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WORKING PAPER

Unlocking and supporting renewable gas in Europe: Policy insights from a comparative analysis

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The scaling up of renewable gases is now being presented as a critical and effective component of the EU's long-term decarbonization strategy. Yet, the support schemes implemented for biogas and biomethane are far less studied than the ones dedicated to renewable power generation (e.g., solar or wind). The present manuscript bridges this gap. After a concise review of the supporting policies implemented in the EU, we conduct a comparative analysis of the mechanisms implemented in Germany, Denmark, and Italy and use it to gain policy insights. Our analysis is based on primary data extracted from policy statements that have been harmonized. Results show that incentivizing the supply-side lowers the risk associated with early investments and market development. Conversely, they highlight inhomogeneity among countries in accounting for demand and end-use in their policies. Finally, they point at the feedstock availability and the geographic and economic structure of a country as factors influencing the development of a market for renewable gases. The analysis stresses the value of policy mix in promoting renewable gases in the EU's energy mix and provides further evidence supporting the need for an evolution of renewable gas sector policies away from electricity generation.

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KEYWORDS

Renewable gas | Biomethane | Biogas

Policy mix | Subsidies | Comparative analysis

Executive summary

The ambitious EU Green Deal objective of carbon neutrality by 2050 necessitates significantly restructuring the European energy sector. Increased end-use electrification and widespread use of low-carbon power sources like wind and solar are unquestionably necessary for this decarbonization, albeit they are not the only solutions available.

Together with the COP27 methane commitment, the REPowerEU Plan, announced in May 2022, focuses on renewables like solar and wind electricity but also on renewable gases, like hydrogen and biomethane, and on expanding their share in the EU energy market. Hence, a thorough analysis of the national policies guiding the use of biomethane and biogas in Europe is needed.

This work investigates whether the current supporting programs can successfully mobilize European renewable gas potential and achieve the public policy decarbonization objectives of the EU. Such an analysis must examine the supporting mechanisms already in use in Europe; compare their strengths and shortcomings; and consider the future social and physical roles renewable gas will fulfill. It indeed intends to offer helpful direction by developing tailored policy viewpoints and identifying best practices.

Due to the fundamental character of the investigated energy vector and the necessity to take this complexity into account when subsidizing, it has become clear from the study that support for biogas is far more complex than that for renewable electricity. Having selected three case studies (i.e., Germany, Denmark, and Italy) and comparatively analyzed their biogas and biomethane policy strategy, the study has identified comparable supply-side initiatives among MS to promote installed biogas/biomethane capacity. It also emerged from the study the varied effect of the demand and end-use supporting mechanisms on the biogas/biomethane industry between MS and MS.

Once more, the analysis demonstrates how, in contrast to the supply side, as in the case of renewable energy, the demand-side inclusion in the subsidy discourse predominates in the country-specific best practices for biogas and biomethane. Indeed, understanding that their ability to replicate the electricity subsidy program was constrained when dealing with biogas and biomethane, Member States who shifted subsidies to demand-side fossil fuel substitutions have improved the prospects for these energy vectors in their economies.

The comparative analysis offered in this paper demonstrates the overarching and strategic level of policy design and how it might be implemented to enhance further the growth of renewable gas in the EU energy system because particular policies are not interchangeable between one country and another. But in addition to discussing whether the electricity sector's success in promoting renewable energy might serve as a model for the renewable gas industry, other important issues came to light in the study that should be addressed in future research (e.g., the role of Guarantee of Origins, the value of biomethane in the context of circular economy, policy integration across sectors).

The policy discussion to support biogas and biomethane's competitiveness versus other energy sources and assist their market development in achieving REPowerEU Plan's decarbonization goals should be better informed by looking more thoroughly at their future possibilities and challenges, which depend heavily on the massification of sectoral dynamics, new business models, interaction with infrastructure issues, and increased access to funding

1. Introduction

The EU's ambitious goal to reach carbon neutrality by 2050 (i.e., the 2019 EU Green Deal) calls for a profound reconfiguration of the European energy system. Such decarbonization indubitably requires the increased electrification of end-uses and a massive deployment of low-carbon power generation, such as wind and solar, though these options are not to the exclusion of others.

In particular, biofuels and hydrogen can also efficiently contribute to that decarbonization, especially in the hard-to-abate sectors that are fueled by fossil hydrocarbon resources [1]. Among these other options, it is fair to write that the decarbonization potentials of biogas and biomethane and the policies needed to unlock them are currently comparatively less studied than that of hydrogen.

That overlook is surprising because decarbonization is not a unique public goal that calls for a deeper understanding of the economics of renewable gas supplies. The war in Ukraine and its repercussions have marked the resurfacing of energy security and affordability concerns in European policy discussions. By nature, renewable gases have the potential to reduce the EU's reliance on external energy sources. Against this background, it is interesting to highlight the recent emphasis put on these technologies in the recent policy plans unveiled by the EU.

Together with the methane pledge at COP27, the REPowerEU Plan introduced in May 2022 focuses not only on renewables, such as solar and wind power, but also on renewable gases, such as hydrogen and biomethane, and on increasing their share in the EU energy offerings [2]. Yet, scaling up the EU biomethane production that currently attains 3 billion cubic meters (bcm) to 35 bcm is challenging and requires: attracting investment in biomethane production capacity; promoting easy market access, enabling grid connection, and improving the price signal for biomethane and implementing an EU-wide Guarantee of Origin system; and finally, mobilizing sustainable feedstock [3].

Altogether, these discussions call for a detailed evaluation of the national supporting policies governing the deployment of biomethane and biogas[1] in Europe. The purpose of this work is thus to examine whether these supporting schemes can cost-effectively mobilize the European potential and meet the EU's abovementioned public policy goals. Such an analysis requires reviewing the supporting mechanisms that are currently implemented in Europe and comparing their performances, merits, and limitations, considering the future social and physical functions that will be met by renewable gas [4]. By nature, such an analysis is aimed at providing useful guidance by drawing adapted policy perspectives and identifying best practices.

To investigate, we conduct a structured comparison of the essential features of the policy implemented in three different EU Member States (MS) and assess their relative merit. In particular, the work examines the policy developments over the past decades in Germany, Denmark, and Italy, to understand whether there is an optimal design on the policy strategy and instrument mix that creates a market driver to promote low-carbon/renewable gases, and support its share in the decarbonization of the gas grid pathway as a means to reach the target that has been set by the European Commission (EC).

Our analysis addresses whether renewable gas may benefit from the same regulations that have effectively lowered the cost of renewable electricity toward the decarbonization of the EU energy system. Many Member States have support mechanisms to incentivize biomethane, although very few have specific renewable gas targets [5]. If on the one hand, some, such as

[1] Consistent with earlier literature, we follow the standard delineation between biogas and biomethane, where the anaerobic digestion of organic matter in an oxygen-free environment results in the production of biogas, a combination of methane, carbon dioxide, and trace amounts of other gases; and biomethane is a refined/upgraded biogas or gasified solid biomass that can be injected in the network.

France and Denmark, target a specific percentage of demand being covered by biomethane by 2030 (i.e., 10 and 100% natural gas substitution, respectively), most EU countries subsidize renewable gas only in relation to its end-use, namely for the most part electricity generation (i.e., Germany) and transport (i.e., Italy) [6, 7].

Since most of the policy developments are context-dependent, studying the substrate on which they have been built up is key to understanding how countries in the EU have transitioned to RES in the last decade and how relevant a system approach to policy is in successfully delivering change. Most of the authors agreed that the architecture of the value chain is heavily influenced by each MS structural and regulatory factors. Hence, successful policies and policy support mechanisms in one country may not necessarily provide the same results in another since they rely on that country's larger context, policy, and economic framework [7, 8].

Through the creation of a unique and novel database from primary data collection in sources (e.g., stakeholder's reports, public administration websites, and international organizations) documenting the energy policies and supporting schemes and incentives of different European countries, the analysis provides an original perspective on the country's specificity of biogas/biomethane production. The work highlights similar supply-side strategies of incentivizing installed capacity for biogas/biomethane among MS. An additional significant finding relates to demand and end-use supporting mechanisms between MS and MS that have a different impact on the biogas/biomethane industry. To this end, what has emerged from the work is that support for biogas is much more complex than that for renewable electricity as it is the intrinsic nature of the considered energy vector and the approach to subsidizing needs to account for this complexity.

Again, the work reveals how the inclusion of the demand-side in the subsidy discourse prevails in the country-specific best practices for biogas and biomethane, as opposed to the supply-side as in the case of renewable electricity. And indeed, countries that realized that the potential of replicating the electrical subsidy scheme was limited when dealing with biogas and biomethane and redirected subsidies to substitute fossil fuel on the demand-side have created a stronger outlook for these energy vectors in their economy.

To the best of our knowledge, there is no detailed and standardized analysis between different MS to investigate the relationship between "support scheme-deployment" for biogas and biomethane. This work aims at filling the gap by conducting a comparative analysis of the link between the gas market, the system's dependence on natural gas, and the presence of policies and incentives for biogas and biomethane in selected EU countries. To this end, this analysis has been based on a direct search in multiple databases and policy guidance in different MS, with primary data selected and harmonized directly from policy statements, hence, the work reviews the variety of schemes that have been implemented and examines their performances considering the public policy objectives that have motivated their implementation.

Although many different strategies have been proposed and implemented both at the country and the EU level, the literature suggests a lack of understanding of the dimension of biogas policies and how they influence the production and use of biogas to create a driver market for renewable gases. But where the case of solar and wind have stimulated a vast literature, this policy perspective contributes to the small and very much needed literature attempting to shed light on the evolution of policy strategies and supporting mechanisms of biogas/biomethane, which the literature has mostly overlooked.

In the following sections, attention will be devoted to the EU natural gas supply chain, installations, financial support of RES in Europe, the European biogas sector, and the evolution of policy strategy in selected EU Member States. Section 2 describes the evolution of renewable gas-related policies at the EU level and in selected Member States over a decade (i.e., 2009–2019). Section 3 presents a comparative analysis of the key complexities of the evolution of renewable gas policy, analyzing and discussing the evidence and critical issues that have influenced the renewable energy policy scenario in selected EU Member States. The final section summarizes the findings, conclusions, and policy implications with key insights from the previous sections and provides future research directions.

2. Background

This section clarifies both the background and the motivation of our analysis. After a brief review of the evolution of the policies supporting the deployment of renewable gas in Europe, we present the essential features of the situation prevailing in Denmark, Germany, and Italy. These three countries together illustrate the diverse approaches currently prevailing in Europe.

2.1 The history and development of renewable gas policies in the EU

Given the prominent role of natural gas in the energy system today and moving forward, it is interesting to investigate how it has been supported in its renewable form by policy mechanisms and how that support compares to the support for other renewable energies in the same timeframe [9]. Another critical point is to understand whether having a strong dependence on natural gas for an energy system has made any difference in the presence of policies and the number of incentives for renewable gas.

The work focuses on the financial support for renewable energy for electricity generation, on which policies have been concentrating over the last two decades.

When looking at the financial support of renewable energy for electricity generation, RES installations (i.e., including solar, wind, geothermal, hydropower, bioenergy, solid biomass, and biogas) were financially supported as early as the late 80s/early 90s, well before the first EU Directive on Renewable Energy was adopted in 2001 (2001/77/EU). In particular, the collective EU weighted average support is now more than 10-fold in 10 years (2009–2019), going from weighted average support per unit of gross electricity consumed of 9 €/MWh in 2010 to 97.95 €/MWh in 2019, with demand-pull support instruments favored over other types of support (see Table 1) [10–19].

Table 1 RES supported electricity in the EU 2009–2019 (Source: Authors' elaboration on [10–13, 15–18])

Year	2009*	2010**	2012/13	2015	2017	2018	2019
Weighted average support per unit of gross electricity consumed (€/MWh)	7,2	9	110.22	110.2	96.29	99.62	97.95
Average support (€/MWh)	-	7	81.41	-	-	-	-

* RES supported accounted for: 10% of gross electricity generation

** RES supported accounted for: 8% of gross electricity generation and 9% of final electricity consumption

The strategy has developed from initially applying financial instruments to then evolving into market-based ones to help progressively integrate electricity generated from RES into the market. Hence, from 2001 to 2017, Feed-in Tariff (FIT) was the most common support for RES, followed by the introduction of Feed-in Premium (FIP) and Green Certificates (GC) starting in 2017. Support has moved from FIT, a mechanism that does not operate under market conditions, falling under the financial instrument support mechanisms category, to market-oriented ones, as both FIP and GC operate under market conditions.

Despite the heavy presence of gas in the primary energy demand and in different end-uses in 2019 [20], there has been a historical gap in support for developing renewable gases in different end-uses. Although biogas has been incentivized for electricity production, at lower rates than other RES (e.g., wind, solar, and hydropower), it has received little support elsewhere in the end-use supply chain [6].

In the near future, a vast majority of installations, primarily wind, and starting from 2024 also solar PV and hydropower, will need to confront a new environment now that the FIT scheme is reaching the end of its supporting time [19]. Starting from 2021 RES will be forced to compete in full market conditions, increasingly having to integrate into the market.

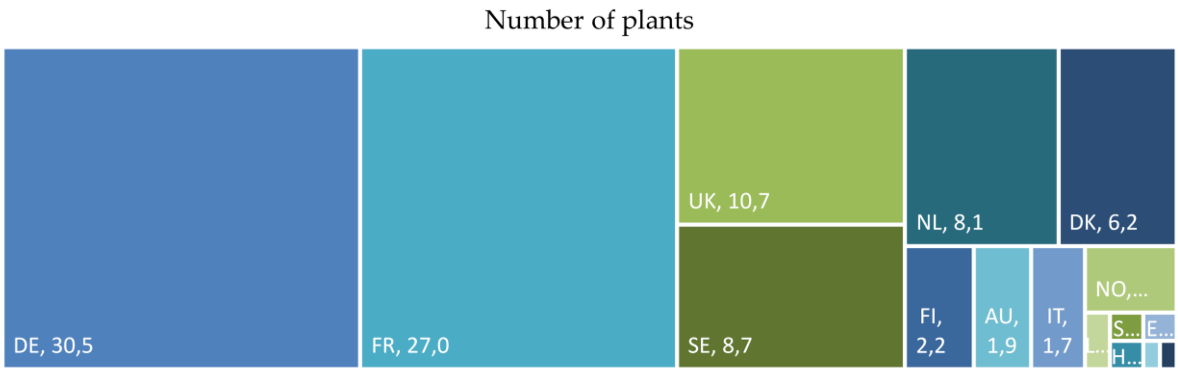
To this end, although biogas and biomethane are still a small portion of the overall bioenergy consumption (< 3%) and a small share of the overall biogas output is upgraded, with biomethane representing 0.1% of natural gas demand, the number of biogas plants in Europe, which is the region that produces the most biogas and biomethane in the world, rose by +1855 and +160% respectively from 2011 to 2018 [21,22], highlighting the potential biogas and biomethane could have in the energy transition process, also under the REPower EU plan.

2.2 Three complementary approaches, the cases of Germany, Denmark, and Italy

In this background, with the goal of better gauging the dynamics of the evolution of policies and getting an insight into the efficiency of policy support in the promotion of biogas and biomethane, the following three Member States have been selected as benchmarks based on an established production of biogas as well as on recent developments in their biogas/biomethane policies (or lack thereof) to investigate the link between biogas/biomethane and RES policy and market creation: Germany, Denmark, and Italy.

In particular, in the selection of which countries' policy strategy and technological developments to analyze over a 10-year period (2009–2019), the preference criteria have been not only the degree of market maturity but also diversity concerning both recent developments of production levels and feedstock utilization.

All three MS are among the top 10 EU MS based on the number of operating biomethane plants as well as their capacity and per capita electricity generation from biogas, with Germany being a pioneer and leader of gas production for CHP use, representing 53% of the whole EU's biogas electricity; Denmark, with a third of Germany's per capita electricity production from biogas, being one of the most advanced markets in biomethane; and Italy being an active market in the shift toward biomethane for different end-uses, and one of the largest markets for natural gas in transports, contributing 13% to the EU biogas electricity production in Europe [23, 24] (see Figure1).



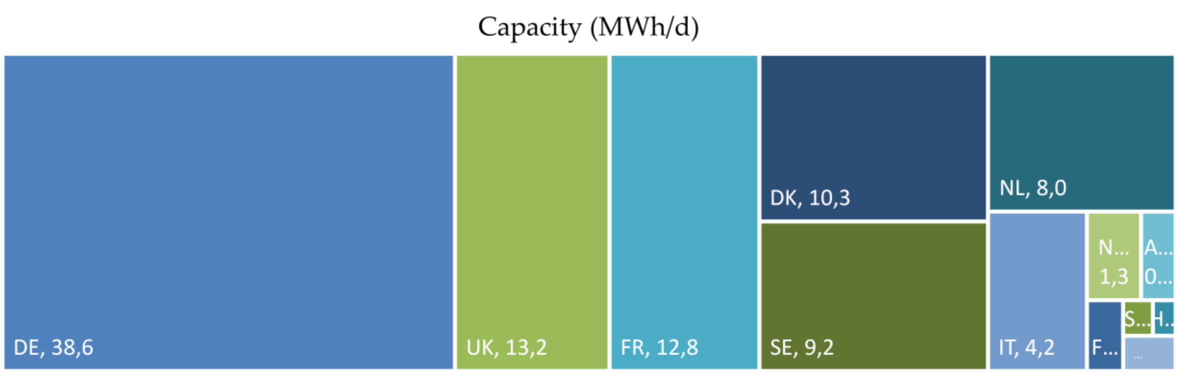


Figure 1 Development of the European biomethane sector based on the number of plants (a) and capacity (MWh/d) (b) (%). (Source: Authors' elaboration on confidential data from [25])

The three selected markets are not the only biogas/biomethane markets that have reached a significant level of maturity. Other developed markets in the EU are the UK, France, Sweden, and the Netherlands.

Several reasons concurred in not taking them into account as case studies. Although among the top biomethane producers, the UK and the Netherlands had no biomethane targets in place at the time of writing; hence the pace for future development is not expected to be as dynamic as it is in less mature markets, such as Italy, for instance.

On the other hand, Sweden has been investing in biomethane mainly for transport and filling stations because they do not have a comprehensive gas grid infrastructure. This last aspect, along with an extremely low per capita electricity generation from biogas, makes it a less suitable case file for this study [21].

Finally, although France is a very active and mature market regarding the development of biomethane, the support shown for biomethane in Italy in the wider end-use supply chain has been highly favorable [7, 23].

From this analysis, general trends can be highlighted for the development of the biogas/biomethane sector in recent decades. In particular, from early 2000 the predominant model for the sector has been biogas from energy crops, high FIT, and electricity and local power generation via combined heat and power (CHP) units. The sector is now shifting toward a different model that is putting a greater emphasis on biogas upgrading into biomethane to be injected into the grid and away from electricity generation, on feedstock differentiation, and on subsidy reduction, where policies are pushing the sustainability of the sector and the reduction of costs for biogas production [23, 24]. Hence, from FIT to FIP and from CHP to grid injection, the strategy has been to create a more competitive market and to widen the scope of utilization for renewable gases, upgrading from biogas to biomethane (see Table 2 and Table 3).

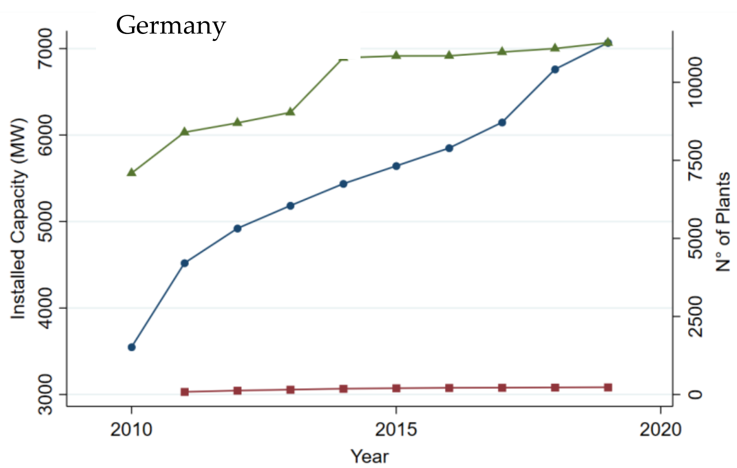
Table 2 Policy implications in the biogas market development in Germany, Denmark, and Italy [6, 23].

Biogas	DE	DK	IT
Main end-use	CHP	CHP; gas grid	CHP
Market development	Stall (2012/2014 FIT tariff reduction; 2017 auctioning and defined target growth)	Downturn since 2015 with tendering mechanism	Stall (2013 FIT reduction and shift to FIP)

Table 3 Policy implications in the biomethane market development in Germany, Denmark, and Italy [6, 23].

Biomethane	DE	DK	IT
Supporting Scheme	Abolished in 2014	FIP (3 components) (2012-2020)); Tenders with price ceiling (2020)	Certificates (2018 Biomethane Decree)
Main end-use	CHP	CHP; gas grid	Transport, gas grid
Future strategy	Unclear	Upgrading development	Substantial upgrading in other sectors

The political approach over 10 years (i.e., 2010–2019) is well summarized in Figure 2, where the stall in the market development for biogas from 2012–2014 and the unclear strategy on biomethane (see Figure 2) is apparent for Germany. For Denmark, the downturn in biogas in favor of biomethane starting from 2014; and for Italy, the reliance on biogas that has been stalling since 2013 as well as the timid uptake of biomethane following the 2018 Biomethane Decree, going from 1 biomethane plant in 2018 to 12 in 2019 and 17 in 2020 [25, 26].



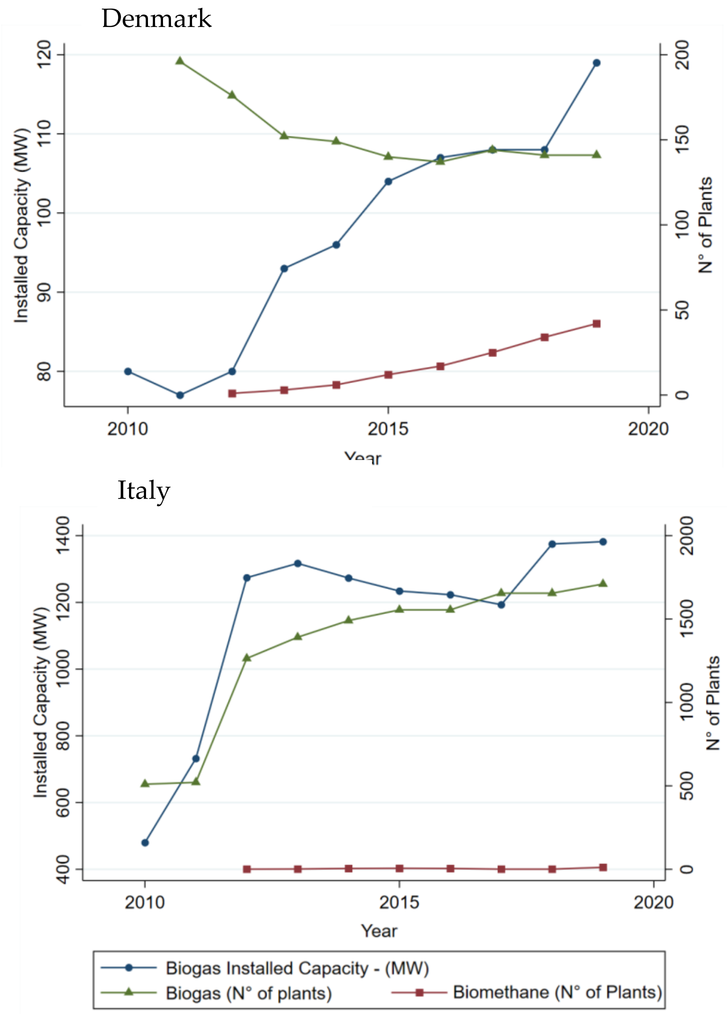


Figure 2 Installed capacity (MW) by number of plants in Germany, Denmark, and Italy from 2010–2019. (Source: Authors' elaboration on [26]) (Only annual data are available)

In addition, similar to the global trend, in Europe, from 2010, installation costs and levelized costs of energy (LCOE) have been dropping significantly for solar PV and wind offshore thanks to the supporting mechanisms policy adopted by various European governments, closing the gap with biogas installations and LCOE costs, which were lower to begin with. In particular, LCOE in the EU27 countries has dropped -21% from 2010 to 2018 for wind onshore, -80% for solar PV- Rooftop, and -75% for solar PV – Utility-scale since 2008. This has led to LCOE ranging between €41–89/MWh for wind in 2018, €70–188/MWh rooftop solar PV, €43–168/MWh for Solar PV Utility-scale in 2018, and €64–180/MWh for biogas-fired plants in 2018 [27, 28].

It is clear that the challenges to the development of biomethane are less linked to the scale of deployment if compared with other renewable energy sources (i.e., wind and solar) (see Figure 3 and Figure 4). However, they are linked to installation size, production costs (i.e., investment and operational costs, feedstock supply and costs, plant size and efficiency and operations costs) as well as competition from the availability of much cheaper traditional fossil fuels, at least up until 2022. So now policies have started to push the sector's sustainability and the reduction of biogas production costs [6].

In particular, in Denmark and Italy, there has been a strong push to upgrade biogas, and biomethane has been employed for various applications in different sectors spanning from transportation to chemical production, to heat, and to injection into the grid. Greater attention has been paid to feedstocks: organic wastes, agricultural by-products, and sequential crops. On the other hand, in Germany and Denmark, subsidy schemes for biogas have been progressively reduced in favor of auctions and tenders, which has brought a stall and a downturn of the biogas market in those MS [33–36, 38–41].

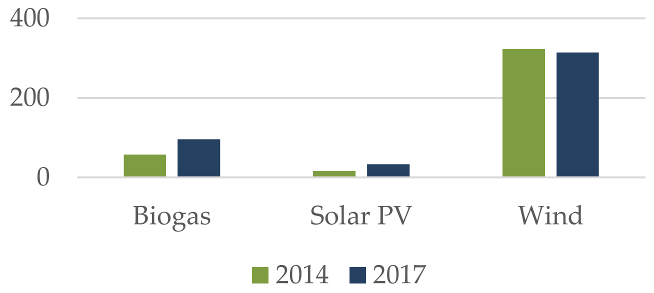


Figure 3 RES incentives costs in Denmark in 2014 and 2017 (MEUR). (Source: Authors' elaboration on [10–13, 15–18])

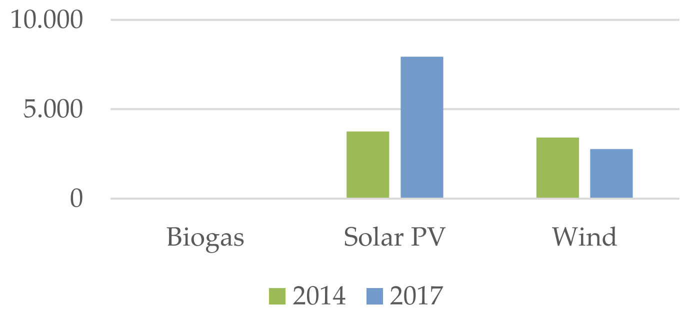


Figure 4 RES incentives costs in Germany in 2014 and 2017 (MEUR). (Source: Authors' elaboration on [10–13, 15–18])

3. Key complexities of renewable gases policies evolution – a comparative analysis

As in the run up to the decarbonization of the energy system, natural gas has substituted other more carbon-intensive fuels and biomethane is starting to show its full potential. We assess and compare the performances of the various supporting policies implemented in three MS carrying out a preliminary comparative analysis to examine the link between the gas market, the system's dependence on gas and the presence of policies and incentives.

The analysis is based on the information collected with an in-depth analysis of the evolution of policies for biogas/biomethane in the three selected Member States and the database created with historical data (2010–2019) by the authors from data collected from different sources both publicly and not publicly available: CEER, IRENA, IHS, Our World Data, Eurostat, IEA, and FAOSTAT (see Table A1 and Table A2 in the Appendix).

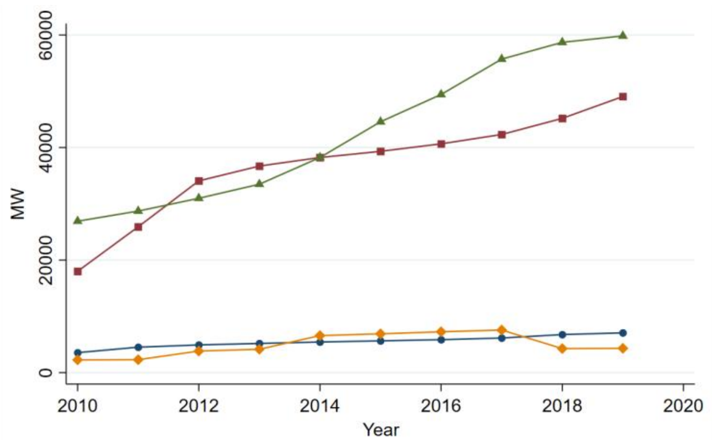
The comparative analysis focuses on the link between first supporting mechanisms of RES with electricity production, and then its synergy with natural gas, exploring how support has evolved based on the country's rate of dependence on natural gas in the energy mix, as well as the relative weight of the end-use of natural gas. In addition, we investigate how different policy approaches have supported other long-term objectives in the development of the biogas and biomethane market.

Differences and similarities in their long-term strategies can be inferred and are discussed in the following sections.

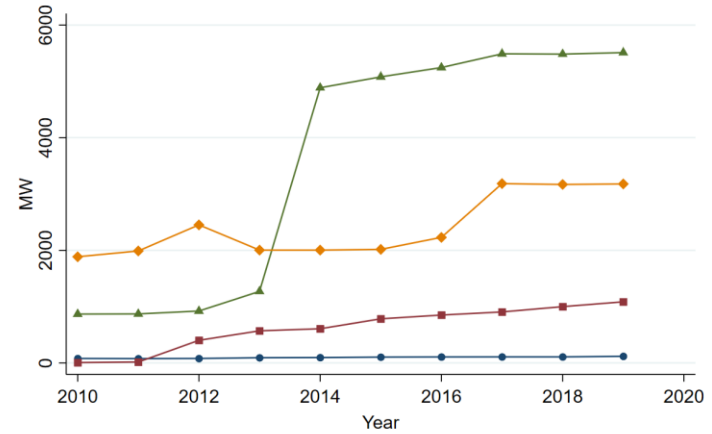
3.1 Support of RES with a focus on electricity production

The analysis shows that, when supported, the installed capacity and renewable energy produced reflect the national renewable energy development strategies and the geographic characteristics of the country. In Germany and Denmark, greater support has been given to wind power; in Italy, incentives have favored solar photovoltaic, and the installed capacity has followed the same pattern (see Figure 5). It also appears clear from the graphs that wind, solar, and biomass are preferred to biogas, in terms of both installed capacity and supported energy (see Figure 6).

Germany



Denmark



Italy

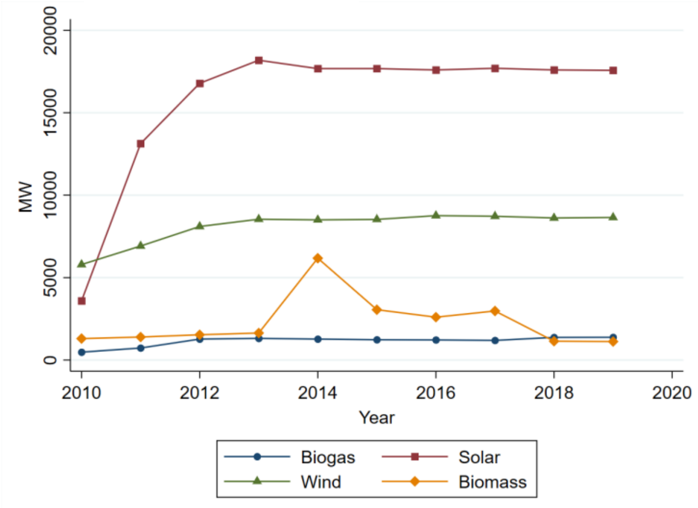
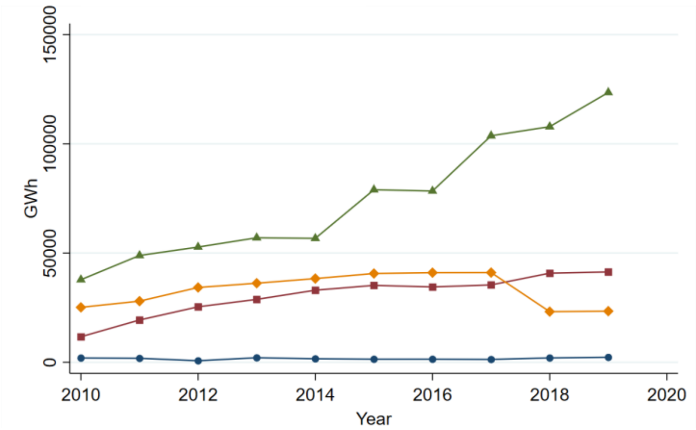
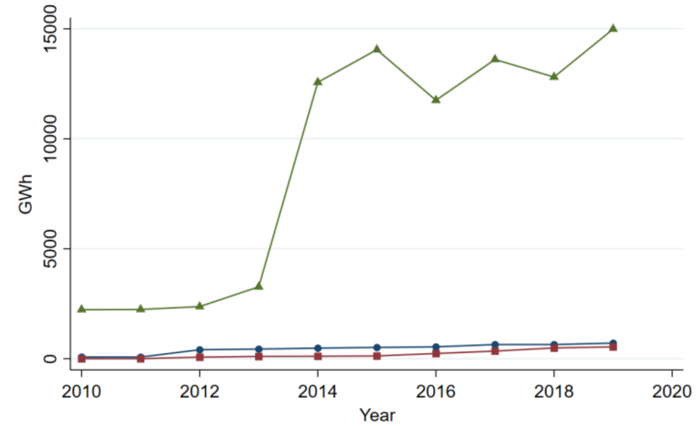


Figure 5 Renewable energy installed capacity from 2010 to 2019 in Germany, Denmark, Italy (MW) (Authors' elaboration on own database)

Germany



Denmark



Italy

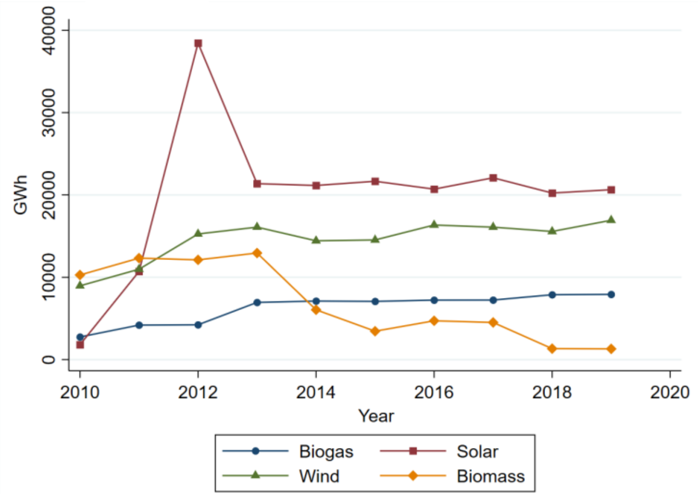


Figure 6 Renewable energy produced receiving support from 2010 to 2019 in Germany, Denmark, Italy (GWh) (Authors' elaboration on own database)

3.2 Support of biogas/biomethane based on rate of dependence on natural gas in the energy mix

In addition, considering the significant percentage of natural gas dependence accounted for in each of the three selected Member States (i.e., 15.7% in Denmark, 26.5% in Germany, and 42.1% in Italy [29]), the share of biogas has been compared to the natural gas presence in the energy mix for each country. There is no apparent correlation between the natural gas share in a country's energy mix and the share of biogas on the total installed capacity in the same country.

Similar to what has been observed in the support received by biogas for total supported energy and total installed capacity, regardless of the significant reliance on natural gas in their energy mix of each of the Member States considered, the share of biogas was around 5% or lower in a 10-year span in all three of the Member States included in the analysis (see Figure 7).

A reason for that might be that renewable gases compete for the same infrastructure as fossil gas, which has been historically cheaper than the former, up to three times lower (i.e., 18€/MWh vs. 55–100€/MWh respectively) [3]. In addition, as mentioned in Section 2, other types of RES (i.e., wind and solar PV) had a more significant challenge ahead in terms of technology advancement and scale than biogas had, where technology costs sharply decreased over time as the scale of deployment increased [6].

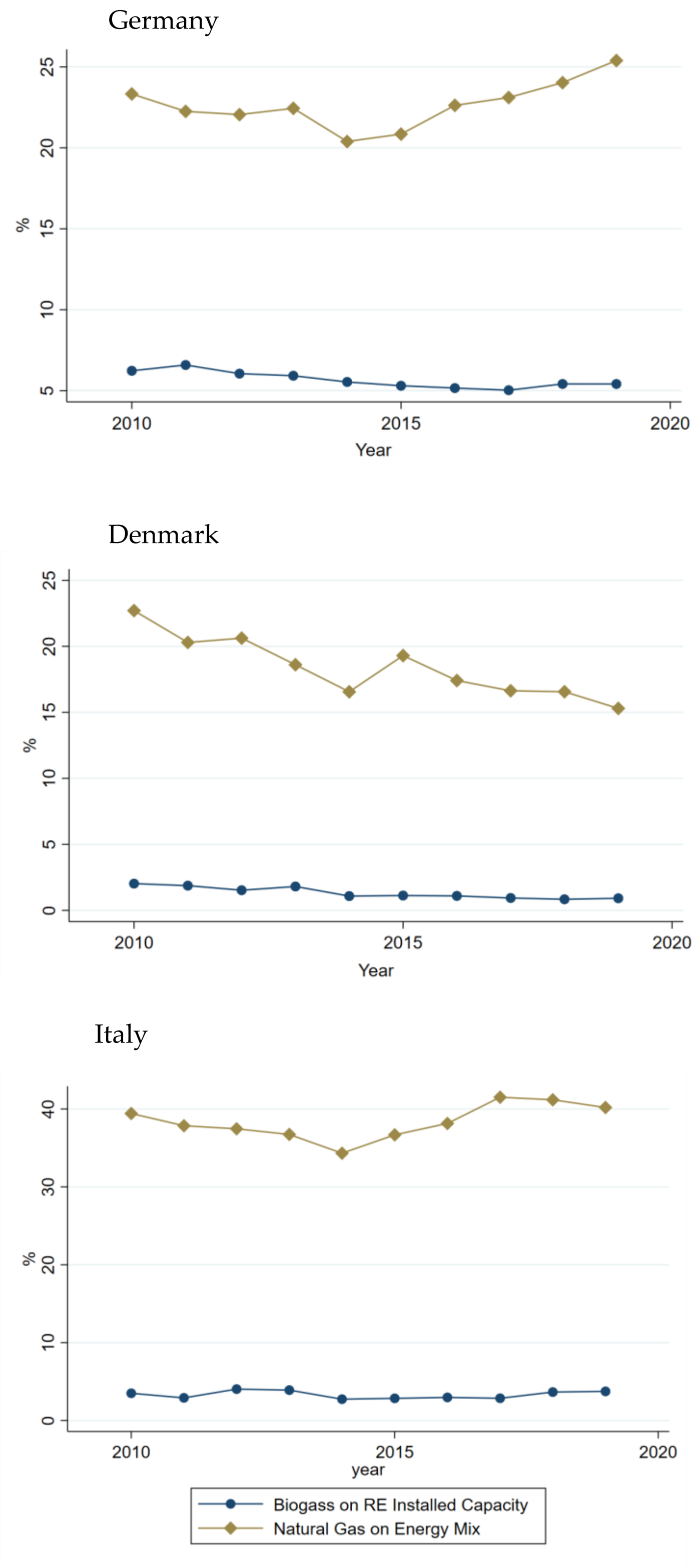


Figure 7 Share of biogas on renewable energy total installed capacity and share of natural gas on total energy mix from 2010 to 2019 in Germany, Denmark, Italy (%) (Authors' elaboration on own database)

3.3 Support of biogas/biomethane based on end-use

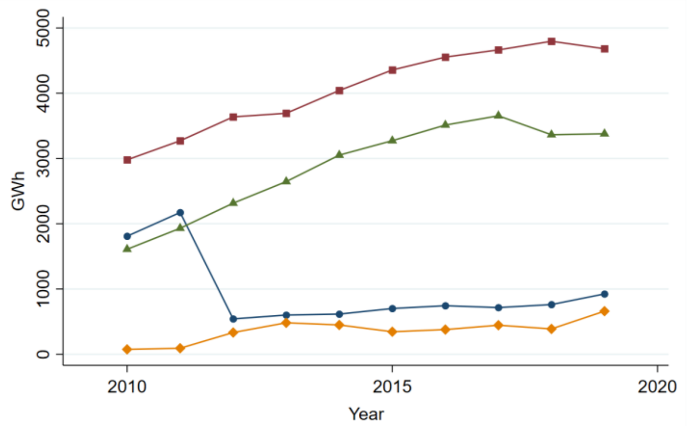
When looking at consumption by sector in Germany, favored sectors for biogas utilization are the commercial public, and households, but not so much the industry sector, unlike in Denmark and Italy (see Figure 8). A reason might be that Germany has a large availability of alternative sources: a high percentage of natural gas in the energy mix and coal [29]. In addition, biogas cannot be used for grid injection, hence, the extensive use of CHP and district heating.

On the other hand, sequencing in demand-pull policy measures in Denmark has led to the industry and commercial sectors being favored over households and transports, accounting for 44%, 29%, and 2% of the total end-use, respectively. Both the Heat Supply Act of 2000, which required the biogas industry to deliver gas for district heating, and the Energy Agreement of 2012, which called for differentiated feed-in support and biogas/biomethane grid injection, have had an impact on the biogas industry structure and on how it developed from then on.

Feed-in support output for direct use of biogas for heat and power production (i.e., FIT) and final use in industry (i.e., FIP) were set higher than for households and transport. In addition, to incentivize the biogas upgrade for grid use, when upgraded into biomethane and then injected into the grid, it receives more support (i.e., FIP) than when used directly in CHP and district heating [8].

Following the policy ambition of 100% substitution of natural gas with biomethane in the grid by 2050 and 70% of gas in the grid coming from biogas by 2030 in the Energy Agreement, starting in 2018, the strategy of Denmark has been twofold: (i) preventing increases in subsidy costs and (ii) opening up the demand market for biomethane to target those sectors in which biomethane had seen low adoption rates till then (i.e., transport and to a lesser extent households), hence, the introduction of tenders as a support mechanism of biogas/biomethane. Since then, the biomethane percentage in the grid has been increasing incrementally, going from 10% in 2017 to 15% in 2019 and reaching 21% in 2020 and 25% in 2021 [30].

Germany



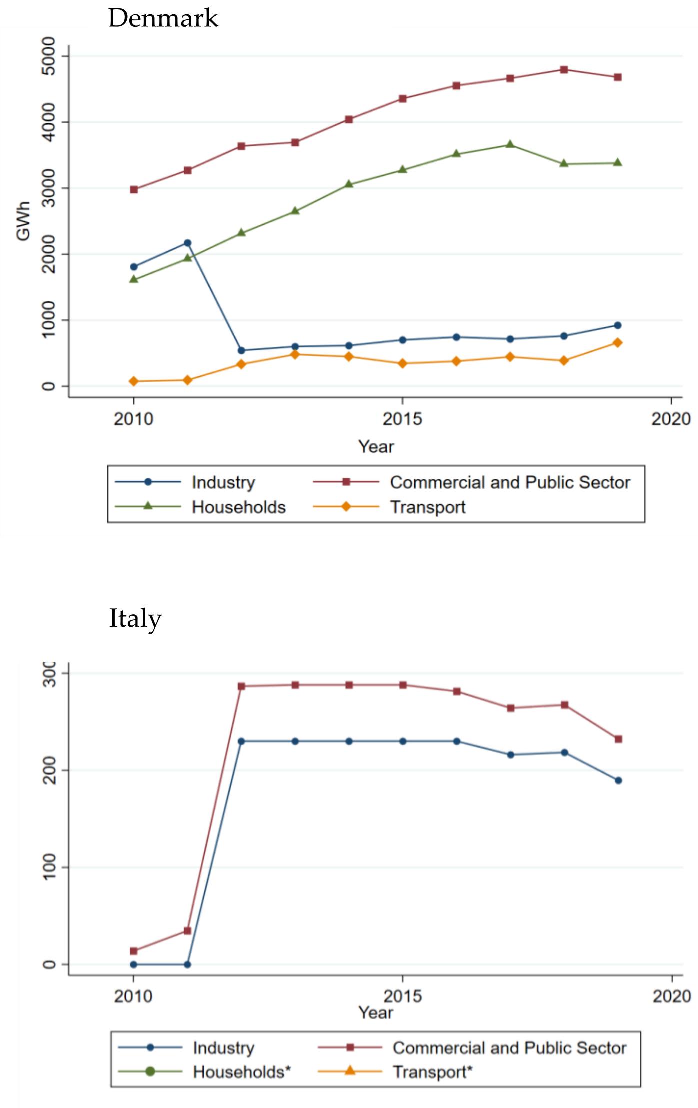


Figure 8 Biogas consumption by sector in Germany, Denmark, Italy from 2010 to 2019 (GWh) (Source: Authors' elaboration on own database) * Data not available

3.4 Impact of policies on the evolution of the biogas/biomethane sector in Germany, Denmark, and Italy

Given the lower incentive support extended to biogas and biomethane and the concurrent and similar development path of the policy strategy in the three examined countries, the analysis has been to evaluate further whether policies had an impact on the evolution of the biogas and biomethane sector over the period 2010–2019. To this end, it can be observed how those have been beneficial in helping the sector boom and how the market follows the enactment of the policies in all three countries examined (see Figure 10, Figure 12, and Figure 14).

One common trait in the evolution of the policies and their impact on the installed capacity of biogas in the three MS considered over the same 10-year timeframe has been the shift from FIT to FIP and then auctioning. As [31] points out in its analysis of the overall measures and public support framework for biomass for energy, this strategy has turned out to be faster and more flexible in adjusting the support levels of cost reductions and fully integrating biogas into the electricity market.

Introducing FIT as a first supporting measure to support the use of biogas/biomethane has its advantages. Indeed, FIT are long-term contracts that provide stability, driving technological development and maximizing production. In addition, by giving fixed-term support, they reduce the initial risk for investors [31]. But as much as they prove useful in the early stages of the creation of supply, they can be costly, as experienced in Denmark, where a new supporting scheme was introduced following a significant spike in the tariff between 2016 and 2017 [6].

In addition, FIT does not provide sufficient market integration to allow the new technologies to independently compete in the market, as they do not respond to price signals. Hence, the market's future development was contingent on the effectiveness of cost-cutting measures as well as a sector-coupling approach to policy [31].

As the analysis shows (see Figure 10, Figure 12, and Figure 14), the common strategy of MS has been to transition from FIT to FIP, followed by the current predominant support mechanism of tenders. The way FIP instruments work, and more so tenders, is that they respond to the price signals of the electricity market, allowing for an efficient combination of electricity supply with demand and for the opportunity of higher revenues than FIT as well as for effective policy mixes in the country, which include different policy domains (e.g., environmental, labor, etc.…) due to the selection of bids that can be based on specific criteria [31].

Contrasting the biogas/biomethane policy evolution over the biogas/biomethane receiving support with the installed capacity for biogas in Germany (see Figure 9 and Figure 10 respectively), Denmark (see Figure 11 and Figure 12 respectively) and Italy (see Figure 13 and Figure 14 respectively), it can be noted that when the policy support increases, so does the installed capacity, and vice versa when the support decreases, a plateau in the installed capacity can be observed. This is more evident in the Danish and Italian biogas and biomethane strategy, but it can also be recognized in the German policy evolution with some caveat.

The comparison for Italy and Denmark shows that with each increase in incentive or the introduction of a new supporting mechanism (e.g., the shift from FIT to FIP), the market has responded with an increase in installed capacity. In Denmark, since 2010 the market has seen constant growth. With the introduction of the FIP scheme between 2010 and 2012, the biogas sector boomed, to be followed by a sharp spike in installed capacity from 2018 on when there was a steep rise in the tariff and the introduction of a new supporting scheme (see Figure 11 and Figure 12). This is reflected in the renewable gas consumption by sector, where it has been mostly used in the industry, commercial, and public sectors (see Figure 8).

Similarly, in Italy, there was strong market growth from 2010 to 2012 with the introduction of substantial incentives through the FIT scheme. Still, when an FIP scheme was instituted with decreasing incentives, the market immediately stalled. Thus, as shown in Figure 14, from 2013 to 2018 the installed capacity curve flattened until 2018, when the biomethane decree was enacted to promote biomethane in uses other than industry and public and commercial sectors where it had been solely utilized up until then (see Figure 13, and Figure 14).

Finally, in Germany, the first European MS in biogas and biomethane capacity, it seems that the market has not been following the evolution of the policy schemes, as the installed capacity has been steadily growing since 2010 (see Figure 5). The sector started flourishing with the introduction of the Renewable Energy Source Act (EEG) in 2000. In 2013 there was a decrease in the compensation rate of FIT, but the installed biogas/biomethane capacity continued to surge.

The reason can be twofold. On the one hand, the category "biogas" in the data collected in the database does not indicate the portion of biogas that is upgraded into biomethane, hence, what is seen on the graph as an upward curve might be referring to an increase in biomethane capacity and not biogas per se. On the other hand, the German government incentivized a biomethane upgrade from 2013 to 2017. Hence, the upward installed capacity curve could have resulted from the policies put in place to advance biomethane in the energy system and curb biogas expansion (see Figure 9 and Figure 10). Concurrently, between 2013 and 2017, the very high development of PV and wind in the country (see Figure 6) might have drawn electricity prices down, disincentivizing due to the production from biogas CHP.

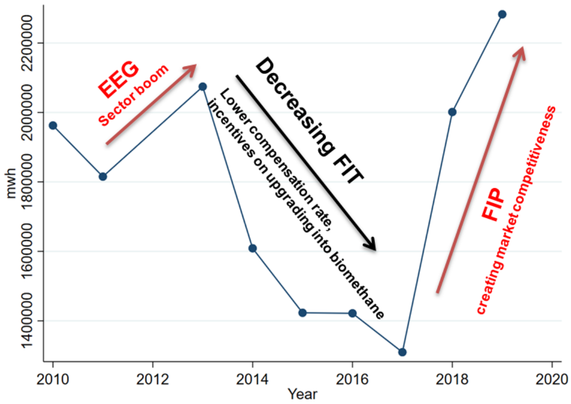


Figure 9 Evolution of policies for biogas/biomethane support in Germany over a 10-year period (Authors' elaboration on own database)

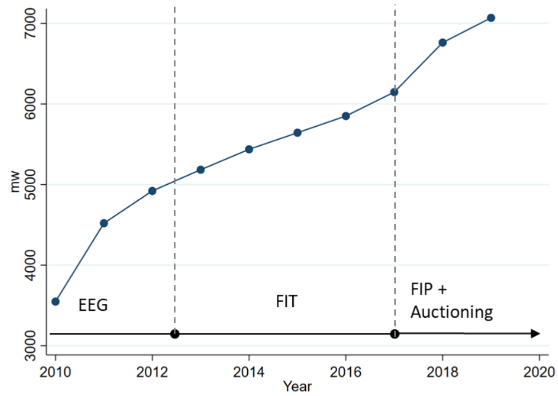


Figure 10 Evolution of biogas/biomethane installed capacity in Germany over a 10-year period (Authors' elaboration on own database)

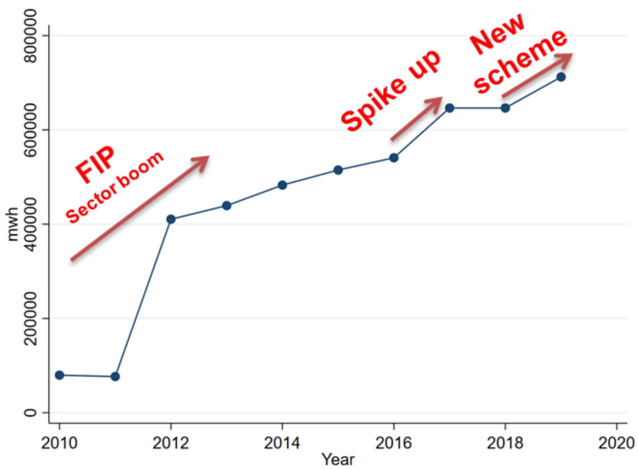


Figure 11 Evolution of policies for biogas/biomethane support in Denmark over a 10-year period (Authors' elaboration on own database)

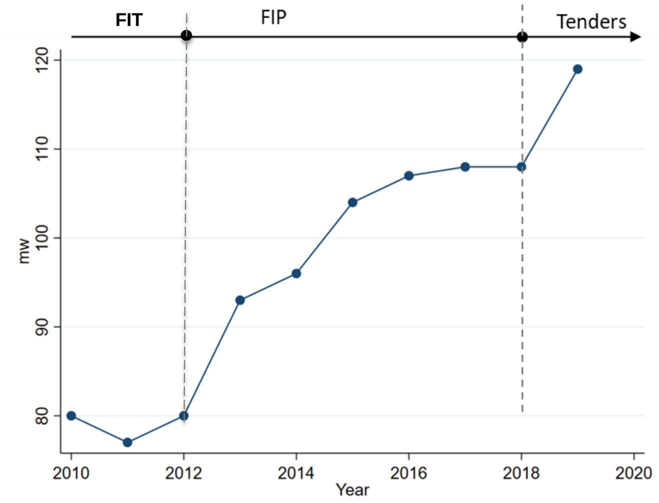


Figure 12 Evolution of biogas/biomethane installed capacity in Denmark over a 10-year period (Authors' elaboration on own database)

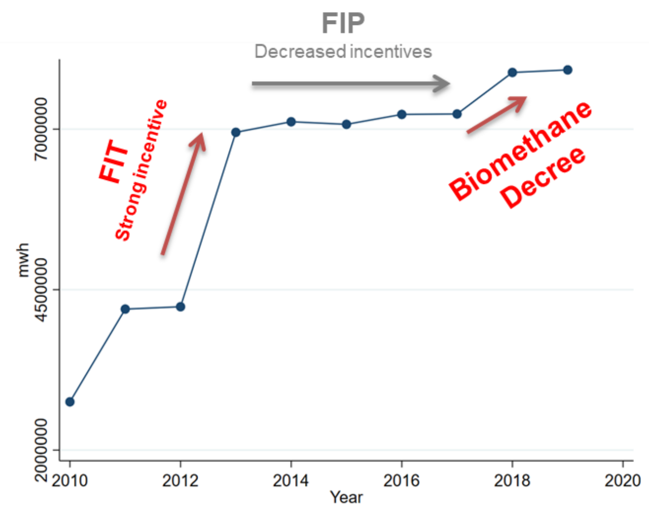


Figure 13 Evolution of policies for biogas/biomethane support in Italy over a 10-year period (Authors' elaboration on own database)

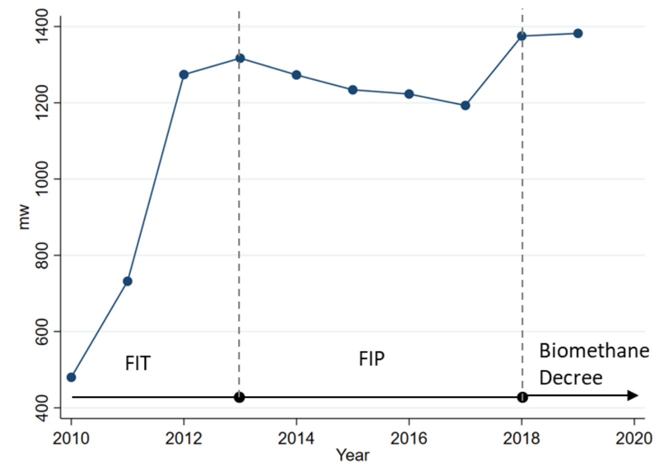


Figure 14 Evolution of biogas/biomethane installed capacity in Italy over a 10-year period (Authors' elaboration on own database)

4. Conclusions and Policy Implications

The present work investigates the relationship between "support scheme – deployment" for biogas, biomethane, and RES. In doing so, it gives an insight into the efficiency of policy support in promoting biogas and biomethane with a focus on electricity production. What this investigation has unveiled are missing support, market perspective, and policy framework that has disappointed a more harmonious EU-wide framework for the deployment of renewable gas (i.e., biogas and biomethane) in other sectors beyond electricity production, where it has so far been confined and funded.

As presented, (i) production costs, such as investment and operational costs, feedstock supply and costs, plant size and efficiency, and operations costs; (ii) competition from much cheaper natural gas availability, which was the case in Europe prior to the recent political turmoil; (iii) together with the lower economic support received by biogas if compared to other RES, have been among the main challenges to the development of biogas/biomethane over recent decades.

The comparative analysis presented in the study shows a clear connection between success and setbacks in biogas/biomethane evolution and policy changes among Member States. In particular, the realization that the substitution of fossil fuels with biogas and biomethane could be most effective when applied along the whole energy chain, both upstream but with greater potential on the end-use side, rather than only on the production side as it has been done for renewable electricity, is what has created a different deployment outlook for biogas and biomethane in best practice countries. To this end, subsidizing demand-side deployment brings synergies in the decarbonization of different sectors, hence it is a policy that has side effects because the direct incentive to biogas and biomethane leads to an indirect subsidy of a different end-use sector (e.g., transport in Italy) and it goes beyond the decarbonization of electricity production.

The analysis has revealed similarities across the Member States in how they incentivize the supply-side, showing strong evidence with policy to decrease the risk connected to initial investments (i.e., FIT) and market creation (i.e., FIP). As highlighted, there is a link between the incentive and the installed capacity of biogas and biomethane.

Also, differences across the Member States in creating a self-standing market for biogas and biomethane have emerged from the analysis, especially in how demand and end-uses have been accounted for by policies. As observed, to increase the market volume, most Member States focused on biomethane where the scope widens (i.e., grid-injection) compared to biogas, whose main end-use rests in CHP.

Finally, the development of biogas and biomethane is country-specific. It is influenced not only by each country's geographic and economic structure but also in great measure by feedstock availability. To this end, there has been a limited value chain perspective and policy efforts have been concentrated on production, whereas end-use and feedstocks have received little attention. But when end-use has been given attention that is where best practices have been found.

Since specific policies are not interchangeable between one country and another, the comparative analysis presented in this work reveals the overarching and strategic level of policy design and how that can be applied to further improve the development of renewable gas in the EU energy system. But alongside the debate on whether the electricity experience in supporting renewables can inspire the renewable gas sector, from the analysis emerged additional paramount questions that future works should pay attention to.

Some under-researched issues with potentially significant implications for policy design pertain either to more sustainable production and increased supply and/or the consumption of renewable gases. In relation to these three areas of focus specific additional topics that should receive consideration from a policy perspective are: (i) a framework to ensure policy coordination and wider policy integration across different sectors (i.e., agriculture, waste management, energy, and transport); (ii) the design for incentive gain sharing among participants in the value chain, drawing from Denmark's experience; (iii) the possibility to impose renewable portfolio standards and the need to examine the merits and limitations of such a policy in the context of biomethane; (iv) the role of Guarantee of Origin, which has been proposed as a crucial public support mechanism to promote a more harmonized use of renewable gas at the EU level to create a single EU cleaner energy market; and finally (v) the value of biogas and biomethane production as a way to valorize emissions in other sectors exploiting industrial, residential, and agricultural wastes in the context of the circular economy.

Since attaining the REPowerEU Plan decarbonization goals also depend on placing greater emphasis on biogas and biomethane, the future possibilities for biomethane and biogas rely heavily on the massification of sectoral dynamics, new business models, interaction with infrastructure issues, and increased access to funding. Looking more closely into those issues could further inform the policy debate to bolster biogas and biomethane's ability to compete against other energy sources and facilitate their market development.

Appendix

Table A1 Source for policy evolution analysis

	Country	**Source**
1	Germany	[5,6,21–23,32–35]
2	Denmark	[5,6,21–23,30,34–37]
3	Italy	[5,6,21,23,33,35,36,38,39]

Table A2 Source for data input collection

	Data	**Database**
1	Installed capacity	[10–13,15–18,26]
2	Energy volumes receiving support by technology	[10–13,15–18,26]
3	Energy volumes receiving support by supporting scheme	[10–13,15–18,26]
4	Natural gas end-use share volumes	[25–27]
5	Share of natural gas in the energy mix	[25–27]
6	Biogas total consumption	[26]
7	Biogas consumption by sector	[26]
8	Biogas and biomethane plants' number	[25,26]
9	Biogas and biomethane feedstock type	[25,26]

10	Land use data on agriculture and livestock	[40]
11	Electricity from natural gas	[41]
12	Natural gas per capita	[42]
13	GDP per capita	[26]
14	CO2 annual emissions	[43]
15	Natural gas price	[25,44]

References

[1] European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions. The European Green Deal 2019;COM(2019).

[2] European Commission. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS REPowerEU Plan 2022;COM(2022):1–21.

[3] EBA. Breaking Free of the Energy Dependency Trap DELIVERING 35 BCM OF BIOMETHANE BY 203O. 2022.

[4] Rijke J, Brown R, Zevenbergen C, Ashley R, Farrelly M, Morison P, et al. Fit-for-purpose governance: A framework to make adaptive governance operational. Environ Sci Policy 2012;22:73–84. https://doi.org/10.1016/j.envsci.2012.06.010.

[5] Eba MD, Biogas-e ST, Fernández D, Aebig R, Mccarthy PJ, Rgfi BO, et al. Renewable gases in Europe D6 . 1 | Mapping the state of play of renewable gases in Europe Mapping the state of play of renewable gases in Europe renewable gases in Europe. 2020.

[6] Eyl-Mazzega M-A, Mathieu C, Boesgaard K, Daniel-Gromke J, Denysenko V, Liebetrau J, et al. Biogas and Bio-methane in Europe: Lessons from Denmark, Germany and Italy. 2019.

[7] Gustafsson M, Anderberg S. Biogas policies and production development in Europe: a comparative analysis of eight countries. Biofuels 2022;0:1–14. https://doi.org/10.1080/17597269.2022.2034380.

[8] Lyng KA, Skovsgaard L, Jacobsen HK, Hanssen OJ. The implications of economic instruments on biogas value chains: a case study comparison between Norway and Denmark. Environ Dev Sustain 2020;22:7125–52. https://doi.org/10.1007/s10668-019-00463-9.

[9] Sesini M, Giarola S, Hawkes AD. Strategic natural gas storage coordination among EU member states in response to disruption in the trans Austria gas pipeline: A stochastic approach to solidarity. Energy 2021;235:121426. https://doi.org/10.1016/j.energy.2021.121426.

[10] CEER. Status Review of Renewable and Energy Efficiency Support Schemes in EU 2008:1–53.

[11] CEER. Status Review of Renewable and Energy Efficiency Support Schemes in Europe 2012:1–53.

[12] CEER. Status Review of Renewable and Energy Efficiency Support Schemes in Europe (Ref : C12-SDE-33-03) 2013:1–53.

[13] CEER. Status Review of Renewable and Energy Efficiency Support Schemes in Europe in 2012 and 2013 2015:1–53.

[14] CEER. Key support elements of RES in Europe: moving towards market integration 2016:1–90.

[15] CEER. Status Review of Renewable Support Schemes in Europe. Council of European Energy Regulators Asbl 2017:14–23.

[16] CEER. Status Review of Renewable Support Schemes in Europe for 2016 and 2017 2018:126.

[17] CEER. Status Review of Renewable Support Schemes in Europe for 2018 and 2019 2021.

[18] CEER. CEER Report on Renewable Energy Support in Europe (REf: C10-SDE-19-04a) 2011.

[19] CEER. CEER Paper on Unsupported RES 2020.

[20] IEA. World Energy Outlook 2020 2020:1–461.

[21] EBA. EBA Statistical Report 2020. 2020.

[22] IEA. Outlook for biogas and biomethane. Prospects for organic growth. World Energy Outlook Special Report. 2020:93.

[23] Brémond U, Bertrandias A, Steyer JP, Bernet N, Carrere H. A vision of European biogas sector development towards 2030: Trends and challenges. J Clean Prod 2021;287. https://doi.org/10.1016/j.jclepro.2020.125065.

[24] Banja M, Jégard M, Motola V, Sikkema R. Support for biogas in the EU electricity sector – A comparative analysis. Biomass Bioenergy 2019;128:105313. https://doi.org/10.1016/j.biombioe.2019.105313.

[25] IHS. Connect. European Gas Supply and Demand Tracker 2022.

[26] Eurostat. Eurostat database 2022.

[27] IRENA. RENEWABLE POWER GENERATION COSTS IN 2019. 2019.

[28] Badouard T, Moreira de Oliveira D, Yearwood J, Torres P. Final Report Cost of Energy (LCOE) Energy costs , taxes and the impact of government interventions on investments 2020.

[29] OECD. OECD Inventory of Support Measures for Fossil Fuels 2019.

[30] al Seadi T, Lorenzen J. IEA Bioenergy Energy from Biogas: Denmark Country Report 2019 2019.

[31] Banja M, Sikkema R, Jégard M, Motola V, Dallemand JF. Biomass for energy in the EU – The support framework. Energy Policy 2019;131:215–28. https://doi.org/10.1016/j.enpol.2019.04.038.

[32] IEA Bioenergy. Implementation of bioenergy in Germany – 2021 update 2021.

[33] IEA. IEA/IRENA policies database 2017. https://www.iea.org/policies?sector=Buildings.

[34] Snam/IGU/Rystad Energy. Global Gas Report 2022 2022:76.

[35] IEA Bioenergy ExCO. IEA Bioenergy Countries' Report-Update 2021: Implementation of Bioenergy in the IEA Bioenergy Member Countries 2021.

[36] Geerolf L. The Biogas Sector Development: Current and Future Trends in Western and Northern Europe The Biogas Sector Development: Current and Future Trends in Western and Northern Europe 2018:71.

[37] Støckler M, Harder B, Berman D, Jensen TYHW. Biogas Production - insights and experiences from the Danish Biogas Sector 2020:56.

[38] Barbera E, Menegon S, Banzato D, D'Alpaos C, Bertucco A. From biogas to biomethane: A process simulation-based techno-economic comparison of different upgrading technologies in the Italian context. Renew Energy 2019;135:663–73. https://doi.org/10.1016/j.renene.2018.12.052.

[39] IEA Bioenergy. Implementation of bioenergy in Italy – 2021 update 2021:1–22.

[40] FAOSTAT. Database 2022. https://www.fao.org/faostat/en.

[41] Ritchie H, Roser M. Share of electricity production by source. Energy Published in Our World in Data Online at: OurworldindataOrg/Energy 2021.

[42] Ritchie H, Roser M. Natural gas consumption per capita, 1965 to 2021. Energy Published in Our World in Data Online at: OurworldindataOrg/Energy 2021.

[43] Ritchie H, Roser M. CO2 annual emissions. Energy Published in Our World in Data Online at: OurworldindataOrg/Energy 2021.

[44] Sesini M, Giarola S, Hawkes AD. Solidarity measures: Assessment of strategic gas storage on EU regional risk groups natural gas supply resilience. Appl Energy 2022;308:118356. https://doi.org/10.1016/j.apenergy.2021.118356.

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