Università
Bocconi

GREEN
Centro di ricerca sulla geografia,
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l'ambiente e le reti

RENEWABLE GAS OBSERVATORY

Bocconi University

2022 RESEARCH SUMMARY

Con il patrocinio di:
Assocostieri
Assogas
Assogasliquidi – Federchimica
Assogasmetano
Confagricoltura
Egea
Eni
Hera
Igw
Inewa
Nordurpower
Q8
Sol

INDEX

1. INTRODUCTION

The year 2022 was disrupted by the war in Ukraine which led to a general rise in the prices of raw materials and, in particular, of energy. The sanctions against Russia and the consequent decrease in gas exports to Europe, the attack on the Nord Stream 2 gas pipeline, and the persistence of military operations have led to an increase in the price of gas, which has already been underway since the second half of 2021, giving rise to a dangerous inflationary spiral. In such a context, the problem of security of supply, which had been put in the background for many years with respect to the issues of competition and the environment, has emerged overwhelmingly in its entirety.

The answer to the aforementioned problem, in addition to an increase in energy efficiency and to identifying alternative sources of supply, consisted in a further push by the European Commission towards de-carbonization through the promotion of renewable sources, both electrical and thermal, such as biofuels and biomethane.

For the latter, the RepowerEU plan envisaged an increase in the production target contemplated by the Fit for 55 plan according to which the Member States should reach 18 Bcm by 2030.

In February 2022 the European Commission also presented the Complementary Climate Delegated Act introducing certain gas and nuclear activities into the EU Taxonomy under stringent conditions encompassing particularly low maximum emission thresholds for natural gas power generation which effectively establish the need to mix fossil gas with non-fossil gas.

On 15 September 2022, the new Decree for the incentive of biomethane in Italy was published. It contains a completely different system from that envisaged by the previous decree relating to the use of renewable gas in the transport sector. The new provisions concern the promotion and use of biomethane in all economic sectors in the belief that it can significantly contribute to the greening of natural gas networks and with the aim of giving a new acceleration to the national market development.

Despite the increase in requests for connection to the grid and a certain increase in the number of operating plants in the area, the production of biomethane still appears to be far from the 1.1 Bcm target set in 2018.

In this research report, after a brief description of the economic and energy situation, the analysis of the evolution of the market in terms of number of plants and production will be presented together with the illustration of the new incentive system, as well as with the analysis of the economics of biomethane production both as regards the construction of new plants and the conversion of existing biogas plants.

2. THE ECONOMIC AND ENERGY CONTEXT

The consequences of the invasion of Ukraine, the rise in prices, the monetary tightening operated by central banks and the deceleration of the Chinese economy are the determinants of the slowdown in the world economy. In 2022, the eurozone's GDP grew by 3.5%. For 2023, the International Monetary Fund (IMF) has slightly raised the rather negative global growth forecasts published at the end of 2022 due to demand that has proved “surprisingly resilient” in the US and Europe, decreasing energy prices and the reopening of the Chinese economy. Yet, global growth is projected to fall to 2.9 percent in 2023, and to rise to 3.1 percent in 2024 at the aggregate level. As already highlighted the forecast is 0.2 percentage point higher than predicted in the October 2022 World Economic Outlook[1] but below the historical (2000–19) average of 3.8 percent.

[1] https://www.imf.org/en/Publications/WEO/Issues/2023/01/31/world-economic-outlook-update-january-2023#:~:text=Global%20growth%20is%20projected%20to,19)%20average%20of%203.8%20percent.

For advanced economies growth is projected to decline sharply from 2.7 percent in 2022 to 1.2 percent in 2023.
Growth in the euro area is in particular projected to bottom out at 0.7 percent in 2023 and to rise to 1.6 percent in 2024.
However, many unknown factors remain, such as the future trend in the cost of energy and other raw materials and the duration of the conflict in Ukraine.

Table 1 – World GDP growth in 2022 and forecasts

%		**Projections**	
	2022	2023	2024
World Output	**3.4**	**2.9**	**3.1**
Advanced Economies	**2.7**	**1.2**	**1.4**
United States	2.0	1.4	1.0
Euro Area	3.5	0.7	1.6
Japan	1.4	1.8	0.9
United Kingdom	4.1	-0.6	0.9
Canada	3.5	1.5	1.5
Other	2.8	2.0	2.4
Emerging and Developing Markets	**3.9**	**4.0**	**4.2**
Emerging Asia	4.3	5.3	5.2
Emerging Europe	0.7	1.5	2.6
Latin America and Caribbean	3.9	1.8	2.1
Middle East and Central Asia	5.3	3.2	3.7
Sub-Saharan Africa	3.8	3.8	4.1

Source: IMF, 2023.

2.1 Energy and gas prices in 2022

2022 ended with Brent around $80/bbl and WTI at $75/bbl that is with oil prices down about a third from their June highs. The forecasts for 2023 are variable and between 75 $/bbl of CITI[2] and 100 $/bbl of BofA[3], and fundamentally conditioned by the assumptions relating to the growth of global supply and demand.

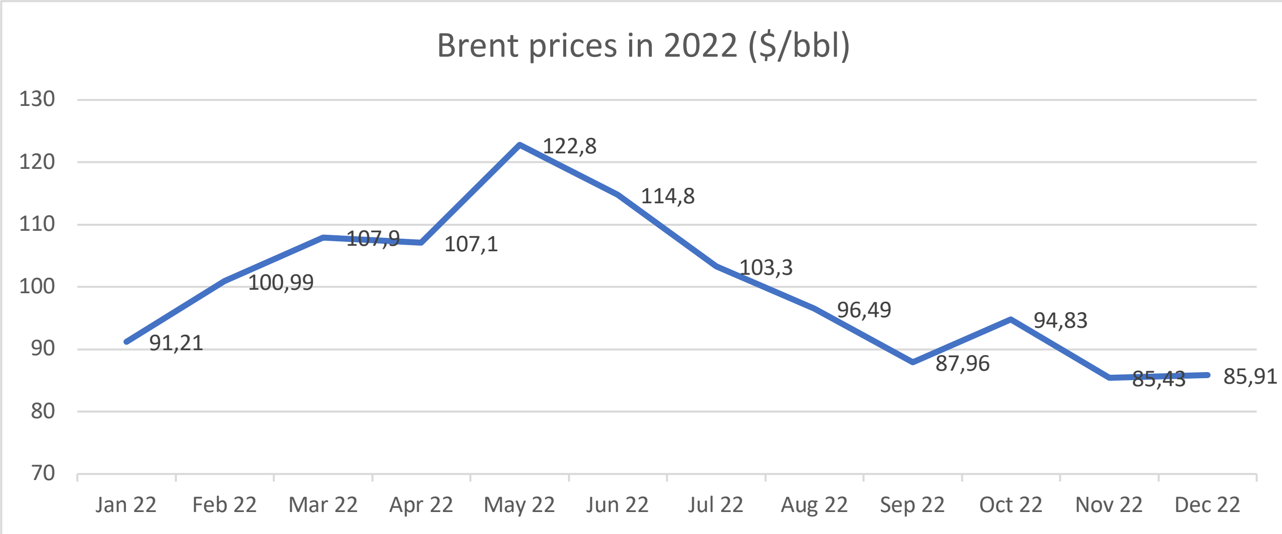
Between 1 January and 31 December 2022, the price of natural gas on the Amsterdam market (TTF) increased by 42%, marking a consolidation of the upward trend already recorded in the second half of 2021, and reaching much higher peaks as that of August (2,4 €/MWh).

The price has also shown extraordinary volatility and huge differences between Europe and the USA where the gas price raised as well but increases were much lower leading to a ratio between European and US prices that moved from historical 4-5 to 7-8.

Oil prices did not show the same volatility as gas prices and the traditional cost ratio (under energy parity), with reference to which the price of oil is at least twice the price of gas, has been reversed.

[2] https://www.privatebank.citibank.com/newcpb-media/media/documents/outlook/outlookwealthreport2023.pdf
[3] Bank of America: www.bankofamerica.com

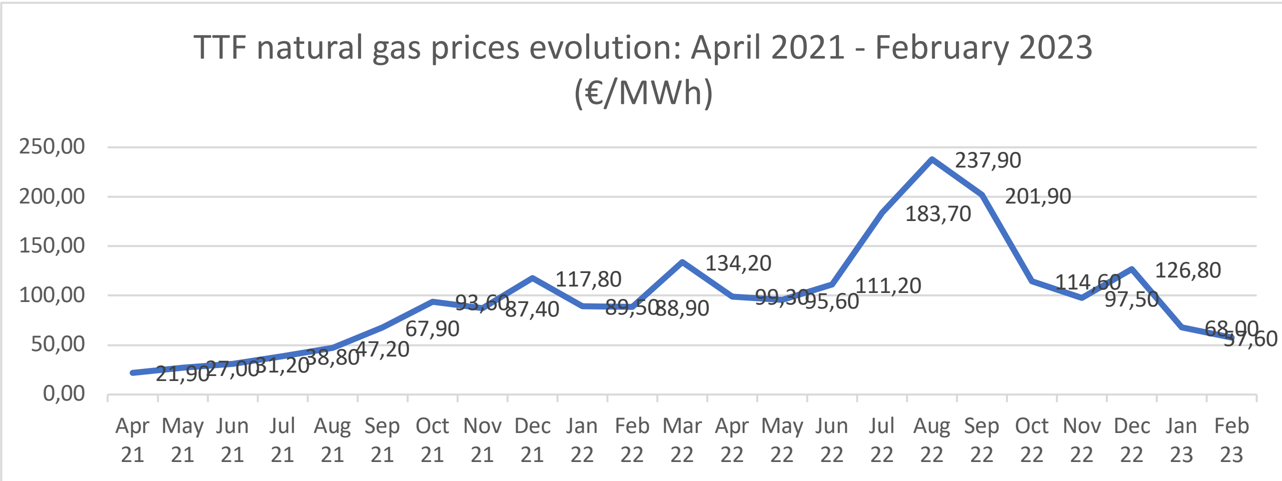
Figure 1 – Oil prices evolution: January 2022 – December 2022 ($/bbl)



Source: authors' elaboration on Platt's data.

These anomalous trends underlined the exceptional nature of the 2022 energy context and the recent scarce correlation between the two markets.

Figure 2 - TTF natural gas prices evolution: April 2021 - February 2023 (€/MWh)[4]



Source: authors' elaboration on ICE data.

Being the price of electricity determined to a large extent by the (spot) price of gas (and by the price of ETS[5] emission permits) and since most of the natural gas consumed in Italy is imported (>95%) the unprecedent rise in price quotations led to never recorded prices on the power market with heavy impacts on the spending of industries and households.

The increase in energy prices, emphasized by the Russian-Ukrainian conflict, and the consequent interruption of supplies from Russia, has brought general attention back to one of the fundamental issues of energy policy, namely the security of supply, neglected in recent years in favor of competition and environmental protection.

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[4] https://www.theice.com/products/27996665/Dutch-TTF-Gas-Futures/data?marketId=5519350

[5] Emission Trading Scheme.

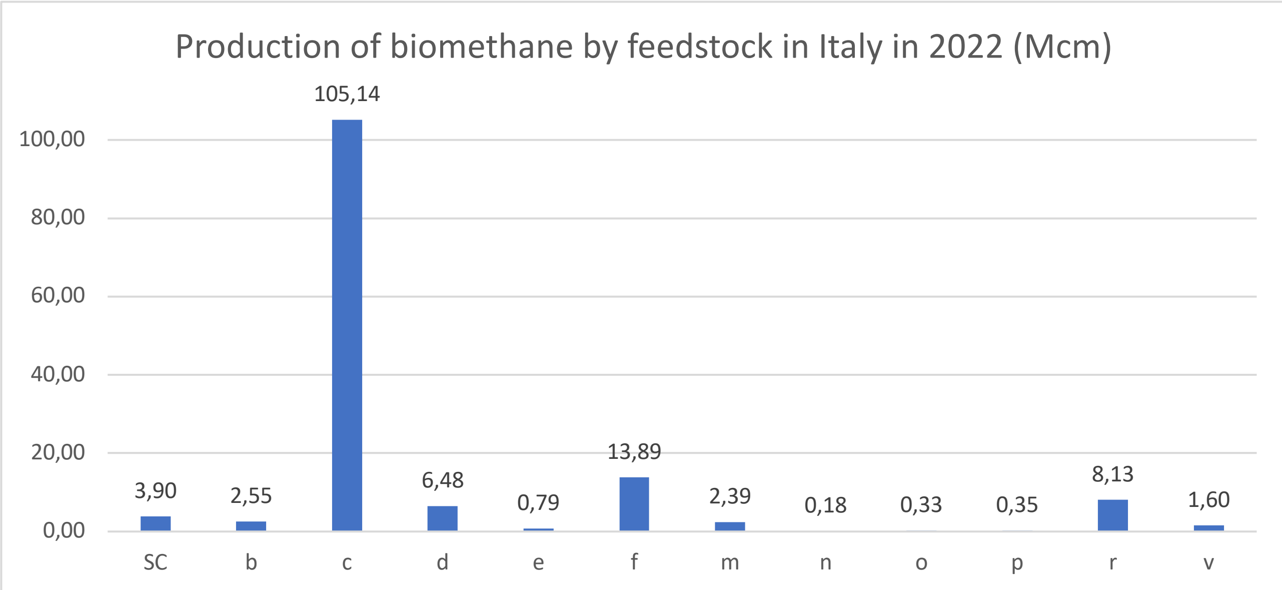
This has intensified efforts in promoting domestic energy sources such as renewable sources including biomethane.

3. THE CURRENT SITUATION OF THE BIOMETHANE MARKET IN ITALY

3.1 Biomethane production

According to the GSE[6] "meter", between January and October 2022 (last available data) theoretical biomethane production (s.c. producibility) amounted to about 320 Mmc/year corresponding to the 29% of the production target set by the 2018 Decree (1,1 Bcm).

Figure 3 – Production of biomethane by feedstock[7] in Italy in 2022 (Mcm)



Source: GSE, 2022.

The amount of incentivized biomethane was about 160 Mmc, 110 of which were directly withdrawn by the GSE itself for a counter-value of 137 M€.

Biomethane is mainly produced with organic solid urban waste (FORSU) followed by animal slurries e sewage sludges and can be therefore classified as "advanced biomethane".

Making a comparison with the quantities that were incentivized in the first 10 months of the year in 2020 and 2021 an upward trend can be easily observed: an increase of 91% occurred between 2020 and 2021 while production grew by 25% between 2021 and 2022.

Yet, the produced amount still represents a share of total producibility that has decreased since 2020.

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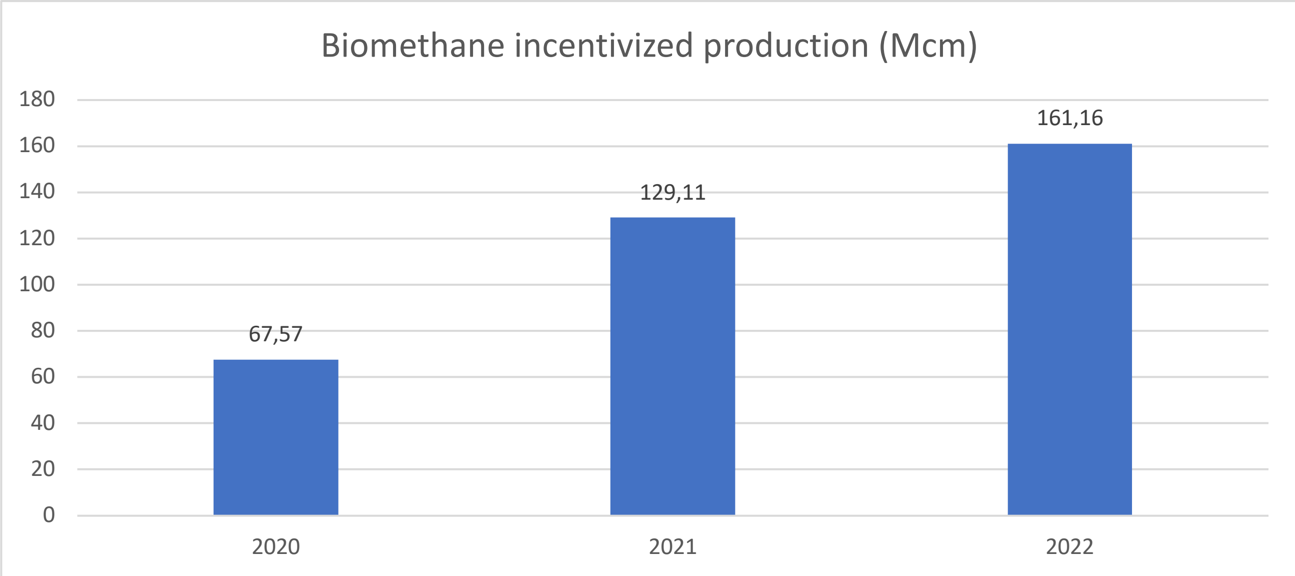
[6] Gestore dei Servizi Energetici.

[7] Double counting advanced feedstocks: (b) unsorted municipal waste other than household waste; (c) sorted solid organic waste; (d) industrial waste not suitable for use in the human or animal food chain; (e) straw; (f) animal manure and sewage sludge; (m) grape marc and similar; (n) shells; (o) husks; (p) cleaned cobs of corn seeds; cellulosic material of non-food origin; bacteria if the energy source is renewable.

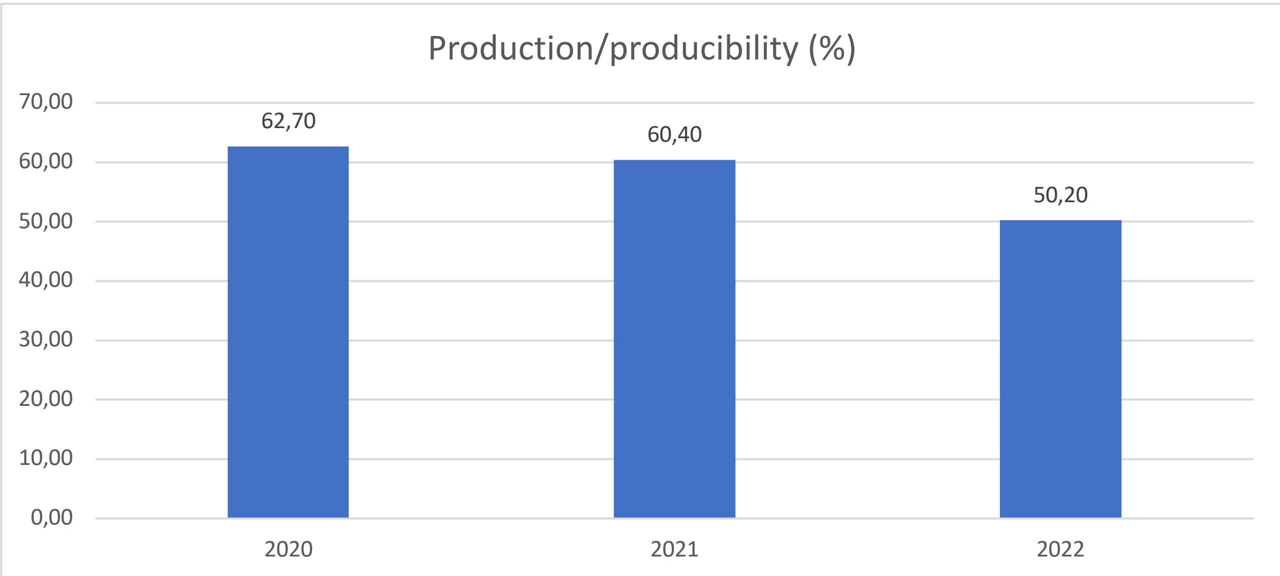
Figure 4 – Incentivized biomethane quantity in the first 10 months of the year in Italy (Mmc)



Source: authors' own elaboration on GSE data, 2023.

In particular in 2020 the produced amount represented the 63% of theoretical production while in 2021 and 2022 the ratio decreased to 60 % and 50% respectively witnessing criticalities relating to plants operation and/or substrates supply.

Figure 5 – Biomethane production vs producibility in Italy: historical trend



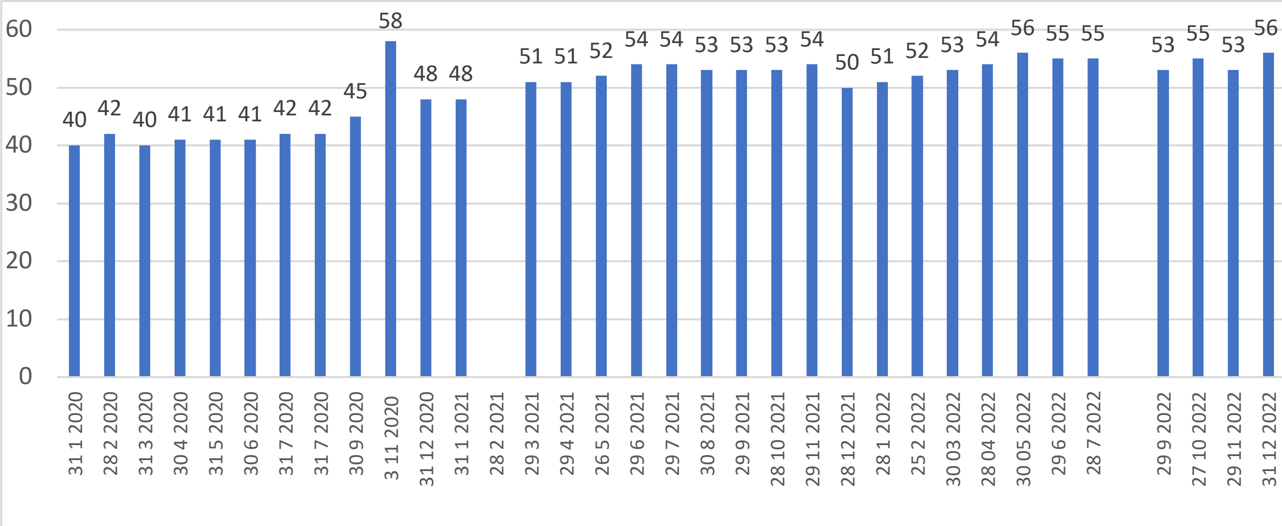
Source: authors' own elaboration on GSE data, 2023.

3.2 Operating plants

The analysis of the accepted offers for connection to the natural gas transport network available on the Snam SpA website shows 56 connections at the end of 2022 corresponding to a nominal transport capacity of about 900 kcm/day, that is a theoretical biomethane production of 328 Mcm/year.

Both accepted offers and, particularly, corresponding transport capacity at the connection points show a certain degree of variability during the year.

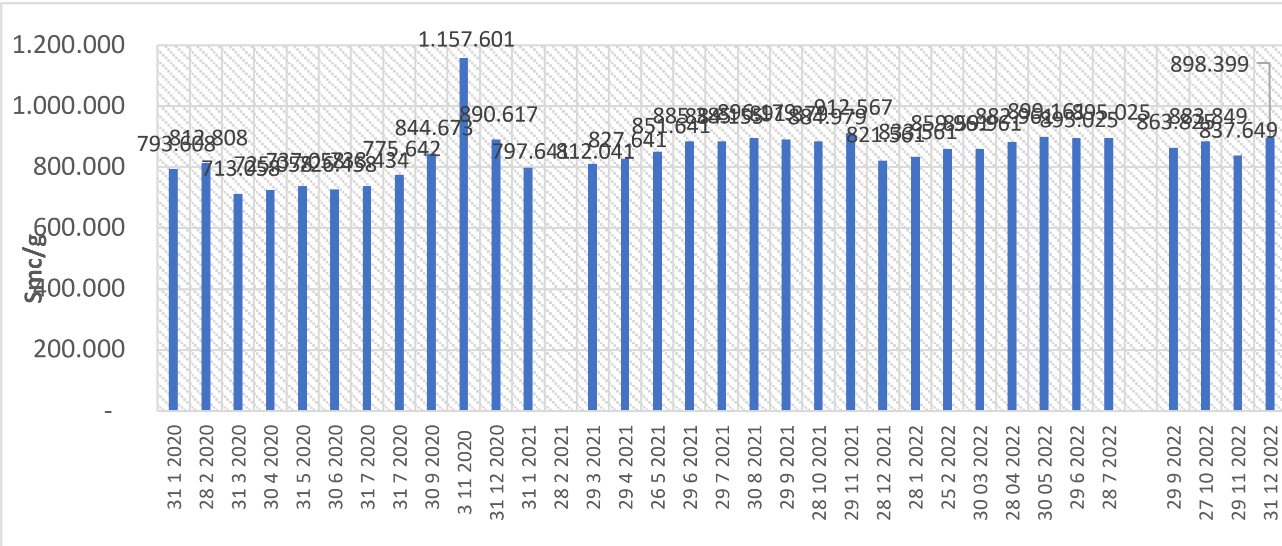
Figure 6 – Accepted biomethane connection offers (January 2020 – December 2022)



Source: authors' own elaboration on Snam data, 2023.

This can be explained on the basis of plants which, despite having obtained the possibility of connection to the network, did not become operational.

Figure 7 – Transport capacity at biomethane plants entry points (January 2020 – December 2022)



Source: authors' own elaboration on Snam data, 2023.

4. NORMATIVE NOVELTIES

There were numerous regulatory changes during 2022.

4.1 The REPowerEU[8] plan

After the adoption, in 2021, of the Fit for 55 Package[9], an extensive and articulated work program aimed at reducing GHG emissions by 55% by 2030 and achieving climate neutrality (net zero emissions) by 2050, in 2022 the RepowerEU plan was published providing for a strengthening of the previously set targets relating to emissions, energy efficiency and renewable sources. In addition to the increase in the emission reduction target, the plan envisages a reduction in energy consumption

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0230&from=EN

[9] https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

by 13% compared to the 2020 business-as-usual scenario with an increase of 4 percentage points compared to what decided in the Fit for 55 Package and a penetration of renewables on final energy consumption of 45% against the 40% considered so far. In particular, a target generation capacity of 510 and 592 GW is foreseen for wind and solar respectively, marking a certain increase (+ 9% and + 12%) compared to what was foreseen in the previous package.

Table 3 – Fit for 55 vs REPowerEU provisions

	2018 Directives	**Fit for 55**	**REPowerEU**
GHG emissions	-40%	-55%	-55%
Energy saving	-32,5%	-36/37% FEC[10]; -39-41% PEC[11]; -9% vs Ref 2020	-13% vs Ref 2020
RES sahre	min 32% FEC	min 40% FEC; 2030 installed capacity: 469 GW wind 530 GW solar	min 45% FEC; 2030 installed capacity: 510 GW wind 529 GW solar

Source: authors' own elaborations.

The primary goal of REPowerEU consists in reducing the dependence on all fossil fuels from Russia, but especially on gas.

Table 4 – REPowerEU policies to reduce Russian gas dependence

	Bcm
Import diversification from outside Russia	
Increase in LNG imports in existing facilities	50
Increase in gas import in existing pipelines	10
SUBTOTAL	**60**
Reduction in domestic consumption	
Efficiency increase in buildings	37
Efficiency increase in industry	12
Behavioral measures	10
SUBTOTAL	**59**
Substitution ofgas with biomethane and H2	
Biomethane consumption increase	17
Green hydrogen consumption increase	12
SUBTOTAL	**29**
Electricity production	
Increased production from wind and solar	9
Delayed coal phase out and increase in generation from coal plants	24
No nuclear phase out (France and Belgium)	7
Increase in power generation from sustainable biomass	1
SUBTOTAL	**41**

Source: authors' own elaborations.

In 2021 the EU imported 155 Bcm of gas from Russia equal to 37% of consumption and 45% of total net import. According to Eurostat, in the same year, gas demand rose by 4.3%.

[10] Final Energy Consumption.

[11] Primary Energy Consumption.

The above-mentioned reduction target is supposed to be reached also by means of a reduction in domestic natural gas demand of about 2/3 by 2030. The decrease should be the product of (in order of importance):

- a replacement of gas in electricity production with RES,[12] coal and nuclear;
- the implementation of energy efficiency policies (especially in the industrial and residential sectors)
- the substitution of gas with other fuels in energy end uses (such as coal, oil and hydrogen after 2027);
- an increase in the price of gas (price effect);

The envisaged measures would allow a consumption reduction of about 190 Bcm, an amount higher than the 2021 import, in order to have flexibility margins.

4.2 The Complementary Delegated Act and the EU Taxonomy

The Complementary Climate Delegated Act[13] was released by the European Commission in February 2022 and approved by the Parliament in July 2022. The Act entered into force on 1 January 2023.

Table 5 – SCC for gas activities as indicated in the Complementary Delegated Act

ACTIVITY	4.29 POWER GENERATION	4.30 HIGH EFFICIENCY COGENERATION and 4.31 PRODUCTION OF HEAT/COOL IN DISTRICT HEATING/COOLING SYSTEM
	TECHNICAL SCREENING CRITERIA (TSC)	
General criterion	LCA GHG emissions lower than 100gCO2eq/kWh	LCA GHG emissions lower than 100gCO2eq/kWh
Plants with construction permit granted by the end of 2030	Direct GHG emissions (scope 1) lower than 270gCO2eq/kWh or annual direct GHG emissions of the activity do not exceed an average of 550kgCO2e/kW of the facility's capacity over 20 years; power to be replaced cannot be generated from renewable energy sources; the activity replaces an existing plant using solid or liquid fossil fuels; the newly installed production capacity does not exceed the capacity of the replaced facility by more than 15%; the facility is designed to use renewable and/or low-carbon gaseous fuels (switch expected by 31 December 2035);	In case of cogeneration the activity achieves primary energy savings of at least 10% compared to separate production of heat and electricity; in case of heat/cool production the thermal energy generated is used in an efficient district heating and cooling system as defined in Directive 2012/27/EU; direct GHG emissions of the activity are lower than 270 g CO2e/kWh; the power and/or heat/cool to be replaced cannot be generated from renewable energy sources; the activity replaces an existing combined heat/cool and power generation or heat/cool production activity that uses solid or liquid fossil fuels; the newly installed production capacity does not exceed the capacity of the replaced facility; the facility is designed to use renewable and/or low-carbon gaseous fuels (switch is expeted by 31 December 2035); the replacement leads to a reduction in emissions of at least 55% GHG per kWh of produced energy; the refurbishment of the facility does not increase production capacity.
Additional requirements	At construction, measurement equipment for monitoring of physical emissions, such as those from methane leakage, is installed or a leak detection and repair programme is introduced or at operation, physical measurement of emissions are reported and leak is eliminated.	At construction, measurement equipment for monitoring of physical emissions, such as those from methane leakage, is installed or a leak detection and repair programme is introduced or at operation, physical measurement of emissions are reported and leak is eliminated.

Source: authors' own elaborations.

It includes certain nuclear and gas activities among the "transitional" ones, that is "activities that cannot yet be replaced by technologically and economically feasible low-carbon alternatives but do contribute to climate change mitigation and with the potential to play a major role in the transition to a climate-neutral economy if subject to strict conditions, without crowding out investment in renewables".

More specifically, the Complementary Climate Delegated Act covered the following gas related activities:

- (4.29) Electricity generation from fossil gaseous fuels;
- (4.30) High-efficiency co-generation of heat/cool and power from fossil gaseous fuels;
- (4.31) Production of heat/cool from fossil gaseous fuels in an efficient district heating and cooling system.

[12] Renewable Energy Sources.

[13] https://finance.ec.europa.eu/publications/eu-taxonomy-complementary-climate-delegated-act-accelerate-decarbonisation_en

Articulated Substantial Contribution Criteria (SCC) to the Climate Mitigation objective have been foreseen that are mainly concerned with unit GHG emissions to be verified and certified by independent parties.
Eligible gas facilities shall switch fully to renewable or low-carbon gases by 31 December 2035 (sunset clause).

The use of fossil gas in the transport sector does not represent and eligible activity, neither under the transitional point of view.
In the Climate Delegate Act[14] published in 2021 different activities relating to renewable gases were considered.

Table 6 – Renewable Gases in the Taxonomy

SECTOR	ACTIVITY	NUMBER
ENERGY	Electricity generation from renewable non-fossil gaseous fuels	4.7
	Manufacture of biogas and biofuels for use in transport	4.13
	Cogeneration of heat/cool and power from renewable non-fossil gaseous fuels	4.19
	Production of heat/cool from renewable non-fossil gaseous fuel	4.23
WATER	Anaerobic digestion of sewage sludge	5.6
	Anaerobic digestion of bio-waste	5.7

Source: authors' own elaborations.

Activities 4.7, 4.19 and 4.23 need to respect the same unit emission threshold of 10gCO2eq/kWh to be calculated adopting an LCA perspective and calculated on the project-specific data.
It should be noted that:

- for electricity generation or cogeneration from other RES (4.1/4.17 photovoltaic, 4.2 CSP, 4.3 wind, 4.4 ocean tides and waves) no LCA emission threshold is indicated;
- the same holds for the production of heat/cool from solar thermal heating (4.21);
- in case of hydroelectricity (4.5) the facility is a run-of-river plant and does not have an artificial reservoir and the life-cycle GHG emissions must be lower than 100gCO2eq/kWh;
- in case of geothermal electricity or cogeneration (4.6/4.18), or geothermal production of heat and cool (4.22) the life-cycle GHG emissions must be lower than 100gCO2eq/kWh as well.

As far as the manufacture of biogas and biofuels for use in transport (4-13) is concerned the SCC state that agricultural and forest biomass used in the production process complies with the sustainability and GHG emissions saving criteria laid down in the RED II Directive (Article 29, paragraphs 2 to 5 and paragraphs 6 and 7 respectively) and that food-and feed crops are not used for the manufacture of biofuels to be used in the transport sector.

[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R2139

The greenhouse gas emission savings from the manufacture of biofuels and biogas for use in transport are at least 65 % compared the relative fossil fuel comparator (FCC) set out in the same Directive.
In case of anaerobic digestion of organic material (sewage sludge – 5.6, separately collected bio-waste – 5.7, landfill gas – 5.10) the produced biogas shall be used directly for the generation of electricity or heat or upgraded to bio-methane for injection in the natural gas grid or used as vehicle fuel or as feedstock in the chemical industry.
In the dedicated bio-waste treatment plants, the share of food and feed crops used as input feedstock, measured in weight, as an annual average, is less than or equal to 10% of the input feedstock.

4.3 The 2022 Decree

The Decree of the Ministry of Ecological Transition n. 240 of 15 September 2022, *Implementation of articles 11, paragraph 1 and 14, paragraph 1, letter b), of the legislative decree of 8 November 2021 , No. 199*[15]*, in order to support the production of biomethane fed into the natural gas network, in accordance with Mission 2, Component 2, Investment 1.4, of the PNRR*, (so-called «Biomethane Decree»), was published in the Official Gazette n. 251 of 26 October last.
The Decree entered into force on 27 October 2022 with the aim of supporting the production of biomethane fed into the natural gas network in compliance with the sustainability requirements set out in Directive 2018/2001/EU, from new agricultural and organic waste plants or from revamped existing agricultural biogas plants.
In particular, through the assignment of incentives (capital grants and incentive tariffs) for a total amount of 1,730.4 million euros from the PNRR, the Biomethane Decree opens up the possibility of allocating biomethane also to uses other than transport.
Just plants:

- for which the construction is not started before the publication of the ranking pursuant to art. 5, paragraph 2;
- which enter into operation by 30 June 2026,

can be incentivized.
In particular, in order to have access to competitive procedures, plants must comply with the following requirements:

- possession of the authorization to build and operate the plant;
- possession of the connection estimate issued by the competent TSO or DSO and accepted by the applicant for plants to be connected to the networks with third party connection obligations;
- compliance of the produced biomethane with the criteria established by Directive 2018/2001/EU for the purposes of respect of the principle of "do not cause significant harm (DNSH)", with the relevant requirements set out in Annex VI, note 8, of Regulation 2021/241 /EU, as well as at least with one of the following GHG emissions reduction requirements:
    - the plant produces biomethane for the transport sector starting from advanced raw materials referred to in Annex VIII to Legislative Decree n. 199 of 2021, and achieves a reduction of at least 65% of GHG emissions (compliance with this requirement allows access to the public procedures until the producibility target of 1.1 Bcm/year assigned to the transport sector is reached pursuant to Decree 2 March 2018);
    - the plant produces biomethane for other uses and achieves a reduction of at least 80% in GHG emissions.

[15] Decree embedding the Directive 2018/2001 on the promotion of renewable energy sources (s.c. RED II).

The granted incentive is made of two components:

- a tariff aimed at covering operational costs of production;
- a capital contribution.

The first one is recognized on net biomethane production from the entry into operation of the plant and for 15 years.

Table 7 – Reference tariffs

TYPE OF PLANT	CAPACITY in Scm/h	€/MWh
Small agricultural	Up to 100	115
Other agricultural	>100	110
Organic waste	Any	62

Source: biomethane Decree 2022.

Tariffs are differentiated between organic waste and agricultural plants. In the latter case they are further differentiated according to the size of the plant.
Recognized capital contributions amounts to the 40% of the maximum eligible investment.
The latter is differentiated between organic waste and agricultural plants.
In the latter case the contribution is further differentiated according to the size of the plant and between new and reconverted plants.

For organic waste plants both the tariff and the capital contribution do not vary according to the size of the plant and, hence, do not consider economies of scale.
The introduction of a capital grant is a new element with respect to the previous incentive scheme contained in the Ministerial Decree of 2 March 2018 "*Promotion of the use of biomethane and other advanced biofuels in the transport sector*" dedicated to plants coming into operation by 31.12.2022, deadline extended to 31.12.2023 by the Ministerial Decree of 5 August 2022.

Table 8 – Capital contributions

TYPE OF PLANT	**CAPACITY** Scm/h	**MAXIMUM ELIGIBLE INVESTMENT - new plants** (€/Scm/h)	**MAXIMUM ELIGIBLE INVESTMENT – old plants** (€/Scm/h)	**CAPITAL CONTRIBUTION** %
Agricultural	Up to 100	33,000	12,600	40
	100<C<500	29,000	12,600	40
	C>500	13,000	11,600	40
Organic waste	Any	50,000	-	40

Source: biomethane Decree 2022.

Access to incentives takes place following the awarding of public competitive procedures in which production capacity are made available:
• year 2022: 67,000 Scm/h;
• year 2023: 95,000 Scm/h;
• year 2024: 95,000 Scm/h.

In 2022 only one competitive procedure will be called and from 2023 there will be at least two procedures per year, with an opening period of 60 days.
The GSE will evaluate the projects and, within 90 days of the closure of each tender, will publish the relative ranking of the admitted projects.
The incentives cannot be combined with other public incentives or support schemes however denominated.
For the procedures called in 2022 and 2023, the reference tariffs at the basis of the auction will be those indicated in Annex 2 of the Biomethane Decree. From 2024 and possibly up to 2026, the tariffs based on the auction will be reduced by 2%.
Plants with a production capacity equal to or less than 250 Scm/h that feed biomethane into networks with third-party connection obligations can request the payment of the due tariff in the form of an all-inclusive tariff (FiT[16]).
For plants with a production capacity exceeding 250 Scm/h, as well as for all production plants that feed biomethane into natural gas networks other than networks with third-party connection obligations, the tariff is paid in the form of a premium tariff calculated according to modalities referred to in article 2, paragraph 1, letter v) and in this case the guarantees of origin are assigned to the producer.

4.4 The GHG emissions reduction criteria

In the first Directive on renewable sources (2009/28/EC), emission abatement criteria (-65%) were envisaged only for biomethane used in the transport sector. In the second Directive (2018/2001/EC) these criteria concern the use of biomethane also in electricity generation and heat production: the emissions of the reference fossil fuel is equal to 94, 183 and 80 gCO_2eq/MJ for transport, electricity and net production respectively.

The required abatement is 70% starting from 2021 and 80% starting from 2026.
The GHG reduction potential of biofuels and biomass fuels for transport are calculated using the following formula:
GHG emission savings = (E*F(t)* - E*B*) / EF(t)
where: EB = total emissions from the use of the biofuel/biomass fuel; EF(t) = total emissions from the fossil fuel comparator.
The greenhouse gas savings to produce heat and electricity and/or cooling can be calculated using the following formula:
GHG emission saving = (EC*F(h&c, el)* - EC*B(h&c, el)*) / EC*F(h&c,el)*
where ECB(*h&c,el*) = total emissions from heat or electricity from biomass; ECF(*h&c,el*) = total emissions from the fossil fuel comparator.
According to the RED II, that provides standard abatement values for the whole biomethane production chain, the calculation of CO2eq emissions and the relative savings compared to the FFC can be influenced by both:

- the biomasses used;
- the characteristics of the plant.

It is the case of zootechnical effluents, for example, for which emissions relating to their storage (*and avoided due to their anaerobic digestion*) are taken into account, turning into negative emissions and to an increased amount of GHG savings compared to the FFC.

[16] Feed in Tariff.

Table 9 – GHG reduction criteria: RED I vs RED II

	TRANSPORT SECTOR		OTHER USES	
	RED I	**RED II**	**RED I**	**RED II**
FFC	83.8 gCO_2eq/MJ	94.0 gCO_2eq/MJ	Not considered	183.0 gCO_2eq/MJ of electricity; 80.0 gCO_2eq/MJ of heat
GHG SAVING	65% from 2021	65% from 2021	Not considered	70% from 2021; 80% from 2026

Source: authors' own elaborations.

For this reason the inclusion of animal slurries in the production process will favour the fulfilment of the GHG obligation criteria.

Table 10 – Standard GHG emission values in the RED II (Annex VI)[17]

gCO_2eq/MJ	RED II																							
	Open digestate												Closed digestate											
	Without off-gas burning						With off-gas burning						Without off-gas burning						With off-gas burning					
	C	P	U	T	C	Cr	C	P	U	T	C	Cr	C	P	U	T	C	Cr	C	P	U	T	C	Cr
Standard emission value	0	118	27	1	5	-124	0	118	6	1	5	-124	0	4	27	1	5	-112	0	4	6	1	5	-112
Total standard emission value	26.4						5.4						-75						-96					
Standard GHG saving	72%						94%						179%						202%					

Source: authors' own elaborations.

As mentioned before, in the 2022 Biomethane Decree, a minimum GHG emissions abatement of 65% and of 80% compared to the FCC is required for use in the transport sector and other uses respectively. Considering the values of the comparators for the selected destinations it is substantially possible to assess that production of biomethane must lead to emissions lower than 33 gCOQeq/MJ and 16 gCOQeq/MJ in case of use in the transport and other sectors.

Table 10 – GHG reduction criteria in the 2022 Biomethane Decree

BIOMETHANE IN THE TRANSPORT SECTOR	BIOMETHANE FOR OTHER USES
Production from advanced biomass	No substrate constraints
Avoided emissions at least = 65%	Avoided emissions at least = 80%
FFC = 94 gCO2eq/MJ	FFC = 80 gCO2eq/MJ
Emissions lower than 33 gCO2eq/MJ	**Emissions lower than 16 gCO2eq/MJ**

Source: authors' own elaborations.

[17] C=Cultivation/P=Processiing/U=Upgrading/T=Transport/C=Compression/Cr=Credits for animal slurries

In order to verify the suitability of different diets with regard to the respect of GHG emissions abatement thresholds it is necessary to consider the content of Annex VII to Decree 199/2021.

The reference goes in particular to the following references:

- **Section C - Standard disaggregated values for biomass fuels:**
  - *C2: standard disaggregated values for gaseous biomass fuels:*
    - Table 2: Biomethane;
- **Section D - Total of typical and standard values for biomass fuels supply chains:**
  - *D2: total of typical and standard values for biomass gaseous fuels supply chains:*
    - Table 2: Typical and standard value of biogas for biomethane;
    - Table 4: Typical and standard value – biomethane – corn/manure mixes.

By considering values reported in the D2 (standard aggregated GHG unit emissions) and C2 (standard disaggregated GHG unit emissions) Sections, standard GHG emissions percentage aggregated reduction can be quantified as reported **in Section A - Typical and standard values of greenhouse gas reductions for biomass fuels if produced without net carbon emissions following land use change (%)**, *sub-Section A2: typical and standard value for biomass gaseous fuels*, Tables:

- 3: Biomethane for transport (GHG emissions reductions related to biomethane refer only to compressed biomethane compared to the reference fossil fuel of 94 g CO2eq / MJ) and
- 4: Biomethane for transport – corn/manure mixes (GHG emissions reductions related to biomethane refer only to compressed biomethane compared to the reference fossil fuel of 94 g CO2eq / MJ).

As shown in Table 11, in the case of biomethane used in the transport sector, it is possible to comply with certainty with the criteria for reducing GHG emissions only in the case of mono-diet with animal manure or a mixed diet which includes the aforementioned animal slurries with closed digestate. The same applies for liquid biomethane used in the same sector.

Table 11 – Biomethane GHG abatements under different technologies and diets

BIOMETHANE GHG REDUCTIONS				
	TRANSPORT SECTOR		OTHER USES	
	FFC = 94 g CO2/MJ (-65%)		FFC = 183 g CO2/MJ (-80%)	FFC = 80 g CO2/MJ (-80%)
SINGLE - DIET	BIO-CNG	BIO-LNG	POWER GENERATION	HEAT PRODUCTION
animal slurries open digestate (with or wihout exhaust gases combustion)	72 - 94%	70 - 93%	88 - 99%	73 - 99%
animal slurries closed digestate (with or without exhaust gases combustion)	179 - 202%	178 - 200%	143 - 155%	199 - 225%
corn full plant open digestate (with or wihout exhaust gases combustion)	17 - 39%	13 - 38%	60 - 72%	9 - 35%
corn full plant closed digestate (with or wihout exhaust gases combustion)	41 - 63%	39 - 62%	72 - 83%	36 - 63%
Organic wastes, open digestate (with or wihout exhaust gases combustion)	20 - 42%	18 - 40%	61 - 73%	11 - 38%
Organic wastes, closed digestate (with or wihout exhaust gases combustion)	58 - 80%	54 - 79%	81 - 92%	69 - 83%
MIXED DIET				
corn and animal slurries (20-80) open digestate (with or wihout exhaust gases combustion)	35 - 57%	33 - 55%	67 - 80%	29 - 55%
corn and animal slurries (20-80) closed digestate (with or wihout exhaust gases combustion)	86 - 108%	84 - 106%	95 - 107%	89 - 115%
corn and animal slurries (30-70) open digestate (with or wihout exhaust gases combustion)	29 - 51%	28 - 50%	66 - 78%	23 - 49%
corn and animal slurries (30-70) closed digestate (with or wihout exhaust gases combustion)	71% - 94%	70 - 93%	88 - 99%	73 - 99%
corn and animal slurries (40-60) open digestate (with or wihout exhaust gases combustion)	25 - 48%	23 - 46%	9 - 75%	18 - 44%
corn and animal slurries (40-60) closed digestate (with or wihout exhaust gases combustion)	62 - 84%	61 - 83%	83 - 95%	61 - 88%

Source: authors' own elaborations.

In case of electricity generation it is necessary to use exclusively animal manure for the production of biogas or a mixed diet including at least 70% of manure with closed digestate. As far as the production of heat for residential or industrial use is concerned, compliance with environmental criteria seems particularly limiting: it is in fact possible to comply with them only in the case of minimum use of animal manure equal to 80% by weight and with closed digestate.

5 THE ECONOMICS OF BIOMETHANE PRODUCTION

The Application Rules of the 2022 Biomethane Decree (Annex 1 of the Directorial Decree of 13 January 2023) clarify some interpretative aspects of the same Decree. They are very articulated and consist of 124 pages.

Paragraph 6.2 clarifies the concepts of:

- *Reference tariff:* tariff that represents the base of the auction and that varies with the type and production capacity of the plant as seen before. The DM 2022 indicates its value for 2022 and 2023.
- *Offered tariff* represented by the reference tariff reduced by the reduction percentage offered in the tender; the latter cannot be lower than 1%;
- *Payable tariff* that may differ from the offered tariff in the event of "decalage[18]" and is fixed for the entire incentive period (15 years).

Paragraph 6.5 specifies that In the case of plants that have access to the all-inclusive tariff (Tariffa Omnicomprensiva – TO), that is plants with capacity up to 250 Sm3/h, the incentive is made up of two terms:

- the incentive component calculated by multiplying the net biomethane production by the difference between the TO due and the average market price of natural gas[19]; in the calculation, the gross production cannot be greater than the Q of sustainable bio-methane and the maximum monthly producibility;
- the withdrawal component consisting in the valorization of the entire quantity of bio-methane produced and injected into the gas network with third party connection obligation.

The all-inclusive tariff therefore includes both the incentive and the value of the biomethane injected into the network and withdrawn by the GSE as well as the value of the Guarantees of Origin (GO).

Net production corresponds to total nominal production net of energy consumption of the auxiliary services (SA), that is the consumption of all plant sections directly involved in the process ob biomethane production, treatment, storage and transportation as stated in paragraph 3 of the Application Rules.

Plants with capacity higher than 250 Smc/h have access just to the first component (Tariffa Premio - TP). In this case GOs remain in the availability of the producer who directly sells the produced biomethane on the market.

Both the all-inclusive tariff and the premium tariff are guaranteed for 15 years from the date of entry into commercial operation of the plant.

Tariffs are calculated according to the different ways in which biomethane is fed into the natural gas network (s.c. Configurations). Calculation methodology basically differs with reference to the point of measurement of production.

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[18] Decalage occurs in case of delay in the entry into operation of the plant. It implies the monthly reduction of the incentive tariff by 0.5% for a maximum of 9 months after which the right to incentives expires.

[19] PGME = quantity-weighted average monthly price of natural gas recorded on the day-ahead natural gas market (MGP-GAS) in continuous trading and on the intraday natural gas market (MI-GAS) in continuous trading managed by GME (Gestore del Mercato Elettrico) in the month of withdrawal.

Table 12 – Different Configurations in the calculation of biomethane incentives

CONFIGURATION	DESCRIPTION	METERING POINT	INCENTIVE
A	Connection to network with third party connection obligation (TPCO)	Grid injection point	TO (plants up to 250 Smc/h) TP
B	Self-consumption	Grid injection point	TP
C	Transportation via cylinder wagon	Cylinder wagon loading point	TP
D	Connection to TPCO network via cylinder wagon	Cylinder wagon loading point	TO (plants up to 250 Smc/h) TP
E	Connection to liquefaction plant	Downstream of the liquefaction or storage system	TP
F	Connection to closed network	Grid injection point	TP

Source: authors' own elaborations.

Granted incentives, together with fixed and operational costs, directly affect the economics of biomethane production.

5.1 New plants

For new facilities the cost-benefit analysis has been carried out with separated reference to plants in which biomethane is produced using the organic part of the solid urban waste, other organic waste plants and agricultural plants.

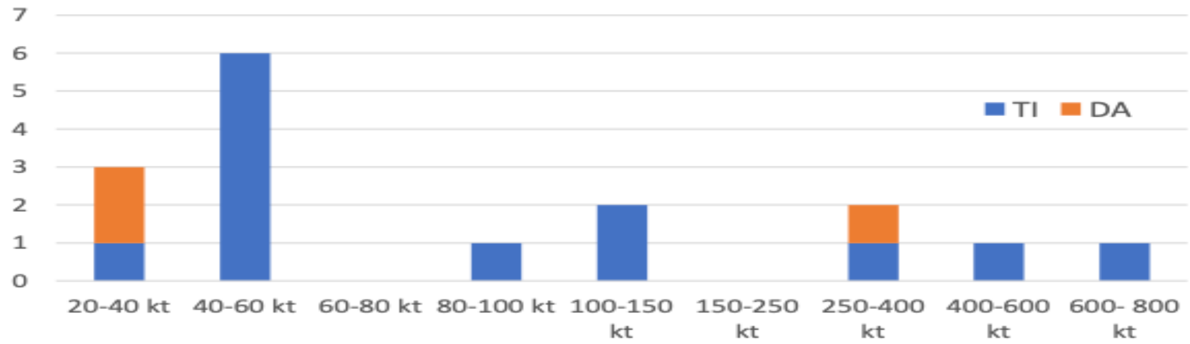
5.1.1 Economic evaluation of the production of biomethane from the organic part of solid urban waste (FORSU)

The distribution of the plants in operation by size[20] is very irregular. Small plants with capacity lower than 40,000 t/y and medium-small plants with capacity in the 40-60,000 t/y range represent the majority. There are 2 intermediate size plants (80-150 kt) and 3 large or very large plants (> 250 kt/y).
There are only 3 plants with anaerobic digestion and they are very different from each other. The biggest one is located in Faenza, shows a capacity of 320 kt, and processes almost exclusively sewage sludges.
Integrated Treatment plants produce almost exclusively methane (8 out of 11) and have a very diversified size, from 30,000 t/y to the 765 k/y of Montello.
The evaluation of costs, revenues and the consequent profitability of the production of biomethane from urban organic waste in Italy is subject to considerable variability which depends, among other things, upon:

- technological differences;
- size of the plants;
- location of the plants;
- authorization regime and granted incentive.

[20] Size corresponds to the authorized treatment quantity.

Figure 8 – Number of plants by size



Source: authors' own elaborations on ISPRA data, 2023.

The presented results are variable and subject to a consistent degree of uncertainty due to the lack of a significant number of plants in operation or under construction for which the investment and operating data are known.
To overcome these difficulties three types of sources were considered:

- publications and studies on costs and performances;
- press reports or communications from subjects proposing the construction of specific plants;
- direct contacts with some participants of the Observatory working group.

Table 13 – Quantitative assumptions in the evaluation of the economics of production from FORSU

	RANGE	**REFERENCE VALUE**
Plant size: quantity of processed waste per year	From 25,000to 125,000 t/yr (six dimensional classes: 25, 50, 60, 75, 100 e 125 kt/yr)	60,000 t/yr (reference plant)
Quantity of urban green and mowing	From 20% to 40% of FORSU	30% FORSU
Scraps (% of incoming FORSU)	From 8% to 15% of FORSU	13% FORSU
Quantity of compost (ACM)	From 15% to 35% of FORSU	25%
Biomethane production	From 50 to 80 cm per ton of FORSU	70 cm/ton of FORSU
Biogas composition	55-60 % CH4, 40-45% CO2	58% biomethane

Source: authors' own elaborations.

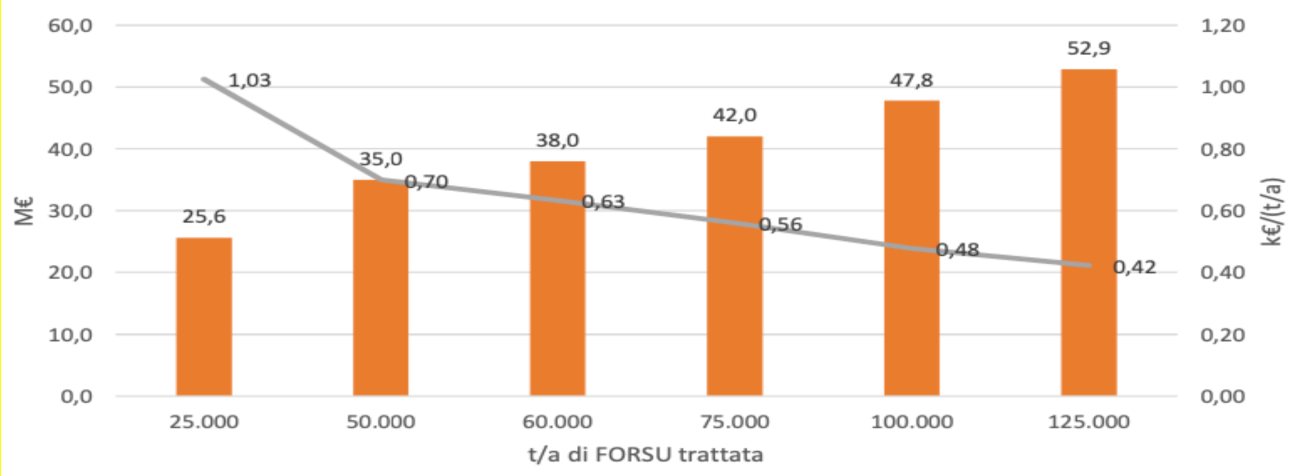
The presented results represent hence an estimate of the mean values and their variability in relation to the values of the most important variables.
Calculations were made with reference to a plant producing both biomethane and quality compost (Ammendante Compostato Misto - ACM) in the logic of circular economy.
Costs and revenues relating to capture and sale of CO_2 were left out of the analysis.

5.1.1.1 The Capex

Reference technology is represented by an IT plant with mesophilic semi-dry process and CO_2 separation with pressurized water or membranes.
Literature demonstrates that investment cost do not change significantly over different anaerobic digestion and upgrading technologies.
Quantitative data are reported in Table 13.
To determine the investment costs of plants of different sizes we can apply the formula:
$C = C_{ref} * (q/q_{ref})^{SF}$

according to which two problems need to be solved: having a reliable value for the reference plant; estimating the economies of scale (if any).
All biomethane plant studies indicate that such economies are important even if different for the different parts of the plant and variable as the size of the plants increases. According to the literature a Scale Factor (SF) of 0.45 was adopted and a cost of the reference plant equal to 38 M€ was considered.

Figure 9 – Total and unit capex per plant size



Source: authors' own elaborations.

The 2022 Decree establishes that the maximum eligible investment cost (on which a 40% capital contribution is recognized) for organic waste plant is unique and equal to 50,000 €/Scm/h.
The expected capital contribution improves the economic results of all the plants, but such improvement is much lower for the small ones, thus worsening their relative convenience.

The costs of connection to the grid are also endowed with strong economies of scale and depend on the distance of the plant from the grid.

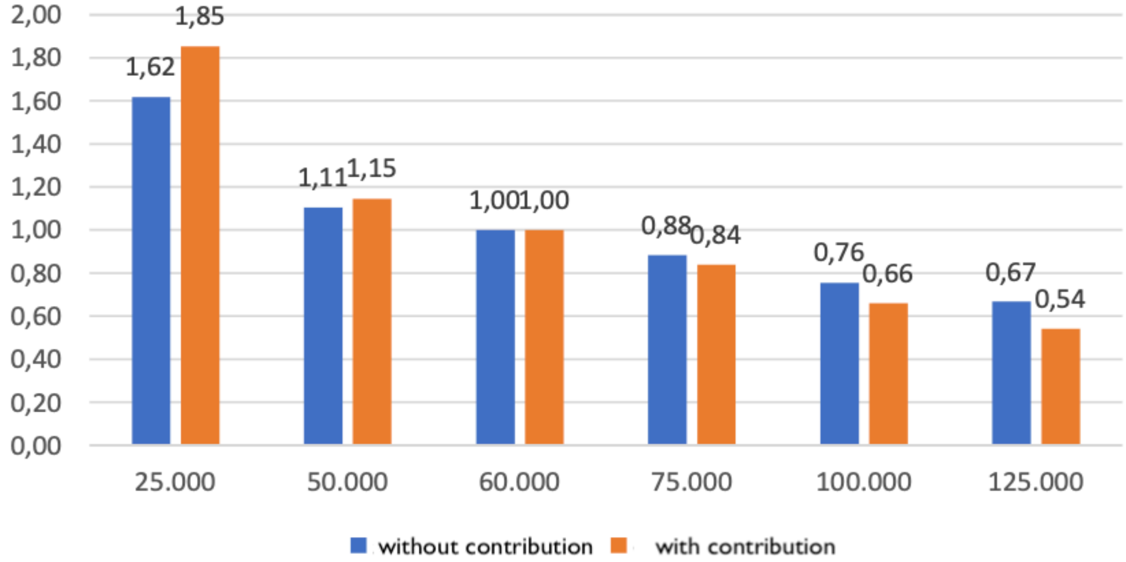
Table 14 – Capex distribution for capacity classes (gross and net of the capital contribution)

Processing capacity of the plant	**Hourly production CH4**	**Maximum eligible cost**	**40% of eligible contribution**	**Gross capital cost (estimation)**	**Nel capital cost (estimation)**
t/a	Smc/h	M€	M€	M€	M€
25000	219	10.94	4.38	25.60	21.25
50000	438	21.88	8.75	35.00	26.26
60000	**525**	**26.25**	**10.50**	**38.00**	**27.50**
75000	656	32.81	13.13	42.00	28.89
100000	875	43.75	17.50	47.80	30.32
125000	1094	54.69	21.88	52.90	31.00

Source: authors' own elaborations.

Since it would be difficult to conduct a specific analysis on the subject, it was assumed that the distance is the same for all the considered facilities and that economies of scale are included in the evaluation of the Scaling Factor of the plant.

Figure 10 – Capex/t vs Capex/t reference plant ratio



Source: authors' own elaborations.

5.1.1.2 The Opex

Operating costs consist of the following main components:

• cost of personnel involved in plant operation. This cost is also subject to economies of scale. A SF ranging from 0.5 (for 25 kt/y) to 0.65 for 125 kt/y) was assumed;

• costs of electricity and other energy products used in the production process;

• maintenance costs (affected by the economies of scale of the plant);

• waste disposal costs relating to the pre-treatment of solid organic urban waste and compost production;

• miscellaneous (insurance, water, overheads, any royalties...).

Based on the analysis conducted on various data sources, the values reported in Table 15 were adopted.

Table 15 – Opex assumptions

	Unit value range	Reference values
Unit labor cost and number of employees	average cost per employee (constant) Numer of employees variable with economies of scale	55,000 €/yr - 30 (for reference plant) with SF ranging from 0.50 to 0.65
Electricity cost	constant (difficult to predict)	100 €/MWh
Annual maintenance cost	from 3 to 5% of capex	3%
Various		1%
WACC	from 6 to 10%	8%
Waste disposal cost	20% of organic waste withidrawal price	120 €/ton
Plant useful life		20 years
Load factor	From 90% to 95%	8000 h/yr (91.3%)

Source: authors' own elaborations.

5.1.1.3 Cost sensitivity analysis

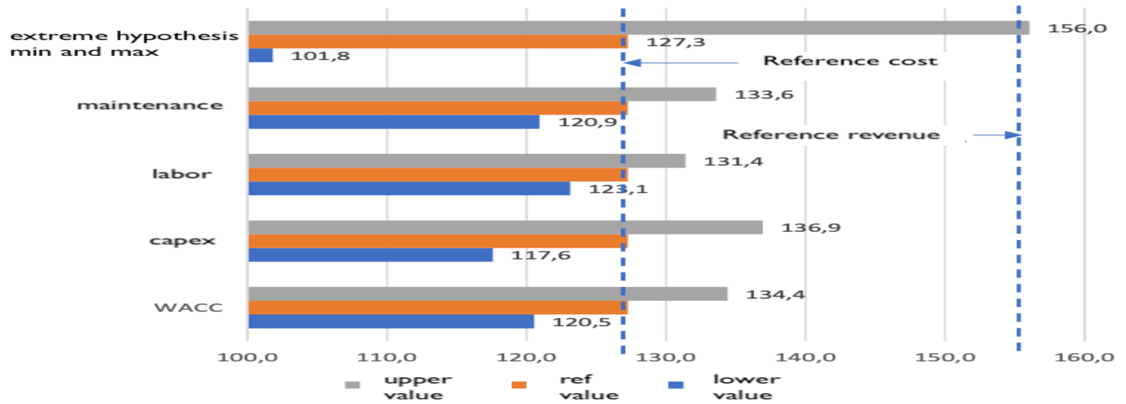
Table 16 – Value used for the sensitivity analysis

	Lower value	Reference	Upper value
WACC	6%	8%	10%
Capex	Ref - 15%	38 M€	Ref + 15%
Labor cost	Ref - 15%	1.65 M€/a	Ref - 15%
Maintenance	2% Capex	3% Capex	4% Capex

Source: authors' own elaborations.

A sensitivity analysis was carried out with reference to the production costs of the reference plant (60 kton/yr). Remaining within the scope of the considered variability, it is evident that no single cost item is able to modify the reference cost (127 €/ton) by more than 6%. The joint action of the variation of all the considered variables could instead change the unit cost by ± 20% approximatively. However, in the worst case, resulting from the consideration of the maximum value for all cost items the unit cost (156 €/to) would become approximately equal to the unit revenue (155 €/t).

Figure 11 – Cost sensitivity analysis



Source: authors' own elaborations.

5.1.1.4 The revenues

Revenues consist of:

- organic waste withdrawal compensation;
- greenery withdrawal compensation;
- sale of compost;
- sale of biomethane;
- sale of GOs;
- premium tariff TP.

The latter varies according to the gas price and the GO price and can also become negative.

The 2022 Decree establishes that:

- the «reference tariff» (T_{rif}) for all plants fueled with organic waste is equal to € 62/MWh;
- plants with capacity greater than 250 Scm/h (almost all in the presented analysis) must opt for the «premium tariff» (TP);
- the «premium tariff» is substantially represented by a two-way Contract-for-Difference (CFD): producers receive or pay to the GSE a monthly sum per MWh fed into the network given by: TP = (1-discount %) * T_{rif} – (MGP gas +M GO);

- only plants with production ≤ 250 Scm/h can choose the «all-inclusive tariff» making the ex-ante transfer of produced biomethane and GOs to the GSE.

Table 16 - Revenues

REVENUES	VALUE RANGE	REFERENCE VALUES
1. Forsu withdrawal	70 - 130 €/t	100 €/t
2. Green withdrawal	20 - 40 €/t	30 €/t
3. Compost withdrawal	5 - 20 €/t	6 €/t
4. Biomethane sale	20 - 40 €/MWh	30 €/MWh
5. GOs sale	1- 64,5 €	3 € (2022 average price)
6. TP	§ 2.1 of 2022 Decree	TP = (1 - discount %) * T_{rif} - (Pgas + PGO)
T_{rif}	§ 2.1 of 2022 Decree	62 €/MWh
Min discount on Trif		1%

Source: authors' own elaborations.

It should be noted that the single revenues components 4. – 5. – 6. show a negligible impact on final financial results since the incentive system foreseen by 2022 Decree is such that:

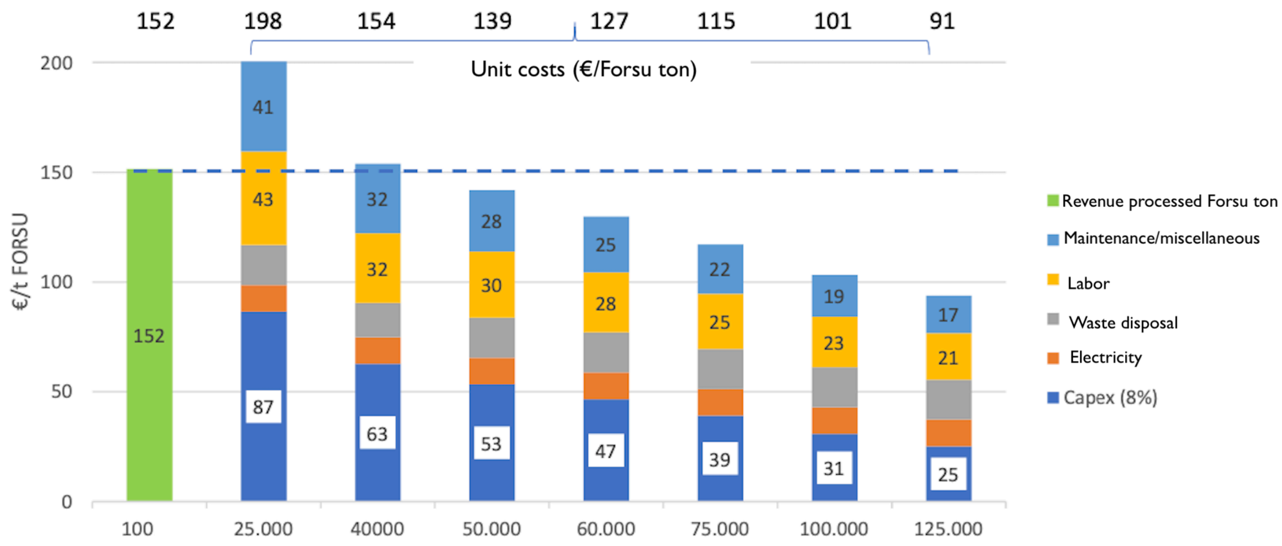
*4. + 5. + 6. = (1-discount %) * Trif*

5.1.1.5 The results

Results (both costs and revenue) are presented with reference to one processed ton of urban waste basically two reasons:

- the first purpose of the plants consists in exploiting solid organic urban waste in the logic of circular economy;
- the cost-effectiveness of the plants mainly depends on the price of withdrawal of the waste used for the production of biogas.

Figure 11 – Unit revenue and costs for different plant size



Source: authors' own elaborations.

The break-even occurs for plants able to process more than 40,000 ton/year of organic solid urban waste. The former, however, is very sensitive to the price at which the FORSU is withdrawn.

«Large» plants (size ≥ 75,000 t/y) have substantial profit margins (under the chosen assumptions) and could therefore withdraw the OFMSW at prices significantly lower than €100/t.
The revenue structure does not vary according the size of the plants.
The dominant item is by far the revenue coming from the withdrawal of the waste (65%) followed by the sale of gas, GOs and the premium rate which have a cap given by the reference rate. The rest weighs less than 7%.
The cost structure is quite complex instead.
The main items are represented by the investment cost, labor cost and maintenance cost. The cost of waste disposal and the purchase of energy have a slightly smaller weight which increases with the size of the plant.

5.1.1.6 Profit and loss: comparison with 2nd March 2018 Decree

In order to compare the incentive guaranteed by the 2022 Decree with those recognized under the old incentive system it is necessary to highlight the main differences. As far as Capex is concerned the new Decree envisages a refund of the 40% of the (eligible) investment costs. With reference to revenues it has to be underlined that under the 2022 Decree biomethane and GOs are sold but "compensated" with the premium tariff (TP) calculated on the MGP-GAS and MI-GAS platforms, while in the framework of the 2018 incentive scheme the price of gas released to the GSE is equal to the 95% of the monthly average gas price (MGP) and the certificate of release in consumption (CIC) are transferred to the GSE for the first 10 years at the price of 375 €, then sold on the market.
For the purpose of comparison the following assumptions were made:

- same operative conditions and costs;
- CIC price constant at 375 €;

MGP gas price equal to 30,38 €/MWh (half the all-inclusive-tariff of 62 €/MWh with a 2% discount).
Applying the same assumptions of the base case to a plant subject to DM-22 or DM-18 the comparison shows that:

- the two measures have a substantially equivalent profitability;
- the 2018 MD is slightly more advantageous;
- small plants do not reach the break-even with neither of the Decrees.

5.1.2 Economic evaluation of the production of biomethane from agricultural substrates

As previously mentioned, the 2022 decree recognizes the incentive component on production net of the energy consumption of auxiliary services (Art. 2, paragraph 1, letter e), if the latter are not self-powered, in compliance with the Do No Significant Harm principle.
In this section, therefore, the economics of biomethane production will be evaluated taking into account the aforementioned consumption that refers to:
the energy consumption of any equipment, subsystem or system included in each section of the control perimeter, strictly functional to keeping the biomethane production plant in operation, regardless of the ownership and location of the equipment itself;
the consumption of electricity necessary to comply with the obligations deriving from environmental regulations as well as from decrees authorizing construction and operation, such as: i) compliance with the emission limits into the atmosphere, water and soil; ii) constraints on the use of natural resources; iii) air quality monitoring; iv) environmental protection;
There are three different and alternative methods for identifying the consumption of the SAs.
The easiest one is represented by the "*forfait* option" as clarified in § 6.4.1 of the Applicative Rules. Under this option auxiliary plant consumptions are calculated according to literature values.

The former are indicated for the different plant sections starting from the processing of the substrates and biogas production to the liquefaction of the produced biomethane and expressed as a % of biomethane gross production.

On the basis of the forfeit values the total auxiliary energy consumptions relating to the different production configurations are indicated in the Applicative Rules.

Table 17 – AS % consumption under different production configurations

CONFIGURATIONS		Auxiliary Services max %
A	injection into the transport network	28.5
	injection into the distribution network	25.5
B	self-consumption	25.5
C	cylinder wagon	30.0
D	network via cylinder wagon	30.0
E	liquefaction plant	41.5
F	closed network	25.5

Source: 2022 Biomethane Decree Applicative Rules.

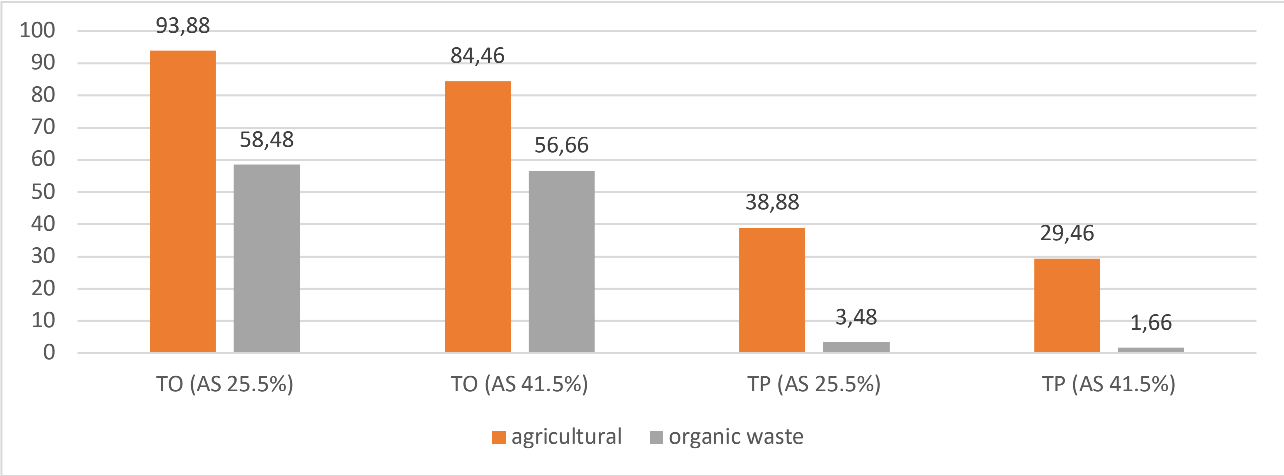
The distinction between gross and net production to the purpose of incentive calculation makes the reference tariff (nominal tariff) differ from the tariff effectively granted (real tariff) to the plant.

For example, hypothesizing a plant with a capacity of 250 Smc/h, a gas price of 50 €/MWh, a GO price of 5 €/MWh and a tariff discount offered in the tender of 1%:

- the agricultural plant would receive:
  - 93.88 €/MWh (15% less than the reference tariff) that would decrease to 84.46 €/MWh in case of access to the all-inclusive-tariff (TO) and AS consumptions moving from 25.5 to 41.5%;
  - 38.88 €/MWh that would lower to 29,46 €/MWh in case of premium tariff (TP) and AS consumptions moving from 25.5 to 41.5%.
- the organic waste plant would be granted:
  - 58.48 €/MWh (6% less than the reference tariff) that would decrease to 56.66 €/MWh in case of access to the all-inclusive-tariff (TO) and AS consumptions moving from 25.5 to 41.5%;
  - 3.48 €/MWh that would become 1.66 €/MWh in case of premium tariff (TP) and AS consumptions moving from 25.5 to 41.5%.

In the case of non-self-supplied AS, the difference between the «nominal» and «real» tariff is considerable and can significantly affect the economics of biomethane production.

Figure 12 - Incentives for 250 Smc/h plant in different hypothesis of non self-powered AS - €/MWh

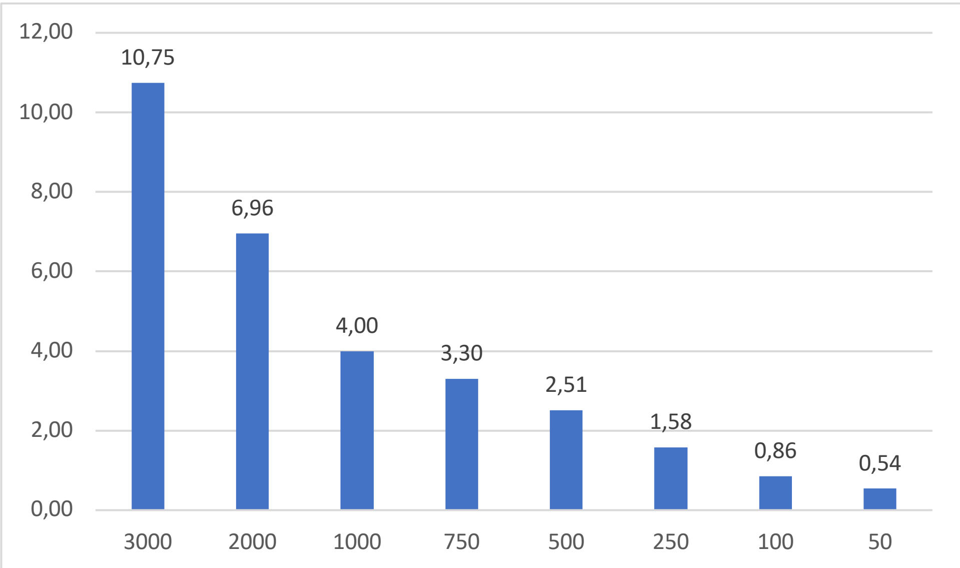


Source: 2022 Biomethane Decree Applicative Rules.

Used data was obtained from different sources:

- empirical studies carried out on samples of limited extension (maximum 40 plants);
- national and international association sources;
- corporate biomethane calculators.

Figure 13 - Total DA Capex in M€ by plant capacity (kW)



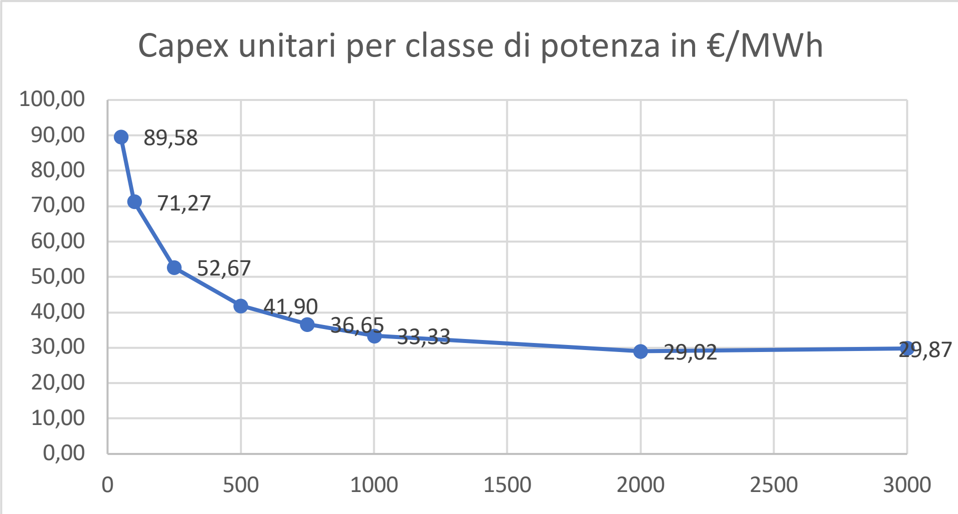
Source: authors' own elaboration.

The data relating to Anaerobic Digestion (AD) fixed costs (expressed in €/kW) present a substantial convergence even when referring to different technologies.

Those relating to management costs, on the other hand, show a certain variability (under equal conditions).

Those used in the analysis are essentially average values obtained by excluding data of older sources.

Figure 14 – Unit DA Capex per plant size (€/MWh)



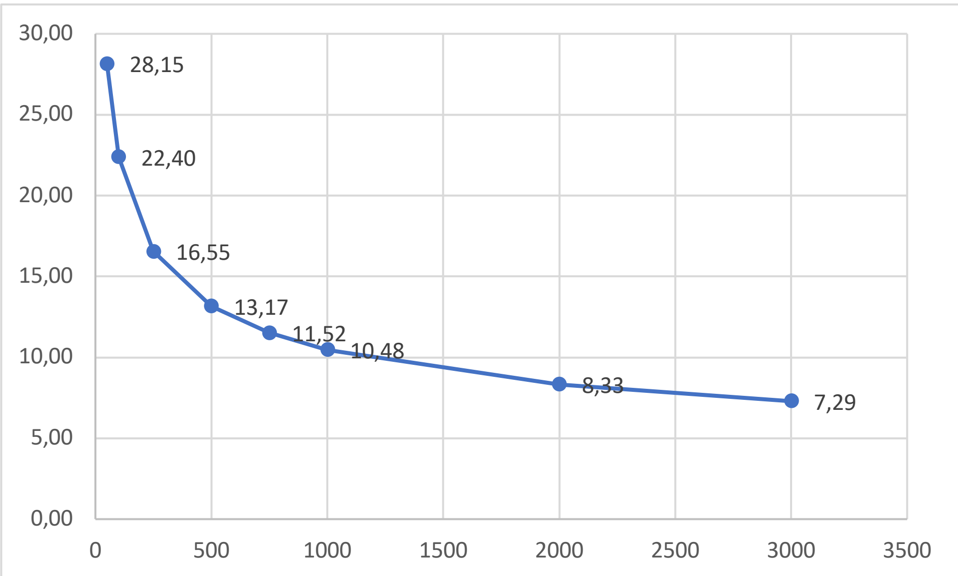
Source: authors' own elaboration.

The reference plant is a 250 Smc/h plant. Fixed costs "scale" with increasing installed power by a factor of 2/3 according to the formula

$$(C/C_0) = (P/P_0)2/3$$

with:
C = cost to be estimated
P = power of the plant whose cost is to be estimated;
C_0 and P_0 are the values of the reference system.
The assumed load factor is equal to 8000 h/year and the useful life amounts to 15 years.
The same scale factor was assumed for the upgrading technology.

Figure 15 – Unit UP Capex for different plant capacities (€/MWh)



Source: authors' own elaboration.

Total capital costs (DA+UP) were reduced by the capital contribution recognized under the new biomethane Decree incentive system in order to determine the net unitary Capex to be used in the following cost-revenue analysis.

Table 17 – Total (DA+UP) net unit capex

Capacity	total capex	recongnized CCC	total net capex	unit net capex
kW	*M€*			*€/MWh*
3000	13.38	3.90	9.48	26.32
2000	8.96	3.59	5.38	22.41
1000	5.26	2.10	3.15	26.29
750	4.34	1.73	2.60	28.90
500	3.30	1.32	1.98	33.04
250	2.08	0.83	1.25	41.72
100	1.12	0.33	0.79	66.16
50	0.71	0.17	0.54	90.23

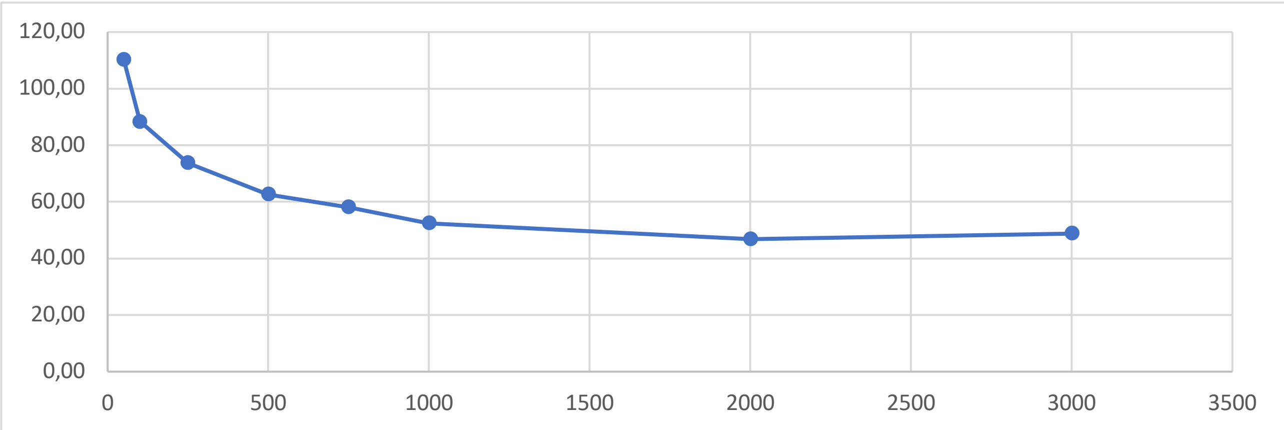
Source: authors' own elaboration.

Operational costs included:

- maintenance;
- electricity costs;
- labor costs;
- financial expenses.

The price of electricity was assumed equal to the average unique national price (PUN) of the last 5 years, that is 116 €/MWh. The WACC amounts to 6%.
Also variable costs show considerable economics of scale[21].

Figure 16 – Unit Opex (€/MWh) by plant size (kW)



Source: authors' own elaboration.

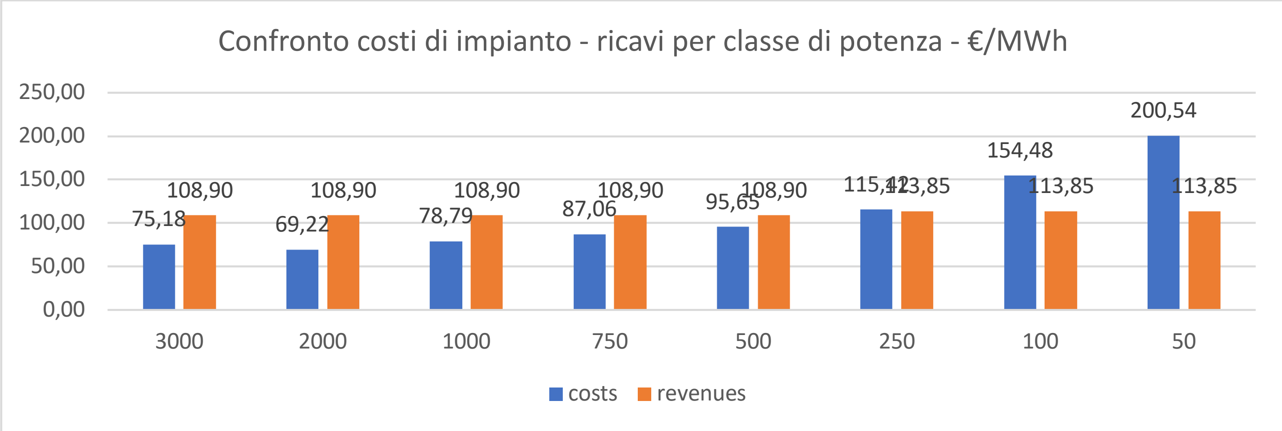
The production costs have been contrasted to the revenues represented by the all-inclusive tariffs increased by the capital contributions (CCC) recognized by the new incentive scheme.
The situation would not change if considering the premium tariffs in the place of the feed-in-tariff insofar as in case of price of gas and/or price of the GO higher than the difference between the latter and the incentive component the producer would be obliged to return the difference to the GSE[22].

[21] This is due to the non-continuous relationship between capacity and certain variable costs such as labor.

[22] The logic is the one of the two-ways CFD described in the previous paragraph according to which the TP is given by the difference between the TO and the sum between the market price of gas and the GO.

In the first comparison energy consumption of auxiliary services (AS) are not considered. The hypothesis is that consumptions are fully self-powered. The price of gas is assumed equal to 50 €/MWh and that of the GO is 5 €/MWh.

Figure 17 - Plant cost-revenue comparison (€/MWh) for different plant sizes (kW)

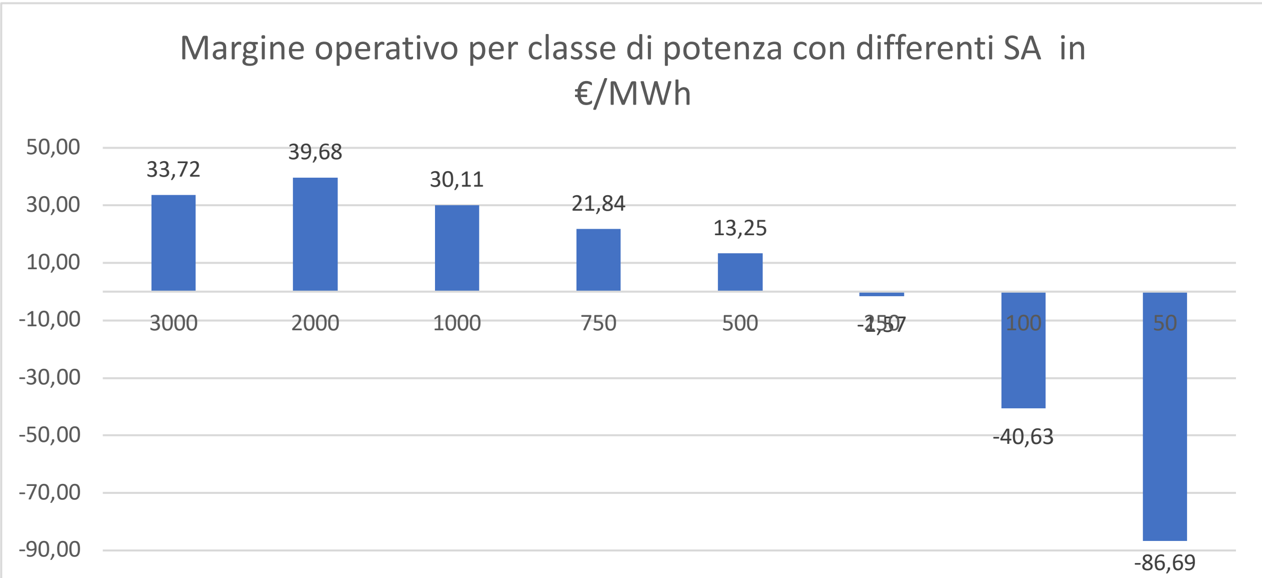


Source: authors' own elaboration.

From an initial comparison between the unit costs of the plant and the unit revenues, in the hypothesis of fully self-powered AS[23], it can be seen that only plants with a capacity greater than 250 kW are able to break even.

However, for plants with a positive operating margin, for the purpose of assessing economic sustainability, it is also necessary to consider the costs of feedstocks.

Figure 18 – Gross operative margins (€/MWh) for different plant sizes (kW)



Source: authors' own elaboration.

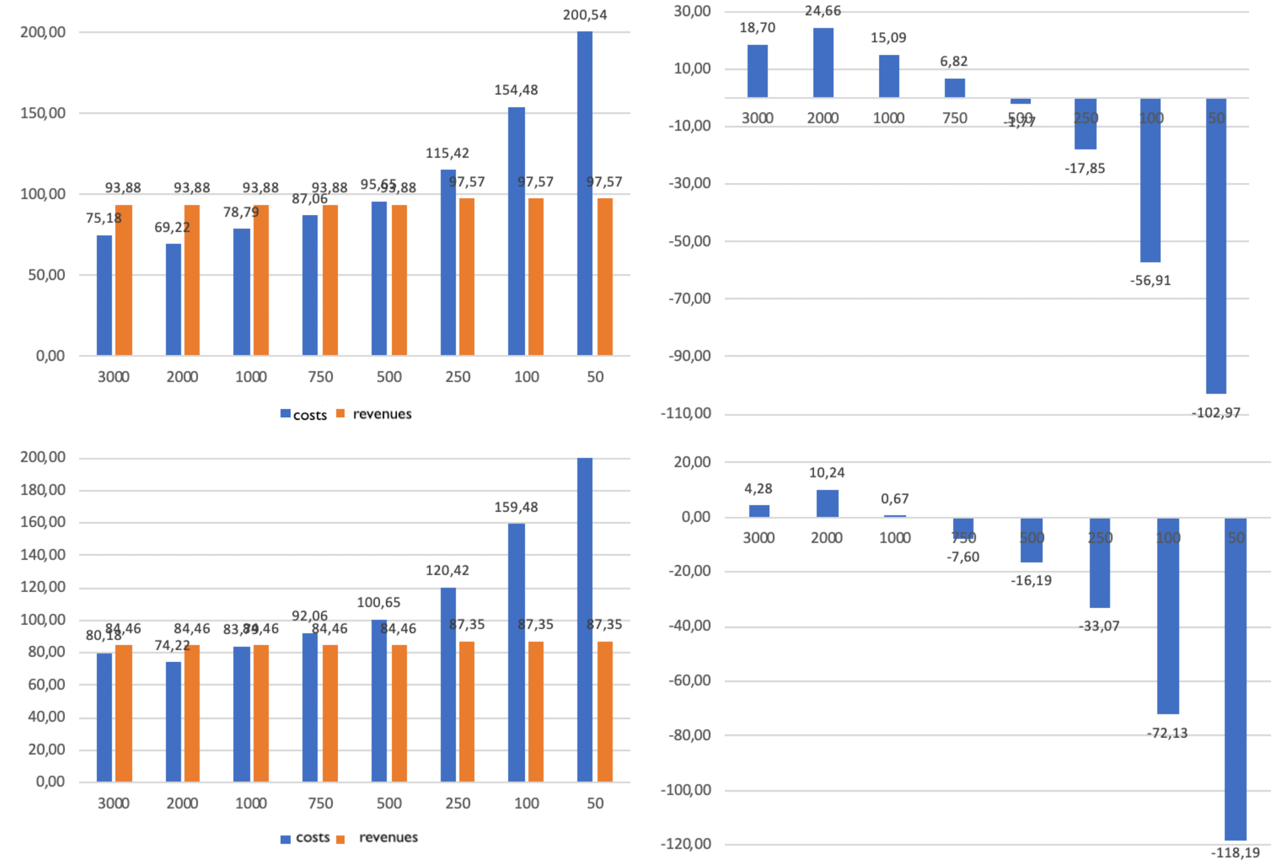
If including the energy consumption of AS the economic situation of biomethane production significantly worsens.

The comparison between (plant) costs and unit revenues, carried out considering the two limit values of the AS *forfait* consumption range referred to in § 6.4.1 of the Rules, equal to 25.5 and

[23] This means that gross and net production coincide.

41.5% (consumption entirely not self-powered and production of liquefied bio-methane), demonstrates that:
in the hypothesis of AS consumption equal to 25.5% the minimum economic power is greater than 500 kW;
in the hypothesis of AS consumption equal to 41.5%: the capacity required to break even is greater than 1000 kW.
In the latter case, the costs include liquefaction costs estimated at 5 €/MWh (Configuration E).

Figure 19 – Plant cost-revenue comparison and Gross operative margins (€/MWh) by plant size (kW), AS 25.5% (upper figures) and AS 41.5% (lower figures)



Source: authors' own elaboration.

For the costs of the substrates, reference was made to values available in the literature, on corporate websites or on national and international associations.
They vary considerably depending on:

- the type of supply (cultivation on own or rented land; direct availability or purchase on the market);
- the distance from the production plant (transport costs);
- the type of diet (agricultural crops, agricultural waste, animal manure).

Processing the data available in the literature allowed to estimate a cost between:

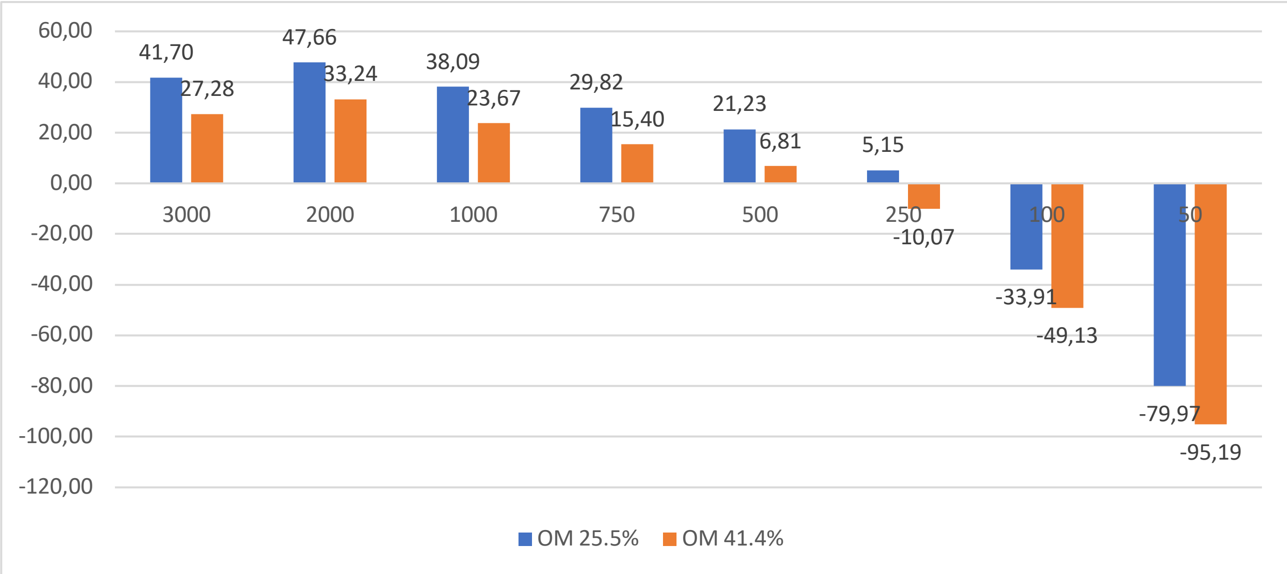
- 38 and 48 €/MWh for animal manure;
- 40 and 150 €/MWh for agricultural waste;
- 38 and 113 €/MWh for crops.

The determination of feedstocks costs is complicated by the fact that the digester is often fed with mixed diets, deriving from the combination of several substrates.

Considering the mono-diet costs, included in the range of 38 - 150 €/MWh, and the above presented gross operative margins, it is evident that even large-sized plants could have survival problems.

In such a context the valorization of side products such as compost fertilizer or CO_2 could be of key importance.
To calculate the unitary revenue from the sale of the compost, a production of 30 t/kW and a (optimistic) market value of 12.5 €/ton were considered.
By adding the aforementioned revenue to the incentives foreseen by Ministerial Decree 2022, the margins that can be used to finance the plant diet increase significantly:
in the event of ASs at 25.5%, plants with power starting from 250 kW show positive margins;
in case of ASs at 41.5% it is necessary to move to a capacity of 500 kW.
Yet, the margins remain such as to require an accurate assessment of the plant's diet.

Figure 20 - Gross operative margin (€/MWh) by plants size (kW) including revenues coming from compost sale



Source: authors' own elaboration.

5.1.2.1 Production of liquified biomethane and comparison with the 2018 Decree

In case of production plant connected to a liquefaction plant (Configuration E) incentivized biomethane production is reduced by 16%[24].
Unlike the Decree of 2 March 2018, the 2022 Decree does not provide specific incentives for the construction of "pertinent" liquefaction plants:
the costs relating to the construction of a liquefaction plant are included in the "eligible expenses" of the CCC as clarified in the Application Rules in §6.1
however, given the number of costs included and the ceiling fixed for their amount, it is difficult to think that the contribution could have a substantial impact on investments in liquefaction.

In this section of the Report a comparison between the incentives that a plant producing liquified biomethane would receive under the new incentive scheme and those that would be released in case of application of the 2018 Decree is presented.
The evaluation is made considering the following assumptions:

[24] "Forfait" ASs energy consumption of the liquefaction section of the plant are equal to the 16% of production according to the Applicative Rules of the 2022 Decree.

- plant with capacity of 250 Scm/h with access to both the TO and the TP;
- load factor equal to 8,000 hours/yr;
- production of advanced biomethane (double counting: 1 CIC for 5 Gcal);
- construction of a pertinent liquefaction plant with a cost of €400,000. Such an investment leads to an increase in the number of CICs assigned by 20% pursuant to the 2018 Decree);
- market price of gas = €50/MWh;
- non-self-powered ASs consumption (flat rate option 41.5%);
- price of GO = €5/MWh.

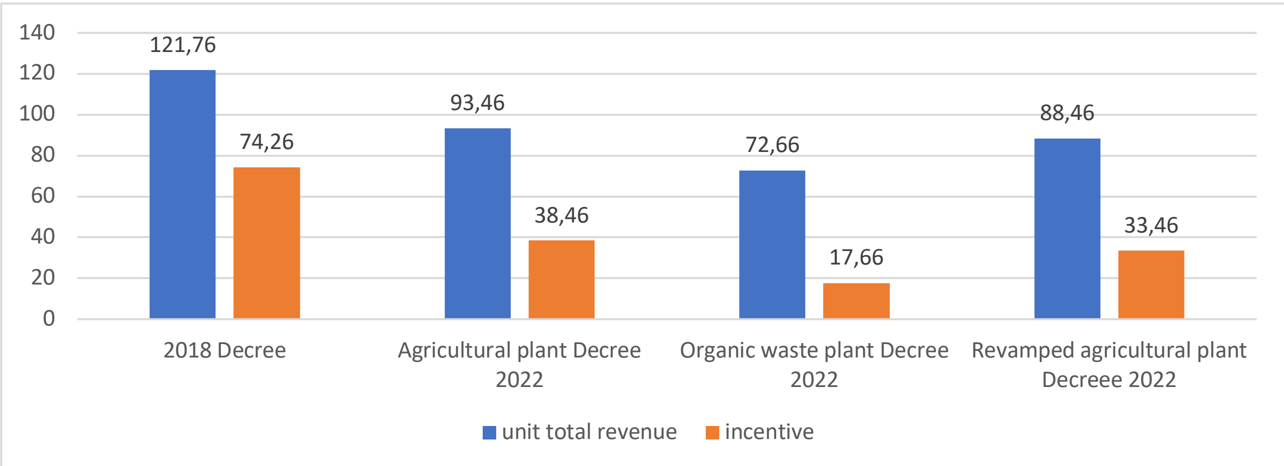
The total revenue was calculated as:

- the sum between CIC, additional CIC recognized for the liquefaction plant and value of the biomethane fed into the gas grid and released to the GSO in case of the 2018 Decree;
- the sum of the all-inclusive-tariff and the capital contribution (CCC) in case of the 2022 Decree.

The incentive was calculated as:

- the sum between CIC and additional CIC in case of the 2018 Decree;
- the sum between the premium tariff (TP) and the capital contribution (CCC) in case of the 2022 Decree.

Figure 21 – Liquified biomethane incentives: 2018 Decree vs 2022 Decree (€/MWh)



Source: authors' own elaboration.

If the incentive regime of the 2018 Decree were applied, the plant in question would obtain:

- 122 €/MWh with withdrawal of the biomethane by the GSE;
- €74/MWh in the event of independent sale;

regardless of diet.

With the new decree, the incentives change to:

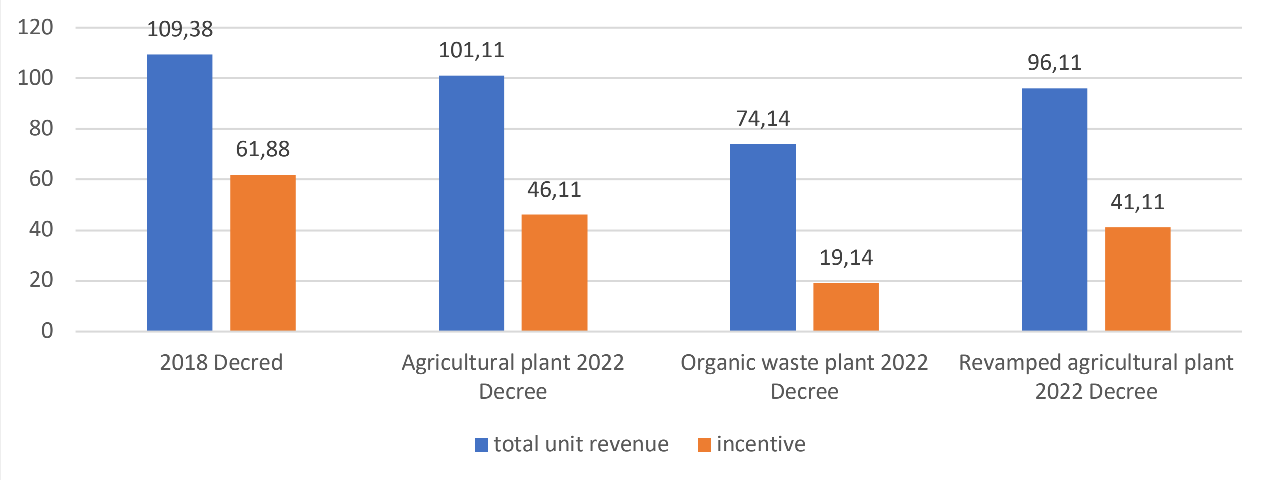
- 93 and 73 €/MWh in the case of TO;
- 38 and 18 €/MWh in the case of TP;

for agricultural and waste plants respectively.

Even the converted agricultural plant receives lower incentives than those that would be granted pursuant to the 2018 Decree.

The plant that produces liquid biomethane with not self-powered ASs is not favored by the application of the new Decree.

Figure 22 – Incentive comparison: 2018 Decree vs 2022 Decree (€/MWh)



Source: authors' own elaboration.

The comparison between incentive schemes was made also with reference to a biomethane production plant connected to the gas transport network (Configuration A).
The assumptions regarding plant size and prices are the same described before with the exception of the energy consumption of Ass in this case equal to 28.5% of total production in case of "*forfait*" quantification.
Unit total revenue was calculated as:

- the sum of CIC and gas price in the case of the 2018 Decree;
- the sum of TO and CCC in the case of the 2022 Decree.

The incentive was calculated as:

- the value of CIC (2018 Decree);
- the sum of TP and CCC (2022 Decree).

Following the incentive regime of the 2018 Decree, the plant in question would obtain:

- 109 €/MWh with withdrawal of the biomethane by the GSE;
- €62/MWh in the event of independent sale;

regardless of diet.
With the new decree, the incentives change to:

- 101 and 74 €/MWh in the case of TO;
- 46 and 19 €/MWh in the case of TP;

for agricultural and waste plants respectively.

In the case of not self-sustained ASs equal to 28.5%, the difference in the guaranteed incentives (with the application of the two incentive schemes) is lower than in the previous case but still appreciable for both agricultural (new and old) and organic waste plants.

5.2 Existing agricultural plants reconversion

One of the targets of the 2022 Decree consists in promoting the conversion of existing agricultural biogas plants to biomethane production.

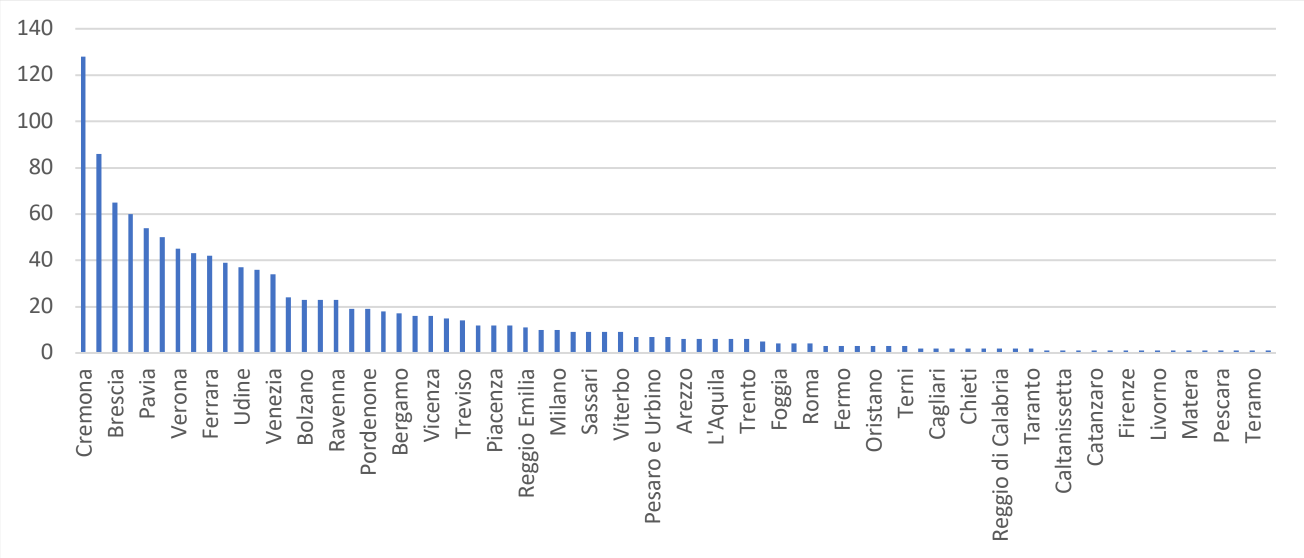
Agricultural plants are defined in Article 2, §1, letter g) of the Decree as plants for the production and use of biogas forming part of the production cycle of a farm orthat use materials deriving from agricultural, forestry, breeding food and agro-industrial activities that do not constitute wastes;

In order to estimate the number of existing plants that could be converted, and, hence, of the corresponding capacity and potential biomethane production, a data base, Database of Italian BIogas plants (DIBI) was built.

5.2.1 The DIBI Database

The Database contains 2,132 facilities: 1,166 (55%) are those owned by farms[25]. The remaining are fuelled with landfill gas, FORSU, sludges, organic and urban waste, sometimes in blend with animal slurries[26].

Figure 23 – Number of plants by province



Source: authors' own elaboration.

They represent the 36% of total capacity (900 out of 2500 MW).

Available variables for each plant are the following:

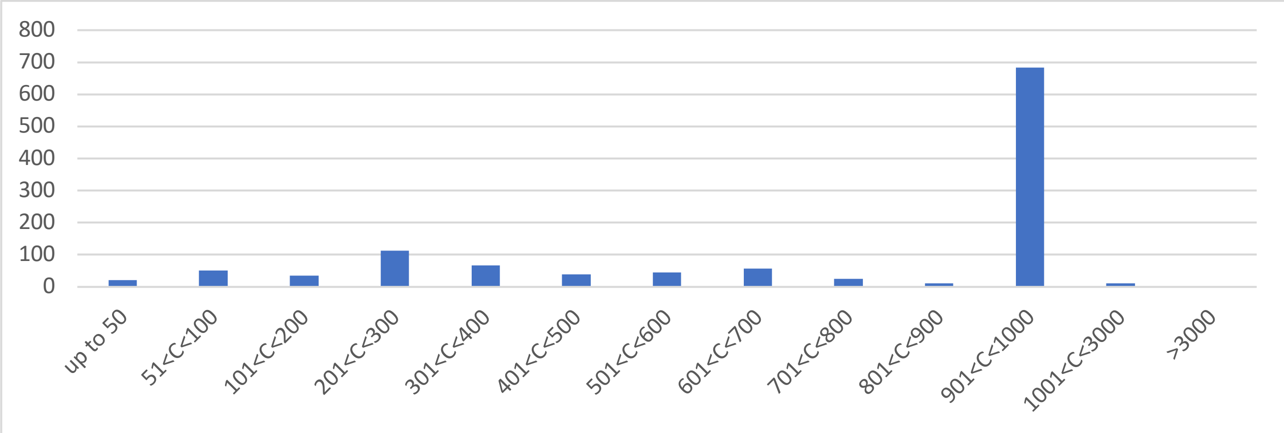
1. date of entry in operation;
2. capacity in kW;
3. location, province and region;
4. operating company;
5. used feedstock.

As for the geographical distribution it is evident that the most plants are located in the North of Italy. The Region with the higher density is Lombardy.

The 99% of the considered plants has a capacity lower than 1 MW.

[25] Art. 1, §1, letter g) of 2022 Decree.
[26] Art. 1, §1, letter ee) of 2022 Decree.

Figure 24 – Agricultural existing biogas plants capacity distribution (kW)

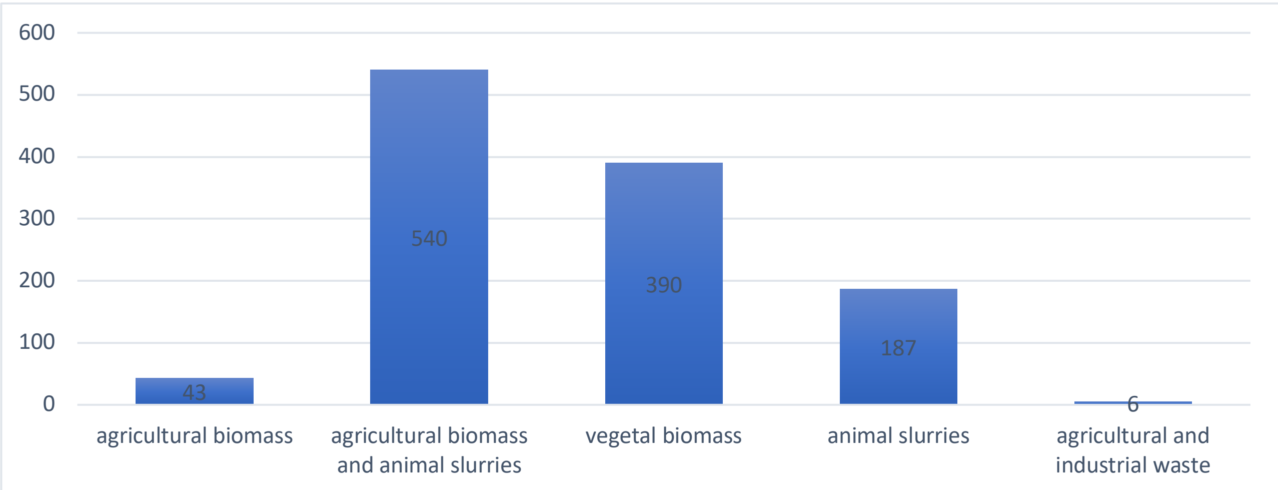


Source: authors' own elaboration.

The frequency distribution of feedstocks is the following:

- agricultural biomass and animal slurries (46.3%);
- vegetal biomass (33.4%);
- animal slurries (16.1%);
- agricultural biomass (3.7%);
- agricultural and industrial waste (0,5%).

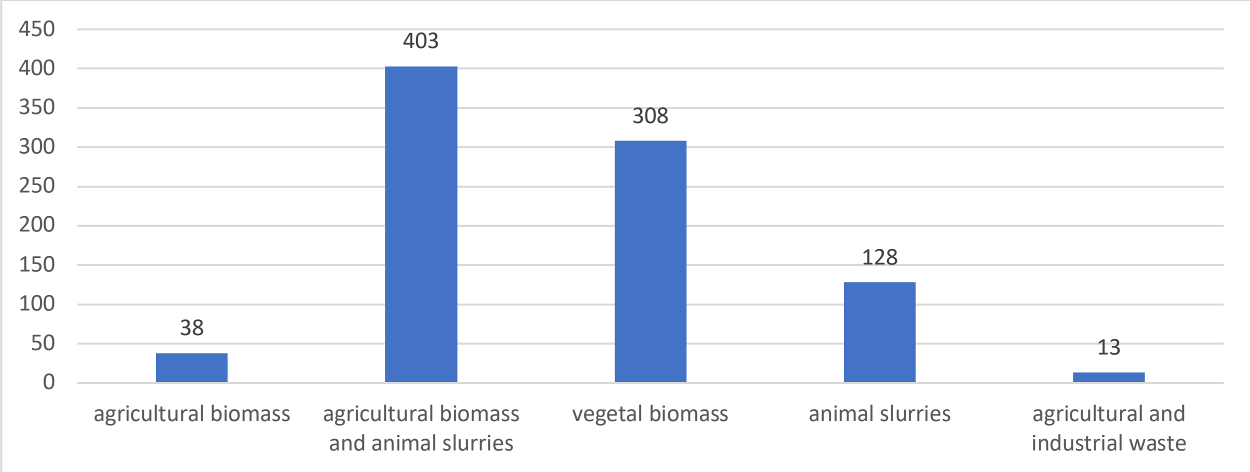
Figure 25 – Number of plants by feedstock



Source: authors' own elaboration.

The frequency distribution of total installed capacity by feedstock represents the same pattern: the most of capacity is related to agricultural biomass/animal slurries (45.3%), vegetal biomass (34.6%) and animal slurries (14.4%) plants.

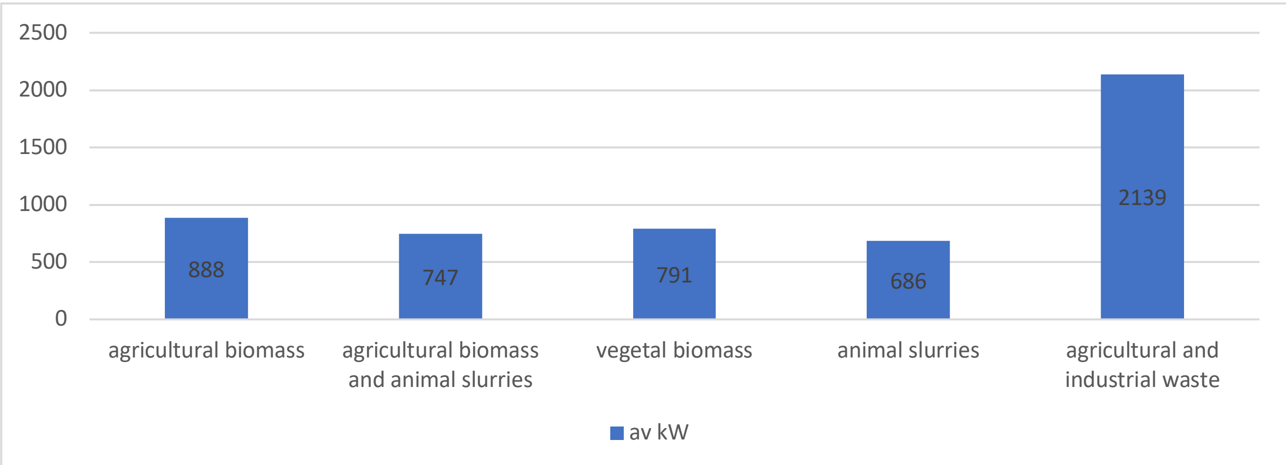
Figure 26 – Total installed capacity by feedstock in MW



Source: authors' own elaboration.

As of average plant capacity by feedstock the situation changes insofar as the biggest plants are fuelled with agricultural and industrial waste (av. size > 2 MW), while the remaining plants show capacities in the range of 686 – 888 kW.

Figure 27 – Average capacity by feedstock



Source: authors' own elaboration.

5.2.2 Estimation of future reconversions and of the consequent biomethane production from existing agricultural biogas plants

The possibility to convert existing biogas plants depends on both:

- *reconversion costs;*
- *the compliance with sustainability criteria* (65% and 80% GHG emissions reduction for biomethane to be used in the transport and in other sectors respectively).

The contemporary existence of the two constraints could make the conversion problematic for a few existing plants.

As for reconversion costs it is necessary to consider that, as outlined in the previous chapters of this Report, the 2022 Decree foresees a capital contribution also to reconverted agricultural existing biogas plants, though the recognized amount is lower than the one reserved to new plants. In order to evaluate the possibility of the conversion to biomethane production such contribution needs to be contrasted to reconversion costs.

Table 18 – Frequency distribution by feedstock classes and capacity

Capacity distribution (kW)	agricultural biomass	agricultural biomass + animal slurries	vegetal biomass	animal slurries	agricultural and industrial waste
up to 50	4	10	4	3	1
51<C<100	1	19	19	11	1
101<C<200	1	23	5	7	0
201<C<300	2	56	27	27	0
301<C<400	3	28	22	15	0
401<C<500	2	20	12	3	0
501<C<600	2	25	13	8	0
601<C<700	3	29	18	7	0
701<C<800	0	7	12	7	0
801<C<900	1	6	3	1	1
901<C<1000	22	309	254	98	0
1001<C<3000	1	8	1	0	2
>3000	1	0	0	0	1
Total	*43*	*540*	*390*	*187*	*6*

Source: authors' own elaboration.

With regard to the sustainability criteria a further assessment is necessary aimed at evaluating if the plants diets are compatible with the required GHG emissions reductions.

Reconversion costs mainly depend on the size of the plant.
According to our estimation the portion of reconversion costs that can be covered by the capital contribution varies between 13 and 35%.

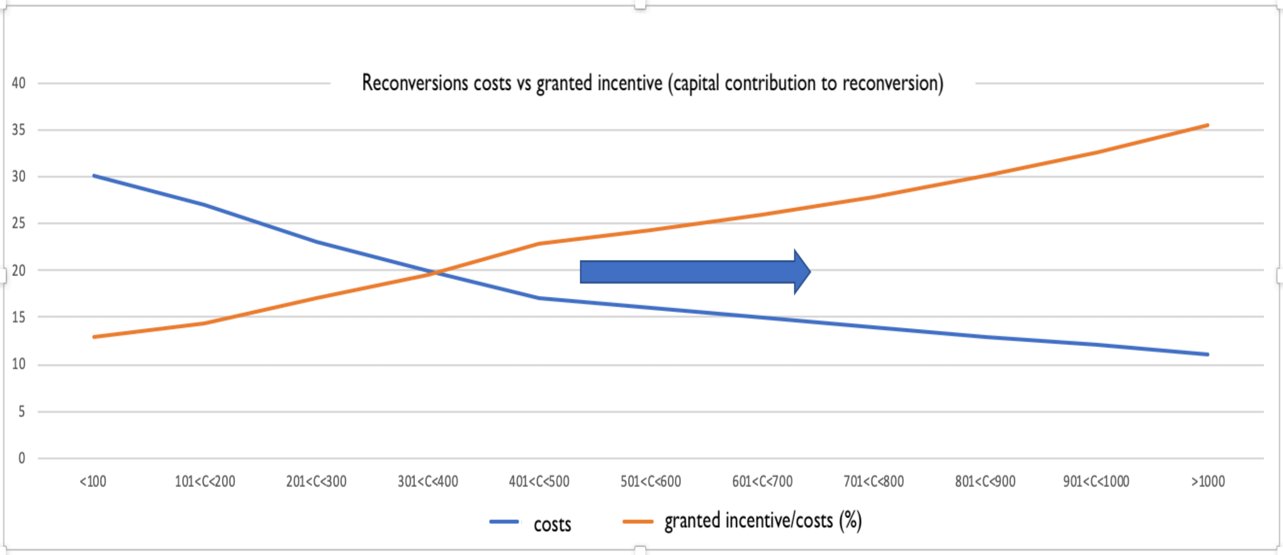
A preliminary evaluation, supported by sectoral operators, reveals that the revamping to biomethane production is feasible with a contribution at least equal the 20% of total costs.
In the following formula X should in other words reach a minimum value of 0.2.

$$\mathbf{FIT * \sum E > (FC * \sum E) + (RC - X)}$$

With:
FIT = feed in tariff
E = sum of biomethane produced over the plant lifetime in MWh
FC = feedstock cost per unit of energy produced
RC = reconversion cost
X = capital incentive for old plant reconversion

Considering the above-mentioned percentage threshold just plants with a capacity higher than 300 kW were hence considered for the purpose of the future biomethane production estimation.

Figure 28 – Reconversion costs (€/MWh) and granted capital incentive



Source: authors' own elaboration.

It is hence possible to hypothesize that 945 plants out of 1.166 will be converted, that is the 81% of the existing biogas installations corresponding to a capacity of 852 MW. This would lead to a production of biomethane of about 638 Mcm per year.
It is however necessary to take into account the additional constraint represented by the sustainability criteria, and, in particular, by the percentage abatement of GHG emissions required by the incentive system.

Table 19 - Plants that could undergo an economically feasible conversion considering capacity

DISTRIBUZIONE POTENZA IN KW	agricultural biomass	agricultural biomass + animal slurries	vegetal biomass	animal slurries	agricultural and industrial waste
up to 50	4	10	4	3	1
51<C<100	1	19	19	11	1
101<C<200	1	23	5	7	0
201<C<300	2	56	27	27	0
301<C<400	3	28	22	15	0
401<C<500	2	20	12	3	0
501<C<600	2	25	13	8	0
601<C<700	3	29	18	7	0
701<C<800	0	7	12	7	0
801<C<900	1	6	3	1	1
901<C<1000	22	309	254	98	0
1001<C<3000	1	8	1	0	2
>3000	1	0	0	0	1
Totale	*43*	*540*	*390*	*187*	*6*
NUMBER OF PLANTS THAT COULD BE RECONVERTED UNDER THE ECONOMIC POINT OF VIEW	**35**	**432**	**335**	**139**	**4**

Source: authors' own elaboration.

Considering the feedstocks used by the selected plants and the GHG emissions abatements achievable according to the diets reported in Table 11 the number of plants that would be able to benefit of the 2022 Biomethane Decree incentives if reconverted slightly decreases.

Table 20 - Plants that could undergo an economically feasible conversion considering capacity and GHG reduction criteria

CAPACITY DISTRIBUTION kW	agricultural biomass	agricultural biomass + animal slurries	vegetal biomass	animal slurries	agricultural and industrial waste
up to 50	4	10	4	3	1
51<C<100	1	19	19	11	1
101<C<200	1	23	5	7	0
201<C<300	2	56	27	27	0
301<C<400	3	28	22	15	0
401<C<500	2	20	12	3	0
501<C<600	2	25	13	8	0
601<C<700	3	29	18	7	0
701<C<800	0	7	12	7	0
801<C<900	1	6	3	1	1
901<C<1000	22	309	254	98	0
1001<C<3000	1	8	1	0	2
>3000	1	0	0	0	1
Totale	*43*	*540*	*390*	*187*	*6*
NUMBER OF PLANTS THAT COULD BE RECONVERTED ACCORDING TO GHG EMISSIONS CRITERIA	**0**	**432**	**335**	**139**	**0**

Source: authors' own elaboration.

It is in particular possible to hypothesize that 906 out of 945 plants will be converted, for a total capacity of 802 MW and a corresponding biomethane production of about 600 Mmc/yr.

It is however necessary to point out that emissions criteria can be respected just if:

- *in case of mixed diet (agricultural biomass and animal slurries), the portion of the latter is higher than 70%;*
- *the type of vegetal biomass used is such to grant emissions abatement corresponding to the upper end of the interval;*
- *digestate is closed;*
- *exhaust gases combustion takes place.*

600 Mcm would represent the 100% of the intermediate production target set by 2023 by the 2022 Decree, to the 55% of the production ceiling foreseen for the transport sector by the 2018 Decree and to the 24% of the total production target of 2,5 envisaged by the 2022 Decree.

5.2.2.1 Liquified biomethane production from reconverted existing agricultural biogas plant: a forecast

Biomethane could play a key role in the decarbonization of heavy road transport where it could be blended with LNG.

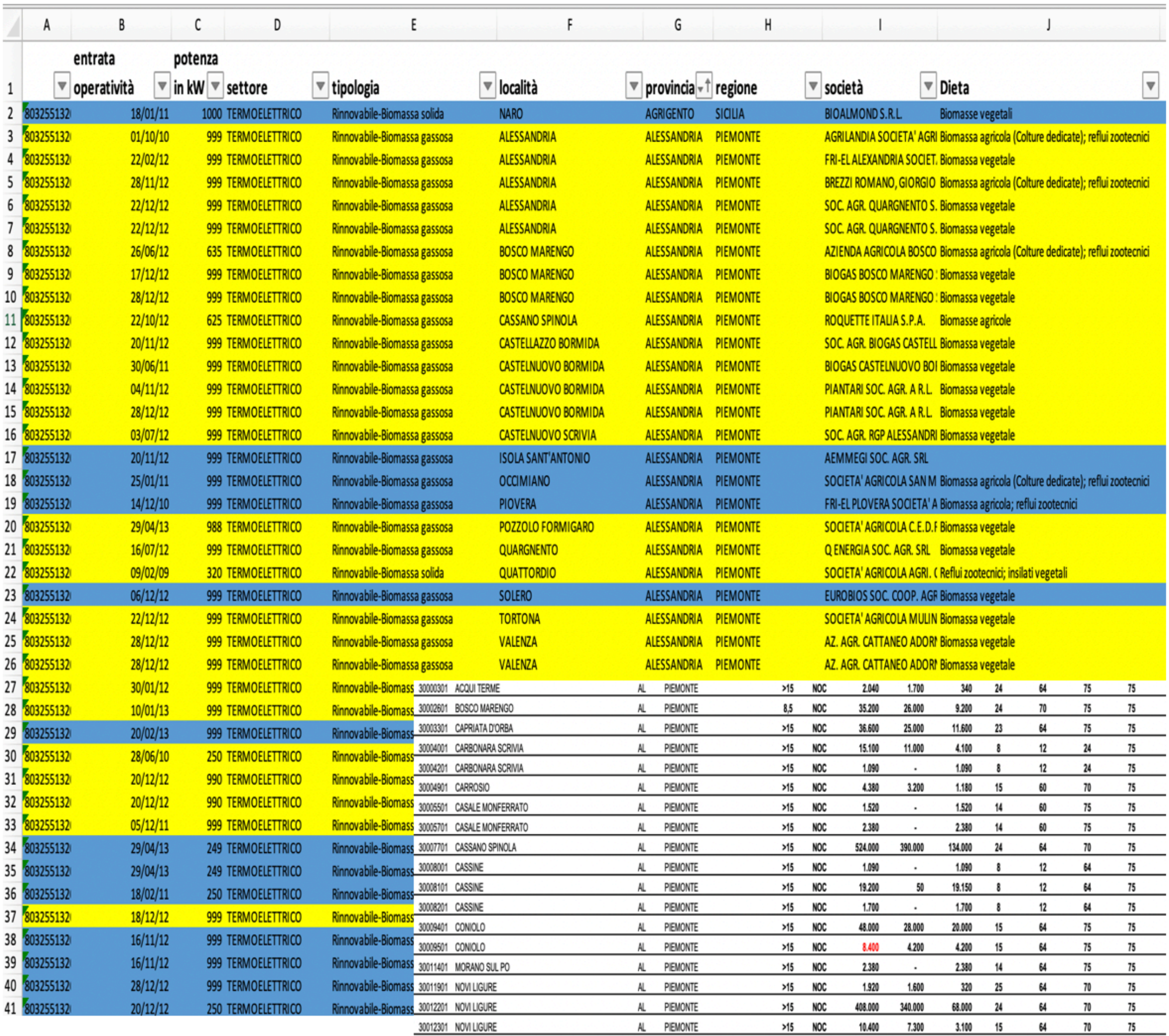
In order to estimate the share of the above-mentioned production that could be distributed after being micro-liquified it was necessary to verify the distance between existing agricultural biogas plants and the natural gas network.

The underlying hypothesis was that, in case of:

- too high network connection costs;
- or a technical constraint to connection overwhelmingly due to distance;

reconverted plants would opt for biomethane micro-liquefaction and maybe apply to the incentives foreseen for liquefaction plants as established by the Ministerial Decree, n.191, released on 27th June 2022, in the framework of the *Complementary Investment Plan*[27].

Figure 29 – Selection of plants located near the natural gas transport or distribution network: joint analysis of DIBI database and existing connection and delivery points



	A	B	C	D	E	F	G	H	I	J
1		entrata operatività	potenza in kW	settore	tipologia	località	provincia	regione	società	Dieta
2	803255132	18/01/11	1000	TERMOELETTRICO	Rinnovabile-Biomassa solida	NARO	AGRIGENTO	SICILIA	BIOALMOND S.R.L.	Biomasse vegetali
3	803255132	01/10/10	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	ALESSANDRIA	ALESSANDRIA	PIEMONTE	AGRILANDIA SOCIETA' AGRI	Biomassa agricola (Colture dedicate); reflui zootecnici
4	803255132	22/02/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	ALESSANDRIA	ALESSANDRIA	PIEMONTE	FRI-EL ALEXANDRIA SOCIET.	Biomassa vegetale
5	803255132	28/11/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	ALESSANDRIA	ALESSANDRIA	PIEMONTE	BREZZI ROMANO, GIORGIO	Biomassa agricola (Colture dedicate); reflui zootecnici
6	803255132	22/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	ALESSANDRIA	ALESSANDRIA	PIEMONTE	SOC. AGR. QUARGNENTO S.	Biomassa vegetale
7	803255132	22/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	ALESSANDRIA	ALESSANDRIA	PIEMONTE	SOC. AGR. QUARGNENTO S.	Biomassa vegetale
8	803255132	26/06/12	635	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	BOSCO MARENGO	ALESSANDRIA	PIEMONTE	AZIENDA AGRICOLA BOSCO	Biomassa agricola (Colture dedicate); reflui zootecnici
9	803255132	17/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	BOSCO MARENGO	ALESSANDRIA	PIEMONTE	BIOGAS BOSCO MARENGO :	Biomassa vegetale
10	803255132	28/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	BOSCO MARENGO	ALESSANDRIA	PIEMONTE	BIOGAS BOSCO MARENGO :	Biomassa vegetale
11	803255132	22/10/12	625	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	CASSANO SPINOLA	ALESSANDRIA	PIEMONTE	ROQUETTE ITALIA S.P.A.	Biomasse agricole
12	803255132	20/11/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	CASTELLAZZO BORMIDA	ALESSANDRIA	PIEMONTE	SOC. AGR. BIOGAS CASTELL	Biomassa vegetale
13	803255132	30/06/11	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	CASTELNUOVO BORMIDA	ALESSANDRIA	PIEMONTE	BIOGAS CASTELNUOVO BOI	Biomassa vegetale
14	803255132	04/11/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	CASTELNUOVO BORMIDA	ALESSANDRIA	PIEMONTE	PIANTARI SOC. AGR. A R.L.	Biomassa vegetale
15	803255132	28/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	CASTELNUOVO BORMIDA	ALESSANDRIA	PIEMONTE	PIANTARI SOC. AGR. A R.L.	Biomassa vegetale
16	803255132	03/07/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	CASTELNUOVO SCRIVIA	ALESSANDRIA	PIEMONTE	SOC. AGR. RGP ALESSANDRI	Biomassa vegetale
17	803255132	20/11/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	ISOLA SANT'ANTONIO	ALESSANDRIA	PIEMONTE	AEMMEGI SOC. AGR. SRL	
18	803255132	25/01/11	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	OCCIMIANO	ALESSANDRIA	PIEMONTE	SOCIETA' AGRICOLA SAN M	Biomassa agricola (Colture dedicate); reflui zootecnici
19	803255132	14/12/10	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	PIOVERA	ALESSANDRIA	PIEMONTE	FRI-EL PLOVERA SOCIETA' A	Biomassa agricola; reflui zootecnici
20	803255132	29/04/13	988	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	POZZOLO FORMIGARO	ALESSANDRIA	PIEMONTE	SOCIETA' AGRICOLA C.E.D.F	Biomassa vegetale
21	803255132	16/07/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	QUARGNENTO	ALESSANDRIA	PIEMONTE	Q ENERGIA SOC. AGR. SRL	Biomassa vegetale
22	803255132	09/02/09	320	TERMOELETTRICO	Rinnovabile-Biomassa solida	QUATTORDIO	ALESSANDRIA	PIEMONTE	SOCIETA' AGRICOLA AGRI. (	Reflui zootecnici; insilati vegetali
23	803255132	06/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	SOLERO	ALESSANDRIA	PIEMONTE	EUROBIOS SOC. COOP. AGF	Biomassa vegetale
24	803255132	22/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	TORTONA	ALESSANDRIA	PIEMONTE	SOCIETA' AGRICOLA MULIN	Biomassa vegetale
25	803255132	28/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	VALENZA	ALESSANDRIA	PIEMONTE	AZ. AGR. CATTANEO ADORI	Biomassa vegetale
26	803255132	28/12/12	999	TERMOELETTRICO	Rinnovabile-Biomassa gassosa	VALENZA	ALESSANDRIA	PIEMONTE	AZ. AGR. CATTANEO ADORI	Biomassa vegetale
27	803255132	30/01/12	999	TERMOELETTRICO	Rinnovabile-Biomass					
28	803255132	10/01/13	999	TERMOELETTRICO	Rinnovabile-Biomass					
29	803255132	20/02/13	999	TERMOELETTRICO	Rinnovabile-Biomass					
30	803255132	28/06/10	250	TERMOELETTRICO	Rinnovabile-Biomass					
31	803255132	20/12/12	990	TERMOELETTRICO	Rinnovabile-Biomass					
32	803255132	20/12/12	990	TERMOELETTRICO	Rinnovabile-Biomass					
33	803255132	05/12/11	999	TERMOELETTRICO	Rinnovabile-Biomass					
34	803255132	29/04/13	249	TERMOELETTRICO	Rinnovabile-Biomass					
35	803255132	29/04/13	249	TERMOELETTRICO	Rinnovabile-Biomass					
36	803255132	18/02/11	250	TERMOELETTRICO	Rinnovabile-Biomass					
37	803255132	18/12/12	999	TERMOELETTRICO	Rinnovabile-Biomass					
38	803255132	16/11/12	999	TERMOELETTRICO	Rinnovabile-Biomass					
39	803255132	16/11/12	999	TERMOELETTRICO	Rinnovabile-Biomass					
40	803255132	28/12/12	999	TERMOELETTRICO	Rinnovabile-Biomass					
41	803255132	20/12/12	250	TERMOELETTRICO	Rinnovabile-Biomass					

30000301	ACQUI TERME	AL	PIEMONTE	>15	NOC	2.040	1.700	340	24	64	75	75
30002601	BOSCO MARENGO	AL	PIEMONTE	8,5	NOC	35.200	26.000	9.200	24	70	75	75
30003301	CAPRIATA D'ORBA	AL	PIEMONTE	>15	NOC	36.600	25.000	11.600	23	64	75	75
30004001	CARBONARA SCRIVIA	AL	PIEMONTE	>15	NOC	15.100	11.000	4.100	8	12	24	75
30004201	CARBONARA SCRIVIA	AL	PIEMONTE	>15	NOC	1.090	-	1.090	8	12	24	75
30004901	CARROSIO	AL	PIEMONTE	>15	NOC	4.380	3.200	1.180	15	60	70	75
30005501	CASALE MONFERRATO	AL	PIEMONTE	>15	NOC	1.520	-	1.520	14	60	75	75
30005701	CASALE MONFERRATO	AL	PIEMONTE	>15	NOC	2.380	-	2.380	14	60	75	75
30007701	CASSANO SPINOLA	AL	PIEMONTE	>15	NOC	524.000	390.000	134.000	24	64	70	75
30008001	CASSINE	AL	PIEMONTE	>15	NOC	1.090	-	1.090	8	12	64	75
30008101	CASSINE	AL	PIEMONTE	>15	NOC	19.200	50	19.150	8	12	64	75
30008201	CASSINE	AL	PIEMONTE	>15	NOC	1.700	-	1.700	8	12	64	75
30009401	CONIOLO	AL	PIEMONTE	>15	NOC	48.000	28.000	20.000	15	64	75	75
30009501	CONIOLO	AL	PIEMONTE	>15	NOC	8.400	4.200	4.200	15	64	75	75
30011401	MORANO SUL PO	AL	PIEMONTE	>15	NOC	2.380	-	2.380	14	64	75	75
30011901	NOVI LIGURE	AL	PIEMONTE	>15	NOC	1.920	1.600	320	25	64	70	75
30012201	NOVI LIGURE	AL	PIEMONTE	>15	NOC	408.000	340.000	68.000	24	64	70	75
30012301	NOVI LIGURE	AL	PIEMONTE	>15	NOC	10.400	7.300	3.100	15	64	70	75

Source: authors' elaboration on DIBI database and Snam data, 2023.

The aim of the Decree, granting a maximum capital contribution equal to 50%, consists in incentivising:

- the realisation of gas liquefaction plants necessary for the transport sector decarbonisation;
- the construction of refuelling points for liquefied natural gas (LNG) and Bio-LNG in the port areas with the related storage capacities;
- the purchase of specific naval units for bunkering activities to ensure the availability of LNG and Bio-LNG mobile refuelling services in the port area.

[27] https://temi.camera.it/leg19DIL/temi/il-piano-nazionale-complementare-al-pnrr.html

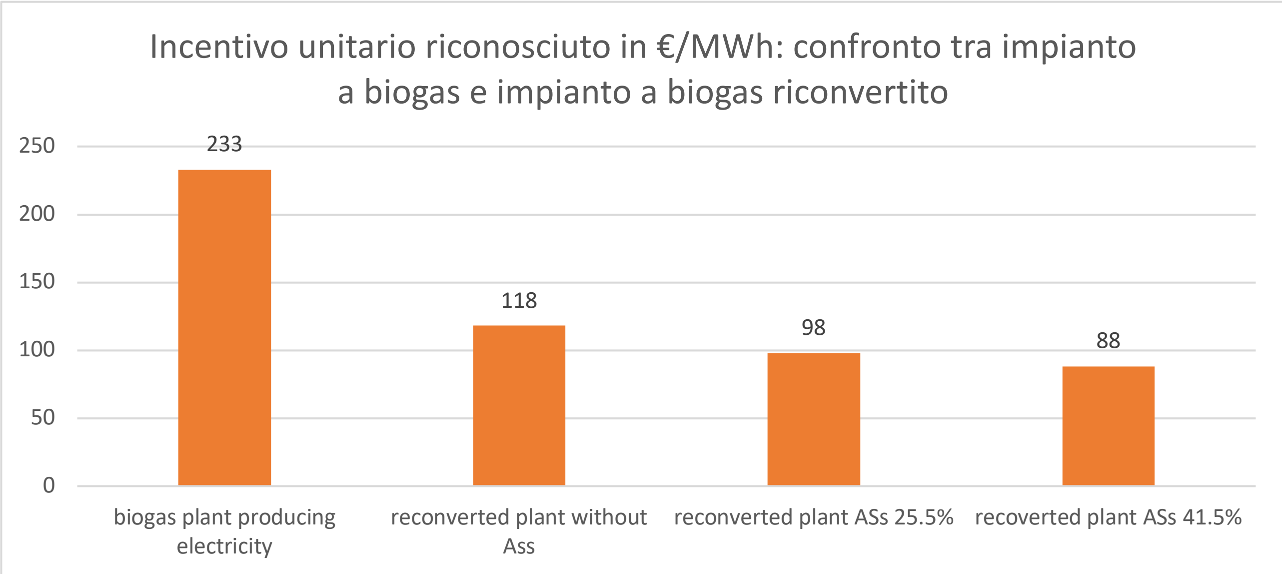
Plants that will reasonably sell liquified biomethane were identified by considering their distance from the natural gas network and by choosing those located in the proximity of connection or delivery points on the transport and distribution networks

The analysis showed that 423 plants out of 906 could distribute 282 Mcm of liquid biomethane (LBM) per year.

5.2.3 Reconversion of existing agricultural biogas plants in the light of the current electricity production incentive scheme

Reconversion of existing biogas plants needs to be evaluated also with reference to the incentive they benefit from for the production of electricity which represents their opportunity cost.

Figure 28 –Biogas plant and reconverted biogas plant: incentives comparison (€/MWh)



Source: authors' own elaboration.

The Law n. 145/2018 (art. 1, paragraph 954) extended the access to the incentives foreseen the Ministerial Decree of 23 June 2016 to power plants fueled with biogas, with an electrical capacity not greater than 300 kW and forming part of the production cycle of an agricultural or livestock company if biogas is derived for at least 80% from sewage sludges and agricultural feedstocks and for the remaining 20% from second harvest crops.

Here the comparison is made considering a 300 kW plant. In case of electricity generation, the all-inclusive-tariff of 233 €/MWh is considered; in case of conversion to biomethane production, the incentive is calculated considering the tariff and the capital contribution foreseen by the 2022 Biomethane Decree in the three hypotheses:

- ASs 100% self-powered;
- ASs equal to 25.5%;
- ASs equal to 41.5%.

As highlighted in Figure 28 the incentives the plant would be granted in case of conversion to biomethane production are 49, 58 and 62% lower than the tariff granted in case of electricity generation.

6 CONCLUSIONS

As underlined by the European Commission in the REPowerEU plan the acceleration of the energy transition requires the strengthening of the exploitation of domestic renewable resources such as biomethane.

With the promulgation of the 2022 Decree, the legislator intends to incentivize the production of biomethane in Italy by raising the production target set by the incentive system established by the 2018 Decree from 1.1 to 2.6 Bcm/year.

The new Decree, unlike the previous one, accessible just for plants coming into operation within the end of 2023, does not impose a constraint on the final use of biomethane, opening the way to its consumption in sectors other than transport, and is based on a two-component incentive consisting in an all-inclusive tariff and a contribution to the initial investment, with the aim of giving a definitive, new acceleration to the development of the market.

Analyzing in detail the production costs and the revenues obtainable from the production and sale of biomethane, calculated starting from the new incentives, however, it emerges that:

- small plants are penalized compared to larger ones because the tariff component is not differentiated (or is marginally differentiated) depending on the size of the plant, while large plants benefit from significant economies of scale with reference to both fixed costs (anaerobic digestion and upgrading) and fixed variable costs;
- the same occurs for the capital contribution in the case of organic waste plants that are granted the same incentive independently on their capacity;
- as a consequence, and depending on the amount of energy consumption of auxiliary services, the “minimum economic capacity”, that is the capacity required to reach the break-even point, needs to be greater than 500[28] and 1,000[29] kW;
- also for such plant sizes the difference between revenue and cost (gross operative margin) is such to make the choice of the feedstock a critical issue with the exception of plants fueled with the organic part of solid urban waste or other “negative cost” raw materials for which the procurement of the substrates necessary to the production of biogas represents a revenue instead of a cost;
- the incentives that would be guaranteed by the application of the 2018 incentive scheme are generally higher than the ones obtainable under the 2022 Decree both for new and old plants and especially for the Configuration E relating to the production of liquid biomethane due to the high auxiliary consumption entailed, and to the absence, in the new Decree, of incremental incentives in the event of construction of “pertinent” liquefaction plants;
- tariffs currently granted for the production of electricity from agricultural biogas plants are considerably higher than the revenues the plant would be granted in case of conversion to biomethane production, thus making the option scarcely attractive though the latter often represents the only opportunity to prolong the economic life of the plant.

The criticalities outlined in the presented analysis raise some doubts on the participation in the forthcoming competitive procedures.

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[28] ASs consumption equal to 25.5%.

[29] ASs consumption equal to 41.5%.

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