An overview of feed-in tariffs, premiums and tenders to promote electricity from biogas in the EU-28

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Abstract

The EU has assumed objectives for energy sustainability and the fight against climate change. In this regard, the generation of biogas allows contributions to the 2020 established targets. The EU is leader in the production of biogas, representing 60% of total global production in 2011. The estimates of the contribution of biogas to electricity generation for 2020 in the EU-28 represent 1.5% within the total energy mix.

This paper analyzes the measures implemented in the EU-28 to promote biogas, relating them to the country targets established in their National Renewable Energy Action Plans. Currently, 19 countries apply some measure of price and/or amount: 14 use Feed-in Tariffs, 6 Premium Tariffs and 1 uses tenders.

A trend has been observed to reduce public financial support to promote biogas, linked to the reduction of the cost of this technology, and to the attempt to increasingly link it to the markets. However, excessive linking to the market hinders its development, putting the attainment of 2020 targets at risk. Consequently, the Feed-in Tariff or Premium Tariff systems, used in each country, must be designed in agreement with the peculiarities of the development of their markets, to be able to guarantee suitable development.

Keywords

Biogas promotion, Renewable energies, Feed-in tariffs, Premium tariffs, Tenders, National Renewable Energy Action Plans.

1. Introduction

The European Renewable Energy Directive 2009/28/EC [1] has created a common framework for the promotion of energy from renewable sources. With this framework, the European Union (EU) assumes energy objectives for energy sustainability and the fight against climate change. Its basic objectives for 2020 are a reduction of 20% in greenhouse gas emissions, a 20% energy share coming from renewable sources and the increase of energy efficiency by 20% [2]. These global objectives for 2020 relate to the Member States that have implemented specific action plans, named as National Renewable Energy Action Plans-(NREAPs), for achieving the targets in line with this directive. Additionally, the Member States have agreed to a new 2030 framework for climate and energy for the period between 2020 and 2030. The

new targets for 2030 are a 40% cut in greenhouse gas emissions, a 27% share of renewable energy consumption and the increase of energy savings by 27% [3].

The generation of biogas for electricity production allows contributions to the first two energy objectives established by Directive 2009/28/EC. However, the production of biogas also allows additional benefits to be obtained, as this can be produced from the decomposition of organic waste deposited in rubbish dumps, purines and waste from agricultural, industrial and extractive activity, urban waste and other biodegradables. Therefore, it is logical to propose the use of these wastes by means of their conversion into different forms of energy (electricity, heating and cooling and transport), whilst reducing the environmental impact and the emission of methane, a greenhouse gas more detrimental than CO_2, emanating from such wastes.

The EU is leader in the production of biogas, representing 60% of total global production in 2011 [4], with a production in 2013 of almost 13.4 Mtoe. Electricity production is the main biogas energy recovery form. In 2013, output stood at about 4,499 ktoe of final energy [5] (the proxy data for 2014 being equal to 4,627 ktoe [6]), with Germany being one of the countries with greater progress in terms of gross production of electricity from biogas [7]. Heat production output stood at about 2,525 ktoe in 2013 (the proxy value for 2014 being equal to 2,595 ktoe [6]), whereas the use of biogas as biofuel in vehicles is very limited, except in Sweden, Germany and Finland [8]. Therefore, the fundamental use of biogas can be associated with electrical generation. The estimates of the contribution of biogas to electricity generation for 2020 in the EU-28, defined by each country in their NREAPs, are equal to 63.9TWh, which represents 1.5% within the total energy mix [9].

For the attainment of these objectives and the promotion, in general, of the use of Renewable Energies Sources for Electricity production (RES-E), the countries have been establishing diverse promotional measures that are contemplated in their respective NREAPs. Previous studies have focused on the analysis of the measures used to promote the RES-E in the EU and their effectiveness, such as Cansino et al. [10], Haas et al. [11], Shrimali and Kniefel [12], Batlle et al. [13], Marques and Fuinhas [14], Schmalensee [15], and Del Río and Mir-Artigues [16], among others. Likewise, some other previous studies have focused on the effectiveness of a specific measure, such as Feed-in-Tariffs (FITs). Among the latter can be highlighted the studies by Haas et al. [17], Del Río [18], and Jenner et al. [19]. Additionally, some studies have focused on the measures implemented to promote RES-E derived from a specific technology, such as photovoltaic [20-22], wind [23] or biomass [24].

Following the previous studies, the aim of this paper is to analyze the price and quantity measures implemented in the EU-28 to promote biogas (Feed-in Tariffs [FITs], Premium Tariffs [FIPs], and tenders), relating them to the country targets established in their respective NREAPs. This analysis is interesting because, although biogas is not the main contributor to biomass electricity, very good progress is expected. Recent developments increased the share of biogas above the expected 2015 levels, being 35% above the level forecast for 2012 **[25]**.

Additionally, focusing on regulatory measures is interesting because they are implemented in the long term, 15-20 years, and usually through a Power Purchase Agreement (PPA), allowing profitability guarantees to be offered to the investment projects. Thus, according to Resch et al. **[26]**, the possible combination of the three regulatory measures mentioned previously, increases the confidence of investors to undertake RES-E projects. Other support mechanisms, such as subsidies or low-interest loans, among others, can be classified as complementary or exceptional support since, at the time of undertaking the project, no future guarantees are given about its profitability **[27]**.

In order to carry out this analysis, the main sources that have been taken into account, but which are far from exhaustive, are the information included in the RES-Legal database **[28]**, the Global Renewable Energy Policies and Measures from the IEA database **[29]**, the NREAPs **[30]**, EurObserv'ER **[5, 31-33]** and CEER report **[34]**.

This work is structured as follows. Section 2 analyzes the present situation of biogas electricity generation in the EU-28 and their targets for 2015 and 2020. Section 3 covers the regulation policy measures implemented in the EU-28 countries related to this energy. Section 4 discusses the effects of these policies. Finally, the conclusions are presented.

2. Present situation and objectives

Figure 1 shows the electricity from renewable sources targets in the EU-28 countries in 2010, 2015 and 2020. The differences between countries should be highlighted, with electricity from renewable sources being especially relevant in Germany, Spain, France, U.K., Sweden, Italy and Austria.

[Fig. 1]

The generation of electricity through renewable energy has been established using various sources, one of which is biogas. Figure 2 shows the contribution of each renewable energy source to electricity production in the EU-28 in 2012. In that year, the percentage of electrical energy obtained by biogas was 6%, in agreement with the data collected from the NREAPs. In addition to its relative importance, it is also possible to emphasize its growth, because the contribution of biogas to electricity generation through renewable energies has risen to 45% in only two years. It is notable that at the end of 2013, the electrical energy coming from biogas plants in Europe rose to 52,300 GWh and the number of power stations reached 1,611 plants [5].

[Fig. 2]

In the EU-28, there are three main biogas production sources. Firstly, biogas can be obtained by a passive mechanization process, directly recovered from landfills. Secondly, biogas may also be generated from urban wastewater and industrial effluent treatment plants (sewage sludge gas). Finally, it can be produced by other plants: Purpose-designed energy conversion mechanization plants and the multi-product mechanization plants. The first, as stated in EurObserv'ER [35], comprise mechanization units on farms that convert slurry, crop residues and energy crops. Additionally, they include food-processing industry mechanization plants and solid waste mechanization plants. The second include those that can convert different types of organic waste.

Figure 3 shows the primary energy production of biogas from these three main sources in the EU-28, in 2010 and 2013. As shown in this Figure, the main biogas production comes from the third above-mentioned source, with a share of 69% of total biogas energy production in 2013. Landfill biogas represents 22% and the rest comes from sewage sludge plants. These percentages vary from 2010. The landfill biogas percentage has been reduced by four points, increasing the biogas generated by other plants. Nevertheless, this four-percentage point decrease is not due to a landfill energy production reduction, but to a lower growth than that achieved by the other two main sources. Thus, while the average growth rate of primary biogas production was equal to 23.01% during this period, landfill biogas was only 3.2%. The other main sources of biogas growth rate were sewage sludge gas and other biogas, at 17.7% and 31.73% respectively.

[Fig. 3]

Figure 4 shows the primary energy production of biogas by EU-28 countries and sources in 2013. Three countries are the main biogas producers in the EU-28: Germany (50%), U.K. (14%) and Italy (14%). Nevertheless, differences are observed in biogas sources. The U.K. is highlighted in landfill biogas production, representing 53% of total production. Italy and France are other relevant producers, with 14% and 10% participation. Sewage sludge biogas is mainly produced by Germany (31%) and the U.K. (23%). Finally, other biogas production is mostly concentrated in Germany (67%) and in Italy (15%).

[Fig. 4]

Table 1 shows the production and evolution of the electricity generated from biogas in the EU-28 countries. Column 2 shows production in 2010 and 2013. Column 3 shows the growth between previous years, in absolute and relative terms. The last row in Column 3 shows that electricity generated from biogas increased by 20,467.20 GWh in the EU-28, the growth rate being equal to 64%. Column 4 shows the ranking in production and growth terms. Five countries are highlighted for their high 2013 production: Germany, Italy, the U.K., the Czech Republic and France. Graph A in Figure 5 shows that Germany, Italy and the U.K. generated 56%, 14% and 11% of total biogas electricity, respectively. The countries with the smallest biogas electricity production, in 2013, were Bulgaria, Malta and Sweden, the latter, despite its high RES-E target. In terms of growth, Germany, Italy, the Czech Republic and France are the foremost countries in the EU ranking, with Poland now added to this list. It should be pointed out that some countries have negative growth rates: Austria, Bulgaria, Denmark, Ireland and the Netherlands.

[Table 1 and Fig. 5]

Table 2 shows the targets for electricity generated from biogas that the EU-28 countries have established for 2010, 2015 and 2020, in order to reach their 2020 RES-E target. It can be observed that there are great differences between country targets, which cannot always be justified by differences between country sizes. Additionally, it can also be observed that targets tend to grow through time, but with different positive trends. It is also worth noting that some countries have constant targets, such as Ireland and Sweden, and some have decreasing values, such as the U.K. Graph B in Figure 5 shows the countries with the highest targets for 2020. Germany's biogas electricity target represents 37% of the EU-28 target. Italy

and the U.K. follow in importance, with 10% and 9% values respectively. The targets of ten countries represent 90% of the total EU-28 target.

Table 2 also shows the level of compliance of countries' targets, as a percentage of the biogas electricity generation related to the target value. Three levels have been considered. First, the 2010 biogas electricity generation with respect to the 2010 target. Second, the 2013 biogas electricity generation with respect to the 2015 target, Finally, the 2013 biogas electricity generation with respect to the 2020 target. The year 2013 was chosen as it is the last year for which data are available. Numbers in bold have been used to show the countries that have surpassed their respective target. In 2010, only fifteen countries reached their targets, although the EU-28 did reach them overall. Among the countries which have not done so, only 5 were near the target value, Malta did not generate any biogas GWh and Romania was far removed from its target, with only a 5.6% level of compliance. In 2013, seven countries had already reached the 2015 targets: Austria, the Czech Republic, Finland, Germany, Italy, Latvia and Portugal. Likewise, Hungary, Poland and the U.K. were very close to their targets. However, several 2010 compliant countries are now far removed from their 2015 targets. This is the case with Denmark, Greece, Luxemburg and the Netherlands. Nevertheless, the EU-28 target has been compliant overall. Finally, it is worth remarking that five countries have also reached their 2020 targets: Austria, Germany, Italy, Portugal and the U.K. However, the U.K. has reached it because the target was reduced for 2015 and 2020, and Portugal has very low targets. Globally, in 2013, the level of compliance with the 2020 target was equal to 82.81%, so it is predicted that the 2020 target will be fulfilled.

[Table 2]

3. Regulatory measures for the promotion of biogas

There are several instruments of energy policy to impel the use of RES-E. For the specific case of biogas, three types of regulatory measures are highlighted which affect prices and quantity. The FITs and FIPs stand out among the price regulation measures, whereas tenders are an example of quantity regulation measures. Other support mechanisms can occasionally be applied, such as subsidies or low-interest loans, although they can be considered more as complementary or exceptional support.

3.1. Feed-in tariffs (FITs)

Feed-in tariffs (FITs) are the minimum prices guaranteed by the national governments for each kW generated, injected into the network or used for self-consumption. The primary policy objective of the FITs is to offer guaranteed fixed prices for a certain period of time for RES-E. The FITs include both the price of the electricity and the additional support, given as a unique joint payment.

The factors that can be taken into account by governments for the determination of the FIT prices are very diverse. Factors such as the renewable energy source and its cost, the installed capacity of the plant, the energy generated, the location, the period of emission of electrical energy to the network, etc. **[36-37]**, give rise to divergences between the different countries that apply the FITs. The guaranteed price is established for a broad period of time, approximately 15 to 20 years, so that the producers affected by this measure have a clear orientation on the repayment that they are going to receive throughout the life of the project.

Thus, the stability present in the FIT, due to the fore-knowledge of the fixed price throughout the evolution of the project, gives an immunity to possible price volatility, and is one of the greater attractions of this system of promotion. Nevertheless, the difficulty for governments in establishing a sustainable and profitable level of FIT for the promotion of the different types of RES-E over a long period, can become one of its main handicaps.

Table 3 shows the fourteen EU-28 countries that apply FIT policies. In addition, some of the basic characteristics of their system are included.

[Table 3]

In the case of Croatia, to receive this support until the end of 2015, it was necessary to acquire the condition of "qualified producer" and to sign the contract of provision with the Croatian Energy Market Operator (HROTE). A new Renewable Energies Act has provisions to convert this FIT system into a Premium Tariff (FIP) support scheme. However, this new scheme is not as yet adopted **[28]**. Likewise, France also foresees reshaping its support schemes. The new system will combine FITs and an additional remuneration. Nevertheless, the enforcement decree is not yet published, therefore, the current regulations apply. In addition, until 2014, the Czech Republic had implemented both FITs and FIPs, nevertheless, at the beginning of that year the support linked to renewable energy was suspended due to the high costs **[38]**.

The second column of Table 3 shows whether the country has progressive fixed price reduction systems, whereby the fixed prices diminish throughout the considered period. The main reason for this mechanism is to provide an incentive for the reduction of electricity generation costs and greater speed in the development of renewable energies during the first years [39]. Although most of the countries resort to this initiative, countries such as Croatia, Ireland and Bulgaria do not apply this regressive mechanism, generally adapting their tariffs to the evolution of prices. In addition, the case of Portugal should be highlighted, as it fixes FITs at two levels for micro-production and mini-production units, presenting a higher tariff for the first eight years of activity and a lower tariff for the following years.

However, it is not possible to define a general pattern of adjustment of the tariff to the rate of inflation, due to the latent divergences both in the methodology used, and in the jurisdictions of each country. Therefore, some countries adapt their FITs through a pre-established formula that readjusts the whole of the tariff, whereas others make a partial adjustment with a percentage on this tariff. In addition, this process can be undertaken throughout a different timescale (monthly, quarterly, annually, etc.). Thus, for example, Ireland adjusts its FIT to 100%, which protects the real value of the income of the project, whereas Germany makes the calculation of the tariff, assuming an average inflation of 2% [28]. Thus, a quarterly 0.5% reduction is applied. Nevertheless, for landfill gas and sewage gas the annual reduction rate is 1.5%. For other forms of biomass, Greece adjusts it to 50% of the prices index [33], and France applies an adjustment that oscillates between 40-100% of the base price of electricity, based on the type of technology [37]. In Slovenia, FITs are also adjusted to the evolution of the prices, but the tariff is guaranteed for at least three years. Likewise, FITs will not be reduced if they are used as measures to achieve the required emission limits. Finally, in the U.K., a "contingent degression" system is applied. The degression rates are adjusted depending on the deployment level. If the deployment level reaches the biogas cap, the tariff will be reduced by 10%. Currently, the cap is equal to 5 MW [28].

The third column of Table 3 shows the period that the FITs are applied for each country, and it can be seen that all the countries guarantee their FITs for between 10 and 20 years, although a duration of at least 15 years is recommended to offer a low risk to investors [26].

Finally, the fourth column of Table 3 shows the main price determining factors in each country, based on their established FIT system, while the fifth column shows the current FIT amounts. Additionally, Figure 6 shows the price ranges that the biogas plant operators can

obtain if they opt for the FIT system, and demonstrates the diversity and variability of these guaranteed tariffs based on the country.

[Fig. 6]

This Figure shows that Germany displays the highest guaranteed prices, although it is also the country with the widest range, and also one of the countries that presents the lowest minimum payment, behind Hungary, Bulgaria and Austria, which present the lowest guaranteed minimum prices.

The guaranteed prices will vary depending on different factors, with the two main factors generally being the installed capacity or the size of the plant, and the technology of the plant or origin of the biogas. With respect to the first, higher prices are offered to the small biogas plants, with the exception of Luxembourg, which increases its FIT amount for greater capacities. With respect to the second, Hahns and Jentsch **[39]** indicate, for example, that electricity generated from agricultural biogas has been having higher prices than the gas originating from waste waters or rubbish dumps, for the case of Germany, Bulgaria, Austria and Greece. Currently, as shown in the last column in Table 3, generally the highest FITs are applied for electricity generated by biomass plants and anaerobic digestion plants, while the lowest tariffs are applied for biogas electricity generated from landfill plants.

In the case of France, the established tariff is also related to energy efficiency. In this way the operators of the plants can receive a bonus on the FIT prices which will depend on the amount of exported electricity, and the degree of support for the attainment of the set energy objectives. Thus, there is an incentive of 0.04€/kWh for those which reach an energy efficiency of at least 70% **[28]**. In addition, there is a second bonus for biogas obtained from the treatment of waste water, the amount of which can reach up to 0.026€/kWh for facilities up to 1 MW capacity, whenever the mechanization plant obtains a proportion of the same, greater or equal to 60% **[33]**. Likewise, farmers may obtain a revaluated tariff with the aim of improving their profitability if the producer is the holder of a purchase contract and has filed an identification application.

In the case of Ireland, it is also possible to emphasize the positive valuation when designating the amount of its FITs when dealing with Combined Heat and Power (CHP) plants. Unlike conventional electricity plants, CHP plants capture the heat that in other cases is expelled in the process of obtaining electricity, considering it as lost energy. The conventional electrical

plants will also have access to the FIT system although with lower tariff ranges. Likewise, the FITs depend on the plant capacity. Thus, plants with a capacity below 500 kW have higher tariffs. Nevertheless, currently, the Irish government is working on a new scheme that will be available from 2017. The new scheme will be subject to the new procedures on public energy support approved by the European Commission in 2014 **[40]**, which pursue a move to market-based support **[41]**.

The quantity of the bonus in Greece and Slovenia varies based on the receipt of some extra income, that is to say, whether the biogas plant has received some governmental support such as subsidies, or has adhered to some funding program financed by the EU, etc. In Greece, the support must exceed 20% of the total cost of investment to be considered relevant. Likewise, currently, in Slovenia, only operators with capacities below 500 kW can receive FITs **[42]**.

In the case of Hungary, the FITs are established based on the electricity consumption, establishing three tariff sections: the peak period, valley period and deep-valley period. The hours associated with each section can change on holidays, depend on the season of the year, etc. These tariffs also depend on the capacity of the plant: below 20 MW, between 20 and 50 MW and above 50 MW.

Finally, Lithuania and Portugal present a variant in the determination of the FITs, as they base it on the results obtained in rounds of tenders. Thus, in Lithuania the FIT prices are fixed quarterly, taking the price of electricity in the three months prior to the call for tenders as reference. This mechanism fixes guaranteed tariffs and maximum FITs for the subsequent tender procedures. Access to the tender rounds is limited to plants with an installed capacity of greater than 10 kW. A support known as surplus electricity is awarded to plants with less capacity, which consists of determining a minimum price, after which the government pays up to 50% of the electricity generated from renewable energy sources for one year. In the case of Portugal, the plants classified as small production units also use this mechanism to determine their tariff. The micro-production and mini-production plants will have their corresponding FIT reference tariff. The tariff is calculated through a bidding system in which producers offer discounts of a benchmark tariff set by the government. The final tariff will be the highest amount resulting from the highest discount offered **[28]**.

3.2. Premium tariffs (FIPs)

The Premium tariffs or feed-in Premiums (FIPs) is a system of support for RES-E that establishes a premium on the existing market electricity price. Thus, it generates two sources of income for the producers: one with the sale of energy in the electrical market and the other with the receipt of the premium **[18-19]**. In a similar way to the FITs, the premium differs based on the criteria applied in each country (energy source or technology used, size of the plant, electricity generation costs, etc.).

The FIPs can be classified as fixed or sliding premiums. In fixed premiums, applied in the case of biogas by Denmark, Italy and Slovenia, a constant amount is added to the existing market price. However, in the case of elevated prices in the market, this model can grant an excess of income with the supplement of the premium. In the same way, the possible fall of the prices does not assure minimum income to the producers, which could drive away potential investors. For that reason, some countries resort to the system of sliding premiums with the intention of controlling how price fluctuations fix the limits of the premium. In the case of biogas, this modality is applied by Germany, Finland and the Netherlands, which apply a variant called the "spot market gap model" consisting of guaranteeing a minimum level of payment, granting a premium equal to the difference between a fixed minimum payment and the price of the electricity. In the case that the market electricity price is higher than the guaranteed minimum, the premium is zero, with the producer receiving only the market price **[38, 43]**.

Table 4 shows the countries of the EU-28 that apply FIP policies, including some of the basic characteristics of their systems of application.

[Table 4]

The divergence of criteria between countries in the manner of estimating quantity, duration, restrictions, extra incentives, legal requirements, etc., makes it impossible to determine a common pattern between the countries in the determination of the FIPs, giving rise to greater diversity and variability in the quantities for each country. The range of the quantities of FIPs for the operators of the biogas plants is shown in Figure 7.

[Fig. 7]

As Figure 7 shows, Germany again presents the highest quantities and is also the country with the widest range, together with Italy. As with the FITs, the installed capacity or size of plant, and the technology or origin of the biogas, are the two main factors for the determination of these quantities. For example in Germany, biogas electricity from biomass has the highest applied FIPs while in Italy, the highest FIPs are applied for biogas from products of biological origin. Nevertheless, in the case of the FIPs, a greater number of specificities and differentiating characteristics are presented for each country. Current FIP values are shown in the last column in Table 4.

Germany and Slovenia enable access to one of the two price measures, FITs or FIPs, based on the capacity of the plants. In the German case, the biogas plants with capacity greater than 750 kW will only be able to opt for FIPs. In Slovenia, a new market premium scheme has recently been introduced for operators above 500 kW. Accordingly, operators of these installations will receive their support in the form of a premium paid on top of the market price, while operators below 500 kW may continue to receive a FIT **[42]**.

In the case of Italy, its FIP system offers the possibility for plants with power lower than 1 MW to qualify for a special tariff, called the all-encompassing tariff, which allows a higher guaranteed minimum, although the maximum, and the duration of the concession, are the same as for the modality of traditional FIPs **[44]**. The FIP value is obtained as the sum of a tariff for a given plant category, plus other support elements (incentives for greenhouse gas reductions in the case of supply-chain-biomass-fueled plants, for compliance with the atmospheric emission requirements, for high-efficiency cogeneration and other additional bonuses), minus the hourly energy market price for a given price zone. Nevertheless, the premium is equal to the sum of the tariff and other support elements, if market prices are negative **[34, 45]**.

Denmark's FIP system is based on variable bonuses, which are added to the income from the sale of electricity in the market. Two bonus classes exist: the maximum bonus, which, linked to the market price, cannot exceed a certain amount fixed by law, and the guaranteed bonus, the total amount of which has no pre-fixed limit **[46]**. For electricity generated by biogas plants, produced by using exclusively biomass, the maximum bonus in 2016 is 11€ct. per kWh. Additionally, guaranteed premiums of 3€ct. and 1€ct. per kWh are also paid. The first is reduced or increased each year if the price of natural gas exceeds or falls below a basic level. The second is reduced annually until 2020, when it will disappear. For electricity generated

by biogas plants produced by using biomass and other fuels, an FIP equal to 6€ct. per kWh is paid for the portion of the electricity generated by biogas. Additionally, guaranteed premiums of 3€ct. and 1€ct. per kWh are also paid for the part of the electricity generated by using biogas [32].

Something similar is found in the German and Finnish systems. In Finland, the FIP tariff is equal to the difference between the fixed target price and the reference market price. The latter is calculated as an average of the hourly prices over the previous three months [34]. Nevertheless, if the reference market price is below 30€, the FIP will be equal to the difference between the fixed target price and 30€. Additionally, Finland has heat bonuses dedicated to biogas plants that produce electricity and heat, and have an energy efficiency of at least 50%, or even 75% if the capacity of the generators is greater than 1 MW. In a similar manner, the FIP tariff in Germany is equal to the difference between the fixed reference value and the average specific market price, which is calculated every month. Germany grants an extra premium, termed the management premium, destined to cover the additional expenses of the plant (personnel, costs of management, infrastructure, etc.), differentiating its amount depending on the renewable energy source. It also offers a second additional premium for biogas producers if they increase their installed capacity to produce more electricity, with the intention of improving their adaptation to market demands.

Therefore, the capacity of the plant and origin of the biogas (biodegradable waste, gases from rubbish dumps, slurry fermentation, etc.) are determinants in fixing the premium amounts in the German, Dutch and Slovenian systems. In the case of the latter, greater flexibility has also been offered for CHP plants opting for the FIP system, extending the range of capacity allowed from 1 MW to 20 MW. Recently, operators of systems above 500 kW offer the produced energy on the market and receive a premium on top of the market price. Slovenia has introduced a two-round tender process to ensure support goes to the best value projects [47].

The Netherlands follow a sliding Premium system determined by tender, popularly called “SDE+”, to establish their FIPs. Thus, based on the origin of the biogas, the government usually establishes five or six annual rounds of tenders, so that the amount of the premium depends on the round in question, normally increasing with the stage of the round, which is why many operators wait until the latter rounds to obtain the highest premium. Nevertheless, there is the risk that, as the year advances, the SDE+ system will close due to budgetary

constraints, with no support being granted to the remaining bidders [43]. Thus, there is an incentive for low-cost bids to be introduced in the first calls, thereby explaining their "first come, first served" designation [48].

Finally, Column 3 of Table 4 shows the duration of the FIP systems for each country. Italy and Germany, two of the large producers of biogas in the EU, are those that offer a longer duration, 20 years. In the case of Denmark, it has various terms and conditions, which depend on the technology used and the commissioning date of the plant.

3.3. Tenders

With respect to the price measures, tenders are an integral part of the RES-E support mechanisms that are linked to the amount. In this system, the governments and regulating authorities request bids for the supply of electrical energy, by means of a specific technology, with the purpose of receiving an energy service at a competitive price and of developing that particular technology, in this case, the RES-E. The process is carried out by means of bidding between the participants, once a fixed amount of capacity from renewable energy sources in the electricity network of the country has been established. The bids are fixed for a certain capacity, technology and location. The government is limited by qualitative and quantitative criteria when selecting the winning bid. However, in practice, it is usually the less expensive bid that is chosen, normally selecting one beneficiary per location [49].

An advantage of this system is its effectiveness in promoting price competition between the different operators and technologies, which reveals the true cost of electricity generation from renewable resources. In addition, most tenders are linked to supply contracts (Power Purchase Agreement [PPA]) executed over a period of 15 to 20 years, according to the prices established in the bid, giving security to the investment [49]. On the contrary, the main disadvantages are the sporadic and intermittent manner in which the tender rounds are made, and the possible collusive behavior of the participants, by jointly raising the price of the energy and not revealing its true cost [50].

In the scope of the EU-28, Italy is the only country that establishes tenders for the case of biogas. The system of incentives is based on the monthly concession of a bonus for the plant operator. This incentive is calculated by adding the premiums or bonuses, that have been granted to the plant, to the tariff bases determined for the energy sources (which includes a

predicted progressive reduction of 2% per annum), so that the price per hour in the electricity market is reduced. The range of variation of this incentive oscillates between 0.085€ and 0.122€ per kWh [28].

Although only Italy uses tenders as a measure for biogas promotion, there are countries that support this system for the determination of their FIT or FIP amounts [51]. Such is the case, as already commented, of Lithuania and Portugal for FITs, and of the Netherlands and Slovenia for FIPs. Thus, the introduction of tenders as a support mechanism represents a more competitive and economically attractive method of fixing the remuneration levels [38].

4. Discussion

Table 5 provides a general view of the price and quantity measures implemented in the EU-28 to promote the use of biogas in electricity generation. Additionally, Table 5 shows the degree of fulfillment of the targets set for 2020, as mentioned in Table 2, and the growth of electricity production from biogas between 2010 and 2013, shown in Table 1.

Firstly, it can be pointed out that nine countries of the EU-28 do not apply any of these support systems to promote biogas. Table 5 shows that these countries generally have levels of fulfillment of the 2020 target and very low absolute growth. Two exceptions can be mentioned: the Czech Republic, which used FIT and FIP systems until 2014, when the system was eliminated because of the high costs they were generating, and Poland, whose absolute growth in the period places it in fourth position, in agreement with Table 1. Support schemes regarding RES-E from biogas in Poland have been based on the so-called certificates of origin.

Those countries with greater growth in the use of biogas for electricity generation have established support mechanisms based on price or quantities. Germany, Italy and the U.K. have systems with very long term guarantees of 20 years duration, which make investments more attractive. Therefore, it can be considered that the application of the support mechanisms is in direct correlation with the development of the biogas industry, which is also reinforced by the fact that all the countries that have already fulfilled the 2020 target, have established some, or several, support systems. Thus, in agreement with the working document of the European Commission [52], it is possible to say that, although there are reports [49] which indicate that some technologies related to biogas can be considered mature and

competitive in the market, in most cases, electricity generation from biogas requires public financial support. Therefore, the absence of support mechanisms is translated into poor growth of electricity generation from biogas.

Table 5 also shows that there are different combinations when choosing the type of system applied by the countries. It is possible to say that a trend is observed towards using systems different from the more traditional FIT system. Thus, it is observed how several countries have adopted FIPs and even tenders. It is also observed that, in agreement with Couture et al., [53], these policies are beginning to be used in combination, in order to meet different goals. On the other hand, it can also be observed how the countries have begun to apply varied designs of FITs to reach diverse objectives, such as favoring smaller project sizes that can help drive significant investment, as in France, or higher end-use efficiency as in France, Greece and Luxemburg. Likewise, it should be noted that policies are being implemented taking into account market evolution. As stated in Couture et al. [53], countries' policies are mostly designed to maintain a high degree of revenue security while simultaneously requiring producers to interact with wholesale spot markets, for example, by using some types of FIP or relating FITs to tenders. It can be noted that the different designs of these measures in each country can help the implemented policy to have greater success, because they allow better adaptation to the circumstances of each particular market.

Some considerations can also be noted with respect to the countries with greater fulfillment of their targets. Austrian biogas plant operators are facing local caps and have a growth practically equal to zero. Germany, a country that has also already fulfilled its 2020 target, continues to maintain its FIT system, although recently it has been revised by the new Renewable Energy Sources Act 2014, which provides for a revised system of fixed feed-in tariffs and marketing premiums. One of the objectives of this Act is to reduce financial costs by slowing the growth of the most expensive electricity generating sectors, such as biogas. In this regard, a set of measures have been articulated which are directed to a better integration of biogas into the electricity market. On the other hand, Italy, a country that has also fulfilled its 2020 targets, has reduced its incentives, due mainly, as Maggioni [45] affirms, to the fact "that renewable sources have already achieved a sensible development in the last years", and, to the criteria of production costs. Contrary to this trend, FIT for electricity produced by cogeneration installations running on biogas will be raised for both new and existing installations. The increase will be between 10 and 20%, considering contracts of 20 years to be necessary to give a better return on investment [54]. From the previous considerations, it

can be seen that there is a trend in recent years to reduce public support linked to cost reduction. Nevertheless, this trend can increase the risk for the investors and thereby reduce the growth of the sector. As stated in Couture et al. [53], policymakers need to weigh the benefits of including biogas producers in markets against the potential negative impacts on sector development.

Finally, it can be highlighted that the countries, when designing their FIT systems, are considering the resources used for biogas generation. For example, the premium for using energy crops and manure has been withdrawn in Germany with the aim of encouraging the use of organic and farming waste. This last limitation, which is in line with the objectives of the EU-28, may have a negative impact on the biogas sector's growth. Thus, Thrän et al. [55] report that about 80 % of biomass resources in biogas plants resulted solely from energy crops in Germany in 2013. Likewise, Italy has also begun to give preference to the use of by-products and farming waste over energy crops. In parallel, the U.K. has plans to establish regulatory control on the use of crops, whilst it is in discussion on cuts to the applied systems [56]. The present political discussions limiting the raw material base can also hinder the growth of this energy. The working document of the European Commission [52] referring to biomass, considered that bioenergy installations should achieve GHG savings of at least 70%, compared to the fossil fuel comparators. This target is hardly attainable when certain technologies are used, among them those technologies that use maize silage or open co-digestion of a mixture composed of 70% manure and 30% maize silage.

The establishment of new requirements of production, and the trend to increasingly orient it to market prices, can endanger the present development of the biogas sector. Nevertheless, the good development of the sector has a fundamental advantage over other types of renewable energies. As a flexible system, it may fill the valleys of wind and sun energies, according to Bourguignon [57].

[Table 5]

5. Conclusions and policy implications

Recently, RES-E from biogas has increased more than initially expected in the EU-28. In the period 2010-2013, electricity generated from biogas grew by 20467.20 GWh, representing a growth rate of 64%. This notable growth has meant that EU-28 targets for 2015 were fulfilled in 2013. Five countries are highlighted for their high 2013 production (Germany, Italy, the U.K., the Czech Republic and France), generating nearly 90% of the total. This important growth in the EU-28 has also seen the first RES-E from biogas production. It is also worth noting, that in 2016, the U.K. decided to exit from the EU. This fact will affect the EU global production in future, as the U.K. is one of the largest producers of biogas in Europe.

Currently, 19 countries of the EU-28 apply some price and/or amount measures to promote the use of biogas and of those countries, 14 use FITs, 6 FIPs and 1 uses tenders. The countries that do not use any of these measures generally have poor levels of biogas growth, and are far from fulfilling their 2020 targets. Additionally, the countries with greater growth of biogas for electricity use and greater levels of fulfillment of their targets (Austria, Germany, Italy, and the U.K.), use some of these systems. It is only possible to indicate the exceptional position of the Czech Republic, which has high growth and an elevated level of fulfillment of its targets and does not currently apply these measures, due to its need to eliminate them for reason of high costs.

In relation to the form in which FITs are applied, it is observed that the majority apply degressive systems (except Croatia, the U.K., Ireland and Bulgaria), although the methodologies applied in each country are different, and they are made with different regularities. The period of application of the FITs also varies between countries, although it is mainly positioned between 15-20 years, with two exceptions: Lithuania and Croatia. Finally, it is possible to say that the amount of the FITs depends on certain factors in each country, emphasizing the installed capacity and the technology of the plant or the origin of the biogas. In general, higher prices are offered for the energy coming from small biogas plants and generated from agricultural biogas. In France, the established tariff is also related to the energy efficiency, in Greece and Slovenia it varies based on the receipt of some extra income (for example, subsidies), and in Hungary they are established based on electricity consumption. In addition, Lithuania and Portugal determine the value of the FITs based on the results obtained during the rounds of tenders. Regarding the amount, Germany displays the

highest guaranteed prices, and is also one of those that offer the lowest guaranteed prices, behind Hungary, Bulgaria and Austria.

In the EU-28, two different FIP systems are applied. Denmark, Italy and Finland apply a fixed premium, whereas Germany, Slovenia and the Netherlands apply a sliding premium modality, called the "spot market gap model". There is no common pattern in the determination of the FIPs. The installed capacity and the technology or the origin of the biogas are also the two main factors for the determination of these amounts. Nevertheless, there is a greater number of differentiating characteristics for each country. Regarding the duration, it oscillates between 12 and 20 years. Italy and Germany are those that offer a longer duration. The higher amounts are offered in Germany, although they have a wider range variation, together with Italy.

Italy is the only country of the EU-28 that establishes tenders for biogas. This system is based on the concession of a bonus for the operator of the plant every month. However, other countries of the EU-28 use tenders to determine the amounts of their FIT (Lithuania and Portugal) and FIP (the Netherlands and Slovenia) tariffs.

In general, it is observed that there is a trend to reduce public financial support for the promotion of the RES-E from biogas, linked to the reduction of the cost of generation of electricity with this technology, and to the attempt to increasingly link it to the markets. However, excessive linking to the market hinders its development, at least in some countries, putting the attainment of 2020 targets at risk, as it cannot be considered that the market is sufficiently mature. Therefore, the FIT or FIP systems used in each country must be designed in agreement with their peculiarities and the level of development of their own markets, to be able to guarantee suitable development.

In addition, there is a trend seen in the design to limit support for the generation of biogas where certain materials are used for its generation, with the purpose of increasing GHG savings. This endangers the use of some technologies, such as those that use maize silage or open co-digestion of a mixture composed of 70% manure and 30% maize silage. Thus, it may be convenient to establish long periods of adaptation, in order that the technologies can evolve sufficiently to reach higher levels of GHG savings. The contrary could result in a good part of the currently used technologies being left without support, hindering the development of these renewable energies.

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Table 1
Electricity generated from biogas in the EU-28. Production and evolution.

	Production (GWh)		Growth (2010-2013)		Ranking	
	2010	2013	Rate	Absolute	2013	Growth 2010-13
AUSTRIA	649	615	- 0.05	- 34.00	9	26
BELGIUM	566	598	0.06	32.00	10	15
BULGARIA	1.6	0.5	- 0.69	- 1.10	28	23
CROATIA	30	63.2	1.11	33.20	20	14
CYPRUS	35	52	0.49	17.00	23	19
CZECH REPUBLIC	635	2294	2.61	1659.00	4	3
DENMARK	357	257	- 0.28	- 100.00	11	28
ESTONIA	10	21	1.10	11.00	25	20
FINLAND	89	140	0.57	51.00	19	12
FRANCE	1053	1521	0.44	468.00	5	5
GERMANY	17430	29000	0.66	11570.00	1	1
GREECE	190	216.4	0.14	26.40	15	17
HUNGARY	118	242.8	1.06	124.80	13	10
ITALY	2056	7448	2.62	5392.00	2	2
IRELAND	206	200	- 0.03	- 6.00	17	24
LATVIA	57	223	2.91	166.00	14	8
LITHUANIA	31	59	0.90	28.00	21	16
LUXEMBURG	55	55.3	0.01	0.30	22	22
MALTA	0	3	n.a.	3.00	27	21
NETHERLANDS	1028	966	- 0.06	- 62.00	6	27
PORTUGAL	100	248	1.48	148.00	12	9
ROMANIA	1	25.8	24.80	24.80	24	18
POLAND	398	882.5	1.22	484.50	8	4
SLOVAKIA	34	204	5.00	170.00	16	7
SLOVENIA	97	141	0.45	44.00	18	13
SPAIN	848	908	0.07	60.00	7	11
SWEDEN	36	12	- 0.67	- 24.00	26	25
UNITED KINGDOM	5735	5930.7	0.03	195.70	3	6
Total EU	31860	52327.2	0.64	20467.20		

Source: Own elaboration from EurObserv'ER [5], IEA [29] and NREAPs [30].

Table 2
Electricity generated from biogas in the EU-28. Targets and level of compliance.

	Target (GWh)			Level of Compliance (%)		
	2010	**2015**	**2020**	**2010** (with respect to 2010)	**2015** (with respect to 2013)	**2020** (with respect to 2013)
AUSTRIA	553	567	581	**117.36**	**108.47**	**105.85**
BELGIUM	393.3	776.8	1439.1	**143.91**	76.98	41.55
BULGARIA	2	269	357	80.00	0.19	0.14
CROATIA	32.8	99	260	91.46	63.84	24.31
CYPRUS	30	84	143	**116.67**	61.90	36.36
CZECH REPUBLIC	624	1754	2871	**101.76**	**130.79**	79.90
DENMARK	194	721	2493	**184.02**	35.64	10.31
ESTONIA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
FINLAND	40	50	270	**222.50**	**280.00**	51.85
FRANCE	935	2129	3701	**112.62**	71.44	41.10
GERMANY	13829	18946	23438	**126.04**	**153.07**	**123.73**
GREECE	181	431	895	**104.97**	50.21	24.18
HUNGARY	85	262	636	**138.82**	92.67	38.18
ITALY	2129	4074	6020	96.57	**182.82**	**123.72**
IRELAND	320	320	319	64.38	62.50	62.70
LATVIA	64	39	n.a.	89.06	**571.79**	n.a.
LITHUANIA	50	228	413	62.00	25.88	14.29
LUXEMBURG	44	123	144	**125.00**	44.96	38.40
MALTA	8	7	85	0.00	37.78	3.51
NETHERLANDS	872	2161	4664	**117.89**	44.70	20.71
PORTUGAL	19	28	28	**526.32**	**885.71**	**885.71**
ROMANIA	19	600	950	5.26	4.30	2.72
POLAND	328	943	4018	**121.34**	93.58	21.96
SLOVAKIA	70	624	860	48.57	32.69	23.72
SLOVENIA	148	351	367	65.54	40.17	38.42
SPAIN	799	1302	2617	**106.13**	69.74	34.70
SWEDEN	53	53	53	67.92	22.64	22.64
UNITED KINGDOM	6830	6300	5570	83.97	94.14	**106.48**
Total EU	28652.78	43242.74	63192.6	**111.19**	**121.01**	82.81

n.a.: not available.
Source: Own elaboration from EurObserv'ER [5], IEA [29] and NREAPs [30].

Table 3

Countries of the EU-28 that apply FIT policies for the promotion of biogas.

Countries	System of progressive reduction	Duration	Determining factors of the prices	Amount for biogas
AUSTRIA	Annual reduction determined by law	15 years	Different prices based on the capacity and technology of the plant and origin of the biogas (sewage gas, landfill gas)	**Biogas plants:** €ct 12.51 – 18.67 per kWh, depending on the capacity. A share of 30% must be deployed by pure agricultural substrates and animal manure **CHP-plants:** the FIT is granted with a premium of €ct 2 per kWh if certain criteria are fulfilled **Biomethane:** €ct 12.51 – 16.51 per kWh **Sewage plants:** €ct 5.76 per kWh **Landfill plants:** €ct 4.80 per kWh
BULGARIA	No, the quantity established in the agreement remains	15 years	Depending on the plant capacity and on the origin of the biogas (from plant and animal waste, household waste, household wastewater)	Power plants working with thermal gasification of biomass: **Capacity >**5 MW: €ct 17.39 per kWh and if comb. cycle used: €ct 19.17 per kWh. If this also comes from biomass or bio-decomposing fractions from industrial and household €ct 22.43 per kWh **Capacity ≤** 5 MW: €ct 17.91 per kWh. If comb. cycle used €ct 19.92 per kWh. If biomass also comes from agricultural waste and waste: €ct 19.84 per kWh. If this comes from industrial and household waste €ct 20.76 per kWh
CROATIA	No	14 years	For biogas from agricultural crops and organic residues, plant and animal origin, biodegradable waste, landfill gas and sewer gas, the tariff varies according to the plant's capacity	Plants with a: **Capacity** ≥ 300 and < 400 kW: €ct 19 per kWh **Capacity** ≥ 400 kW and < 1 MW: €ct 16.5 per kWh **Capacity** ≥ 1 MW and < 2 MW: €ct 16 per kWh **Capacity** ≥ 2 MW and < 5 MW: €ct 15 per kWh
FRANCE	The percentage of tariff subject to reduction is 50%	15 years	Depends on the capacity of the plants and the energy performance	Plants with a: **Capacity** ≤ 150 kW: €ct 9.745 per kWh **Capacity** ≥ 2 MW: €ct 8.121 per kWh Plants with an energy performance of at least 70% may have a bonus of €ct 4, also applied for plants using a share of 60% or higher of livestock manure
GERMANY	New plants will receive the FIT, applicable when they are put into operation and will be apply for the entire period. The annual reduction rate for landfill gas and sewage gas is 1.5% For other forms of biomass a quarterly 0.5% reduction is applied	20 years	According to plant size and fuel (biogas from biomass, landfill, sewage gas)	**Biomass plants:** €ct 5.83 – 27.73 per kWh minus €ct 0.2 per kWh **Landfill plants:** €ct 5.83 – 8.42 per kWh minus €ct 0.2 per kWh **Sewage plants:** €ct 5.83 – 6.69 per kWh minus €ct 0.2 per kWh
GREECE	Not available	20 years with possibility of extension.	Varies according to the energy source (landfill, biogas from biomass) and the generating capacity. It also varies based on the receipt of some additional aid.	**Landfill plants** ≤ 2 MW. €ct 11.4 or 13.1 per kWh with or without government support **Landfill plants >** 2 MW. €ct 9.4 or 10.8 per kWh with or without government support **Biomass plants** ≤ 3 MW. €ct 20.9 or 23 per kWh with or without government support **Biomass plants >** 3 MW. €ct 19 or 20.9 per kWh with or without government support

HUNGARY	No, adjusted annually to the rate of inflation, less 1%	Not greater than the term of amortization of the plant.	Depends on the capacity of the plant, with three different tariff rates depending on the time of day (peak, valley and deep-valley periods)	Plants with a: **Capacity** ≤ 20 MW: €ct 12, 10 or 4 per kWh in peak, valley or deep-valley period, respectively **Capacity** > 20 and ≤ 50 MW: €ct 9, 8 or 3 per kWh in peak, valley or deep-valley period, respectively. **Capacity** > 50 MW: €ct 7, 5 or 5 per kWh in peak, valley or deep-valley period, respectively
IRELAND	No, adjusted annually to the CPI	15 years	Reference prices vary for each technology (landfill gas, anaerobic digestion) depending on the size of the plant and whether it is a CHP plant	**Landfill plants:** €ct 8.56 per kWh **Anaerobic digestion plants:** CHP ≤, 500 kW: €ct 15.7 per kWh CHP > 500 kW: €ct 13.66 per kWh Non-CHP ≤ 500 kW: €ct 11.55 per kWh Non-CHP >500 kW: €ct 10.5 per kWh
LITHUANIA	Not available	10 years (plants greater than 10 kW)	Guaranteed and maximum FIT fixed from a special mechanism based on tenders. They vary based on the size of the plant and the technology (landfill gas, anaerobic digestion or other biodegradable organic waste or substrates)	**Landfill plants** ≤ 10 kW: €ct 11.1 per kWh **Anaerobic digestion plants,** biodegradable organic waste and substrates ≤ 10 kW: €ct 13.4 per kWh
LUXEMBOURG	Percentage established annually by law	15 years	Depends on the nominal electricity capacity of the plant	Plants with a: **Capacity** ≤ 150 kW: €ct 14.7 per kWh **Capacity** > 150 kW and ≤ 300 kW: €ct 13.7 per kWh **Capacity >** 300 kW and ≤ 500 kW: €ct 12.7 per kWh **Capacity** > 500 kW and ≤ 2500 kW: : €ct 11.7 per kWh
PORTUGAL	No, adjusted annually to the rate of inflation	15 years	Depends on the size of the plant and on the origin of the biogas (landfill, fermentation of solid municipal waste, sewage sludge from waste water treatment, waste water and waste from the agricultural and food industries). The plants classified as small production units participate in a price fixing mechanism by means of tenders.	**Landfill plants**: €ct 10.2-10.4 per kWh **Sewage and other plants:** €ct 11.5-11.7 per kWh
SLOVAKIA	Adjusted to the evolution of the prices, except if the plant is involved in other support programs: in such case, reductions of 4%, 8%, 12% and 16%	15 years	Depending on the capacity of the plant and the origin of the biogas (landfill gas or sewage gas, anaerobic digestion, thermochemical conversion)	**Landfill and sewage plants**: €ct 7.03 per kWh **Anaerobic digestion plants** ≤ 250 kW: €ct 12.05 per kWh > 250 kW and ≤ 500 kW: €ct 11 per kWh >500 kW and ≤ 750 kW: €ct 10.3 per kWh >750 kW: €ct 10.23 per kWh **Anaerobic digestion plants** (biomethane obtained from biogas) ≤ 1 MW: €ct 10.75 per kWh **Anaerobic digestion** (bio-degradable waste): €ct 9.55 per kWh **Thermochemical conversion plants**: €ct 9.92 per kWh

SLOVENIA	Only in the case of pertaining to other support programs	15 years	The tariff level mainly depends on the plant size and the origin of the biogas (biomass, biodegradable waste, digester, or landfill). It also varies based on the receipt of some additional support.	**Biomass plants:** €ct 16.175 – 16.555 per kWh minus €ct 0.2 per kWh **Landfill plants:** €ct 7.442 – 9.933 per kWh minus €ct 0.2 per kWh **Biodegradable waste plant:** €ct 13.923 per kWh minus €ct 0.2 per kWh **Digester plant:** €ct 6.61 – 8.59 per kWh minus €ct 0.2 per kWh
UNITED KINGDOM	Adjusted annually to the rate of inflation Additionally, a degression contingent is applied. The degression rates are adjusted depending on the levels of deployment under the FIT. The tariffs are reduced when the deployment exceeds the caps set by the government.	20 years	Payment rates depend on the installed capacity of the plant	Plants with a: **Capacity** ≤ 250 kW: €ct 8.83 per kWh **Capacity** > 250 kW and ≤ 500 kW: €ct 8.15 per kWh **Capacity** > 500 kW: €ct 8.4 per kWh

Source: Own elaboration from RES-Legal **[28]**, IEA **[29]** and EurObserv'ER **[32-33]**.

Table 4

Countries of the EU-28 that apply the FIP system for the promotion of biogas.

Countries	FIP system	Duration	Specificities	Amount for Biogas
DENMARK	Fixed premium	Several terms and deadlines	Maximum and guaranteed bonus	**Electricity generated by biogas plants produced by using biomass**. Maximum subsidy: €ct 11 per kWh. Additionally a guaranteed premium of €ct. 3 and €ct. 1 per kWh is received. The first is reduced or increased each year if the price of natural gas exceeds or falls below a basic level. The second is reduced annually until 2020, when it will disappear **Co-firing**: Maximum subsidy: €ct 6 per kWh. for the portion of the electricity generated by biogas. Additionally, guaranteed premiums of €ct. 3 and €ct. 1 per kWh is received
FINLAND	Sliding premium	12 years	FIP equal to the difference between the fixed target price and the reference market price. If the reference market price is below 30 €, the FIP is equal to the fixed target price minus € 30 Limits for receiving FIP: Capacity >19 MVA Production > the amount in the decision Price of electricity is negative	The target price is €ct 8.35 per kWh Heat bonus: €ct 5 per kWh on top of the target price
GERMANY	Sliding premium	20 years	FIP equal to the difference between the fixed reference value and average monthly specific market price. The reference value will be zero if market price is negative during 6 consecutive hours Management premium, with premiums based on the origin of biogas and depending on the capacity of the plant size	**Biogas from biomass: €**ct 5.85 – 27.73 per kWh minus €ct 0.2 per kWh **Landfill gas:** €ct 5.83 – 8.42 per kWh minus €ct 0.2 per kWh **Sewage gas: €**5.83 – 6.69 per kWh minus €ct 0.2 per kWh
ITALY	Fixed premium	20 years	FIP equal to tariff for given plant category plus other support elements, minus hourly power market price for given price zone	**Products of biological origin:** €ct 1.40-1.80 per kWh **Products of biological origin and non-sourced separated waste:** €ct 1.78-2.36 per kWh **Waste for which the biodegradable part is determined as a fixed amount:** €ct 2.16 per kWh These basic incentives may be increased with other support elements.
NETHERLANDS	Sliding premium	12 years	Premiums vary in each of the tender stages (increases as the stages advance), and also differ according to the technology or origin of biogas and the plant size	**Cofermentation of animal waste:** From €ct 7 per kWh (stage 1) to €ct. 11.3 per kWh (stages 5-6). **Fermentation of other substances**: From €ct 7 per kWh (stage 1) to €ct. 9.5 per kWh (stages 4-6). **Fermentation of animal waste >95%:** €ct. 4 per kWh- **Sewage gas**: €ct 3.3 per kWh
SLOVENIA	Fixed premium	12 years	Recently, operators above 500 kW systems will offer the produced power on the market and get a premium on top of the market price	There are currently no price lists

Source: Own elaboration from RES-Legal [28], EurObserv'ER [32-33] and CEER report [34].

Table 5
Mechanisms of support for biogas in the EU-28.

Countries	Feed-in tariffs	Premium tariffs	Tenders	Compliance of 2020 target (% respect to 2013)	Absolute Growth (2010-2013)
AUSTRIA	✓			**105.85**	- 34.00
BELGIUM				41.55	32.00
BULGARIA	✓			0.14	- 1.10
CROATIA	✓			24.31	33.20
CYPRUS				36.36	17.00
CZECH REPUBLIC				79.90	1659.00
DENMARK		✓		10.31	- 100.00
ESTONIA				n.a.	11.00
FINLAND		✓		51.85	51.00
FRANCE	✓			41.10	468.00
GERMANY	✓	✓		**123.73**	11570.00
GREECE	✓			24.18	26.40
HUNGARY	✓			38.18	124.80
IRELAND	✓			62.70	- 6.00
ITALY		✓	✓	**123.72**	5392.00
LATVIA				n.a.	166.00
LITHUANIA	✓			14.29	28.00
LUXEMBURG	✓			38.40	0.30
MALTA				3.51	3.00
NETHERLANDS		✓		20.71	- 62.00
POLAND				21.96	484.50
PORTUGAL	✓			**885.71**	148.00
ROMANIA				2.72	24.80
SLOVAKIA	✓			23.72	170.00
SLOVENIA	✓	✓		38.42	44.00
SPAIN				34.70	60.00
SWEDEN				22.64	- 24.00
UNITED KINGDOM	✓			**106.48**	195.70

Source: Own elaboration from RES-Legal [28], IEA [29] EurObserv'ER [32-33] and CEER report [34].

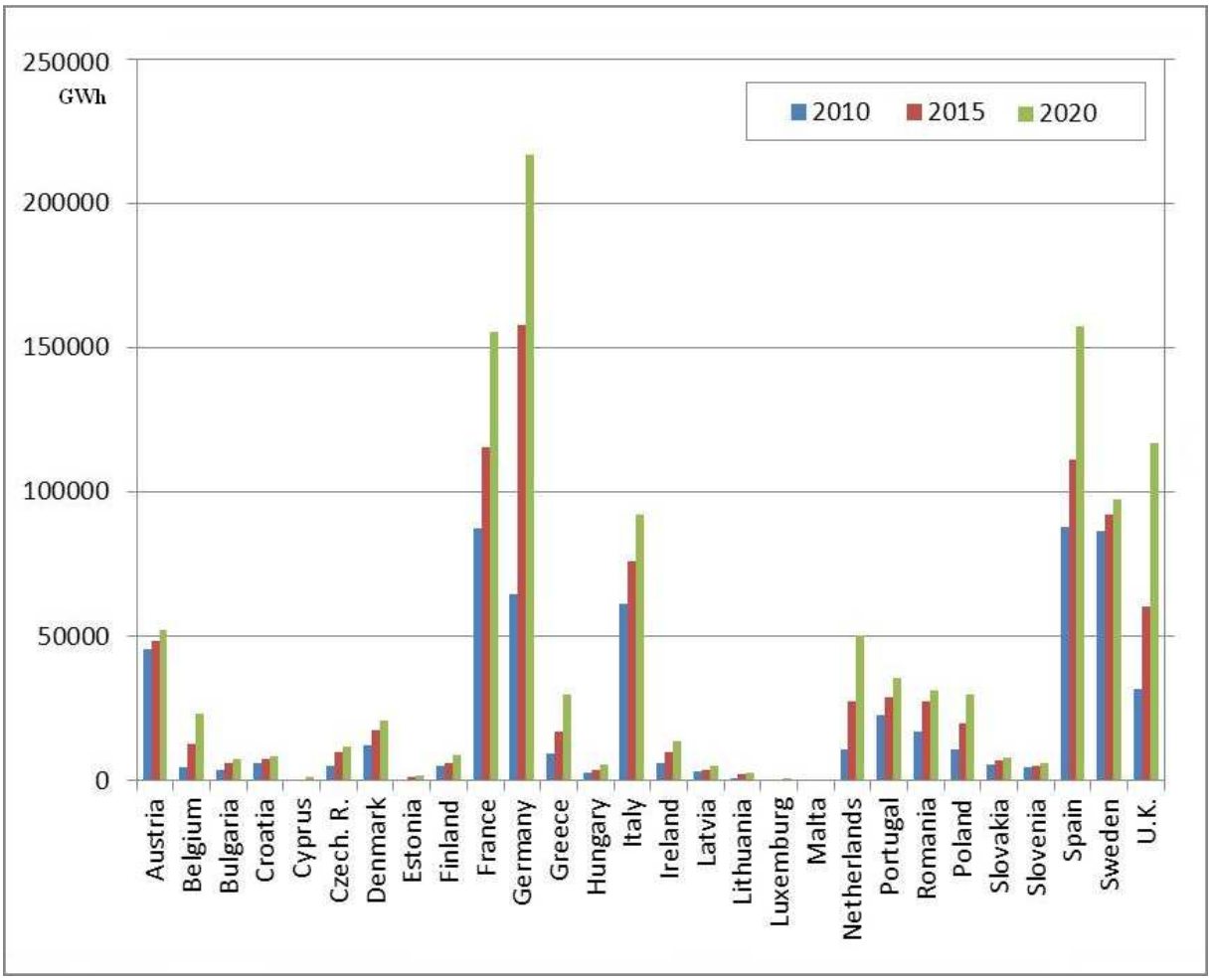

Fig. 1. Electricity production targets with renewable energy sources in each EU country (GWh). Source: Own elaboration from NREAPs [30].

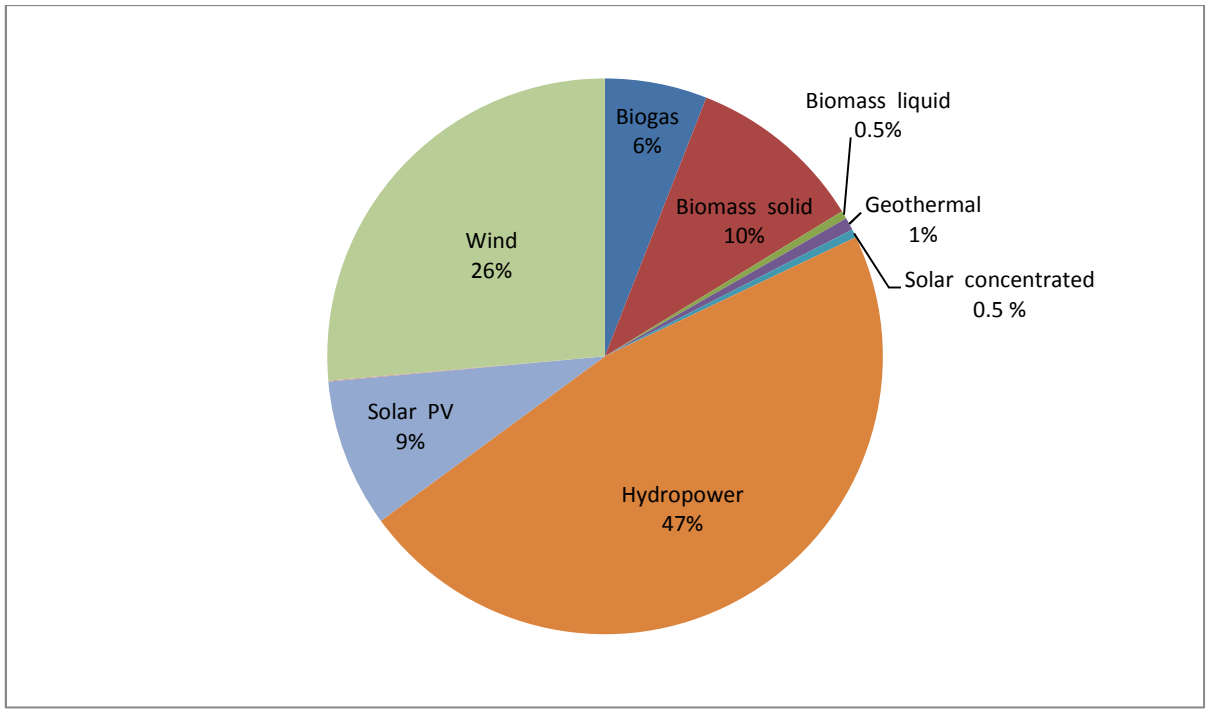

Fig. 2. Contribution of each renewable energy to the production of electricity in the EU-28 (2012). Source: Own elaboration from NREAPs [30].

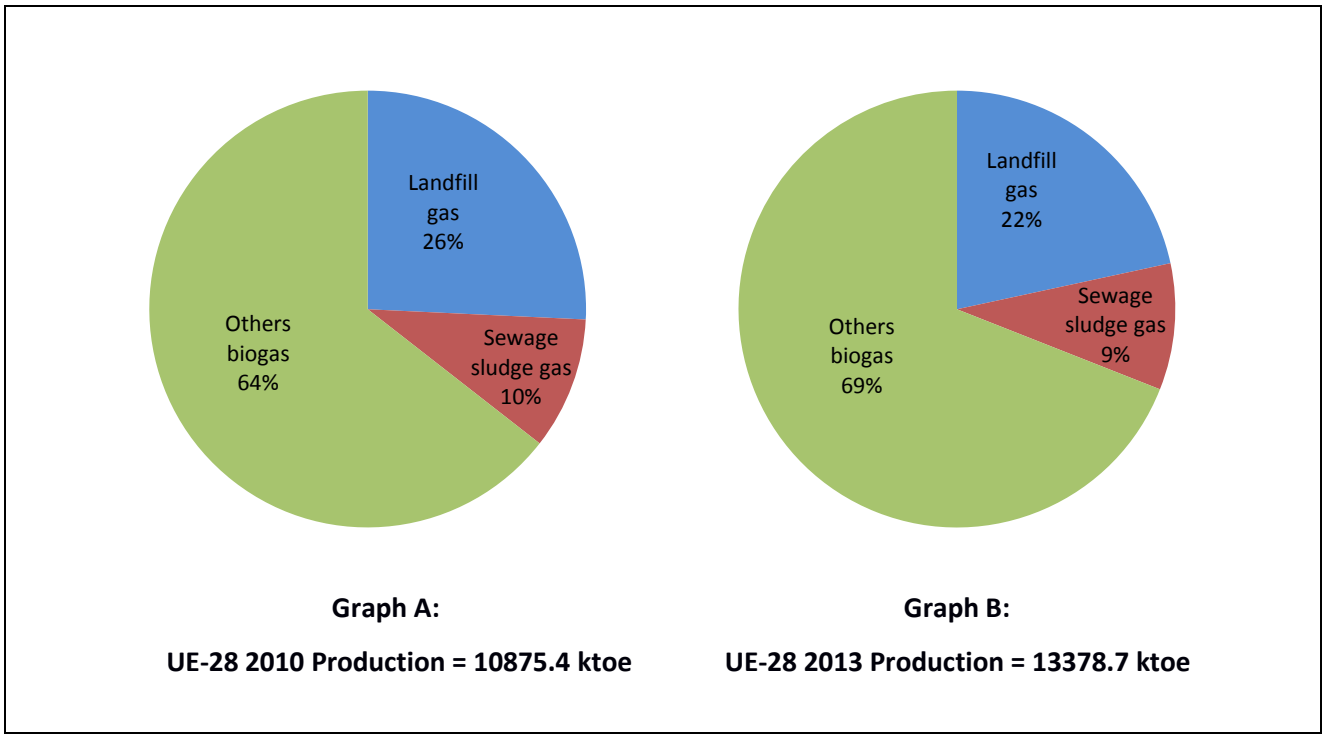

Fig. 3. Primary energy production of biogas in the EU-28.
Source: Own elaboration from EurObserv'ER [5, 31].

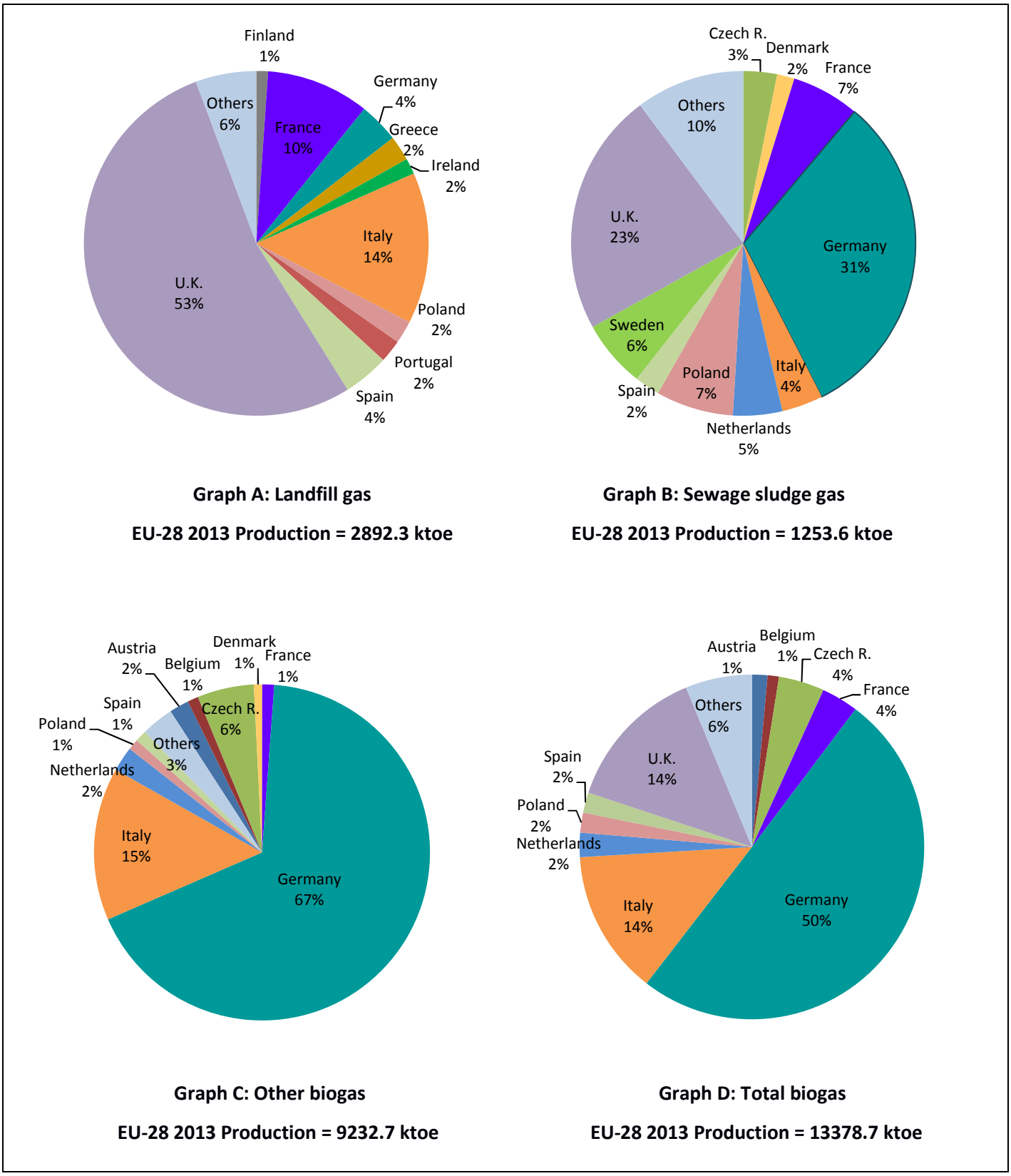

Fig. 4. Primary energy production of biogas in the EU-28.
Source: Own elaboration from EurObserv'ER [5].

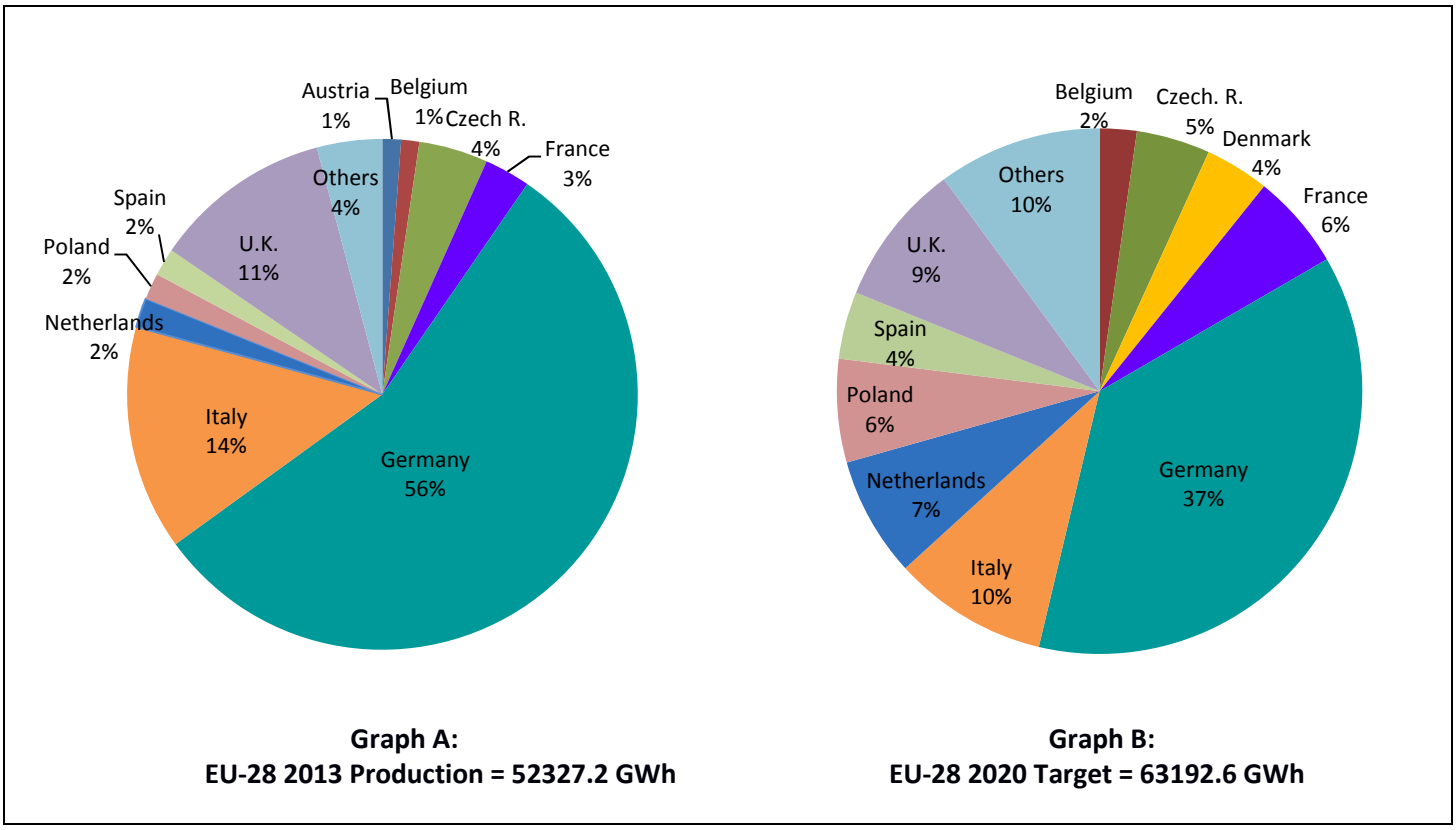

Fig. 5. Electricity generated from biogas in the EU-28, by country, in 2013 and country percentage values of EU-28 Targets for 2020.

Source: Own elaboration from EurObserv'ER [5] and NREAPs [30].

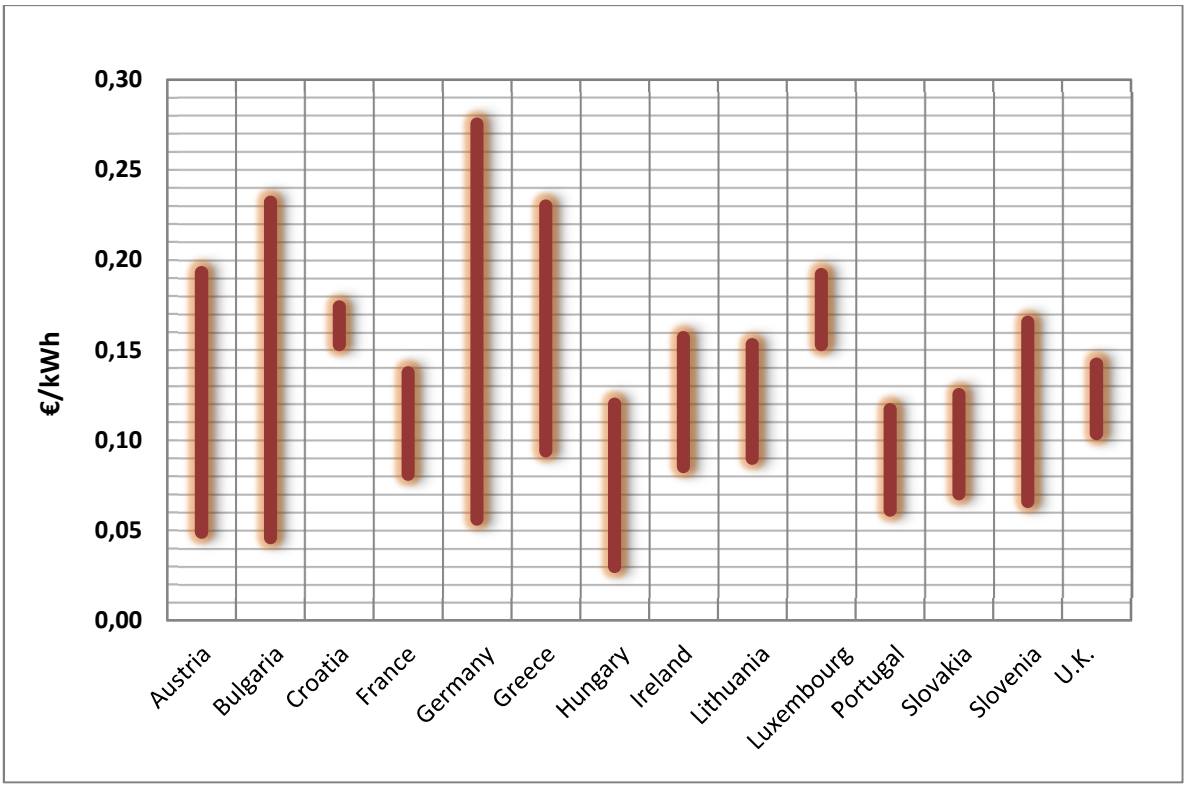

Fig. 6. Extent of feed-in tariffs.

Source: Own elaboration from RES-Legal **[28]**, **IEA [29]** and EurObserv'ER **[32-33]**.

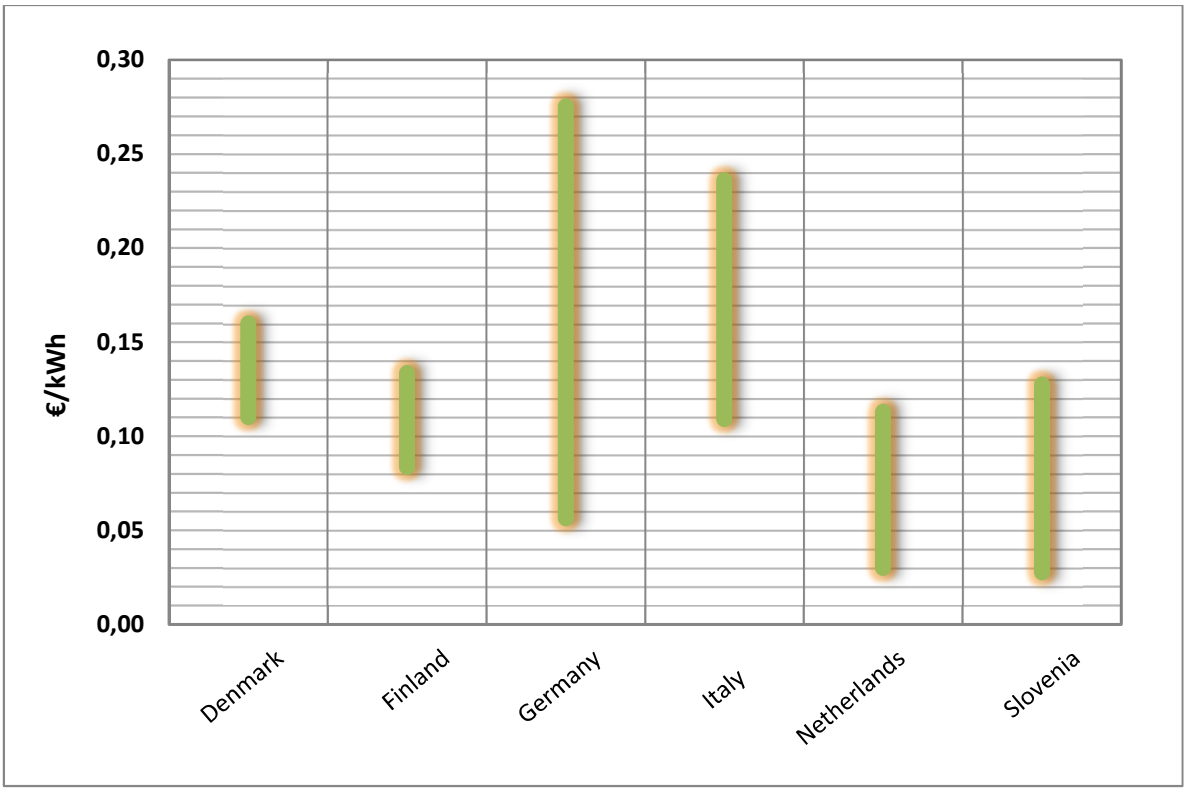

Fig. 7. Quantities of premium tariffs.

Source: Own elaboration from RES-Legal **[28]**, EurObserv'ER **[32-33]** and CEER report **[34]**.