A profitability analysis of small-scale biomethane plants

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Abstract

European countries aim to achieve a more competitive, safe and sustainable energy system. Biomethane is a promising renewable energy carrier and the main point of strength is its flexibility. In fact, this resource can be injected directly into the public gas grid, or can be converted into electricity and heat in cogeneration units, or can be used in the transport sector as vehicle fuel. Literature analysis highlights as the role of subsidies is strategic to develop the biomethane production and countries, as Germany, Sweden, United Kingdom, Switzerland and Netherlands, have registered a significant growth in the last years.

This paper proposes a mathematical and economic model useful to evaluate the profitability of biomethane injected into the gas grid. The indicators used are Net Present Value and Discounted Payback Time. The baseline scenario analyses three different small-scale sizes (50 m^3/h, 100 m^3/h and 150 m^3/h) concerning two typologies of substrates (municipal solid waste msw and a mixture of maize and manure residues). A sensitivity analysis on the main critical variables (subsidies, investment costs of biogas production, transport costs of substrates and percentage of maintenance and overhead costs in biogas production) is conducted. The profitability of biomethane, also for small-scale plants and when are recovered a wide range of waste, can contribute to develop the circular economy and consequently, it plays a role in a sustainable future.

Keywords: *biomethane, economic analysis, small-scale plants, subsidies, sustainability*

1. Introduction

Renewable energy sources represent a key-element of energy policy of European Union(European Commission, 2015). They permits to achieve several aims: the security of supply, the reduction of greenhouse gas (GHG) emissions, lower energy costs, employment opportunities and economic growth (D'Adamo and Rosa, 2016).

Biogas is a mature renewable energy technology and it is produced by anaerobic digestion process treating several feedstocks, as agricultural residues (e.g. manure and crop residues), energy crops, organic fraction of municipal solid waste (msw) and industrial organic waste Budzianowski, 2016). Biomethane is obtained from properly treated biogas through the process of purification and an evaluation of biogas upgrading technologies is proposed by (Morero et al., 2017). The economic impact of upgrading depends by both the quantity of biogas processed and the technology used (water scrubbing, pressure swing adsorption, chemical scrubbing, physical scrubbing and membrane separation (Bauer et al., 2013).

Biomethane is a carrier renewable energy, having properties potentially equivalent to methane. It is very flexible, in fact can be used as a vehicle fuel, distributed in the main gas supply or used to generate green power(Islas-Espinoza et al., 2017).The role of biomethane to achieve GHG reduction goals is explored by several countries (Horschig et al., 2016) and the biogas-biomethane chain is a carbon-negative alternative to consumption of natural gas (Leonzio, 2016). New research aims to obtain better environmental (Hernandez et al., 2017) and technological (Augelletti et al., 2017) performances. The economic point of view is not well analysed. The specific cost production is 0.54 €/m^3 and 0.73 €/m^{3}in the case grid injection and use as transportation fuel, respectively (Rotunno et al., 2017). Furthermore, the discounted total costs for production of biomethane are 0.46-0.82 €/m^{3}and 0.49-0.76€/m^3 for msw and mixed substrates, respectively (Cucchiella and D'Adamo, 2016).

In the framework of the EU-project "Record Biomap" stakeholders aims to propose solutions to make biomethane production profitable also at small and medium scale biogas plants. Their role is analysed in literature (Merlin and Boileau, 2017; Rotunno et al., 2017). This paper evaluates the profitability of small-scale biomethane plants (50 m^3/h, 100 m^3/h and 150 m^3/h) concerning two typologies of substrates (msw and a mixture of of 30% maize and 70% manure residues on a weight basis). The methodology used is the Discounted Cash Flow (DCF) and the financial performance is defined by Net Present Value (NPV) and Discounted Payback Time (DPBT). The role of subsidies is evaluated and their contribution is strategic to the development of the sector. For this motive, Italy is chosen as case study. The dependence on the imports of natural gas is very high in this country and it is useful to evaluate the injection into the gas grid as final destination.

The paper is organised as follows. Section 2 presents the methodology used in this paper and an economic model is defined to evaluate the profitability of a biomethane plant. Starting by input data, it is possible to calculate NPV and BEP (Section 3). Furthermore, a sensitivity analysis is proposed in section 4 in order to give solidity to results obtained. Section 5 presents some concluding remarks.

2. Methods

DCF is a wide economic assessment method estimating the profitability of a project. Two indicators (NPV and DPBT) are used.NPV is defined as the sum of the present values of the individual cash flows and DPBT represents the number of years needed to balance cumulative discounted cash flows and initial investment(Pechmann et al., 2016).

2.1 Model description

From the revenues side, the subsidy is calculated on the amounts of biomethane fed into the grid excluding the energy consumption of biomethane production process. It is valid for 20 years and it is an all-inclusive price equal to twice the 2012 market value for natural gas (up to 500 m^3/h biomethane in according to a decree dated 5 December 2013 by the Italian Ministry of Economic Development). Furthermore, this value is increased by 10% for plants with a production capacity ≤ 500 m^3/h and the combination of incentive and corrective coefficient is increased by 50%, if the feedstock is 100% made from residues or waste. Another item of revenue is represented by msw, in fact the associated processing of urban waste is a paid service and its value is greater than the counter-balancing costs for pre-treatment to obtain the solid organic fraction(Cucchiella et al., 2015).

From the costs side, three phases are identified: (i) biogas production; (ii) upgrading and (iii) distribution. Additional compression is not needed, if the gas distribution grid operates at levels of pressure similar to those in output by upgrading phase (Jürgensen et al., 2015). Investment costs are lower than operational ones. The most relevant item is represented by maintenance and overhead, specially for msw substrate during the biogas production phase (Cucchiella and D'Adamo, 2016). The use of membrane separation technology is proposed minimizing the investment cost of upgrading phase (Bortoluzzi et al., 2014).

The mathematical model used to evaluate the profitability of biomethane plant is reported below:

$$NPV = \sum_{t=0}^{n} (I_t - O_t)/(1 + r)^t \quad (1)$$

$$\sum_{t=0}^{DPBT} (I_t - O_t)/(1 + r)^t = 0 \quad (2)$$

$$Q_{biogas}^{nom} = S_{biogas} * n_{oh} * \%CH_4 \quad (3)$$

$$Q_{feedstock} = Q_{biogas}^{nom}/(p_b^u * (\%vs/ts) * (\%ts/(ww + ts))) \quad (4)$$

$$Q_{biogas} = Q_{biogas}^{nom} * (1 - l_{bs}) \quad (5)$$

$$Q_{biomethane}^{nom} = S_{biomethane} * n_{oh} \quad (6)$$

$$Q_{biomethane} = Q_{biogas} * (\%CH_4) * (1 - l_{us}) \quad (7)$$

$$Q_{biomethane}^{sub} = Q_{biomethane} * (1 - p_{esc}) \quad (8)$$

$$R_t^{subsidies} = Q_{biomethane}^{sub} * ((2p_{ng}^{2012} * c_{c,si}) * c_{c,su}) \quad □t=0...n_s \quad (9)$$

$$R_t^{ofmsw} = Q_{ofmsw} * (R_{gross,t}^{ofmsw} - C_t^{ofmsw}) \quad □t=0...n \quad (10)$$

$$O_t = C_{lcs,t}^{1°s} + C_{lis,t}^{1°s} + C_{lcs,t}^{2°s} + C_{lis,t}^{2°s} + C_{lcs,t}^{3°s} + C_{lis,t}^{3°s} + C_{l,t} + C_{s,t} + C_{ts,t} + C_{mo,t}^{1°s} + C_{df,t}^{1°s} + C_{e,t}^{1°s} + C_{i,t}^{1°s} + C_{mo,t}^{2°s} + C_{df,t}^{2°s} + C_{e,t}^{2°s} + C_{i,t}^{2°s} + C_{o,t}^{dis} + C_{tax,t} \quad (11)$$

$$C_{inv}^{1°s} = C_{inv}^{u,1°s} * S_{biogas} \quad (12)$$

$$C_{lcs,t}^{1°s} = C_{inv}^{1°s}/n_{debt} \quad □t=0...n_{debt}-1 \quad (13)$$

$$C_{lis,t}^{1°s} = (C_{inv}^{1°s} - C_{lcs,t}^{1°s}) * r_d \quad □t=0...n_{debt}-1 \quad (14)$$

$$C_{inv}^{2°s} = C_{inv}^{u,2°s} * S_{biomethane} \quad (15)$$

$$C_{lcs,t}^{2°s} = C_{inv}^{2°s}/n_{debt} \quad □t=0...n_{debt}-1 \quad (16)$$

$$C_{lis,t}^{2°s} = (C_{inv}^{2°s} - C_{lcs,t}^{2°s}) * r_d \quad □t=0...n_{debt}-1 \quad (17)$$

$$C_{inv}^{3°s} = C_{inv}^{dis} \quad (18)$$

$$C_{lcs,t}^{3°s} = C_{inv}^{3°s}/n_{debt} \quad □t=0...n_{debt}-1 \quad (19)$$

$$C_{lis,t}^{3°s} = (C_{inv}^{3°s} - C_{lcs,t}^{3°s}) * r_d \quad □t=0...n_{debt}-1 \quad (20)$$

$$C_{l,t} = C_l^{u,a} * n_{op} \quad □t=0...n \quad (21)$$

$$C_{s,t} = C_s^u * Q_{feedstock}$$ □t=0…n (22)

$$C_{ts,t} = C_{ts}^u * Q_{feedstock}$$ □t=0…n (23)

$$C_{mo,t}^{1°s} = p_{mo}^{1°s} * C_{inv}^{1°s}$$ □t=0…n (24)

$$C_{df,t}^{1°s} = p_{df} * C_{lcs,t}^{1°s}$$ □t=0…n (25)

$$C_{e,t}^{1°s} = c_e^{u,1°s} * Q_{biogas} * p_e$$ □t=0…n (26)

$$C_{i,t}^{1°s} = p_i * C_{inv}^{1°s}$$ □t=0…n (27)

$$C_{mo,t}^{2°s} = p_{mo}^{2°s} * C_{inv}^{2°s}$$ □t=0…n (28)

$$C_{df,t}^{2°s} = p_{df} * C_{lcs,t}^{2°s}$$ □t=0…n (29)

$$C_{e,t}^{2°s} = c_e^{u,2°s} * Q_{biogas} * p_e$$ □t=0…n (30)

$$C_{i,t}^{2°s} = p_i * C_{inv}^{2°s}$$ □t=0…n (31)

$$C_{o,1}^{dis} = C_o^{dis}$$ □t=0…n (32)

$$C_{tax,t} = p_{tax}^{unit} * ebt$$ □t=0…n (33)

Nomenclature

1°s	biogas production	n	lifetime of investment
2°s	Upgrading	n_{debt}	period of loan
3°s	compression and distribution	n_{oh}	number of operating hours
$c_{c,su}$	corrective coefficient - substrate	n_{op}	number of operators
$c_{c,si}$	corrective coefficient - size	n_s	period of subsidies
$C_{df}^{1°s}$	depreciation fund (1°s)	O_t	discounted cash outflows
$C_{df,t}^{2°s}$	depreciation fund (2°s)	p_b^u	potential of biogas per unit of vs
$C_{e,t}^{1°s}$	electricity cost (1°s)	p_{df}	% of depreciation fund
$C_{e,t}^{2°s}$	electricity cost (2°s)	p_e	unitary price of electricity
$c_e^{u,1°s}$	unitary electricity consumption(1°s)	p_{esc}	% of energy self-consumption
$c_e^{u,2°s}$	unitary electricity consumption(2°s)	p_i	% of insurance cost
$C_i^{1°s}$	insurance cost (1°s)	$p_{mo}^{1°s}$	% of maintenance & overhead cost (1°s)
$C_{i,t}^{2°s}$	insurance cost (2°s)	$p_{mo}^{2°s}$	% of maintenance & overhead cost (2°s)
C_{inv}^{dis}	investment cost (distribution)	p_{ng}^{2012}	price of natural gas in 2012
C_l	labour cost	p_{tax}^{unit}	% of taxes cost
$C_l^{u,a}$	unitary labour cost	R_t^{ofmsw}	revenues by treatment of msw
C_{lcs}	loan capital share cost	$R_{gross,t}^{ofmsw}$	gross revenues by msw
C_{lis}	loan interest share cost	$R_t^{subsidies}$	revenues by subsidies
$C_{inv}^{u,1°s}$	unitary investment cost (1°s)	$Q_{feedstock}$	quantity of feedstock
$C_{inv}^{u,2°s}$	unitary investment cost (2°s)	Q_{biogas}	quantity of biogas
$C_{mo}^{1°s}$	maintenance & overhead cost (1°s)	Q_{biogas}^{nom}	nominal quantity of biogas
$C_{mo}^{2°s}$	maintenance & overhead cost (2°s)	$Q_{biomethane}$	quantity of biomethane
C_o^{dis}	operative cost (distribution)	$Q_{biomethane}^{sub}$	quantity of subsized biomethane
C_s	substrate cost	$Q_{biomethane}^{nom}$	nominal quantity of biomethane
C_s^u	unitary substrate cost	Q_{ofmsw}	quantity of msw

C_t^{ofmsw}	cost of msw	r	opportunity cost
C_{tax}	taxes cost	r_d	interest rate on loan
C_{ts}	transport cost of substrates	S_{biogas}	plant size (biogas)
C_{ts}^{u}	unitary transport cost of substrate	$S_{biomethane}$	plant size (biomethane)
ebt	earnings before taxes	t	time of the cash flow
I_t	discounted cash inflows	ts	total solids
inf	rate of inflation	vs	volatile solids
l_{bs}	losses in the biogas system	ww	wet weight
l_{us}	losses in the upgrading system	$\%CH_4$	percentage of methane

2.2 Input assumptions

This work evaluates the profitability of biomethane plants in function of size and substrates used. It is injected into natural gas and six case studies are proposed by the combination of these variables:

- 50 m^3/h, 100 m^3/h and 150 m^3/h biomethane capacities.
- msw and mixed (with a mixture of 30% maize and 70% manure residues on a weight basis) substrates.

The definition of an optimal size of biogas plant is chosen in order to maximize the grade of saturation of upgrading phase ($Q_{biomethane} \approx Q_{biomethane}^{nom}$) in according to approach used by (Cucchiella and D'Adamo, 2016)– **Table 1**. For example, considering an upgrading size equal to 50 m^3/h that treated msw substrate through a biogas size equal to 150 Kw, the quantity of biomethane is equal to 399,989 m^3/h (there is a little difference with 400,000 m^3/h). Furthermore, the amounts of manure residues necessary to reach the saturation of the plant is very high. In fact, considering an msw 50 m^3/h plant are required 5952 t of this feedstock, while 1163 t of maize and 19,579 t of manure residues are required in a mixed plant.

Table 1. Characteristics of the sizing of biomethane plants

	1° plant size	2° plant size	3° plant size
S_{biogas} mixed (kW)	155	315	470
S_{biogas} msw (kW)	150	300	450
$C_{inv}^{u,1°s}$mixed (€/kW)	4500	4800	5100
$C_{inv}^{u,1°s}$ ofmsw (€/kW)	4700	5000	5300
Q_{ofmsw} (t)	5952	11,905	17,857
Q_{maize}(t)	1163	2363	3525
$Q_{manure\ residues}$(t)	19,579	39,789	59,368
$S_{biomethane}$(m^3/h)	50	100	150
$C_{inv}^{u,2°s}$ (€/(m^3/h))	6300	5800	5300
$Q_{biomethane}^{nom}$ (1000*m^3/h)	400	800	1200
$Q_{biomethane}^{sub}$ mixed (1000*m^3/h)	334	678	1012
$Q_{biomethane}^{sub}$ ofmsw (1000*m^3/h)	340	680	1020

A DCF analysis is characterized by two key-variables: the lifetime of the plant is defined equal to lifetime of the subsidies (20 years)and the opportunity cost is fixed to 5%. Furthermore, the investment cost is covered by third party funds and it is assumed that the end specification of the gas (like composition and pressure) are adjusted to its final use. Economic and technical inputs are proposed in **Table 2.**

Table 2. Input data

Variable	Value	Reference
$c_{c,su}$	1 [a]; 1.5 [b,d]	(Cucchiella et al., 2015)
$c_{c,si}$	1.1	(Cucchiella et al., 2015)
$c_e^{u,1°s}$	0.13 kWh/m^3	(Bortoluzzi et al., 2014)
$c_e^{u,2°s}$	0.29 kWh/m^3	(Browne et al., 2011)
C_{inv}^{dis}	237,500 €	(Smyth et al., 2010)
$C_{inv}^{u,1°s}$	Table 1	(Cucchiella and D'Adamo, 2016)
$C_{inv}^{u,2°s}$	Table 1	(Cucchiella and D'Adamo, 2016)
$C_l^{u,a}$	25,000 €/y	(Cucchiella and D'Adamo, 2016)
C_o^{dis}	20,000 €/y	(Smyth et al., 2010)
C_s^u	10 €/t [c]; 0 € [b,d]	(Bortoluzzi et al., 2014)
C_t^{ofmsw}	49 €/t	(Cucchiella et al., 2015)
C_{ts}^u	2 €/t	(Sgroi et al., 2015)
inf	2%	(Cucchiella and D'Adamo, 2016)
l_{bs}	6%	(Smyth et al., 2010)
l_{us}	1.5%	(Smyth et al., 2010)
N	20 y	(Cucchiella et al., 2015)
n_{debt}	15 y	(Cucchiella et al., 2015)
n_{oh}	8000 h	(Cucchiella et al., 2015)
n_{op}	4	(Cucchiella et al., 2015)
n_s	20 y	(Cucchiella et al., 2015)
p_b^u	350 [d] - 500 [b] – 650 [c] m^3biogas/t(vs)	(Cucchiella and D'Adamo, 2016)
p_{df}	20%	(Cucchiella and D'Adamo, 2016)
p_e	0.13 €/kWh	(Cucchiella and D'Adamo, 2016)
p_{esc}	15%	(Torquati et al., 2014)
p_i	1%	(Cucchiella and D'Adamo, 2016)
$p_{mo}^{1°s}$	10% [a]; 20% [b]	(Browne et al., 2011)
$p_{mo}^{2°s}$	10%	(Cucchiella et al., 2015)
p_{ng}^{2012}	28.52 €/MWh → 0.299 €/m^3 (1 m^3 = 0.0105 MWh)	(Cucchiella et al., 2015)
p_{tax}^{unit}	27.5%	(Cucchiella et al., 2015)
Q_{ofmsw}	Table 1	(Cucchiella and D'Adamo, 2016)
Q_{maize}	Table 1	(Cucchiella and D'Adamo, 2016)
$Q_{manure\ residues}$	Table 1	(Cucchiella and D'Adamo, 2016)
R	5%	(Cucchiella and D'Adamo, 2016)
r_d	3%	(Cucchiella et al., 2015)
$R_{gross,t}^{ofmsw}$	70 €/t	(Cucchiella et al., 2015)
S_{biogas}	Table 1	(Cucchiella and D'Adamo, 2016)
$S_{biomethane}$	Table 1	(Cucchiella and D'Adamo, 2016)
$\%CH_4$	57% [a]; 60% [b]	(Cucchiella et al., 2015)
%ts/(ww+ts)	9.5% [d]; 27% [b]; 30.8% [c]	(Schievano et al., 2009)
%vs/ts	80% [d]; 89.6% [b]; 95.9% [c]	(Schievano et al., 2009)

a=mixed; b=ofmsw; c=maize; d=manure residues with a=30%*c+70%*d. These are % of total mass.

3. Results

As highlighted in section 1, the biomethane is a resource in able to reach the sustainable goal. From an environmental perspective, its use achieves a reduction of GHG emissions than the ones released by the use of natural gas (Budzianowski and Postawa, 2017)and European countries can reduce their reliance on natural gas imports (Foley et al., 2017). This section evaluates the economic impact concerning the six case studies examined in this work. Giving the model assumptions and input data defined previously, NPV and DPBT are proposed in **Table 3**.

Table 3. Profitability analysis of biomethane plants

	50 m^3/h of msw	**100 m^3/h of msw**	**150 m^3/h of msw**
NPV (€)	-889,403	-14,665	615,694
DPBT (y)	>20	>20	3
	50 m^3/h mixed	**100 m^3/h mixed**	**150 m^3/h mixed**
NPV (€)	-3,452,626	-5,037,534	-6,721,719
DPBT (y)	>20	>20	>20

The profitability is verified only in 150 m^3/h biomethane plant obtained by msw substrate. The profit is very relevant (4105 € per m^3/h), but in other scenarios the losses are consistent. They ranges from -69,053 € per m^3/h in 50 m^3/h mixed plant to -147 € per m^3/h in 100 m^3/h of msw one.

The difference between two substrates depends by profits linked to the treatment of msw (equal to 0.29 m^3/h) and by the structure of the incentive scheme ($c_{c,su}$ is equal to 1 and 1.5 for mixed and ofmsw, respectively). Furthermore, the subsidies are conferred only to the amount of biomethane injected into the grid, which is different than producedone ($Q^{sub}_{biomethane} < Q_{biomethane}$).

Also, DPBT analysis provides results coherent with NPV one. In fact, it is equal to 3 years in 150 m^3/h of msw plant and is an interest in value due to principally to the low value of investment costs in comparison to operational ones reinforced also by the assumption of third party financing. In the worse scenario, the investor defines the cut-off period equal to the lifetime of the plant and consequently, a value >20 indicated that the investment cannot be recovered within this date and is unprofitable.

From the revenues side, the discounted total net revenues for msw management are equal to 27% and consequently, the subsidies have a value equal to 73%. When, instead, a mixed substrate is analysed there is only the item of incentives. The discounted total costs for production of biomethane are 0.74-0.93 €/m^3 for mixed substrates and 0.81-0.97 €/m^3 for msw ones. The maintenance and overhead cost represents the most relevant item and transport costs are greater in mixed plants due to the great amount of required manure residues (**Table 4**).

Table 4. Distribution of costs (in percentage)

	50 m^3/h of msw	**100 m^3/h of msw**	**150 m^3/h of msw**	**50 m^3/h mixed**	**100 m^3/h mixed**	**150 m^3/h mixed**
Maintenance&overhead	39	47	50	24	30	32
Investment	14	15	15	15	16	17
Labour	23	13	9	24	14	10
Electricity	9	10	11	10	12	12
Transport	3	3	3	10	12	13

4. Sensitivity analysis

NPV results are based on the assumptions of a set of input variables. This issue can be overcome by implementing a sensitivity analysis on the critical variables (Cucchiella and D'Adamo, 2016) - **Table 5**:

- the range of p_{ng}^{2012} is equal to 24.50-32.50 €/MWh (≈0.257-0.341 €/m^3);
- $C_{inv}^{u,1°s}$ is increased/decreased of 200 €/kW;
- C_{ts}^{u} is increased/decreased of 2 €/t;
- $p_{mo}^{1°s}$is increased/decreased of 5%.

Table 5. Sensitivity analysis - Net Present Value (k€)

		50 m^3/h of msw	100 m^3/h of msw	150 m^3/h of msw	50 m^3/h mixed	100 m^3/h mixed	150 m^3/h mixed
p_{ng}^{2012}	32.50 €/MWh	-299	1167	2388	-3066	-4252	-5549
	30.50 €/MWh	-592	580	1507	-3258	-4642	-6132
	26.50 €/MWh	-1180	-595	-255	-3643	-5423	-7297
	24.50 €/MWh	-1473	-1182	-1136	-3835	-5814	-7880
$C_{inv}^{u,1°s}$	4300-5100 €/kW	-762	240	997	-3368	-4865	-6464
	4700-5500 €/kW	-1017	-268	234	-3538	-5210	-6980
C_{ts}^{u}	0 €/t	-711	341	1150	-2832	-3776	-4840
	4 €/t	-1067	-371	81	-4073	-6299	-8603
$p_{mo}^{1°s}$	15%	-362	1107	2400	-2931	-3907	-4929
	25%	-1417	-1137	-1168	-3974	-6168	-8515

This analysis supports results obtained in baseline scenario. From the point of view of the of msw substrate, the profitability is verified only in 12 scenarios (40%). Also the 100 m^3/h plant is profitable in all optimistic scenarios examined and the other seven scenarios are verified with the 150 m^3/h plant. The variations of NPV more significant are expected with the changes of subsidies and the maintenance and overhead costs. Concerning the first variable, the greatest value of NPV is -299 k€ and 1167 k€ in 50 and100 m^3/h plants, respectively. Instead, regarding the second variable it is 2400 k€ in 150 m^3/h plant. The profitability is never verified if the mixed substrate is analysed. The better financial performances are reached when the unitary transport cost of substrate is null.

5. Conclusions

The climate change is not more an assumption by some researchers and scholars, but it is a concrete event. Policy makers have a key-role in this new context and directives, frameworks and decrees are able to accelerate the transition towards a circular economy. Organic fraction of municipal solid waste, manure residues, energy crops and other substrates can be recovered and the produced biogas can be upgraded. The final destinations of biomethane are wide and in this paper is evaluated the economic potential linked the injection into the gas grid. This choice can be extremely interesting for all countries that have a great dependence by foreign imports. These aspects clarify as the biomethane has a role in a sustainable future.

The availability of a model is useful to verify the profitability in several contexts. In fact, it is often necessary to replace only the input data. In other conditions, instead, it is opportune to integrate the model with other items of revenue and/or cost. The results of this paper demonstrate as the profitability of small-scale biomethane plants is verified only in some scenarios in according to previous works.

A mixed substrate, with a mixture of 30% maize and 70% manure residues on a weight basis, is always unprofitable. The biomethane obtained by organic fraction of municipal solid waste substrate is, instead, financially feasible in baseline scenario when a 150 m^3/h plant is evaluated. In this case study, NPV is equal to 4105 € per m^3/h and DPBT is equal to 3 years. In alternative scenarios, the profitability is verified also for a 100 m^3/h plant. Discounted total costs are equal to 0.74-0.93 €/m^3 and 0.81-0.97 €/m^3 for mixed and msw substrates. The role of subsidies is strategic and new measures are required to favour a greater number of substrates. There is a clear relationship between small-scale plants and the short chain and in this way can be increased the investors. Furthermore, the availability of substrates in places near the plant permits to reduce the environmental effect.

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