{yeardummy} + \gamma X'_{j,t} + u_{i,j,t} \quad (1)$$

where the dependent variable is the log of the average price of the housing values, i , in the sub-municipal area, j , at time t . D is a dummy variable equal to 1 if the observation is in the treatment groups (i.e. in area next to a biogas plant) or 0 otherwise, $Post$ is a dummy that assumes value 1 if the treatment occurs and 0 otherwise. We also add a set dummies able to capture specific biogas plants characteristics, $X'_{j,t}$ such as *Size* (dummy variable assuming value 1 if the installed power is higher than 1Mw), *CHP* (dummy variable assuming value 1 if the plant owns a combined heat and power unit) and *Multiple Plants* (dummy variable assuming value 1 if there are more than one plant). We use a time fixed effect model. Following Bertrand et

al. (2004), to not incur in serial correlation, we run block bootstrap with 500 replications by keeping all the observations that belong to the same province (Efron and Tibshirani, 1994).

Table 4.3- Descriptive statistics

Type of house	No. Observations	Average log(price)	Standard deviation	Min	Max
<i>All sample</i>					
All types	75,193	6.95	.32	5.70	8.43
'High-quality' house	33,339	6.93	.34	5.77	8.43
'Low-quality' house	18,776	6.84	.30	5.70	8.16
Villa	23,078	7.05	.26	6.21	8.27
<i>Treated Area</i>					
All types	10,065	6.95	.26	5.76	7.61
'High-quality' house	4,444	6.93	.29	5.77	7.61
'Low-quality' house	2,550	6.87	.24	6.07	7.50
Villa	3,071	7.03	.21	6.21	7.60
<i>Control Area</i>					
All types	65,128	6.95	.32	5.70	8.42
'High-quality' house	28,895	6.93	.34	5.81	8.43
'Low-quality' house	16,226	6.83	.31	5.70	8.16
Villa	20,007	7.05	.26	6.21	8.23

This model is able to control for regional-specific multiple shocks. However, the treated and the control groups must have similar trends in the year before the opening of biogas plants for identifying the causal effect of the biogas plant. To examine potential pre-existing trends we run the following model:

$$\log(\text{Price}_{i,j,t}) = \alpha_{i,j} + \sum_{t < 2012} \tau_t D_j T_t + u_{i,j,t} \quad (2)$$

where τ_t are the coefficients on time dummies T_t . We then test the jointly significance of the estimated τ_t coefficients before the treatment. If the test does not reject the H_0 we can affirm that the two samples

satisfy the common trend assumption. Tab. 4.4 provides evidence on the acceptability of the common trend assumption.

Table 4.4 - Pre-treatment common test

Sample	Authorization date		Opening Date	
	F test	p-value	F test	p-value
All observations	0.97	0.51	1.64	0.32
High-quality housing	2.43	0.20	2.33	0.22
Low-quality housing	7.53	0.06	1.21	0.44
Villa	2.30	0.22	3.54	0.12

4.3 Results

In this section, we present the results of the analysis. We run several models that take into consideration the differences that in some cases arise between the date of the authorization to build a biogas plant (Table 4.5) and the effective date of the opening (Table 4.6). We also differentiate for type of housing to control for the hypothesis that ‘prestigious’ house values might be more affected than non-prestigious houses. In Tab. 4.5 we report the results in relation to the impact of the authorization of opening a biogas plant on the housing market. In any case the results are not statistically significant. Similar results are obtained when looking at the impact of the opening of a plant on the housing market, with the only exception of a slightly negative and significant effect (lower than 1%) of biogas plants that own a combine heat and power unit on low quality houses. However, what generally emerges is the non significant impact on housing market of the presence of a biogas plant in the nearby of urbanized areas.

Table 4.5 - Diff-in-diff by type of buildings (date of authorization)

Independent variable	log of the average price							
	All residential units		'High-quality houses'		'Low-quality houses'		Villas	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	6.909***	6.909***	6.876***	6.876***	6.805***	6.806***	7.040***	7.040***
	(0.0503)	(0.0504)	(0.0823)	(0.0823)	(0.0465)	(0.0461)	(0.0485)	(0.0486)
Interaction (β_2)	0.00323	0.00204	0.000938	-0.000300	0.00342	0.00474	0.00678	0.00364
	(0.00997)	(0.00699)	(0.0113)	(0.0102)	(0.0105)	(0.00407)	(0.0110)	(0.00559)
Size		0.00223		0.00235		-0.0291		0.0294
		(0.0446)		(0.0361)		(0.0737)		(0.0431)
CHP		-0.00844		-0.00657		-0.00917		-0.0102
		(0.00673)		(0.00973)		(0.00563)		(0.0141)
Multiple plants		0.0354		0.0315		0.0506		0.0232
		(0.0295)		(0.0163)		(0.0569)		(0.0288)
Time dummies	YES	YES	YES	YES	YES	YES	YES	YES
r2	0.116	0.118	0.118	0.118	0.172	0.174	0.0992	0.102
N	75193	75193	33339	33339	18776	18776	23078	23078

Table 4.6 - Diff-in-diff by type of buildings (opening date)

Independent variable	log of the average price							
	All residential units		'High-quality houses'		'Low-quality houses'		Villas	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Constant	6.909***	6.909***	6.876***	6.876***	6.805***	6.806***	7.040***	7.040***
	(0.0503)	(0.0504)	(0.0823)	(0.0823)	(0.0465)	(0.0461)	(0.0485)	(0.0486)
Interaction (β_2)	0.00329	0.00205	0.00131	0.000907	0.00423	0.00471	0.00544	0.00150
	(0.00804)	(0.00419)	(0.00871)	(0.00579)	(0.0126)	(0.00411)	(0.00813)	(0.00511)
Size		0.00520		0.0101		-0.0225		0.0226
		(0.0397)		(0.0322)		(0.0736)		(0.0328)
CHP		-0.00931		-0.0102		-0.00978**		-0.00738
		(0.00571)		(0.00871)		(0.00408)		(0.0141)
Multiple plants		0.0323		0.0262		0.0508		0.0220
		(0.0301)		(0.0180)		(0.0599)		(0.0263)
Time dummies	YES	YES	YES	YES	YES	YES	YES	YES
r2	0.116	0.118	0.118	0.118	0.172	0.174	0.0991	0.101
N	75193	75193	33339	33339	18776	18776	23078	23078

* p<0.1, ** p<0.05, *** p<0.01 (block-bootstrapped standard errors in parentheses)

4.4 Main conclusion and policy Implications

If households evaluate the presence of a biogas plants as a disamenity, policy makers and private actors should face the resistance of local communities because a new biogas plant could lead to a reduction in the price of housing in the nearby of plants. However, analyzing 167 biogas plants opening in Piedmont between 2006 and 2015 by means of a diff-in-diff model, we have provided no evidence of such a claim, namely the opening of biogas plants do not produce any significant negative (nor positive) effect on the housing values of different kind of residential units. Further analysis need to confirm this evidence.

Even though this study does not provide evidence of a significant impact of opening of biogas plant on the housing market, it is necessary to stress the fact that previous studies on social acceptability from local communities have underlined some constraints that may limit the acceptance of biogas plants. In particular three main characteristics seem to be important: oversizing of the plants; odour nuisances, and lack of information from institutions. The absence of significant adverse impacts on property values certainly plays an important role in avoiding the need to allocate incentives to households in relation to the potential reduced property values. However, it might be appropriate to implement a system for incentivising the social acceptability of biogas plants from households through better institutional communication or throughout the provision of discounted price for energy and heat (and biomethane) through a system of vouchers or other measures that can help creating benefits sharing from biogas investments.

5. The economic evaluation of air emissions

In a social CBA perspective, the external cost of air pollution and GHG are relevant to estimate in money metrics the possible external cost saving from biogas energy production compared to other energy production technologies.

Information on the external cost of air pollutants are drawn from different sources. For what concerns the main air pollutants and CO₂ emissions, the main source of information is the 2014 EEA assessment on the cost of air pollution from European industrial facilities, which estimates damage costs for the period 2008-2012. This report presents an updated methodology which allows estimating the costs of selected pollutants from industrial facilities included in the European Pollutant Release and Transfer Register (E-PRTR). The impacts are quantified for a number of pollutants including ammonia (NH₃), nitrogen oxides (NO_x), non-methane organic compounds (NMVOCs), particulate matter (PM₁₀), Sulphur oxides (SO_x), heavy metals (e.g. arsenic, cadmium), organic compounds (e.g. benzene, dioxins) and carbon dioxide (CO₂).

The assessment of external costs associated with CO₂ emissions is more difficult. In fact there are a number of approaches used to this purpose, but differently from the air pollutants there is not an established methodology (EEA, 2014). The EEA assessment for CO₂ is based upon the carbon price values for the EU Emission Trading Scheme (EU-ETS). Therefore, given the centrality of CO₂, we enriched the background on the evaluation of the external cost of this pollutant with the results of a meta-analysis on 211 estimates of the social external costs of CO₂ emissions (Tol, 2008).

5.1 The impact pathway approach and results from EEA 2014

The EEA assessment of the external costs of pollution is based on the Impact Pathway Approach (IPA), which was developed in the 1990s and which follows a logical and stepwise progression from polluting emissions to the determination of the impacts and to a quantification of damage costs in monetary terms. The flow is shown in Figure 5.1. The determined damage costs are based on the emissions to air of pollutants from 14,325 individual facilities in the E-PRTR pollutant register for the years 2008-2012. A sensitivity analysis has been performed using the mean value of statistical life (VSL) and the median value of a life year (VOLY), the latter being monetary measures of effects on health (see Chilton et al. 2004; Viscousi and Aldy 2003; Cameron 2010).

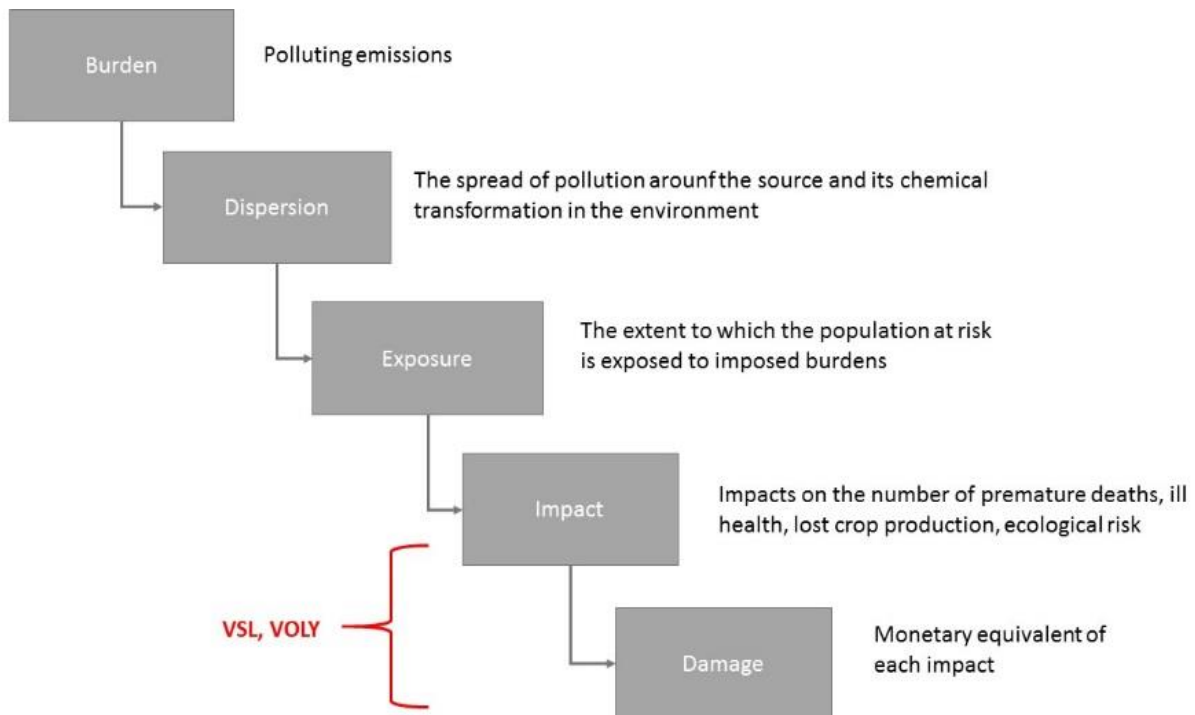


Figure 5.1 - The Impact pathway approach. Adapted from EEA 2014 (p.18)

Table 5.1 below summarizes the estimates of the costs in the EEA’s report. Estimates at the country level are also available. Estimates for air pollution are presented in the form of a range, where the lower bound is the estimate of the external cost computed following the VOLY approach and the upper value is the estimate computed following the VSL approach. The wide range of the estimates witnesses the high sensitivity of the results to the methods used to compute the pollutant specific damage cost. The damage costs of pollutants from heavy metals and organic compounds are predicted using the RiskPoll model.

For what concerns CO₂, the lower and the upper bound of the range reflects the minimum and maximum value for carbon valuation.

Table 5.1 - Estimated damage costs aggregated by pollutant group. 2008-2012. Source: EEA, 2014

Pollutant group	Aggregated damage cost (billion EUR2005)				
	2008	2009	2010	2011	2012
<i>Main air pollutants (NH₃, NO_x, PM₁₀, SO₂, NMVOCs)</i>	58-168	47-136	44-129	43-124	40-115
CO ₂	20-82	18-73	19-76	18-74	18-73
<i>Heavy metals (As, Cd, Cr, Hg, Ni, Pb)</i>	0.53	0.34	0.43	0.34	0.34
<i>Organic Pollutants (benzene, dioxins and furan, PAHs)</i>	0.22	0.11	0.17	0.22	0.10
<i>Sum</i>	79-251	65-209	64-206	62-199	59-189

Notwithstanding the great importance of this assessment, the EEA underlines that some aspects concerning the use of E-PRTR data can be improved. The information reported from the registered facilities are sometimes incomplete, and it would be advisable to improve the methodology of collection of data at the national level before these are passed to the E-PRTR. Furthermore, it would be more effective from the point of view of a dynamic comparison, to improve the traceability of the facility and to increase the amount of information on the nature of the plants and installations, in order to decrease the uncertainty included in the estimation of the external costs. The estimated external costs for Italy for pollutants from the EEA (2014) study are reported in Table 5.2.

Table 5.2 External costs for pollutants for Italy

 Damage (EUR) per tonne emission estimates for NH₃ and NO_x (2005 prices)

Country	NH ₃		NO _x	
	Low VOLY	High VSL	Low VOLY	High VSL
IT Italy	11 221	35 689	7 798	23 029

 Damage (EUR) per tonne emission estimates for PM_{2.5} and PM₁₀ (2005 prices)

Country	PM _{2.5}		PM ₁₀	
	Low VOLY	High VSL	Low VOLY	High VSL
Italy	48 288	154 289	31 356	100 187

 Damage (EUR) per tonne emission estimates for NMVOCs and SO₂ (2005 prices)

Country	NMVOC (including SOA *)		SO ₂	
	Low VOLY	High VSL	Low VOLY	High VSL

Italy	3 179	8 968	14 729	46 150
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Italy: Country-specific marginal damage costs for heavy metals, EUR/kg emission (based on RiskPoll, Ver. 2.0)

Arsenic		Cadmium		Chromium		Nickel	
Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval
355	34–543	30.7	6–50	40.9	7–67	4.1	0.7–6.7

Italy: Country-specific marginal damage costs for organics, EUR/kgemission (based on RiskPoll, Ver. 2.0)

1, 3 Butadiene		Benzene		PAH (as BaP equivalent)	
Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval
0.53	0.10–0.87	0.081	0.015–0.13	1 281	123–1 960

Italy: Country-specific marginal damage costs for organics (RiskPoll, Ver. 2.0)

Diesel particulate matter EUR/kgemission		Formaldehyde EUR/kgemission		Dioxins/furans million EUR/kgemission (PCDD and PCDF)	
Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval	Marginal damage cost	68 % confidence interval
0.60	0.11–0.98	0.23	0.04–0.38	27.0	1.5–37.0

Source: EEA (2014).

5.2 Estimation of the external cost of CO₂ emissions

Different methodologies have been developed to estimate the social cost associated with CO₂ emissions, some of which are surveyed in the EEA report.

The first is the social cost of carbon (SSC), which tries to estimate the long-term damage cost to society caused by the emission of one ton of greenhouse gases (GHGs); a limitation is that this approach do not fully capture the uncertainties related to the long-term societal changes, the future emissions and the related future temperature.

Another popular approach is the target consistent approach, which predicts the cost to society of avoiding dangerous level of climate change; it starts from a GHG target that has to be reached and subsequently derives an associated value of emissions reduction.

The third approach, which is the one used in the report, is based on the modelled ETS carbon price forecasts performed for the EU commission, which provides a reflection of the costs associated with decreasing carbon emission in the EU coherently with the policy goals related to climate change. The lower and upper bound of the range for CO₂ emissions in Table 5.3 are determined as follows (EEA, 2014, p. 24):

- i) a lower value of EUR₂₀₀₅ 9.5 per ton CO₂ (based upon a value of EUR 10 per ton CO₂ in 2010 prices reflecting the modelled ETS price in 2020 based on a reference scenario (implementation of current legislation));
- ii) a higher value of EUR₂₀₀₅ 38.1 per ton CO₂ (based upon a value of EUR 40 per ton CO₂ in 2010 prices) reflecting the projected carbon price in 2030 in a central scenario of 40% domestic GHG emission reduction by 2030 compared to 1990.

For the academic literature on the estimation of the external cost of carbon, Tol (2008) offers a meta-analysis of 211 estimates of the SCC. The aim, is to analyse the variability between different estimates of the damage cost. According to the author, the estimates of the marginal damage are based on estimates of the total cost of climate change which tends to omit some effect of climate change such as interactions between different impacts and other effects on the economy and population. Moreover, these values are often extrapolated from a few detailed case studies, and use simplistic models of adaptation to climate change which ignores uncertainties and uses controversial valuation methods and benefit transfers.

The author collects the estimates of the marginal damage cost from a number of studies for different years (1982 – 2006) measured in 1995 US dollars and actualized to same year. As noted, not all the papers under examination uses a proper marginal computation to estimate the SCC but often only average impacts are considered or the methodology is not better specified; finally, some of the studies reports multiple estimates, since they include a sensitivity analysis around the central value or tries to reproduce results from an earlier study. Table 5.3 summarizes the marginal costs considered in the analysis.

Table 5.3. Estimates of the Social marginal Costs of Carbon (SCC), Source: Tol (2008)

Author	Year	SCC	Author	Year	SCC
Nordhaus	1982	146.7	Roughgarden & Schneider	1999	40.4
Ayers & Walter	1991	119	Nordhaus & Boyer	2000	5.9
Nordhaus	1991	26.8	Tol & Downing	2000	26.1
Haradan	1992	7.3		2000	3.5
Cline	1992	64.9		2000	45.8
Hoymeyer & Gaertner	1992	1,666.70		2000	5.1
Haradan	1993	1.9	Clarkson & Deyes	2002	101.5
	1993	3	Tol	2002	19.9
	1993	8.8		2002	16.1
Nordhaus	1993	5		2002	3.8
Peck & Teisberg	1993	10		2002	6.6
Reilly & Ruchards	1993	14.3		2002	-6.6

	1993	21.2		2002	-0.5
Fankhauser	1994	20.3	Newell & Pizer	2003	5.7
Nordhaus	1994	5.3		2003	10.4
	1994	50		2003	6.5
	1994	200		2003	21.7
	1994	500		2003	33.8
				2003	23.3
Maddison	1995	16.5		2003	1.5
Schauer	1995	8.3		2003	2.9
	1995	112.5		2003	1.8
Plambeck & hope	1996	3		Pearce	2003
	1996	8	Uzawa	2003	160.7
	1996	8	Mendelsohn	2003	1.5
	1996	21	Hope	2003	19
	1996	46	Link & Tol	2004	79
	1996	440		2004	170
Azar & Sterner	1996	85		2004	25.2
	1996	200		2004	94.1
	1996	75	Azar & Sterner	1999	26
	1996	140		1999	9
	1996	32		1999	28
	1996	33		1999	28
	1996	13		1999	25
	1996	13		1999	6
	1996	260		1999	6
	1996	590		1999	2
	1996	230		1999	6
	1996	410		1999	6
	1996	95		1999	6
	1996	98	Tol	1999	60
	1996	39		1999	62
1996	39	1999		23	
		1999		66	
Downing et al.	1996	53.5	1999	65	
	1996	18.3	1999	56	
Hohmeyer	1996	800	1999	317	
Hope & Maul	1996	7	1999	243	
	1996	24	1999	142	
	1996	5	1999	360	
	1996	29	1999	348	
Nordhaus & Yang	1996	6.2	1999	288	
Nordhaus & Popp	1997	11.6	1999	171	
	1997	6.3	1999	172	
Cline	1997	88	1999	73	
Eyre et al.	1999	170	1999	192	
	1999	70	1999	187	
	1999	160	1999	156	
	1999	74	1999	26	

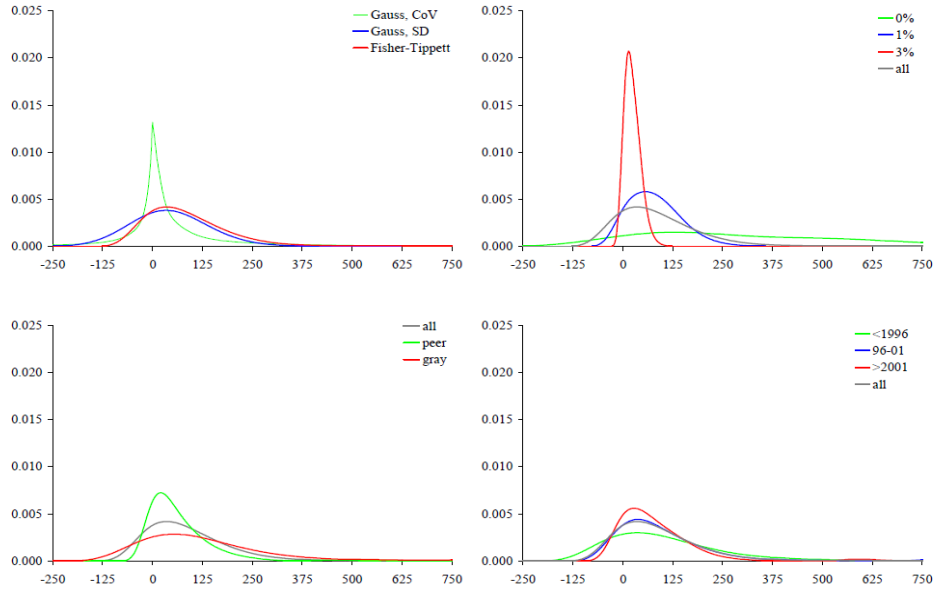
Source: Tol (2008)

The meta-analysis is carried out by looking at the statistical distributions of the estimates, using either a standard Gaussian distribution or a Fisher-Tippet distribution, which allows accounting for right-skewed

values and high variability in the distribution. Both the standard deviation and the coefficient of variation (computed as the standard deviation over the mean value) of the distributions are considered.

Overall, the analysis shows some interesting results. Firstly, there is a high degree in heterogeneity across economic estimates. Secondly, estimates are not only different one to each other, but they become always more pessimistic since the publication of the First IPCC report in 2001. Finally, Tol (2008) stressed that the debate about the SCC (and more generally cost-benefit analysis of climate policy) increased in popularity since the publication of the Stern review (Stern et al., 2006). Interestingly, in all analysis conducted by the author and according to several others, it is stressed that the Stern review is an outlier in SCC distributions.

In order to show some of the characteristics of these SCC estimates, and the high degree of dispersion of these estimates, we report below the Kernel density estimates of the probability functions of the SCC, as in Tol (2008). The graph in the top-left corner, present result for the simple distribution of the SCC. As expected, the Kernel distribution in red (i.e. the distribution of the analyzed studies) has fatter tails with respect to the benchmark distribution (Gaussian). In the top-right corner, the sample has been split using the discount rate. This procedure shows that, an higher discount rate implies a lower estimates of the SCC and thinner tail. The bottom-left picture divide between “all papers”, “peer – reviewed” and working paper (“grey”). Overall published papers tend to have lower and less uncertain estimates (i.e., they have a lower standard deviation). Finally, the last picture in the bottom-right corner, split the sample using the publication date, and show that publications that are more recent tend to have a higher estimates of the SCC (red line).



^aTop left: alternative distributional assumptions; top right: sample split according to pure rate of time preference; bottom left: sample split according to review; bottom right: sample split according to age of study. The Fisher-Tippett distribution is used throughout (except top left).

Figure 5.2. Kernel density distribution of the probability distribution function of the Social cost of carbon.

Source: Tol, (2008)

6. Linking CBA to LCA

6.1 An introduction to Life Cycle Assessment

Life Cycle Assessment (LCA) may be defined as: “*the compilation and evaluation of inputs, outputs - the material and energy flows- and potential environmental impacts of a product system throughout its life-cycle*” [EN ISO 14040]. It is a technique for evaluating the environmental performance of products from ‘cradle to grave’; it allows to identify where impacts occur, assessing the effects at each step and showing where major improvements can be made. LCA analyses the entire process of all the technological activities in stages of a product: from extraction of raw materials for its product and for ancillary materials and equipment, through the actual production and use, to the disposal of the product and of ancillary materials and equipment, if any, including transportation, recycling, by-products, avoided natural resource exploitation.

According to the ISO 14040 and 14044 standards, a Life Cycle Assessment is carried out in four distinct phases as illustrated in Figure 6.1⁸:

1. Goal and Scope Definition: defining the goal and scope of the study.
2. Inventory Analysis: making a model of the product life cycle with all the environmental inputs and outputs. This data collection effort is usually referred to as the life cycle inventory (LCI) stage.
3. Impact Assessment: understanding the environmental relevance of all the inputs and outputs. This is referred to as the life cycle impact assessment (LCIA) phase.
4. Interpretation

The phases are interdependent as LCA is an iterative procedure, meaning that one starts with initial choices and initial requirements that can be adapted later when more information becomes available, and a new cycle should be performed for all the phases of the diagram.

In the first step, the goal and scope, giving a definition and a description of the product, process or activity under investigation; the context, in which the assessment is to be made, is established and the boundaries and environmental effects are identified. This phase will be the guide to ensure the consistency of the LCA to be performed; the reason for executing the study, and the questions which need to be answered are explained in this phase. In the Inventory phase, a model is made of the complex technical system that is used to produce, transport, use and dispose of a product, identifying and quantifying energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges). This results in a flow sheet or process tree with all the relevant processes. In the Impact Assessment phase is aimed at evaluating the significance of potential environmental impacts based on the

⁸ See: ILCD Handbook: Specific guide for Life Cycle Inventory (LCI) data sets, first edition; LIFE CYCLE ASSESSMENT: PRINCIPLES AND PRACTICE, EPA/600/R-06/060, May 2006, Scientific Applications International Corporation (SAIC); Ekvall and Finnveden (2001).

LCI flow results, assessing the potential human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis. The LCA also involves an Interpretation phase, aimed at analyzing collectively the results of the phases underlined in Figure 6.1, to determine the level of confidence in the final results and communicate them in a fair, complete, and accurate manner.

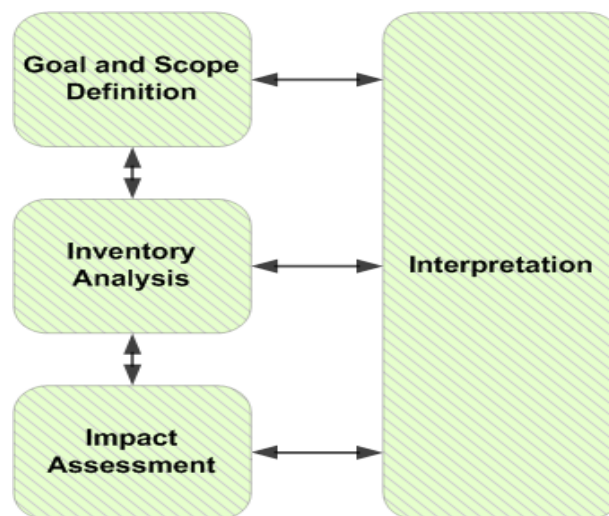


Figure 6.1. The steps of LCA (Source: SAIC, 2016).

6.2 Goal and Scope Definition

The goal and scope of the LCA study should be defined from the beginning. In the goal and scope the most important (often subjective) choices are described, including technical details to guide subsequent work; here a list of what this phase should be able to explain:

- The reason for executing the LCA, and the questions which need to be answered.
- A precise definition of the product, its life cycle and the function it fulfils.
- A description of the system boundaries.
- Any assumptions and limitations;
- A description of the way allocation problems will be dealt with.
- Data source and data quality requirements.
- The requirements regarding the LCIA procedure, and the subsequent interpretation to be used.
- The intended audiences and the way the results will be communicated.
- If applicable, the way a peer review will be made.

- The type and format of the report required for the study.
- The impact categories chosen
- For products comparison, the comparison basis (functional unit).

The goal and scope definition is a guide to ensure the consistency of the LCA, meaning that it should not be used as a static document; during the LCA, adjustments can be made if the initial choices are not optimal or practical. The goal definition is decisive for all the other phases of the LCA. The goal definition guides all the detailed aspects of the scope definition, which in turn sets the frame for the following phases (LCI work and LCIA work). The main part of the scope definition is to derive the requirements on methodology, quality, reporting, and review in accordance with the goal of the study, i.e. based on the reasons for the study, the decision-context, the intended applications, and the addressees of the results.

6.3 Inventory Analysis

Inventory Analysis, or Life Cycle Inventory (LCI), involves the creation of an inventory of flows from nature to a product system and back to nature. Inventory flows include inputs of material (water, raw materials) and energy, and output of the other materials and energy released to air, land, and water. Flows to and from processes can be distinguished in:

- Elementary flows (such as resources and emissions but also other interventions with the ecosphere such as land use),
- Product flows (i.e. goods and services both as "product" of a process and as input/consumables) that link the analysed process with other processes,
- Waste flows (both wastewater and solid/liquid wastes) that need to be linked with waste management processes to ensure a complete modelling of the related efforts and environmental impacts.

During this phase the actual data collection and modelling of the system should be done in line with the goal definition and to meet the requirements derived in the scope phase. The LCI results are the input to the subsequent following LCIA phase, but also the feedback to previous scope phase.

6.4 Impact Assessment

Inventory analysis is followed by impact assessment (LCIA). This phase of the study is aimed at evaluating the significance of potential environmental impacts based on the previous LCI flow results: the inputs and outputs of elementary flows that have been collected and reported in the inventory are translated into impact

indicator results related to human health, natural environment, and resource depletion. Many LCA studies, characterization concludes with the LCIA analysis, since this is also the last compulsory stage according to ISO 14044:2006. The LCIA phase prepares additional input for the interpretation phase of the LCA study.

The LCIA phase applies to LCI data sets exclusively to quantify the achieved completeness and precision, to be evaluated in the system's perspective. It is important to note that LCA and the impact assessment is analysing the potential environmental impacts that are caused by interventions that cross the border between technosphere and ecosphere and act on the natural environment and humans, often only after fate and exposure steps. The results of LCIA should be seen as environmentally relevant impact potential indicators, rather than predictions of actual environmental effects. LCA and LCIA are equally distinct from risk based, substance specific instruments.

Classical life cycle impact assessment consists of the following mandatory elements:

- selection of impact categories, category indicators, and characterization models;
- the classification stage, where the inventory parameters are sorted and assigned to specific impact categories;
- impact measurement, where the categorized LCI flows are characterized, using one of many possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total.

6.5 Interpretation phase

Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment. The results from the inventory analysis and impact assessment are summarized during the interpretation phase. The outcome of the interpretation phase is a set of conclusions and recommendations for the study. According to ISO 14040:2006, the interpretation should include:

- identification of significant issues based on the results of the LCI and LCIA phases of an LCA;
- evaluation of the study considering completeness, sensitivity and consistency checks;
- conclusions, limitations and recommendations.

The life cycle interpretation is the phase of the study where the results of the other phases are hence considered collectively and analysed in the light of the achieved accuracy, completeness and precision of the applied data, and the assumptions, which have been made throughout the LCI study. It serves to steer the improvement of the LCI model. A key purpose of performing life cycle interpretation is to determine the level of confidence in the final results and communicate them in a fair, complete, and accurate manner.

6.6 Examples of LCA applications to Biogas/Biomethane production

Several studies regarding the overall GHG emissions and LCA of biogas or bio-methane based on energy crops (e.g. German Biomass Research Centre, 2009; Institute for Energy and Environmental Research, 2008; Wuppertal Institute, 2006) have been published. A very recent work by Oehmichen and Majer (2016), points out some of the difficulties that can be found in performing an LCA for biomethane production; the whole process is depicted in Figure 6.2.

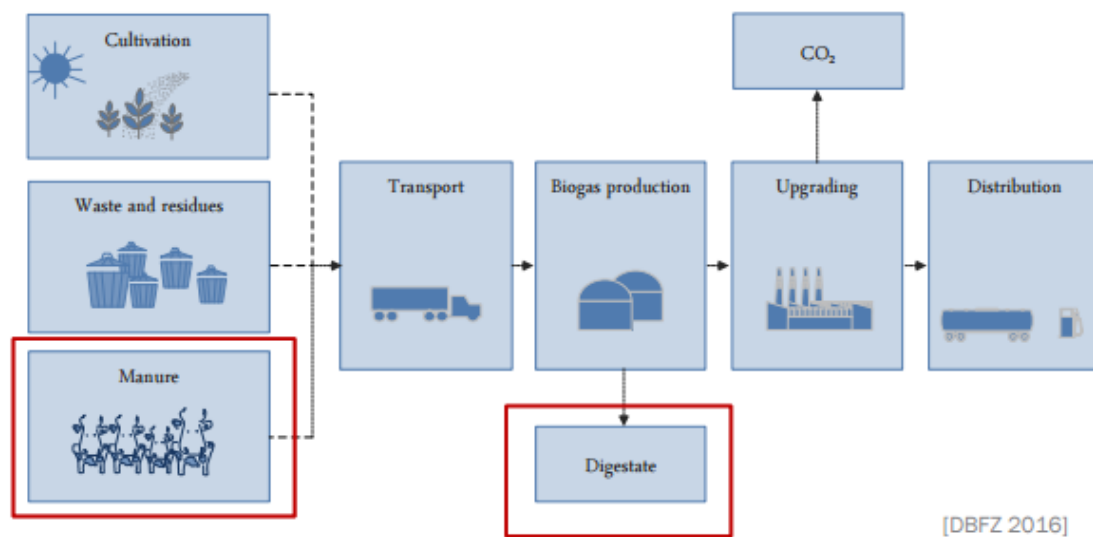


Figure 6.2. LCA Process for Biogas plants (Source: Oehmichen and Majer, 2016).

Oehmichen and Majer (2016) identify the following main challenges.

Allocation of the digestate from biogas/biomethane production. According to EU RED: the emissions resulting from the production of a product and by-product can be divided between both, based on their lower heating value (LHV); Due to high water content, the LHV of digestate is almost zero; LHV increases by separation into solid and liquid fraction. The true value of the digestate can be fully exploited if it is then used as fertiliser and thus, substitutes synthetic fertiliser in agricultural production processes. Separating the digestate into a dry and a liquid phase to reduce its water content can help to allocate a bigger part of the overall emissions to the by-product digestate and thus increase the GHG-mitigation potential of the biomethane.

GHG-emission savings from use of manure. Conventional storage of manure leads to GHG-emissions and can be a significant contributor to emissions from agricultural sector; the use of manure for biogas production can avoid emissions. In addition to that, the GHG-emission savings from the fermentation of agricultural by-products and organic residues and wastes and thus the avoidance of emissions from the conventional treatment of these materials can have a significant impact on the overall result of the GHG-mitigation potential for biomethane. The procedure for including these savings into the calculations is not specified within the EU RED.

Other studies are linked to the LCA of biogas plants. Just to provide two examples, Stucki et al. (2011) perform a LCA with the aim to compare the environmental impact of different substrates as input of the biogas reactor. Carnevale and Lombardi (2015), evaluate the upgrading process from an environmental point of view, in comparison with direct use of biogas in energy conversion devices; in this study the inputs of the digestors were not included, and the study was mostly concentrated on a small part of the whole process of biogas and biomethane production and use.

The LCA results strongly depends on the feedstock used, the technology applied and the assumptions taken for the agricultural and technical aspects and comprehensive comparison of the results is rather difficult. As well, the functional unit and the system boundaries can modify the final results.

7. Social acceptance of biogas plants

7.1 Social acceptance and the NIMBY syndrome

The limited scientific evidence on the costs and benefits associated with biogas plants that go beyond market values and, more precisely, applies also to the actual social and environmental impact of such plants (in monetary terms) with respect to social perception of such effects. Indeed, only a bunch of studies focuses on social acceptance of biogas facilities. The issue at stake is that different negative outcomes generated by biogas technologies are perceived by citizens, namely, increase in traffic, smell, noise, dust, exhaust gas exposure and landscape impacts. These factors may influence local acceptance of the technology (Walter and Gutscher, 2010).

Since the eighties social acceptance has been acknowledged as a pivotal factor to spur the diffusion of renewable energy technologies. Wüstenhagen et al. (2007) highlights that three main dimensions of social acceptance exist. The first component is the broad concept of socio-political acceptance in which stakeholders and policy makers express their opinion on the implementation of environmental policy to support the diffusion of environmentally-friendly technologies. Even though the acceptance of renewable energy technologies at this broader level is generally high, problems arise when the focus moves from the global to the local level and from general to specific green technologies (Bell et al., 2005). Indeed, the second dimension, called 'community acceptance', concerns distributional justice, i.e. the extent to which costs and benefits are shared; procedural justice, i.e. the engagement of local communities to participate in the decision making process; and trust, i.e. the degree to which local communities consider information by investors and other actors as reliable (Huijts et al., 2007). Finally, the third dimension of social acceptance relates to the diffusion of innovation, specifically, technology selection by the market (Nelson and Winter, 1982).

This subsection provides a general overview of the main studies that have investigated the first two dimension of social acceptance, i.e. socio-political and community acceptance of biogas technologies (projects implementation) (Table 7.1). From a theoretical perspective, several researchers have stated that the acceptance of renewable energy technologies is affected by the NIMBY effect (Bell et al., 2005; Wolsink, 2000). Rational choice theory suggests that citizens support renewable energy projects if they are implemented somewhere else. However, the literature has claimed that the one-dimensional perspective of the NIMBY effect is too simplistic to provide an adequate theoretical framework to understand social acceptance. In order to take into account multi-dimensional aspects of this concept, justice theory focuses on perceived benefits and costs, how they are distributed among stakeholders and the extent to which they influence the planning process (Gross, 2007). Soland et al. (2013) adopt this theoretical framework to investigate public acceptance of biogas plants in Switzerland. The distributive aspects of project implementation investigated in the paper concern perceived costs, benefits and smell. For the first time,

procedural justice is analysed which mainly affects how information diffuses, how participation is encouraged and whether trust in operators increases during project phases. A first result of the structural equation model provides evidence into the high acceptance of biogas plants in the country. Moreover, smell and perceived costs negatively affect the social acceptance whereas trust and information timing, quality and quantity positively influence the public support to biogas plants. An interesting finding is that perceived smell and costs affect trust in plant operators. This result underlines the need for an exhaustive analysis of non-market values of biogas plants.

Another pivotal issue that emerges from the studies listed in Table 7.1 concerns the extent to which stakeholders are engaged in the decision process. The importance of distributive justice and participation to the decision making process are stressed in the study by Magnani (2012). The case study focuses on the projected building of a centralised biogas plant in the Alpine valley of Giudicarie Esteriori (Province of Trento, Italy). The exclusion of local communities from the decision process and the unequal distribution of the benefits arising from the prospective biogas plant were the main factors influencing the decision to withdraw the project. The paper emphasises the importance local stakeholders engagement which may increase local acceptance and legitimacy of the process under scrutiny (Capodaglio et al., 2016).

Social acceptance seems to vary across regions and stakeholders (Walter and Gutscher, 2010). The heterogeneity of economic, environmental and social benefits of bioenergy perceived by different actors considerably affects public acceptance (Roder, 2016). Emmann et al. (2013) investigate the acceptance of the biogas technology by farmers in Germany. Their results suggest that biogas acceptance is positively related to personal innovativeness of farmers and negatively correlated with externalities (effects of biogas production on other farmers) and individual attitude towards biogas. An interesting implication of the paper is the crowding out effect of expanding biogas production. Indeed, increasing biomass production may crowd out the production of food due to land use competition.

All in all, the diffusion of biogas technology strongly depends on stakeholder acceptance since a variety of, sometimes contrasting, benefits and costs must be taken into account in project planning. The relatively scant literature emphasises that participation to the decision making process, truthfulness of information and distributive implications favour social acceptance of biogas projects. Another issue to take into account is the complex structure of contrasting benefits perceived by different stakeholders which requires a comprehensive analysis of social, economic and environmental trade-offs. In addition, community acceptance may differ from socio-political acceptance since local acceptance may vary over the project life-cycle. Wolsink (2007) points out that community acceptance follows a U-curve and moves from high acceptance during project planning to lower acceptance throughout the siting phase. Finally, it increases again when the project is running. However, Kortsch et al. (2015) find that the acceptance of biogas plants is substantially constant over time highlighting that, once built, the public support remains quite stable.

Furthermore, it has been observed that regional economic advantages, job-security and energy supply independence positively influence public acceptance of biogas facilities.

Table 7.1 – Studies directly investigating social acceptance of biogas plants in Europe

Paper	Title	Journal	Geography	Material
Soland et al 2013	Local acceptance of existing biogas plants in Switzerland	Energy Policy	Switzerland	Biogas
Kortsch et al 2015	Acceptance of biomass plants e Results of a longitudinal study in the bioenergy-region Altmark	Renewable Energy	Altmark (Germany)	
Magnani 2012	Exploring the Local Sustainability of a Green Economy in Alpine Communities. A Case Study of a Conflict Over a Biogas Plant	Mountain Research and Development	Trento (mountain)	Biogas fed with manure
Emmann et al 2013	Individual acceptance of the biogas innovation: A structural equation model	Energy Policy	Germany	Biogas

7.2 Social acceptance and funding: Why crowdfunding?

The concept of WTP for welfare enhancing projects and WTA for compensating decreasing welfare events has links with the funding of renewable energy projects.

Society may be willing to pay for more secure and cleaner energy. Given the likely presence of (local) winners and losers, policy makers might need to compensate part of society in monetary terms. What is relevant in social terms is the larger amount of winners with respect to losers, in economic magnitude terms. Notwithstanding the low political appeal of taxes, new environmental taxes (on resources, pollution) can create revenues to be earmarked to specific aims. Those revenues can support the development of cleaner energy in a given territory; provide incentives and premiums for cleaner and more efficient projects, funding compensations to the part of society that is negatively affected etc.

Instead of using taxes, local projects can be supported by bottom up schemes that rely on people's donations to 'Trusts' or 'Funds'⁹. Trusts are non-profit/private mixed financial mechanisms that support the start-up of project that deliver market and non-market benefits, like cheaper energy, employment creation, more energy security and CO₂ reduction).

Within this 'voluntary donation' funding system wherein society cooperates to support a given project, the crowdfunding investment framework is now crucial in the energy sector.

Crowdfunding is of two types: donation-based and investing oriented. The first case is a typical voluntary provision of public goods, while the second case is a situation where the donor becomes an 'interest-holder': either by "lending (where funders receive a debt instrument that specifies future terms of payment, usually a fixed rate of interest)" or "equity platforms (where funders receive an equity instrument or a profit sharing arrangement thus participate of business activities and risks)"¹⁰. The two situations can be mixed in front of projects that generate substantial public and private payoffs as well. Renewable energy projects, including biogas/methane plants, might be a relevant case study.

There is scope to extend both the application and analysis of CBA revealed and stated preference techniques on the one hand and jointly analysing the feasibility and effectiveness of mixed systems of funding. Both mechanisms – transparent and robust economic valuation schemes, participatory and transparent funding systems – can increase the social acceptance of biogas projects, and comprehensively assess their socio economic and environmental efficiency and socio-political and economic feasibility.

⁹ Those funding schemes are analysed in a qualitative way in the survey, which in the first round tries to investigate social preferences. The two consequential Future surveys might include monetary evaluations.

¹⁰ See Candelise (2016) for a systematic review of energy crowdfunding platforms.

8. Main results for empirical applications in Italy

There is in general a limited analysis of biogas plants in a 'social CBA' perspective at the international level, and in particular in Italy where the few published studies address the pure financial viability of these projects (see for example Riva et al. 2014). Therefore, the production of such kind of analyses for the ISAAC project requires the selection of available experiences together with original enquiries on both social evaluation and distributional issues of specific social/private costs and benefits.

As a reference for social CBA (ex ante) we keep the approach presented in European Commission (2015) for the appraisal of project within the EU structural funds (see Section 2). This approach involves a clear distinction between the phase of 'financial analysis' of projects and the 'social' (or 'economic') CBA analysis of the same project. While financial analysis of public projects - like those candidate for funding in European structural funds considered in EC (2015) - already involve direct and indirect effects of market value creation to the society, in the case of biogas projects that are purely private investments the financial analysis should include just private costs and benefits and can be framed as a conventional private investment decision. The social CBA analysis of biogas, instead, must include all the direct and indirect, market and non-market effects of the same project. This approach, that largely departs from the one adopted, for example, by Moeller and Martinsen (2013) for Denmark, will allow to draw a clearer distinction between the private and public dimension of biogas projects and then to treat the issue of social involvement and participation in a clearer way. In particular, the issue of public tax/subsidies, which is critical to the always negative welfare and financial results for all different plants scenarios of Moeller and Martinsen (2013), will be addressed in a different way that follows the prescriptions of EC (2015). We nonetheless will exploit the approach by Moeller and Martinsen (2013) for the list of some conventional costs and benefits from biogas (although the set of costs and benefits in that study is not complete and possibly biased towards climate change policy analysis) and for useful hints on the calculation of some single costs and benefits items.

The other parts of this report has been devoted to the analysis of specific elements to be included in applied 'social CBA' analyses of case studies in Italy, in particular indirect and external costs/benefits as methodologically depicted in Section 3.

In Section 4, we developed an original empirical analysis of the possible effects of the approval and entry into operation of biogas plants on housing values. The exercise exploits detailed data on biogas plants in Piedmont and very detailed data on the housing market in Italy at the sub-municipal level (from the Osservatorio Mobiliare Italiano of the Fiscal Italian Agency). The main result of the econometric estimates is that the presence of a biogas plant does affect neither negatively nor positively the housing values in the premises of a biogas plant. This analysis is the first one of this type in Italy and then has to be considered as preliminary and subject to future more detailed works. These results, however, does not mean that the possible indirect economic effect of biogas investments on housing values must be excluded from the range

of socially relevant costs because the perception of these effects can cause implicit costs to the investments to be possibly considered at a different level (see Section 7 on social acceptance).

In Section 5, we reviewed the existing monetary evaluations of air pollution and GHGs to be possibly used in the empirical applications to Italian case studies. In the case of air pollutants, the most reliable source of monetary estimates is the one presented in EEA (2014), which is based on the 'impact pathways approach' and on a massive review of empirical analyses available for Europe. The monetary factors for Italy presented in the study can be a basis for the application to biogas plants in Italy in order to monetise the value of saved emissions from biogas with respect to the assumed substituted energy. Some tools of 'value transfer' could be needed to calibrate the monetary evaluation to specific locations. In the case of the monetary value of CO₂, instead, the range of values produced by the many works of the last few years is very large and largely depends on specific methodological assumptions on marginal abatement costs, carbon taxes, and CO₂ market price in emission trading systems. The choice of the values to be used in empirical applications can either come from further analysis of factors preferred in Italian studies and/or can be solved by taking ranges of CO₂ monetary values.

Given that most part of CBA applied to biogas is based on direct emission factors, we explored the possible shift to an LCA approach to define the emission factors and the environmental value of resources used in the projects (Section 6). In general, to perform an integrated social CBA-LCA can be challenging, but this possibility will be considered in the application to the case studies in Italy depending on available meaningful LCA parameters that can be suitable for the case study itself. In this future applications to Italian test areas, this attempt can involve the link between social CBA of WP6 with the state of knowledge on environmental pressures as carried out in WP2.

Section 7 addressed the issue of social acceptability of biogas investments and plants, which is relevant for the analyses of Task 1 in WP6 (direct survey to the population of the test area). There are very few studies available on social acceptance and the NIMBY syndrome from biogas, differently from waste management facilities and other renewable energy plants, and this can be at odd given the social opposition arising for these plants, in particular in Italy. The analysis in any case suggests the great importance of social acceptability, which can be also supported by a clearly drafted social CBAs in which the distributional issues are clearly disclosed and faced even with creative instruments for community involvement. These instruments can be based on a 'shared benefits' approach and they can involve also creative finance, in particular crowdfunding, and these topics will be addressed in Task 3 of WP6.

9. References

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