European Commission

Optimal use of biogas from waste streams

An assessment of the potential of biogas from digestion in the EU beyond 2020

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Summary

Introduction

Biogas can be produced from a range of feedstocks and utilised in all energy sectors, contributing to the EU's decarbonisation, renewable energy and energy security objectives. Current (2014) biogas production level in the EU is almost 15 Mtoe, which represents about 7.6% of all primary renewable energy production in the EU. Differences between Member States are, however, very significant: only three Member States (Germany, United Kingdom and Italy) are currently responsible for more than 77% of the EU's biogas production. This biogas is mostly used for electricity production, followed by heat production and use as a transport fuel.

As the European Commission is working on the further development and concretisation of the post-2020 climate and energy policies, this study was commissioned to zoom in on the potential role, cost and benefits of biogas, and to assess the key barriers and drivers of biogas deployment in the EU. An important question to address was what policies at both EU and Member State level can best contribute to the effective and efficient growth of biogas deployment in the EU.

The study focussed on biogas production by digestion processes of local waste streams, i.e. on biogas production from sewage sludge, landfill gas and from suitable organic waste streams from agriculture, the food industry and households. Gasification of biomass, renewable methane production via power to gas or increasing mono-digestion of energy crops were considered outside the focus of the study and were not included in the scenario modelling part of this study.

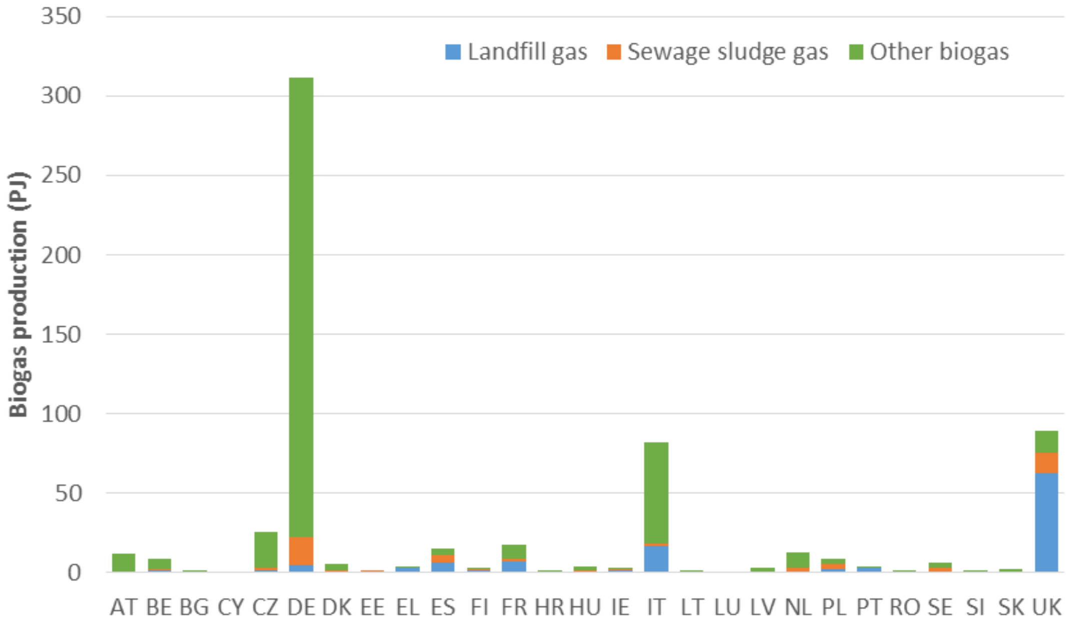
The research was carried out through desktop research and quantitative modelling, with strong support and involvement by stakeholders. Interviews were held with stakeholders from all Member States, and two stakeholder workshops were held during the course of this project to validate the research approach and key findings.

Biogas in the EU

The most recent data (2014) on biogas production per Member State, differentiated by source, is shown in Figure 5. Germany is by far the largest producer of biogas (311 PJ, 7.4 Mtoe) in the EU - 50% of the EU28 total - followed by Italy and the United Kingdom. Looking at the contribution of different feedstocks, biogas from sewage sludge had a share of 9%, landfill 18% and 72% of the biogas was produced in other digesters, mainly farm-based plants and some industrial organic waste digesters.

Most of the biogas is used for electricity production (62%) followed by heat (27%). Biomethane, for direct use in the transport sector or injected into the grid to be used in the built environment or in transport, contributes to about 11% of generated energy from biogas. Upgrading of biogas to biomethane has a substantial percentage of the use of biogas in Sweden, the Netherlands and Germany only. Energy crops (mainly maize) provide about half of the biogas production, followed by landfill, organic waste (including municipal waste), sewage sludge and manure.

Figure 1 Biogas production per Member State in 2014, differentiated by source (EurObserv'ER, 2015) [1]



Cost of biogas production varies significantly, and depends on parameters such as the substrate used and the possibilities to distribute the resulting digestate in the surrounding agricultural area. For most of the biogas produced, however, cost is higher than the price of the energy sources they replace (natural gas, diesel, etc.). Compared to other renewable energy sources, namely wind and solar PV, biogas has the advantage that it can be used to provide flexible power production, including in times of low wind and solar intensity.

When analysing the main drivers for biogas developments across the EU, the existence, stability and reliability of the policy framework and support schemes appears as the number one driver in all countries, independent of whether they already have a mature biogas market in place or not. National targets and goals are also identified as an important driver for the sector, as is the availability of suitable feedstocks (and waste collection processes) for biogas production.

The number one barrier to biogas developments in all three sectors is the opposite of the main driver: the lack of existence, stability and reliability of the framework and support schemes. This is the result of the current revision of the existing support schemes in some Member States and lack of support schemes, especially in heat and transport sectors, in others. In addition, many other barriers were identified throughout the EU, including lack of access to finance, lack of supporting taxing regimes (e.g. in transport), uncertainties related to sustainability criteria and low public awareness or lack of expertise.

Almost all EU Member States have gas infrastructure and storage in place, a natural gas infrastructure for transport and gas quality regulations, all important prerequisites for biomethane deployment and growth. Nevertheless, there are only a limited number of Member States where upgrading of the biogas into biomethane and injection into the grid is supported. In Sweden, the biomethane sector is well developed despite limited gas infrastructure: biomethane is typically distributed by trucks rather than by

[1] In PJ, with 1 PJ = 23.88 ktoe.

the grid. Cross-border biomethane trade is ongoing between some countries but is still very limited and hampered by issues such as country specific quality requirements and lack of harmonised traceability requirements.

Biogas polices in the EU and Member States

A wide range of EU policies are relevant to biogas and biomethane developments, including directives and communications on climate change, renewable energy, transport, agriculture, waste, state aid and natural gas. Many of these are currently being revised or further developed, creating an uncertainty in the market. Because of the importance of effective and stable policy support for biogas deployment and investments, the regulations and communications for the period after 2020 are expected to be crucial to the longer term developments of biogas in the EU.

Looking at the policies on national level, a large variety of support policies for biogas and biomethane is currently in place and there is still a lack of effective support schemes in many Member States. The survey conducted as part of this study indicated a clear correlation between the financial incentives in place and the way biogas is deployed in the Member States. Biogas is mainly supported in the electricity sector, while support for biomethane has its focus on the transport sector.

An overview of the biogas status and policies in each Member State is provided in an Annex of the report.

Growth scenarios for biogas deployment until 2030

In this study, four scenarios covering the playing field of possible biogas development in 2030 were designed and assessed; all based on the presumption that digestion of local biomass waste streams increases towards the total biogas potential that was identified, in all Member States. As shown in the overview of Table 1, the key parameters that were varied in these scenarios were

1. End-use of the biogas: local use in a cogeneration unit (CHP) or upgraded to biomethane for use in transport or heating.
2. Rate of biogas production increase and innovation.

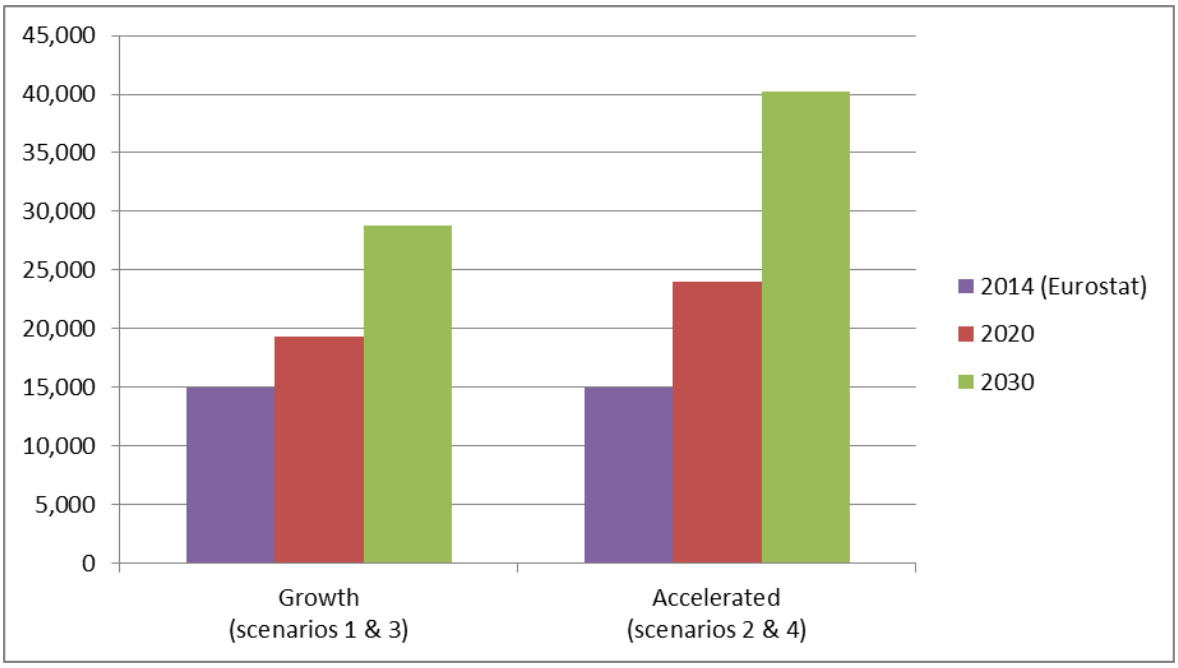
Table 1 Overview of the four scenarios

1	Local use & growth	Local use of the biogas in CHP, with electricity fed to the grid and local use of the heat Growth of feedstock deployment, regular development of investment costs and conversion efficiencies
2	Local use & accelerated growth	Local use of the biogas in CHP, with electricity fed to the grid and local use of the heat Accelerated growth of feedstock deployment, accelerated development of investment costs and conversion efficiencies
3	To gas grid & growth	Upgrading of the biogas to biomethane, fed into the gas grid. Use in built environment or in transport sector. Growth of feedstock deployment, regular development of investment costs and conversion efficiencies
4	To gas grid & accelerated growth	Upgrading of the biogas to biomethane, fed into the gas grid. Use in built environment or in transport sector. Accelerated growth of feedstock deployment, accelerated development of investment costs and conversion efficiencies

With the focus of the study on biogas production by digestion processes of local waste streams, the increased feedstock deployment in these scenarios refers to improved collection and use of available organic waste streams suitable for these processes.

Quantitative estimates of the feedstock potentials, i.e. of the biomass waste streams suitable for digestion, were derived from two feedstock scenarios in the Biomass Policies project, completed with information on the potential of biogas capture from landfill sites. Based on these potentials, the assessment shows that biogas production in the EU could increase from the current level of 14.9 Mtoe towards 28.8 to 40.2 Mtoe in 2030, depending on the amount of feedstock deployed and the learning effects attainable. These results are illustrated in Figure 2. The largest growth potentials are found to be in liquid and solid manure, and in organic wastes.

Figure 2 Growth of biogas production in EU28 in the scenarios in ktoe[2]



The scenarios result in a level of biogas and biomethane production in 2030 that represents 2.7 and 3.7% of the EU's energy consumption in 2030, as forecast in the 2016 Primes Reference Scenario, for the 'growth' and 'accelerated growth' scenarios respectively[3].

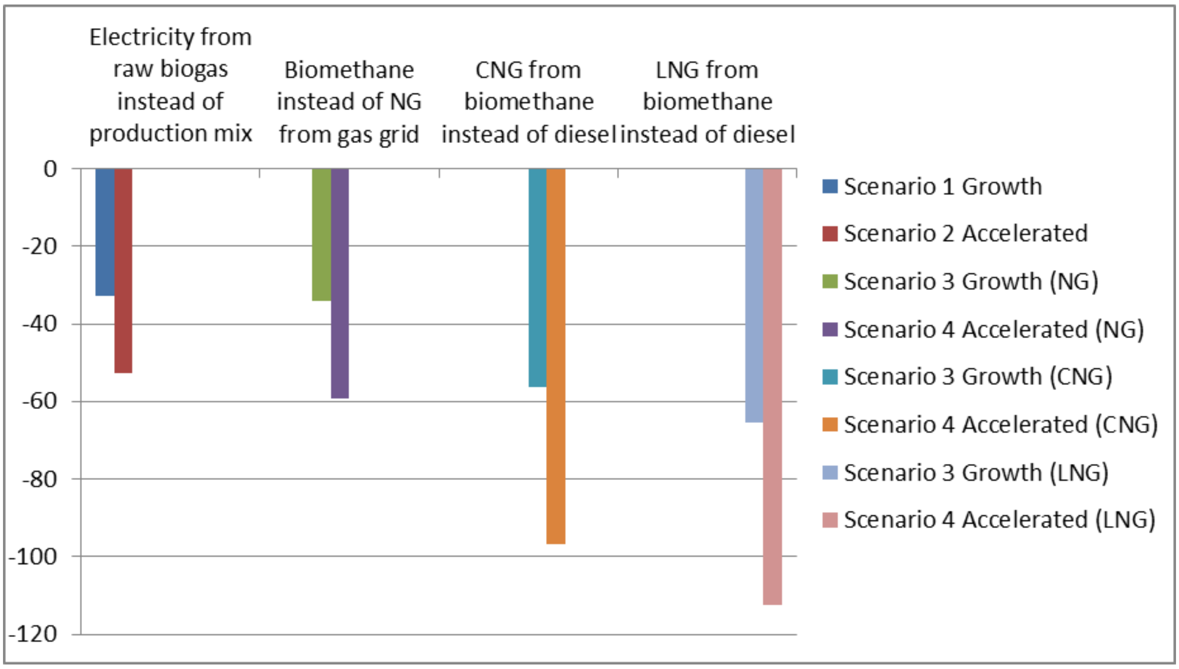
The costs per GJ biogas depend on the feedstocks, the digester technology used and the scale of production. On average, the calculated EU-wide biogas production costs are 14€/GJ in the 'growth' scenarios and 12 €/GJ in the 'accelerated growth' scenarios. If the biogas is upgraded to biomethane at natural gas quality or all production is converted to electricity in a cogeneration unit, the resulting cost levels are 1.3 to 2.0 times the current EU prices in the EU for natural gas and electricity. Accelerating learning curves due to market stimulation and innovation stimulation reduce cost, but this was found to be insufficient to become competitive with natural gas at the current price level.

[2] 1 ktoe = 41,868 GJ.

[3] Note that these percentages are based on biogas and biomethane energy content, and do not adhere to the RED methodology used to calculate the contribution of RES to the target (Article 5 of the RED).

Greenhouse gas (GHG) emission reductions achieved by the increasing biogas production between 2014 and 2030 are shown in Figure 3 for the various scenarios (incl. different utilisations of the biomethane in Scenarios 3 and 4). These results were found to be very dependent on which fuel or energy mix is replaced by the biogas or biomethane: in this figure, the electricity produced by the biogas is assumed to replace the average electricity mix in 2030 and biomethane in transport replaces diesel. Policies that ensure that only fossil power production is replaced (rather than the average mix) and measures that increase heat utilization of cogeneration could both significantly increase the GHG reduction in Scenarios 1 and 2. In all scenarios, it was assumed that on average, 25% of the heat produced in CHP could be utilised, which is estimated to be the current average in the EU.

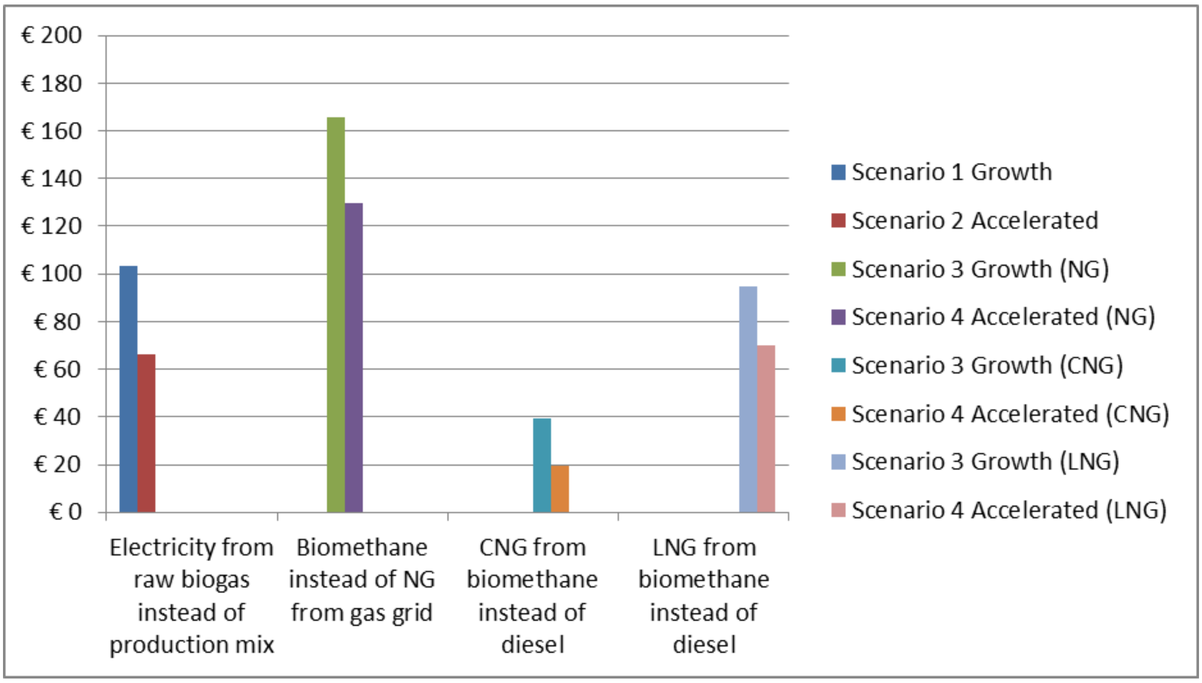
Figure 3 GHG emission reductions of each scenario and end-use in 2030 (of new capacity between 2014 and 2030) in MtCO$_2$-eq



When expressing the results in terms of cost per ton CO$_2$-eq reduction, shown in Figure 4 for 2030, we find that the most cost-effective route to reduce GHG emissions is upgrading of the biogas to biomethane and then using it as bio-CNG (Compressed Natural Gas) or bio-LNG (Liquified Natural Gas), in both cases replacing diesel. If accelerated growth is assumed, electricity form CHP is somewhat more cost-effective than bio-LNG (66 €/tCO$_2$-eq instead of 70 €/tCO$_2$-eq). In line with the findings above, better utilization of heat from the CHP and ensuring that the electricity produced replaces fossil energy sources rather than the average electricity mix can greatly enhance the cost-effectiveness of the first two scenarios. If we assume that the fossil mix in each country in 2030 is replaced rather than the overall production mix, the cost-effectiveness of Scenario 2 improves from 66 €/tCO$_2$-eq to 38 €/tCO$_2$-eq.

The positive effect of accelerated learning curves can clearly be identified in all results.

Figure 4 GHG emission reduction cost-effectiveness of each scenario and end-use in 2030, in €/tCO_2-eq



A different kind of contribution to the deployment of renewable energy sources (RES) is that in a future with high shares of renewable electricity production from intermittent sources such as wind and solar PV, electricity production from biogas can play an important role in complementing these technologies, especially in times of low output from these sources. When comparing the scenarios on this aspect, the 'local use' scenarios have the most potential to contribute to the future electricity system, since more electricity is produced in these scenarios than in the 'to grid' scenarios. Flexibility of power production in these scenarios may be limited by heat demand, though, which will be determined by other factors.

Looking at resource efficiency, biogas production from waste streams that cannot be re-used or recycled and have no other applications is well in line with circular economy and resource efficiency efforts in the EU. In terms of energy efficiency, we find that in our scenarios the most efficient process is biomethane production and utilisation in a domestic boiler, the least energy efficient process is bio-LNG utilization in a truck. If a larger part of the heat from CHP can be utilized, however, the energy efficiency of the 'local use' scenarios can increase significantly.

Main policy recommendations

To ensure further growth of biogas and biomethane production and use in the EU, it is strongly recommended to implement an attractive, reliable and stable policy support scheme and a positive long-term outlook for the various stakeholders involved, on both the EU and Member State level. Agreement and implementation of EU-wide effective and robust sustainability criteria for biogas and biomethane are an important essential part of this policy package, as well as ambitious climate and renewable energy targets for 2030 (and beyond).

EU level recommendations

On EU level, harmonisation of developments and facilitation of biomethane cross-border trade would support further growth of biogas and biomethane production and use. EU-wide technical standards and sustainability criteria, as well as harmonization of (administrative) data transfer are key enablers for cross-border trade.

Increasing the use of biomethane as a means to decarbonise the EU transport sector also requires increased shares of (natural) gas vehicles and a network of CNG and/or LNG filling stations. This involves coherence of a range of EU level policies, including the Renewable Energy Directive (2009/28/EC)RED, the Fuel Quality Directive (2009/30/EC) FQD and the Clean Power for Transport Directive (2014/94/EU). Implementation of an EU-wide system of Guarantees of Origin (GoO) for biomethane can facilitate administrative trade of the biomethane and improve disclosure and transparency.

It is furthermore recommended to encourage Member States to decarbonise heating further in the EU's energy policies. Strengthening incentives to use the heat from biogas in a CHP can increase GHG savings, increase the share of RES in heating and improve energy efficiency. Looking at agricultural policies, it is recommended to differentiate the requirements regarding the use of digestate in the Nitrates Directive (91/676/EEC), based on the share of manure in the feedstock and the nitrogen content of the digestate. EU-wide harmonisation of regulations regarding which co-substrates are allowed in anaerobic digestion, preferably in the form of sustainability criteria for biogas and biomethane, would support the further development of the EU internal market of biogas and biomethane. It is also recommended to ensure compliance with the waste and landfill directives throughout the EU, and to encourage Member States to implement separate collection systems for organic waste streams, if they do not yet have this in place.

Since innovation of the biogas chain can have a range of benefits (e.g. cost reduction, increased GHG savings), continued efforts into R&D of biogas production, conversion into biomethane and the application of biogas are recommended. EU-wide dissemination of biogas-related knowledge and expertise can be improved by setting up a platform for best practices related to biogas production technologies, applications and policies, targeted at farmers, economic actors, municipalities and policy decision makers.

Member State recommendations

Because of the importance of stable and effective Member State policy support for biogas projects and investments, Member States are recommended to develop national strategies for the role of biogas and biomethane to meet future renewable energy and climate goals. This should include an assessment of available organic waste streams that could be suitable feedstocks for biogas production, and establish an outlook for improved waste collection (where relevant) and potential biogas/biomethane production and use. The strategies should take into account related policy areas that may benefit such as agriculture, rural development, waste and circular economy.

Based on this strategy, stable and effective renewable energy targets for 2030 and long-term, stable support policies can be implemented. These policies should include effective and stable minimum sustainability criteria in line with the EU criteria that will be decided on in the coming years. Specific RES targets and support policies for the various sectors can increase investment security; a further differentiation of policy incentives to the sustainability of the renewable energy (e.g. GHG savings) can enhance focus of efforts and investments towards the most sustainable options. In addition, different policy packages are needed for different applications of the biogas and biomethane. Member States can thus design and implement a coherent and integrated policy package that suits national priorities and opportunities.

Member States that do not yet have sufficient support policies in place should focus their efforts on the mobilization of agricultural manure and residue streams since this feedstock category has the largest potential for growth. Integration of the biogas sector as a part of sustainable agriculture may provide opportunities to optimise prevention of GHG emissions from manure storage and wastes and to increase the use of biogas co-products for improved soil management. Member States should furthermore ensure compliance with the waste and landfill directives, including the provisions on bio-waste. It is also recommended to assess whether the administrative procedures and technical rules for biogas and biomethane projects create unnecessary barriers and can be improved. Improving incentives or regulations to increase the use of heat from CHP can increase both the GHG savings from the biogas and the share of RES in the heating sector.

If a Member States chooses to support biomethane for heating or in transport to increase the share of renewables in these sectors and/or increase demand for biogas, financial support to connect biomethane plants to the grid may be necessary. If grid expansion is required, this should be assessed as part of a broader national gas strategy and grid development plan, to identify cost-effective projects. A national registry for biogas Guarantees of Origin can be set up to oversee the issuing, administration and cancellation of GoOs and facilitate transparency and cross-border trade, if Member States do not yet have this in place.

Regions and municipalities are also recommended to assess their potential biogas sources as well as options to develop these opportunities. These can contribute to their energy independence and rural development, increase the share of locally produced renewable energy, and, at the same time, reduce environmental impact of waste streams.

On both national and regional level, attention should be given to knowledge transfer and raising awareness regarding the available benefits of biogas production and usage, especially in Member States where biogas markets are still immature. Potential producers and users can be informed directly; best practices can be advertised, etc. Adequate communication with the public and NGOs should be organised to ensure public support of the developments.

1 Introduction

1.1 Background of this study

Biogas is a very versatile form of bioenergy, as it can be produced from a range of feedstocks and utilised in all energy sectors: for electricity production, heat and cooling and in transport. This biogas production and use contributes to the EU's decarbonisation, renewable energy and energy security objectives.

Due to successful policies in various Member States, EU-wide biogas production increased rapidly in recent years. However, as some of these policies were modified and incentives reduced, this level of growth may not be sustained in the coming years. At the same time, the differences between Member States are significant, in many respects: feedstock potential, current biogas production levels and policies. Only three Member States (Germany, the United Kingdom and Italy) are currently responsible for more than 77% of the EU's biogas production.

Current (2014) biogas production level in the EU is 14.9 Mtoe[4], which represents about 7.6% of all primary renewable energy production in the EU.

Almost 10% of this biogas is produced by wastewater treatment plants, about 21% is landfill biogas and the remainder, 69%, is biogas produced by anaerobic digestion of feedstock such as agricultural, industry or household waste and energy crops.

This biogas is mostly used for renewable electricity production, followed by heat production and use as a transport fuel.

As the Commission is working on the further development and concretisation of the post-2020 climate and energy policies, there is a need to zoom in on the potential role, cost and benefits of biogas, and to assess the key barriers and drivers of biogas deployment. An important question in this respect is what policies at both EU and Member State level can best contribute to the effective and efficient growth of biogas deployment in the EU.

To answer these questions, a project was commissioned by the European Commission, DG Energy, and carried out by a consortium of CE Delft, Eclareon and Wageningen Research (Wageningen Environmental Research and Wageningen Food & Biobased Research). The project was divided into three Tasks:

1. The first Task was a stock-taking and information collection exercise which resulted in a comprehensive overview of the biogas sector in the EU, the support policies in place in the Member States, key drivers and barriers, etc. The results of this task can be found mainly in Chapters 2 and 3 and in Appendix A.
2. In the second Task, a number of biogas scenarios were developed, as well as a model that could quantify the effects and impacts of these scenarios. These scenarios covered all 28 EU Member States and focus on the timeframe 2014-2030. The results of this part are described in Chapter 4.
3. In the third and final Task, the effects of the scenarios are evaluated and analysed. In addition, policy recommendations are developed based on the results of this study, focussing on EU level policies but also including a number of general recommendations for Member State policies. The scenario evaluation can be found in Chapter 5, policy recommendations in Chapter 6.

[4] 2014 primary energy data, Eurostat data.

The main conclusions from the various Tasks and the key recommendations for both the EU and Member States are gathered in Chapter 7.

The research was carried out through desktop research and quantitative modelling, with strong support and involvement by stakeholders. Interviews were held with stakeholders from all Member States as part of the first Task, and two stakeholder workshops were organised during the course of this project to validate the research approach, the key results and resulting recommendations.

1.2 Objective and scope of this study

This study had the following objectives.

- to provide an up-to-date overview of projections of the EU biogas (including biomethane) potentials for 2020 and 2030 in the electricity, heating and transport sectors;
- to identify its possible contribution to EU objectives in the field of climate change mitigation, energy security and resource efficiency;
- to identify existing technical, economic and administrative barriers to further development of biogas;
- to discuss options for policy action on EU level needed to overcome the identified barriers.

The scope of the study is the EU28, and the analysis was carried out both on Member State and EU level. The study focus was the period until 2030, although the longer term EU climate objectives and potential energy developments were taken into account when developing the scenarios and policy recommendations.

The study focussed on biogas production by digestion processes of local waste streams, i.e. on biogas production from landfill gas, sewage sludge and from suitable organic waste streams from agriculture, the food industry and households.

Within this scope, it includes all biogas- and biomethane-to-energy routes, covering the various conversion technologies and energy applications as far as considered feasible until 2030.

2 Biogas in the EU

The following chapter provides an overview of the key findings of Task 1 of the study, the stock-taking exercise. The chapter first describes the data gathering methodology used, and then summarizes our findings on the biogas and biomethane state of play throughout the EU for a wide range of topics:

- current production;
- current feedstock use;
- key drivers;
- key barriers;
- biogas production technologies;
- cost;
- infrastructure;
- inter-EU trade;

An overview of relevant EU policies and Member State support schemes is presented in the following chapter.

More detailed information per Member State can be found in the concise country factsheets that are included in Appendix A of this report. These factsheets were based on comprehensive Member State reports that were drafted for this study (not included in this report).

2.1 Methodology and data sources

The following research techniques were deployed in this stock-taking task:

- research of primary (e.g. laws and documentations of legal processes) and secondary (e.g. policy reports and plans, policy and technical databases, articles, presentations, specific news-websites and blogs) sources;
- stakeholder interviews at Member State and EU level;
- A Stakeholder Workshop in Brussels targeted at biogas experts at national and EU level.

The first step was the research of primary and secondary sources. A large part of this work focused on Member State sources, but some aspects were mainly covered using EU level sources, to allow comparison of data. For example, since the market situation for biogas in the individual Member States varies, the project team focused on centralized data as far as technical data was concerned. This mainly covered feedstock-related issues as well as current production levels. The centralized data was mainly collected from the deliverables under the Biomass Policies project (Elbersen, 2016), the Biomethane & Biogas Report drafted by the European Biogas Association (EBA) in 2015 (EBA, 2015), data on supply transformation and consumption of renewable energies from Eurostat (Eurostat, 2016) and data on renewable energies and biogas from EurObserv’ER (EurObserv’ER, 2015) (EurObserv'ER, 2014). For the remaining issues the focus was on the national sources of information.

In a second step, to gather additional information, but also to fill the gaps in the desktop research, phone interviews have been conducted with the national stakeholders in all EU Member States. For the identification of the stakeholders at national level, the project team looked at biogas associations and farming associations, national and selected regional ministries, biogas research institutions and environmental associations.

To gather objective and reliable data, 1-3 stakeholders per Member State have been interviewed. The selected stakeholders were also requested to review the desktop research results, since one of the key objectives of the interviews was to validate the first research results. In addition, certain qualitative issues have been discussed with the national experts (e.g. barriers and drivers, feedstock availability, effectiveness of the supporting policies in place, relevant planned policy amendments, etc.) Some questions were formulated to provide further input for scenario development in Task 2.

The data collected through desktop research and stakeholder interviews has been revised in a three step information revision process:

- internal revision at each partner by experienced senior members;
- revision through partners;
- feedback from biogas experts at national level.

In a final step, the structured and categorized research results were presented to the experts at the first of the two planned stakeholder workshops, in May 2016. In addition, research results have been circulated through an extensive network of experts to gather the feedback on the results before data is being processed and analysed for the Task 2 "Building biogas scenarios".

2.2 Current production and consumption

The current (2014, the most recent data available) production of biogas in the EU is obtained from three sources: The European Biogas Association, EuroObserv'Er and Eurostat. The Eurostat and EuroObserv'Er data were very similar, whereas the data from the European Biogas Association was lower for some Member States, probably due to incomplete coverage of all biogas producers. Using the Eurostat data, we find that the total biogas production in 2014 was 625 PJ (14.9 Mtoe), with only 167 PJ (4.0 Mtoe) of biogas production in 2005[5]. Biogas accounted for 7.6% of the total primary production from Renewable Energy Sources (RES) in 2014.

The total biogas production per Member State, differentiated by source, is shown in Figure 5. Germany is by far the largest producer of biogas (311 PJ, or 7.4 Mtoe) in the EU which is 50% of the EU28 total, followed by Italy and the United Kingdom (UK). Biogas from landfill had a share of 18%, sewage sludge 9%, whereas 72% of the biogas was produced in other digesters, mainly farm-based plants and some industrial organic waste digesters. Biogas production from landfill is relatively high in the United Kingdom, but this is expected to decrease in the near future as the share of waste deposited in landfill sites decreases and biogas production from existing land sites will decline over time.

[5] In this report, biogas production data are given in terms of energy content. This can be converted to volume by taking into account the energy density of the gas, in terms of MJ/Nm^3, which depends on the methane content of the biogas. For example: Biogas: 23.9 MJ/Nm^3; Landfill gas: 22.3 MJ/Nm^3; Biomethane: 38.9 MJ/Nm^3 (all based on higher heating value).

Figure 5 Biogas production per Member State in 2014, differentiated by source (EurObserv'ER, 2015)

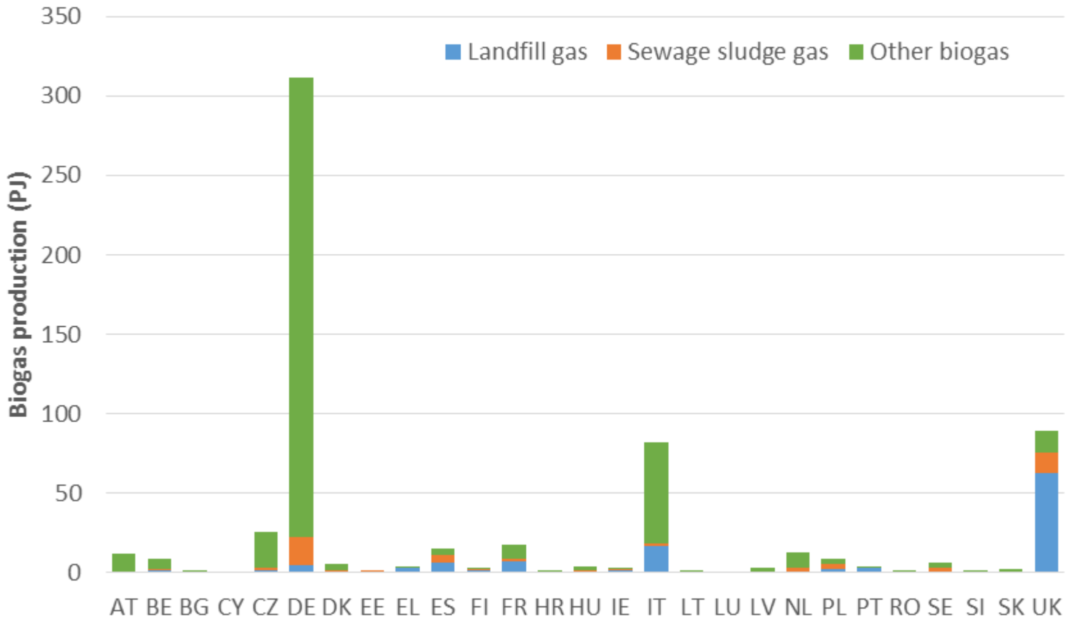
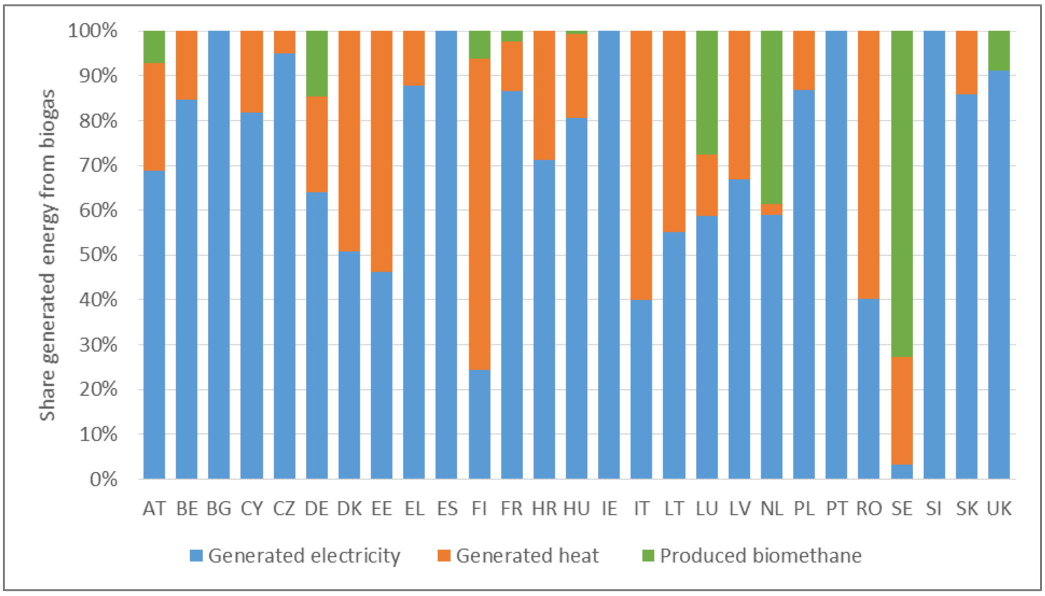


Figure 6 shows the current use of biogas, expressed in share of final energy produced. Most of the biogas is used for electricity (62%) followed by heat (27%). Biomethane, for direct use in the transport sector or injected into the grid to be used in the build environment (for heating or cooking mainly) or in transport, contributes to about 11% of generated energy from biogas. Upgrading of biogas to biomethane is important in Sweden, the Netherlands and Germany; although in absolute terms Germany produces by far the largest amount (33 PJ or 788 ktoe of biomethane). Biogas consumption data per sector is available from Eurostat statistics, but for many countries the data is not complete or included in the category non-specified. According to these data most is used in the sector Services, followed by Industry and Agriculture.

Figure 6 Generated energy from biogas per Member State (EBA, 2015)

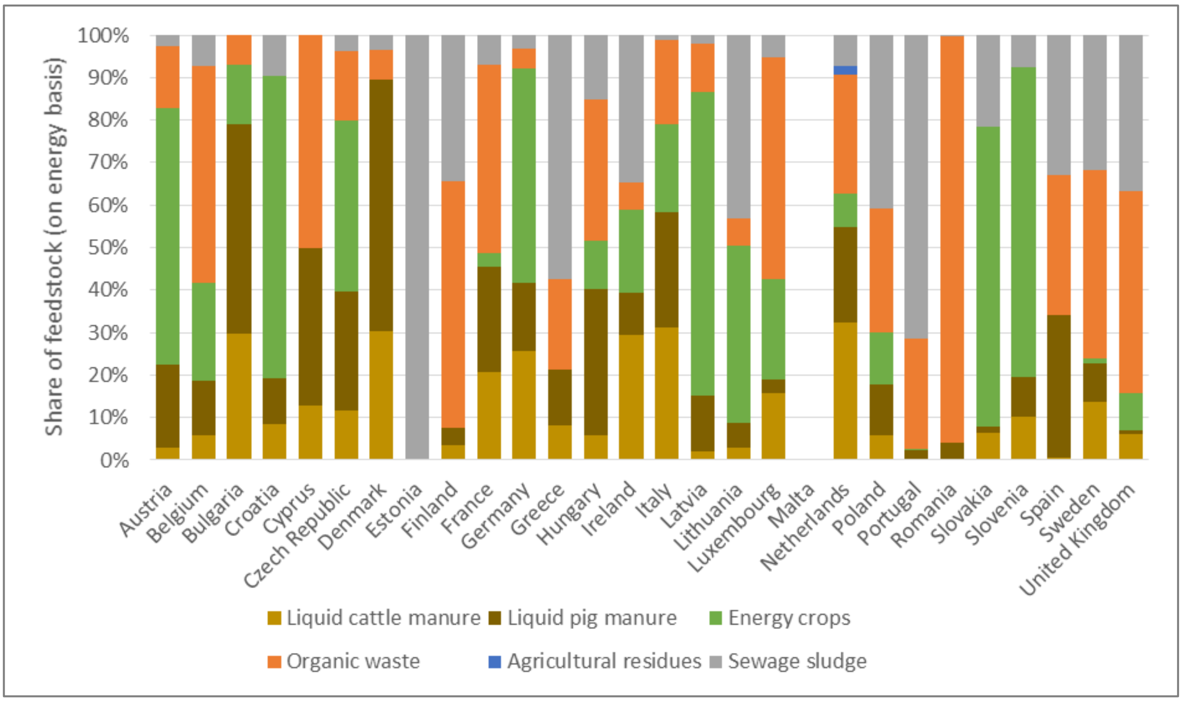


2.3 Current feedstock use

Information on feedstock use for biogas is often not easy to obtain, as this is not centrally registered, and its use is rather variable over time due to changes in feedstock prices and legislation. Based on data from three EU sources (EBA, 2015; DG Environment survey, 2011; Pedroli et al., 2011) and few national data, we made an estimate of the current feedstock use and quantified these based on the 2014 biogas production from the EuroObserv'Er data, as these data distinguish between landfill, sewage sludge and other biogas production.

Figure 7 shows the result of this analysis, the share of the different feedstocks among Member States. Energy crops (mainly maize) provide about half of the biogas production (318 PJ, 7.6 Mtoe), followed by landfill (114 PJ, 2.7 Mtoe), organic waste (including municipal waste) (86 PJ, 2,0 Mtoe), sewage sludge (57 PJ, 1.3 Mtoe) and manure (46 PJ, 1,1 Mtoe). However, in terms of feedstock input on a mass base, manure contributes about 43%. This discrepancy is due to the relatively low biogas yield from manure.

Figure 7 Share of feedstock use for biogas (on energy basis), estimates[6]



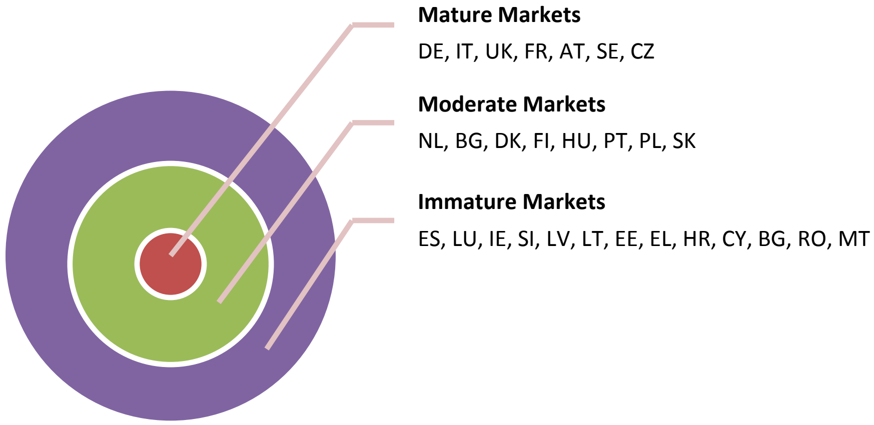
2.4 Key drivers for biogas developments

For a better analysis of drivers and barriers for biogas deployment throughout the EU, Member States are divided into three groups dependent on their market maturity in terms of (absolute) number of biogas plants installed: mature, moderate and immature markets. Mature markets cover the front runners in biogas production in the EU, based on the number of biogas plants installed; Moderate markets include Member States with a moderate number of biogas plants installed; Immature markets cover Member States where biogas production is low. The resulting Member State division is shown in Figure 8.

6 EuroObserv'Er data stated only landfill gas and sewage sludge for Estonia, while EBA data stated also other feedstock use.

This section explores the prevailing drivers in all three markets, with a focus on the mature market since these may be seen as best practices, assuming they have the strongest and most effective drivers[7].

Figure 8 Member State division based on the number of biogas installations



Independently from their market maturity, in almost all markets **the existence, stability and reliability of the legal and political framework and effective support scheme(s)** is perceived as the greatest driver for the use and consumption of biogas and biomethane. The survey indicated a clear correlation between the financial incentives in place and the way biogas is deployed in Member States. For example, in the United Kingdom slow growth of biogas industry started in the 2000s, with the introduction of the Renewables Obligation scheme in 2002. An even greater driver for both biogas and biomethane production was the launch of Feed-in Tariff scheme (2010) and Renewable Heat Incentive (2011). These incentives resulted in the biggest growth of the sector in 2014. This was the first year when biomethane-to-grid plants were constructed and commissioned in significant numbers. In Italy the most significant driving force to promote biogas was the first Feed-in Tariff in 2008-2012, when most of the biogas plants were installed. Since then the number of new biogas plants decreased, as a result of a reduction of tariff rates. In Germany, the most efficient policy for the support and promotion of biogas/biomethane in the electricity sector is considered to be the Renewable Energy Sources Act (**Erneuerbare-Energien-Gesetz** – EEG), even though the support tariffs have been gradually reduced in 2012 and 2014 and compared to the flourishing conditions of 2009 are not so attractive anymore. In the Czech Republic the increase in biogas production has been driven by feed-in tariffs, in France by investment support and feed-in tariffs. Finally, in Sweden, the greatest driver is the energy and CO_2 tax exemptions for biomethane in transport. (USDA, 2016).

It is furthermore notable that the majority of Member States from mature markets use the biogas for electricity and/or heat generation, and in these cases also the support has its focus on these sectors (e.g. Germany, Austria, Czech Republic, France). The main exception is Sweden where most biogas is converted to biomethane and then used in the transport sector, due to the above mentioned supportive tax regulations (USDA, 2016). The second biggest driver identified in mature markets relates to **stakeholder efforts** – collaboration of stakeholders regarding expertise and lobbying

[7] Note that the definition for 'maturity' used here only looks at the number of biogas plants in the country and does not represent, for example, whether or not a large share of the potential biogas production is developed (potential for further growth is shown in Section 5.1).

can contribute to the developments. Stakeholder efforts play a crucial role in Austria and Italy. In Italy, the possibility to inject biomethane into the natural gas grids, as well as the availability of methane distribution plants for natural gas vehicles was initiated by the Fiat Chrysler Automobiles group that urged the government to promote the use of biomethane for cars and reduce natural gas imports.

Stakeholder efforts have not been communicated as a driver in moderate markets. With regards to immature markets it has been mentioned only for Luxembourg.

In moderate and immature markets, the second most relevant driver relates to **feedstock potential**. Feedstock potential is seen as a good driver in Poland, Belgium, Portugal, Spain, Ireland, and Croatia. The majority of these Member States have a significant agricultural sector and therefore a huge amount of agricultural waste to be used for biogas/biomethane production. Feedstock potential plays a lesser role in mature markets. This driver has been mentioned only for France, which also has a strong agricultural profile.

National targets and goals are the number three driver in all three markets analysed. Ambitious national goals are seen as a good driving force in France, Sweden, Denmark, Finland and Luxemburg. While France and Sweden highlighted national climate ambitions and GHG targets as a driving force, targets for the use of livestock manure for green energy and national RES targets are perceived as good drivers in Denmark, and biomethane specific targets in Finland.

The remaining drivers cannot be easily compared among the three markets, since they vary from market to market. Hence for example in mature markets further drivers highlighted during the survey include **growing confidence in biomethane technology** (the United Kingdom), which resulted from resolving certain regulatory issues. In France, **regions with poor electricity and high unemployment rate** in rural areas are seen to provide good opportunities for greater use of biogas and biomethane, ensuring both better electricity supply and additional revenues for farmers.

When it comes to moderate markets, **availability of technical know-how** that ensures profitable management of biogas production plays a role in Belgium (Flanders). In immature markets further drivers include the existence of an **extensive gas network** with the possibility to connect and inject biogas/biomethane into the grid in Spain, and **large customer demand for green gas** in Ireland.

2.5 Key barriers to biogas growth

This section explores the key barriers to biogas growth, identifying the five main barriers per sector (electricity, heating and transport), distinguishing between the three different types of market (i.e. mature, moderate and immature market). The identification of the main five barriers was based on the selection of the main three barriers in each of the sectors per Member State. In a second step the barriers were grouped according to the predefined categories and subcategories in order to identify top five barriers per sector per market. The data collection was to certain extent challenging since in some Member States, especially those with immature but also moderate markets, there is still a lack of business cases.

Figure 9 Barriers for electricity generation from biogas/biomethane

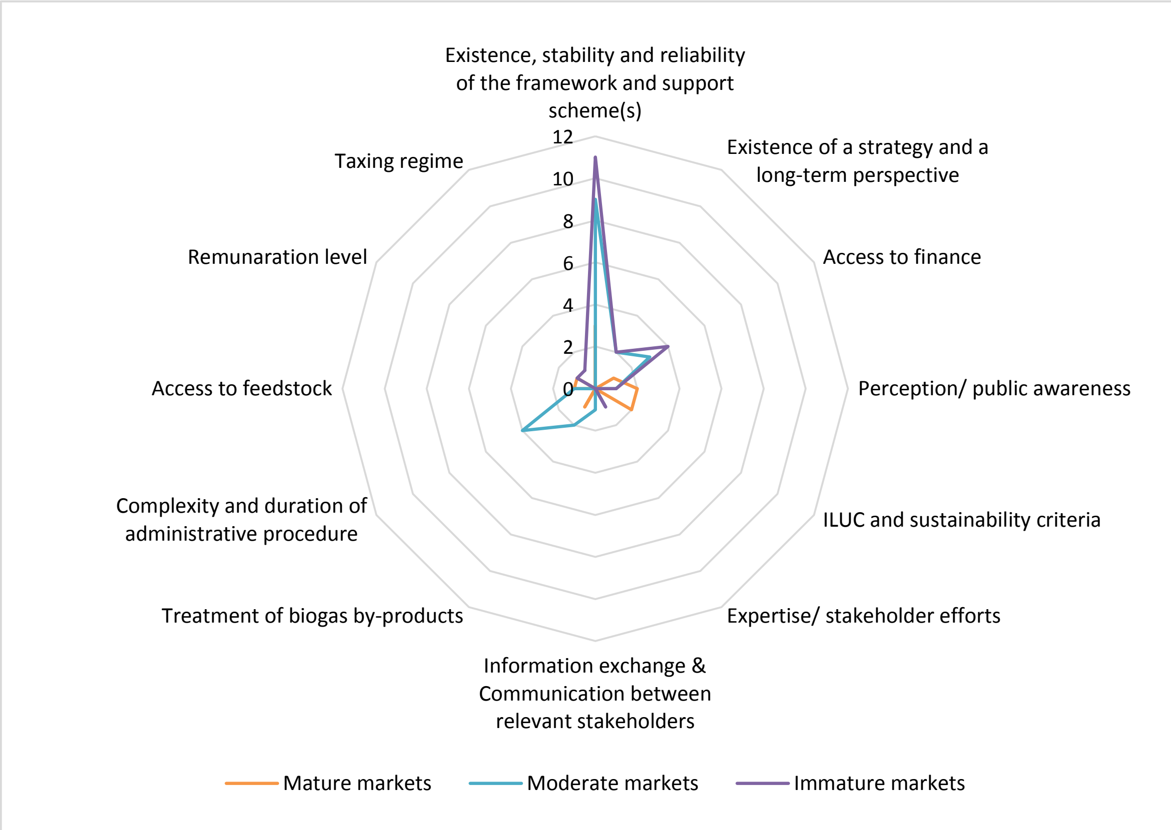


Figure 10 Barriers for heat generation from biogas/biomethane

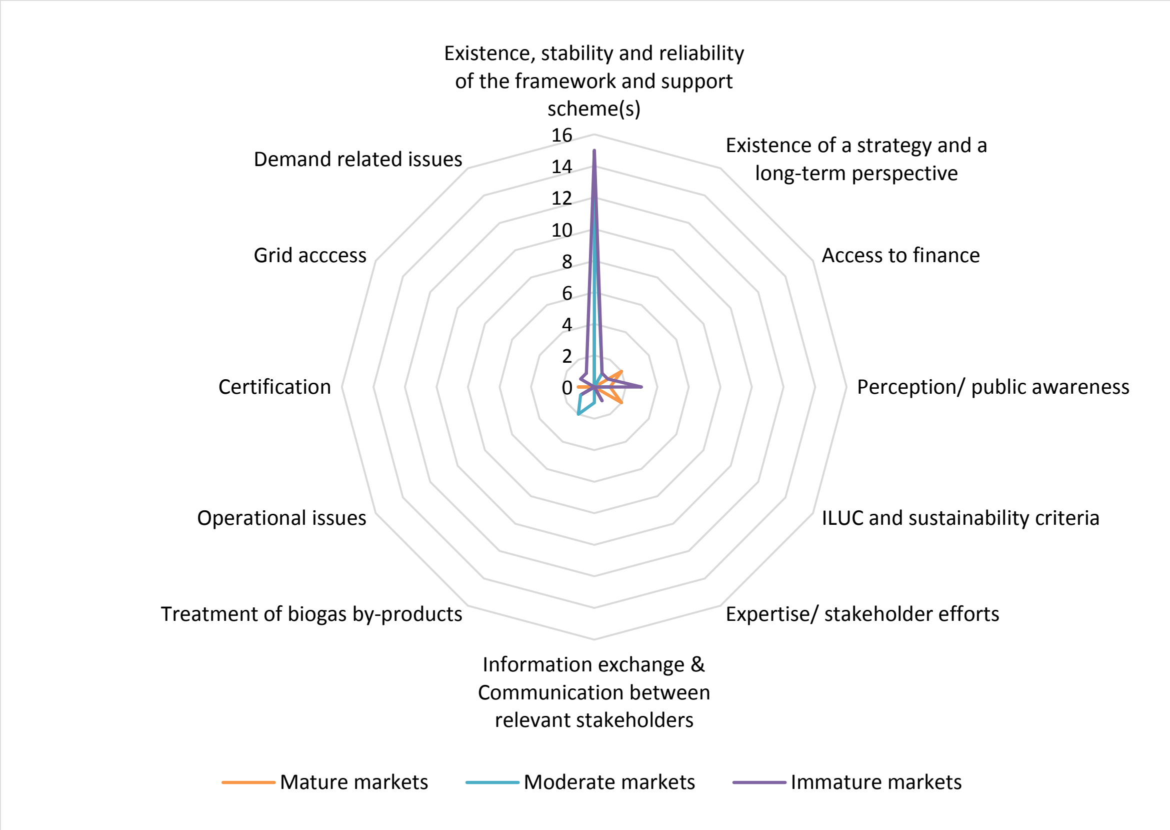
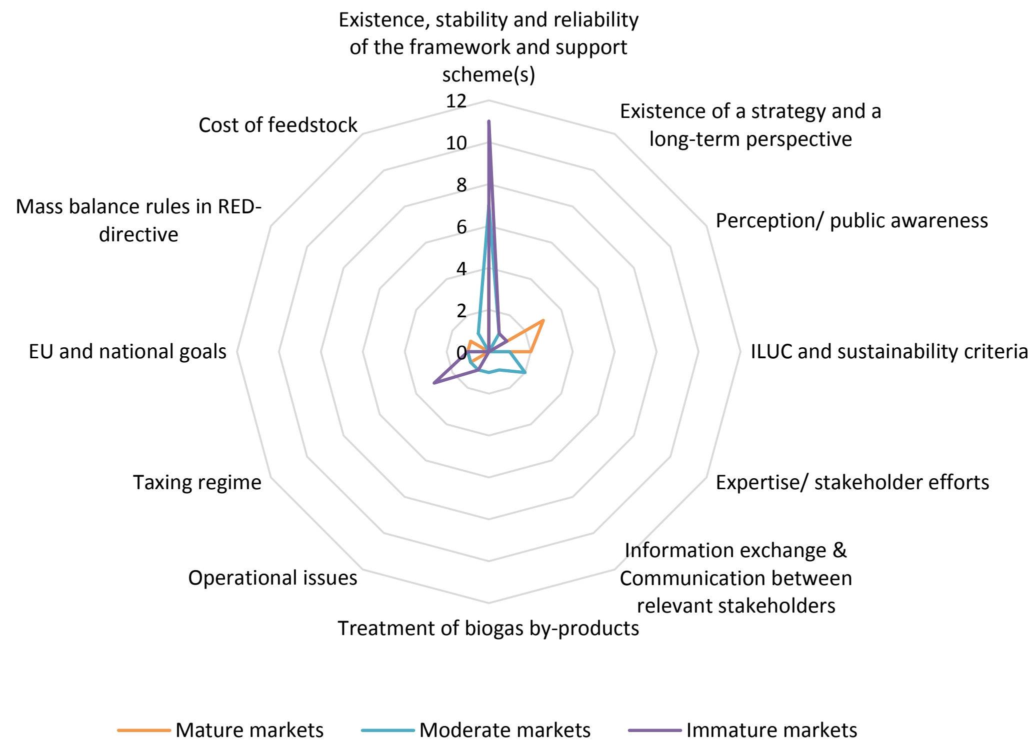


Figure 11 Barriers for biogas/biomethane in the transport sector



Existence, stability and reliability of the framework and support scheme(s)

The key barriers in all three sectors and in all three markets relate to the existence, stability and reliability of the framework and effective support scheme(s) – clearly the key issue that determines biogas growth as it was also identified to be the key driver in the previous section. Since installation of biogas plants is linked to relatively high investment cost, it is of great importance for the implementation of the projects to have financial incentives and a policy framework in place that ensure profitable operation for a number of years. A well established and stable legal and political framework along with stable income from biogas production and possibly support for the investment cost reduces the pay-back time of the project and makes the project attractive to project developers and investors. (Capidaglio et al., 2016)

Barriers related to the policy framework and support have been detected in 22 Member States in the electricity sector, 20 Member States in the heating sector and 16 Member States in the transport sector.

With regards to electricity sector in mature markets, this barrier has been identified in Germany, France, and the United Kingdom. In Germany, lack of support schemes sufficiently promoting the extended usage of biogas is the main barrier for further development of biogas in all three sectors. In the United Kingdom, the main barrier hindering biogas projects in all three sectors is the permanent revision of support schemes. In France, biogas projects suffer from different interpretation of regulatory requirements for emission thresholds in the regions. In moderate markets framework and support schemes related issues have been communicated as a barrier in a number of Member States including Denmark, Finland, Hungary, the Netherlands, Portugal and Poland. The issues vary from country to country – from reliability problems and permanent revision of schemes in the Netherlands to a lack of visibility concerning the schemes beyond 2020 in Denmark, or lack of support schemes for new plants in Italy.

In immature markets there are several Member States suffering from lack of incentives for biogas (Bulgaria, Spain, Ireland, Cyprus, Luxembourg), which hampers the access to financing for biogas projects.

Framework and support schemes related issues in the heat sector have been communicated by less Member States, however the problem in this sector can be expected to be more severe, since the number of Member States having no support for heat generation from biogas/biomethane is greater than in the electricity sector (see Section 5).

In contrast to the other two sectors lack of incentives becomes a barrier also in mature markets (Germany, France, Austria) when it comes to the transport sector (see Section 5).

ILUC and sustainability criteria

The second biggest barrier in the electricity sector in mature markets is related to Indirect Land Use Change (ILUC) and sustainability criteria (Sweden, the United Kingdom). This problem has not been communicated by other Member States for the electricity sector. In mature markets ILUC and sustainability issues are also perceived as a barrier in the heat and transport sector. In addition, it hinders biomethane deployment in Poland – the only Member State that communicated this barrier besides mature markets.

The Renewable Energy Directive (RED 2009/28/EC) and the ILUC Directive ((EU) 2015/1513) determine how Member States may fulfil their 10% target of renewable sources in the transport sector by 2020. It classifies biofuels based on the materials used for their production, distinguishing between biofuels from food crops, from waste and residue streams, and advanced biofuels that may be produced from a range of other feedstocks. The contribution of the first generation biofuels, produced from so-called “food crops” is limited to 7% of the total transport fuels. The remaining 3% renewable energy may be produced from other sources. However, the ILUC Directive has not yet been implemented in national legislation. Furthermore, the feedstock used in a biogas unit is composed of different raw materials, which fall under different categories of biofuels.

With regards to sustainability criteria, the United Kingdom industry is concerned about the incorporation of sustainability criteria into the existing support schemes, which might to some extent discourage the use of crops in anaerobic digestion (AD) as well as the UK government’s proposals to limit gas yield from energy crops to 50% (50% non-crop materials). Sweden communicated that the ILUC regulations limit the production of biogas and biomethane from food-based crops, even if these crops are produced in a sustainable way without having an ILUC effect.

Complexity and duration of administrative procedures

In the moderate markets the second biggest barrier for biogas projects in the electricity sector is the complexity (Hungary) and duration (Belgium, Poland) of administrative procedures.

Interestingly, administrative procedures seem to constitute no barrier in other Member States in any of the sectors. It might be explained by the fact that in the mature markets the processes have been optimized over time, while in immature markets too few projects have been implemented so far to see administrative procedures as a huge barrier. Another explanation might be that other barriers are simply more severe than those related to administrative procedures. As already mentioned there is a great number of Member States without any support schemes in place or schemes being currently revised. Therefore, project developers are not keen in starting new projects until new schemes are in place or at least details on them are disclosed. The uncertainty and related risks are simply too high, which leads to another related barrier in immature markets and moderate markets – access to finance.

Access to finance

Access to finance related issues has been identified in all three markets in electricity sector and in mature and immature markets in the heating sector. This barrier is usually a result of several other barriers identified, such as lack of or insufficient stability and reliability of the framework and support scheme(s), lack of strategy, insufficient expertise of stakeholders or negative perception of biogas/biomethane technologies and low public awareness, which result in a difficulty for project developers to receive project financing.

In the electricity sector, access to finance is the second largest barrier in immature markets (Bulgaria, Spain, Croatia, Lithuania) third largest barrier in moderate markets (Belgium, Portugal) and is among key barriers in mature markets (France). In the heat sector, access to finance is the second biggest barrier in mature markets (Czech Republic, France) and perceived as a barrier in Estonia (immature market).

For example, in France the granting of loans is conditioned to high guarantee requirements of banks. In addition, banks require that the biogas project contracts long-term agreements for feedstock supply, which is particularly difficult for operators. In Portugal, high capital costs are the result of uncertainty regarding new support mechanisms. In Estonia, access to finance is aggravated by the relatively low gas demand, which increases the risks of unviable projects.

Perception and public awareness

The third biggest barrier in mature markets in the electricity sector relates to perception and public awareness, identified in the Czech Republic and France. It has an adverse effect on biogas/biomethane deployment also in moderate markets (Ireland and Slovakia). In the heating sector perception and public awareness is perceived as a barrier in all three markets; however mainly in immature markets (Slovenia, Ireland, Estonia). In moderate markets, this barrier has been communicated only in Poland and in mature markets in France. In the transport sector perception and public awareness is the number two barrier in mature markets (Austria, Italy).

The reasons vary from country to county. In France, general lack of knowledge about biogas technologies among financial stakeholders resulting in high guarantee requirements of banks has been communicated as a barrier. In addition, public acceptance causes problems for project developers in France. The opposition is often based on fears regarding odour nuisance or explosion risks of biogas plants. In the Czech Republic, Ireland, Slovakia, Slovenia and Estonia the stakeholders reported this barrier to be related to a lack of political will, and a negative image of renewable energy of politicians and media. In Estonia and the Czech Republic renewable energy is perceived as a financial burden for the energy consumers.

Perception and public awareness was not mentioned to be a barrier in the transport sector in moderate markets. The explanation here might be the fact that biomethane is currently being developed only in few Member States, mainly in mature markets like Germany (178 plants), Sweden (59 plants), the United Kingdom (37 plants), Austria (14 plants), France (8 plants) and Italy (5 plants), but also in few moderate markets like the Netherlands (21 plants), Finland (9 plants), Denmark (6 plants) and Hungary

(2 plants); in immature markets biomethane is produced only in Luxembourg (3 plants) and Spain (1 plant)8.

Lack of a strategy and a long-term perspective

The third biggest barrier in the electricity sector of immature markets is a lack of a strategy and a long-term perspective. It hinders biogas for electricity projects in Lithuania and Slovenia. In Lithuania, lacking long-term national vision for RES is the key barrier affecting biogas/biomethane in all three sectors. This barrier is among key five barriers in moderate markets (Hungary and Poland). Next to Lithuania, it is perceived as a barrier in the heat sector in Portugal and in the transport sector in Hungary. In Portugal, the industry urges the drafting of a Renewable Heat Strategy to boost the ambition and the deployment of the sector. EBA suggests establishing a common EU strategy for heating and cooling sector by the European Commission (EBA, 2016).

This barrier has not been detected in mature markets in any of the sectors.

Treatment of biogas by-products

The fifth barrier in the electricity sector in moderate markets relates to the treatment of biogas by-products (Belgium, the Netherlands); perceived as a barrier also in heat sector in both countries. Treatment of biogas by-products related issues are among the key barriers in mature markets (Austria) as well; however, the barrier does not appear in immature markets.

In Belgium (Walloon and Brussels-Capital) this barrier concerns the legal status of digestate, which represents no less than 90% of the output of an AD plant (the remaining 10% being biogas). The status of the digestate depends on the nature of the feedstock used in the biogas unit. If the feedstock is not waste (e.g. agricultural substrates valued on site), digestate will be regarded as a product; if on the other side the feedstock is classified as waste, the digestate will be regarded as waste and not as a valuable product. Its legal redefinition constitutes a challenge, since waste is regulated by regional as well as by federal regulations, depending on the type of waste. Therefore, only the production of biogas currently contributes to the profitability of a biogas project, while the economic potential of digestate remains untapped. In this regard, the legislation about the value of digestate should be clarified, preferably on the European level, as this will enable producers to sell their digestate where it is most logical to them.

Other barriers

Other barriers that have been communicated for the electricity sector include issues concerning the **access to feedstock** (Denmark, the United Kingdom), **taxing regime** (Latvia) and **remuneration level** (Austria).

With regards to access to feedstock, Denmark reported a problem in finding suitable biomass for supplementing slurry in order to achieve adequate gas production, while the United Kingdom is experiencing problems with availability of especially food waste. Due to a lack of a mandatory food collection in place – notably in England – availability of food waste suitable for anaerobic digestion is limited in the United Kingdom. The industry therefore suggests introduction of mandatory collection of food waste in the United Kingdom.

[8] These numbers refer to the year 2014 and come from the EBA Biomethane & biogas report 2015 (EBA, 2015).

In immature markets key barriers include also **expertise and stakeholder efforts** related issues (Croatia, Romania, Bulgaria). The problem in these countries relates to a lack of knowledge and expertise among potential investors, farmers, and producers.

If barriers are more or less similar in the electricity and heat sector, some new barriers have been identified in the transport sector.

First, the **EU and national goals** related barriers. This is a barrier in all three markets (Sweden, the Netherlands, Spain), and typically relates to the first two barriers mentioned above. Spain communicated insufficient national targets in the transport sector as the main barrier for the development of biofuels. Sweden stressed the need for ambitious goals at EU level, because Sweden has already reached the 2020 RES-target for transport of 10%. Also the Netherlands highlighted the uncertainty about post-2020 EU biofuel policy. Since in most Member States the national incentives are the direct result of the EU policies for biofuels, the uncertainty about the post-2020 goals might work as a deterrent for producers and investors. Goals beyond 2020 are needed to provide certainty in the long-term perspective to the industry and encourage them to expand the deployment of gaseous biofuels.

Taxing regime related barriers are also among key barriers in all three markets, especially in immature markets (Bulgaria, Spain, Lithuania). Both Lithuania and Bulgaria highlighted the need in and importance of the excise duty exemptions for biomethane. In Lithuania excise duty relief for biomethane has been removed from January 2016. That beneficial tax regulations can be a good driver can be demonstrated by the good practice examples of Finland or Sweden and therefore it is urged by the industry across number of Member States to introduce or maintained them.

Finally, Sweden communicated **mass balance rules in RES directive** related concerns. A high number of end-consumers in Sweden favour 100% biomethane, especially as a transportation fuel and many of them would not accept a mixture of biomethane and natural gas. Therefore, Sweden sees as highly important that the EU regulations continue to allow mass balancing methodology in relation to biomethane blended with natural gas. Today sustainability properties, as well as economic incentives such as tax exemption, are following the biomethane from the point of injection into the natural gas grid and all the way to the final consumer. This has been a major prerequisite to biomethane market development. Without mass balancing methodology, it is believed that the biomethane market would not continue to develop extensively in Sweden.

2.6 Biogas production technologies

Two different biogas production systems exist: dry digesters and wet digesters. Wet digesters have water as the continuous phase, whereas dry digesters have biogas as the continuous phase. Dry digesters are used if substrates are 'dry' and cannot be mixed easily (think of roadside grass or garden waste). Otherwise the wet system is most preferred. Dry systems are in a 'niche' market and need to be competitive with wet systems because, after size reduction, almost any substrate can be treated in a wet system.

At least four types of wet digester systems are applied:

- mixed tank systems;
- mixed tanks in series;
- plug flow systems;
- systems with sludge retention.

Mixed tanks in series are currently most often applied. Plug flow systems have similar costs and achievements, while single mixed tanks are phased out. The two stage digester is currently most often applied. In addition to the types described above, several types of wet systems with sludge retention are applied. These systems are used to treat industrial wastewater (from the agro-food industry) or sludge from aerobic wastewater treatment systems. The biogas production of these is not expected to grow as the amount of waste is limiting. Waste reduction measures may even reduce the production of biogas from these units.

Biogas may be burnt in a Combined Heat and Power (CHP) unit. Typical CHP units have 40% electrical efficiency and 50% heat efficiency. The remaining 10% is lost with the off gases via the chimney. In many occasions, not all heat is applied as no suitable year around demand for heat use is available. Part of the heat is used to heat the digesters. Usually the CHP unit consists of a gas engine. If high temperature heat (steam) is demanded, also gas turbines (with lower electrical efficiency) may be applied.

For biogas upgrading four different methods are used:

- washing: a liquid removes CO_2; this can be based on a temperature or pressure swing;
- cryogenic: cooling and compressing such that CO_2 is removed as a liquid;
- vacuum pressure swing adsorption (VPSA): Packed bed absorbs CO_2;

  membranes: CO_2 or methane permeates through selective membrane (depending on applied membrane).

2.7 Cost

The costs of biogas production are highly depending on the substrate used. Easily digestible substrates (such as energy crops) are more expensive but require less investment costs as energy crops have high energy density and fast production of biogas, resulting in smaller biogas reactors. Difficult substrates on the other hand, are cheap (often with a negative price) but require large investment costs.

It is important to realize that wet substrates produce large amounts of digestate. This digestate needs to be distributed in the surrounding agricultural area or needs to be cleaned to specifications of dischargeable water. The costs of distribution or water treatment are directly related to the volume. The price at the gate of the farmland is very dependent on the local circumstances. In some areas farmers will pay for the organic carbon and nitrogen and phosphorous in the digestate. In other areas (where a nitrogen and/or phosphate surplus exist, such as in the Netherlands and Belgium, but, as a consequence also in the border areas of their neighbouring countries: France and Germany), the farmers will actually receive a gate fee for the distribution of digestate on their land. In these areas the addition of crops may significantly add to the costs of digestate distribution.

The lump sum costs for biogas upgrading are around 0.2-0.31€/Nm^3 CNG independent of the applied method (Valorgas, 2012). The investment costs are 2,700 €/(Nm^3/hr) raw gas and the operating and maintenance costs are 270 €/(Nm^3/hr) raw gas per year. The costs of upgrading are said to decrease with increasing scale to a value of 0.012 €/(kW·hr) at 2,000 Nm^3/hr. The lump sum costs may be calculated from the total cost of upgraded biogas production minus the cost of biogas production (0.063 €/(kW·hr) – 0.053 €/(kW·hr)) = 0.01 €/(kW·hr) (Zuijlen and Lensink, 2015).

2.8 Infrastructure

Concerning infrastructure, the following four parameters were researched:

- availability of gas or even biogas pipelines;
- existing gas storage (buffers);
- infrastructure for natural gas, Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG) for vehicles;
- gas quality.

All in all, it can be concluded that almost all EU Member States have gas infrastructure and storage in place, as well as a natural gas infrastructure for transport, and gas quality regulations. These are clearly important prerequisites for biomethane deployment and growth. There are two exceptions, namely Malta and Cyprus, the two small island country Member States, where there is no natural gas infrastructure available. Cyprus, however, has projects to exploit its own natural gas reserves by 2022, and has initiated designing and constructing a natural gas network along with a natural gas storage facility. In addition, there are countries such as Croatia that do not have gas storage facilities due to the low demand for natural gas in the country.

Countries such as Austria, Denmark, Finland and the Netherlands have the most positive prospects concerning the further deployment of biogas/biomethane in the future. Those countries do not only have sufficient infrastructure available, but there also seems to be willingness to further boost biogas and biomethane production in the future. Characteristically, the Netherlands expects a significant contribution to the future energy mix from the direct feed-in of biomethane into the natural gas grid, namely 24 PJ in 2020. Clearly, besides the four issues listed above, other favourable conditions also need to exist for biomethane production and use to increase.

The availability of **infrastructure for CNG or LNG for vehicles** depends on the policy priorities of each EU member State. There are countries such as Germany and Italy where there is a great number of CNG stations available (925 and 1,022 respectively). However, in Italy their number is not sufficient to satisfy the fuel demand of the existing fleet. Relative to the size of the Member State, Austria has an extensive network of CNG fuelling stations (177), while the same is true for Sweden (218 CNG stations). Apart from that, in Finland, the share of biomethane in the methane/CNG mix in transport sector amounted to 30% in 2015 (IEA Bioenergy Task 37, 2016). This was mainly due to the fact that the price of CBG presented the lowest cost energy option in motorized transport costing EUR 0.77 per gasoline litre equivalent (due to government support). However, other EU Member States show a moderate performance on that field, as many of them have only initiated the process of creating the necessary infrastructure.

2.9 Inter-EU trade

The cross-border biomethane trade related issues have been analysed in several recent projects and reports, such as the BIOSURF project (BIOSURF, 2016) and the EBA Biomethane & biogas report 2015 (EBA, 2015). Biogas trade is negligible.

Initially, biomethane has been traded mainly at a national level only. However, gradually it becomes a cross-border commodity that is traded between EU Member States. Nevertheless, cross-border biomethane trade is still very limited. Internationally biomethane is mainly traded through physical road transport rather than using the natural gas grid. An example could be the existing trade between Switzerland and Germany, where 110 GWh of biomethane were exported from Germany to Switzerland in 2014 (EBA, 2015).

The main problems hindering cross-border trading is the current wording of the Renewable Energy Directive (2009/28/EC), which makes it difficult to trade biomethane injected into the grid within a Member State and among the Member States. This is due to traceability requirements and in particular the mass balancing system that was included in the Directive with a focus on liquid fuels, which is less suitable for the trading of biomethane that has been injected into the natural gas grid (BIOSURF, 2016).

When biomethane is used as a fuel in transport it has to meet the sustainability criteria set in the RED. In addition, there are traceability rules. While there is a common understanding how to use these rules for liquid biofuels, with regards to biomethane to be injected into the grid application of these rules remain unclear. The biomethane can be traced up to the moment of the injection into the grid, after which it is blended with the natural gas.

Cross-border trade in biomethane is more difficult if there is a number of country specific quality requirements. In particular, this might be a barrier where different verification procedures are in place in different Member States. Note that this problem concerns only sustainability criteria additional to those set by the EU. The EU sustainability criteria for biofuels and bioliquids have to be implemented by all Member States through the voluntary schemes approved by the European Commission. (BIOSURF, 2016).

To solve this problem, the BIOSURF project suggests to strictly separate sustainability requirements for biomethane as traded commodity from the additional requirements (e.g. noise or odour emissions, etc.) that are important for the operation of the production plants for example, the conversion of biomethane into an end product or for the treatment of digestate that resulted from the production processes. Those additional requirements could be regulated at Member State level and should not be linked to the use of biomethane or financial support granted for the use of biomethane. For this solution, however, mandatory sustainability criteria for gaseous biomass, especially used in the heat and power sector, is an important prerequisite. With mandatory criteria in place, there would be no need for country specific additional sustainability criteria for biomethane as traded commodity, nor for production of biogas (BIOSURF, 2016).

Another issue is that Member States can exclude certain feedstock for biomethane production (e.g. from support schemes). As a result, biomethane produced has different quality, which also aggravates the cross-border trade. Here again, mandatory sustainability criteria at EU level would be helpful (BIOSURF, 2016).

EBA suggests international harmonization of Guarantees of Origin (GoO) certification systems to enable import and export of biomethane across Member States. Initial steps towards harmonization have already been taken by national biomethane registries in place in several countries including Germany, Denmark, Austria, France, the United Kingdom and Switzerland. It has to be noted, however, that all these countries have a strict mass balancing system and do not allow a separate trade of the physical gas and GoO beyond boundaries between balancing zones. To resolve these issues, EBA suggests considering European gas grid as one balancing zone (EBA, 2015); (BIOSURF, 2016).

3 Biogas policies

Similar to the Member State policies, EU policies relevant to biogas development in the EU span a large range of topics and sectors: renewable energy, climate change, agriculture, waste, transport and (natural) gas regulations and policies all impact biogas. Some of these policies impact the use of specific feedstocks, others only specific end-uses, biogas production or upgrading facilities. Any of these may support or, in some cases, hamper biogas developments, and should therefore be considered when assessing policy options to further support or accelerate biogas developments.

3.1 Key EU policies

The following provides an overview of the key EU policies and regulations relevant for the topic of this study, categorized by issues[9].

Renewable energy

A number of EU directives are in place that promote the use of renewable energy, including biogas. The main directive in this respect is the **Renewable Energy Directive** (2009/28/EC), in 2015 amended with the **ILUC directive** ((EU) 2015/1513). The RED sets, inter alia, binding targets for the share of renewable energy in both total energy and transport energy use of a Member State. Bioenergy, biofuels and biogas also count towards these targets. In addition, the RED defines sustainability criteria for biofuels and bioliquids, incl. bio-CNG (compressed biomethane). Annex V of the RED provides default and typical values for GHG emission savings for three bio-CNG routes (from municipal organic waste, from wet and dry manure). Biogas/biomethane produced from waste streams may count double towards the transport target, providing an additional incentive above biogas and biofuels produced from energy crops. A list of feedstocks which do not fall under the cap on food-based biofuels introduced in the ILUC Directive is provided in Part A of Annex IX. These include manure, landfill and sewage sludge, but also cover crops and algae cultivated on land in ponds or photobioreactors.

The **Clean Power for Transport** package and resulting directive (2014/94/EU) lays out a comprehensive EU alternative fuels strategy, and aims to increase the deployment of refuelling stations for both CNG (in urban/suburban and other densely populated areas by 2020, and along the TEN-T core network by 2025) and LNG (for shipping and heavy-duty vehicles, by 2025). These developments can be seen as a prerequisite for growth of the market share of CNG and LNG vehicles and ships, as thus for increasing market opportunities for the use of biomethane in the transport sector.

Another relevant EU policy is the **State aid guidelines for environmental protection and energy** 2014-2020 (2014/C 200/01). These aim to gradually introduce market-based mechanisms as a replacement for subsidies to RES, and set a number of guidelines for RES support schemes that also apply to biogas, including the core principle of the waste hierarchy[10], and provide a number of specific guidelines for support of biogas production and upgrading, as well as for biogas use for transport (in Annex 2) and for state aid for cogeneration and district heating.

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[9] Only the key elements relevant for biogas deployment are included here. For more detail, we refer to the directives and regulations itself.

[10] From 2014/C 200/01: (118) State aid for energy from renewable sources using waste, including waste heat, as input fuel can make a positive contribution to environmental protection, provided that it does not circumvent that principle.

Climate change

Many of the Member States support biogas as part of their climate policies. The most relevant EU level directives in this respect are the EU Emission Trading Directive (EU ETS Directive; 2003/87/EC) and the Effort sharing agreement for the non-ETS sectors.

The **Effort sharing agreement for the non-ETS sectors** defines GHG reduction targets per Member States, for all emissions that are not included in the ETS. This includes, for example, the emissions from natural gas used in the build environment, emissions from transport fuels and agriculture, and from land use and land use change. Reducing GHG emission from land fill and manure by using these as sources for biogas production thus contributes to these targets, as does the use of biomethane as a transport fuel.

The **ETS** applies the ‘cap and trade’ principle to the amount of greenhouse gas emissions that can be emitted by installations covered by the system. If biogas is used for energy production in these installations, it is considered to be zero-emission, and no emission allowances are required for this part of the GHG emissions.

The **Fuel Quality Directive** (FQD) sets, inter alia, GHG reduction targets for road transport fuels, and increasing the share of biomethane in transport fuel sales can contribute to this target. Since a well-to-wheel approach is used in this directive, biomethane with higher well-to-wheel GHG savings (e.g. from biogas produced from manure) contribute more than biomethane from energy crops.

Agriculture

The **Common Agricultural Policy** (CAP) encourages, through its rural development measures, the production of biogas (anaerobic digestion plants using animal waste), to substitute fossil fuel and reduce methane emissions from the animal waste (COM(2008) 306 final). The EU’s Nitrates Directive (91/676/EEC) aims to reduce water pollution from agricultural sources and fertiliser consumption. The **Fertilisers Regulation** (from 2003) ensures free movement in the single market mainly for conventional, non-organic fertilisers, typically extracted from mines or produced chemically, but does not address organic fertilisers, thus hampering EU cross-border trade of digestate.

Waste

EU regulations on **waste** and, to some extent, **recycling** are also relevant to biogas production, mainly because they determine in part the availability of landfill as a source for biogas and of other suitable feedstock, including sewage sludge and biowaste.

Natural gas

A number of regulations and directives mainly intended for natural gas, notably those on infrastructure and trade, also apply to biomethane:

- Common Rules for the Internal Market in Natural Gas Directive (2009/73/EC);
- Regulation on Conditions for Access to the Natural Gas Transmission Networks (715/2009/EC).

These directives ensure non-discriminatory access to the gas system taking into account the necessary quality requirements and provided such access is permanently compatible with the relevant technical rules and safety standards.

3.2 EU Policy outlook

Most of the current EU directives on renewable energy and climate define targets for 2020, not beyond. However, investments in biogas production, conversion or use would need to be profitable also beyond 2020 to achieve an attractive return on investment. The outlook regarding directives, regulations and policies for beyond 2020 is therefore crucial for biogas developments in the coming years.

- In 2014, the European Council agreed on a framework for the 2030 climate and energy policy framework, which includes, inter alia, the following conclusions.
- A binding EU target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990, with the reductions in the ETS and non-ETS sectors amounting to 43 and 30% by 2030 compared to 2005, respectively.
- Reforming of the ETS, and a change of the annual factor to reduce the cap on the maximum permitted emissions from 1.74 to 2.2% from 2021 onwards.
- The European Council invites the Commission to further examine instruments and measures for a comprehensive and technology neutral approach for the promotion of emissions reduction and energy efficiency in transport, for electric transportation and for renewable energy sources in transport also after 2020.
- An EU target of at least 27% is set for the share of renewable energy consumed in the EU in 2030.
- An indicative target at the EU level of at least 27% is set for improving energy efficiency in 2030 compared to projections of future energy consumption based on the current criteria.

The European Commission has been and is working on a number of proposals for directives on both climate and energy policies until 2030. Some of these were published earlier in 2016, other are expected near the end of 2016 or early 2017. These include:

- ETS and the effort sharing agreement for non-ETS sectors;
- energy efficiency and renewable energy policies beyond 2020;
- sustainability criteria for solid and gaseous biomass in the electricity and heat sector policies;
- a communication by the Commission on decarbonisation of transport.

In addition, a Circular Economy Package and roadmap are being developed. The latter is expected to include capping of landfilling, and a revision of Fertilisers regulation to include digestate. Increased EU focus on heating and cooling can provide additional incentives for local use of biogas for heating.

As part of the EU’s Circular Economy Package, published by the Commission at the end of 2015, a number of legislative proposals on waste were published. With the overarching objective formulated as ‘Turning waste into a resource is an essential part of increasing resource efficiency and closing the loop in a circular economy’, these included a number of issues relevant for biogas, such as a binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030, a ban on landfilling of separately collected waste, measures to promote re-use and stimulate industrial symbiosis. In March 2016, a new proposal for a regulation was published that aims to significantly ease the access of organic and waste-based fertilisers to the EU single market, bringing them on a level playing field with traditional, non-organic fertilisers.

State aid guidelines for the period after 2020 are also to be expected. The current guidelines state that ‘*These Guidelines … should prepare the ground for achieving the objectives set in the 2030 Framework. Notably, it is expected that in the period between 2020 and 2030 established renewable energy sources will become grid-*

competitive, implying that subsidies and exemptions from balancing responsibilities should be phased out in a degressive way.'

The many new regulations and communications for the period after 2020 can be crucial to the longer term developments of biogas in the EU. Ambitious GHG savings and RES targets may provide strong incentives for Member States to enhance (and continue) their biogas support policies.

3.3 Member State support schemes

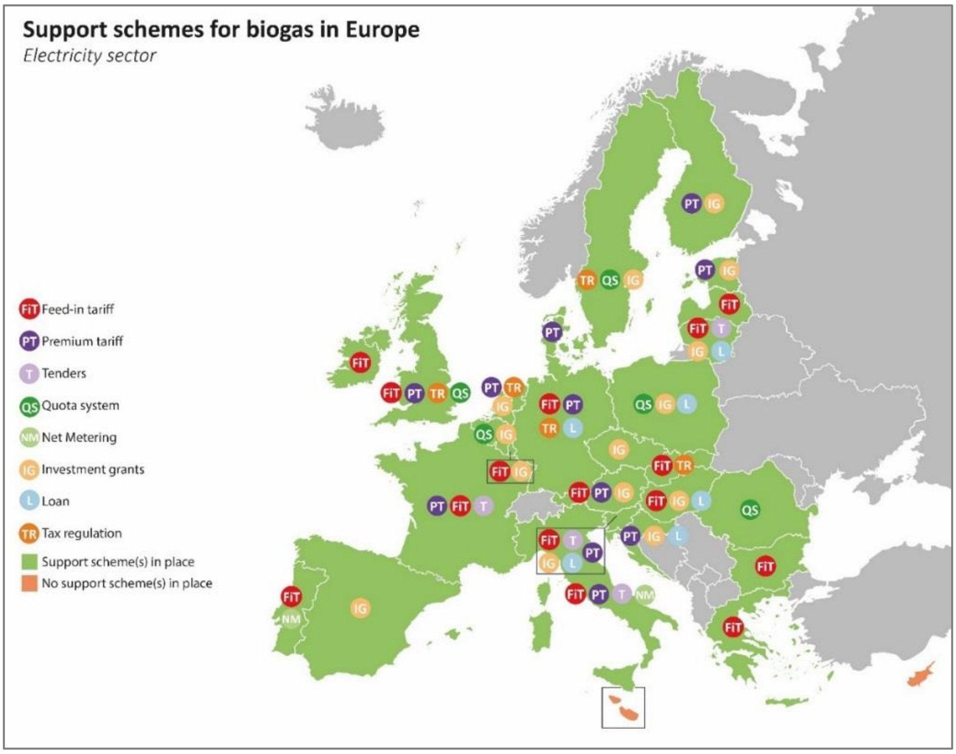
In this section, an overview is provided of the support schemes for biogas and biomethane throughout the EU. More information on support schemes can be found in the country factsheets included in Appendix A of this report.

3.3.1 Electricity sector

The variety of financial incentives and policies supporting biogas and/or biomethane across the EU is shown in Maps 1-5 below. In the electricity sector, the most widespread schemes for biogas include the Feed-in Tariff and Feed-in Premium schemes as well as grants and loans.

The **Feed-in Tariff** as main support scheme is still applicable in Bulgaria, Greece, France, Hungary, Ireland, Luxembourg, Portugal, and Slovakia (see Map 1). In Bulgaria, Portugal, Ireland and Latvia feed-in tariffs are currently not available for new renewable plants. In Latvia, the Feed-in Tariff scheme is under revision since 2011 due to concerns about corruption and a lack of transparency. A new support scheme is awaited, but not earlier than the end of 2018.

Map 1 Support schemes for biogas in the EU in the electricity sector



The **Feed-in Premium** is the key support scheme in Denmark, Estonia, Finland, Croatia, the Netherlands and Lithuania. Under this scheme a premium is granted on top of the market price of electricity, which shall compensate the difference between the price of electricity from renewable sources (base amount) and the wholesale price for electricity. In Lithuania, no new applications are currently accepted as the legally set cap on feed-in premium payments for biofuels, covering biomass and biogas (105 MW by 2020) has already been reached.

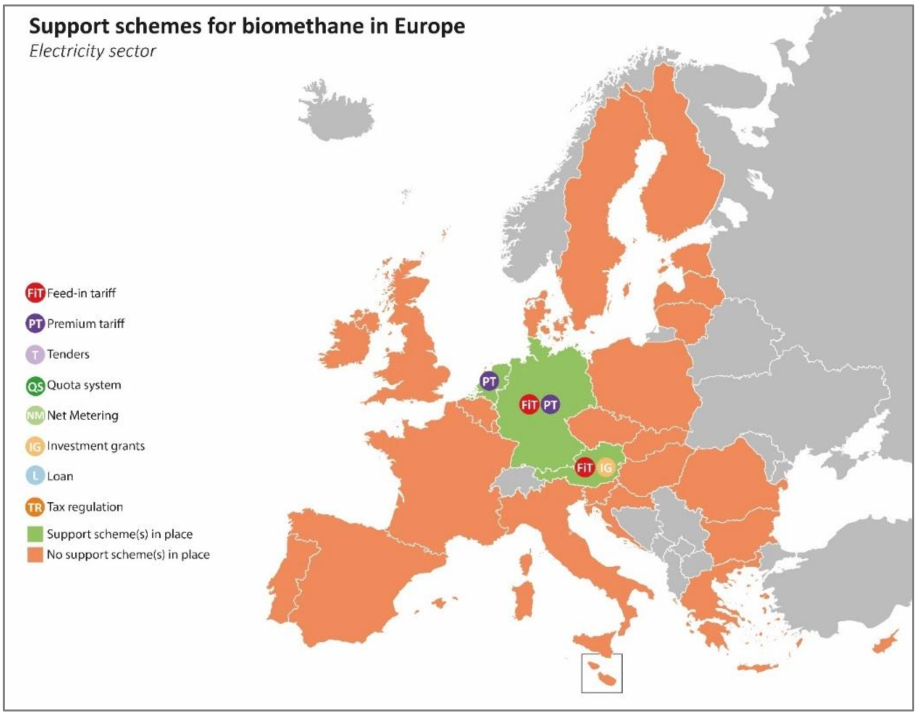
In France, Austria, Germany, Italy, and Slovenia biogas is supported through **both Feed-in Tariff and Feed-in Premium**. France and Germany are currently implementing the shift to feed-in tariffs and feed-in premiums in combination with a tender and Slovenia revises feed-in tariffs and feed-in premiums into a tender process.

A Quota system is in place in Belgium, Poland, Romania, and Sweden. In Belgium, quota system is applicable in all three regions. In Sweden, it is the main support scheme for renewable electricity.

The United Kingdom applies a mix of several support schemes for biogas for electricity generation. Biogas is mainly supported through a Feed-in Tariff and the quota system called 'Renewables Obligation' (RO). From 15 January 2016 all new installations applying for feed-in tariffs are subject to a new system of caps. From April 2017 the RO will close to all new capacities. Since 2014, a financial instrument called Contracts for Difference (CfD) (a Feed-in Premium scheme) is in place in Great Britain (in 2016 to be introduced in Northern Ireland). From April 2017, the CfD will be the only support scheme for RES projects over 5MW.

In a great number of Member States biogas projects are eligible for **grants** or **loans**. In addition, some Member States support electricity from biogas with tax regulations. Contrary to most European biogas markets tax regulation mechanism is one of the most important support schemes in Sweden. Biogas currently receives 100% reduction of energy and CO_2 tax.

Map 2 Support schemes for biomethane in the EU in the electricity sector



In contrast to biogas, biomethane in the electricity sector is barely supported in EU Member States (see Map 2).

There is currently no support scheme for the promotion of biogas or biomethane in the electricity sector in Cyprus, and there seems to be no intentions for the introduction of such a scheme in the future. In Malta, no support measures for the promotion of biogas have been currently and historically in place. Due to a lack of space, the development of energy crops for biogas production is not considered suitable for Malta.

3.3.2 Heat sector

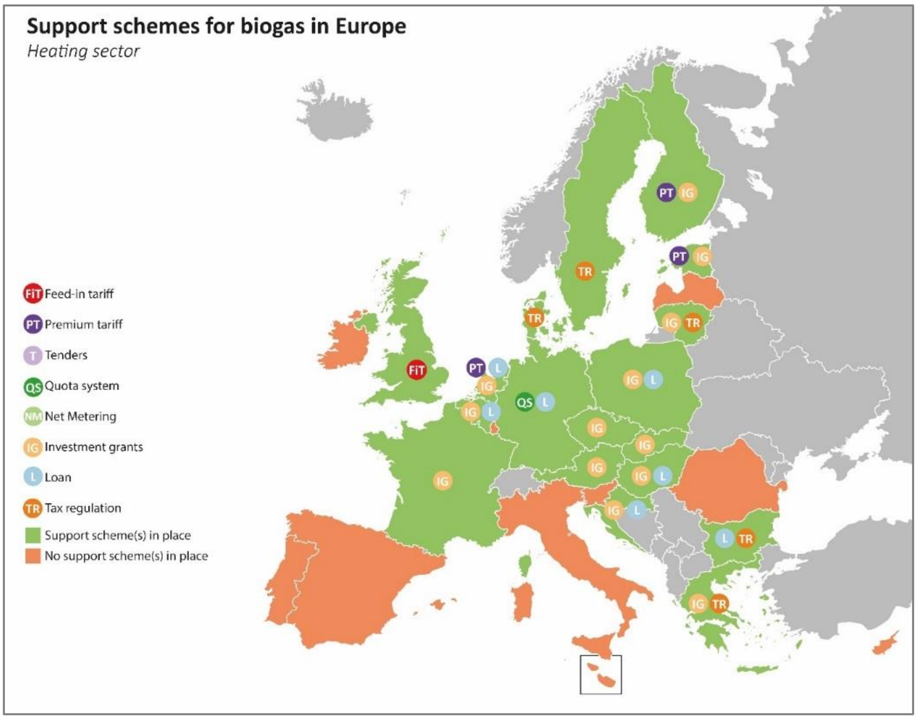
Compared to the electricity sector, biogas in the heating sector is supported less frequently (see Map 3). If no support schemes for electricity generation from biogas are currently in place only in Cyprus and Malta, heat generation receives no support also in a number of other Member States including Spain, Ireland, Italy, Luxembourg, Latvia, Portugal, Romania and Slovenia.

By far the most widespread schemes in the heat sector to support biogas are grants (12 Member States), followed by loans (7 Member States) and tax regulations (5 Member States).

Feed-in Premium in the heat sector is currently applied in Austria, Estonia, Finland, and the Netherlands. In Austria, CHP is an outstandingly fostered technology, which is reflected through a supplementary premium to the basic feed-in tariff (CHP bonus).

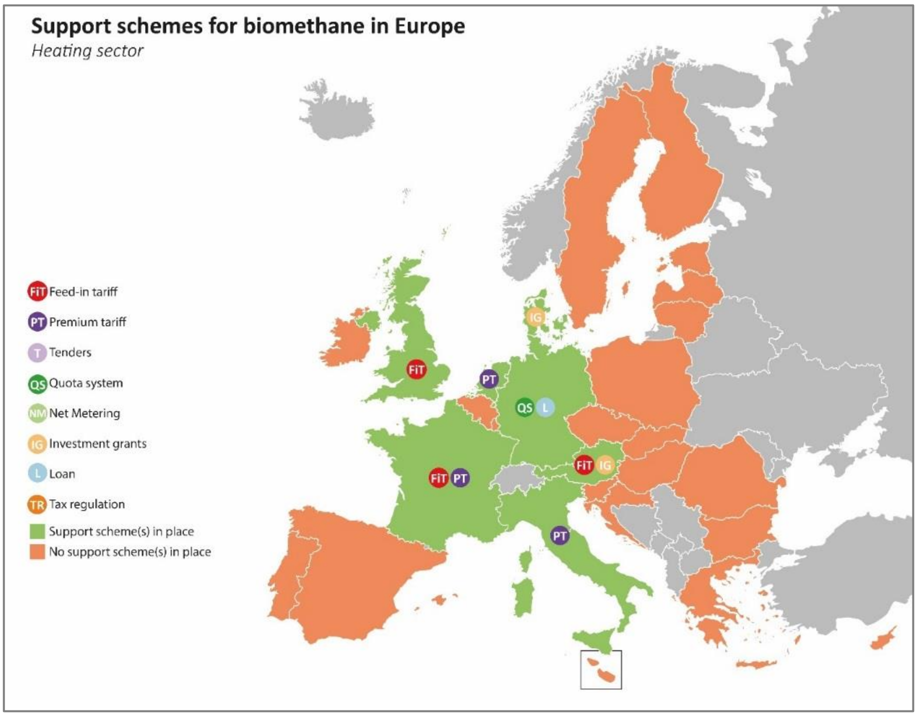
The only Member State applying **Feed-in Tariff** in the heat sector - the so-called 'Renewable Heat Incentive' – is the United Kingdom. The scheme supports biogas combustion and biomethane injection into the gas grid with a fixed tariff per kWh produced. The scheme is available in Great Britain only; in Northern Ireland it was closed to new applicants in March 2016.

Map 3 Support schemes for biogas in the EU in the heating sector



In contrast to biogas, biomethane is supported more in the heat than in the electricity sector (see Map 4).

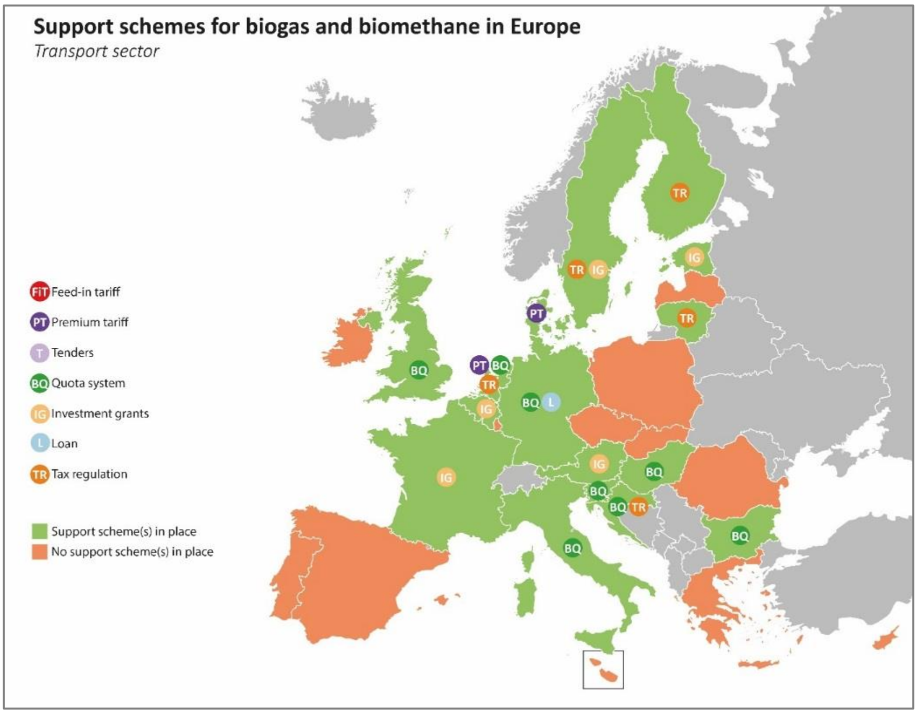
Map 4 Support schemes for biomethane in the EU in the heating sector



3.3.3 Transport sector

The most applied incentive to support biogas and biomethane in the transport sector is the biofuel quota. Biomethane as a fuel in vehicles is covered by this scheme in 8 Member States (See Map 5).

Map 5 Support schemes for biogas and biomethane in the EU in the transport sector



When looking at Maps 1-5, it becomes obvious that biogas across EU Member States is mainly supported in the electricity sector, while support for biomethane has its focus on the transport sector.

While only two Member States (Cyprus and Malta) have no support for biogas for electricity generation, in the heat and transport sectors the number of Member States without any kind of support is much higher: 10 in the heat sector and 12 in the transport sector.

3.3.4 Significant variations in support policies and sustainability requirements

Clearly, biogas support policies vary significantly between Member States and the same holds for the sustainability requirements for eligibility of the support. This can be illustrated with the following illustrative examples of the current diversity of policies and criteria within the EU (status mid 2016), for a number of countries that either fall into the mature or the moderate market category[11].

Biogas in **Austria** is supported mainly through a feed-in tariff. Among the preconditions for the receipt of the tariff are the following requirements:

- CHP plants shall reach an overall efficiency of at least 60%.
- The tariff is only granted if pure agricultural substrates and animal manure with a share of >30% are deployed. If other input materials are used, the tariff will be cut by 20%.
- For CHP-plants operating on the basis of biogas, the feed-in tariff applying for biogas is granted with an additional premium of € 0.02 per kWh if certain criteria of efficiency according to the Act on CHP are fulfilled.

France also uses a feed-in tariff to support renewable electricity. Biogas plants are eligible to the feed-in tariff during 15 years with a number of restrictions, including the requirement that the biogas shall be produced through the pyrolysis or fermentation of substances and waste from agriculture, forestry and related industries, or through the treatment of water, or from domestic waste through the use of biogas. The feed-in tariff for existing biogas plants depends on the capacity, with a lower tariff for larger plants than for plants with lower production capacity. A bonus can be granted for biogas plants using a share of at least 60% livestock manure. A similar scheme (but with slightly different levels of support) is expected for new plants in the near future.

For larger scale plants support is allocated via a tender scheme allowing for a financial compensation guaranteed over 20 years. Feedstock requirements focus on waste streams, the share of food crops shall not exceed 15% per ton of feedstock.

A Heat Fund is implemented to support heat use, e.g. biogas projects using cogeneration of electricity and heat, biogas projects with heat recovery and upgrading to biomethane for grid injection or use as biofuels. Under this fund, CHP project requirements include a minimum operating time of 6,550 hours per year, and a minimum level of annual energy efficiency (of 55% for CHP plants and 80% for boilers and the injection into the gas grid).

[11] This overview is not intended to be complete, the Member State policies are typically too complex and extensive to reproduce here.

Finland provides a premium tariff on top of the wholesale electricity price for a period of 12 years for producers of electricity from biogas, with several requirements. An additional subsidy of EUR 50/MWh as a heat premium on top of the basic subsidy is provided, if the efficiency minimum of the plant is at 50 or 75% if the nominal capacity of generator exceeds 1 MVA.

In **Germany**, small renewable electricity (RES-E) plants up to 100 kW and put into operation after 31 December 2015 are promoted under the Feed-in Tariff scheme. A Market Premium scheme is the main support scheme for electricity from renewable energy sources. A number of special provisions and restrictions for biogas generated from the anaerobic fermentation of biowaste and from the fermentation of manure are in place for both measures, including a capacity limit, an obligation to employ CHP technology and the amount of manure used to produce the biogas is at least 80 mass percent.

The **Netherlands** has implemented the SDE+ scheme which supports biogas-related renewable electricity production for a number of categories, including electricity generated from sewage gas using thermal pressure hydrolysis (a treatment to make sewage waste fermentation more effective), CHP generation using gas from all-purpose fermentation with a nominal electricity capacity of at least 20% of the total nominal capacity, CHP using gas from mono-fermentation of animal manure, and CHP using gas from co-fermentation of animal manure with a nominal electricity capacity of at least 20% of the total nominal capacity. Biogas-related renewable heat production is eligible under the SDE+ scheme for heat generation using gas from mono-fermentation of animal manure, from co-fermentation of animal manure or from gas from all-purpose fermentation. Similarly, biomethane production is eligible under the SDE+ scheme for a number of categories.

In addition, the Dutch manure legislation lists substrates allowed for co-digestion[12].

The **United Kingdom** supports biogas via the Renewables Obligation, Feed-in Tariff scheme and the Renewable Heat Incentive. These policies include sustainability criteria such as a minimum level of GHG savings and land criteria (demonstrating the feedstock came from pre-existing agricultural land are sufficient).

[12] The list can be found at: http://wetten.overheid.nl/BWBR0018989/2016-09-16#BijlageAa

4 Biogas scenarios until 2030

To assess the potential impacts of enhanced biogas deployment in the EU in the period until 2030, four scenarios were developed. These scenarios are used to make a number of ambitious but realistic projections of the biogas and biomethane availability, production costs and CO_2-equivalent emission reductions in 2030.

This chapter first discusses the methodology, and the scenarios that were developed. Then the key aspects are presented of the CE Biogas model that was developed to quantify the potential developments and assess the various impacts. The results of the scenarios are presented and evaluated in the next chapter.

More details on the scenarios and the model can be found in Appendix B.

4.1 Methodology

Four scenarios were developed based on a number of overarching story lines to identify the main variables that drive future developments, taking into account possible policy contexts. The scenarios aim to be realistic and in line with the current status and developments. They have a common starting point: the status quo of 2014, and then cover the ‘corners of the playing field’ of potential biogas developments in the EU until 2030. The scope of the scenarios is biogas production by digestion of local waste streams.

The effects of the scenarios are calculated by the CE Biogas model per feedstock, Member State and time period. This model uses the current feedstock deployment of 2014 as a basis (as presented in Section 2.3) and data for feedstock potential (discussed below in Section 4.3.1). The biogas production and upgrading technologies listed in Section 4.3.2) are implemented in the model together with a learning curve for the investments costs and efficiencies of these technologies (Section 4.3.4).

As the amount of ‘energy crops’ (e.g. maize) is virtually unlimited from a technical point of view, its utilization is expected to be limited by the future sustainability policies. Initially, in the feedstock volumes used in the scenarios no additional use of energy crops was assumed, given expected future sustainability constraints. During the course of the project, however, it was decided to use a different approach because of the large differences among Member States in market maturity and current use of maize in digesters. To keep the energy crops volumes at 2014 levels would imply that some Member States would stay at a high level of energy crops in the scenario calculations, whereas others would have to remain at zero. This would not reflect a realistic situation. Therefore, in the scenario calculations it was assumed that maize is only used in co-digestion with manure in at least a mass ratio of 80% manure and 20% maize. The potential amount of maize is thus determined by the assumptions regarding the amount of manure used for co-digestion (i.e. following the feedstock potentials). The result is a limited growth for maize use in digesters in the scenarios for those Member States that have large growth potentials for manure as feedstock for digesting.

To evaluate the effects of the scenarios, a reference situation was adopted in which the situation of 2014 is assumed to remain constant over time. Comparing results of the scenarios with this reference situation allows us to clearly distinguish between the developments that are assumed in the scenarios. In the next Chapter the results and the evaluation of the scenarios will be provided.

4.2 High level scenario design

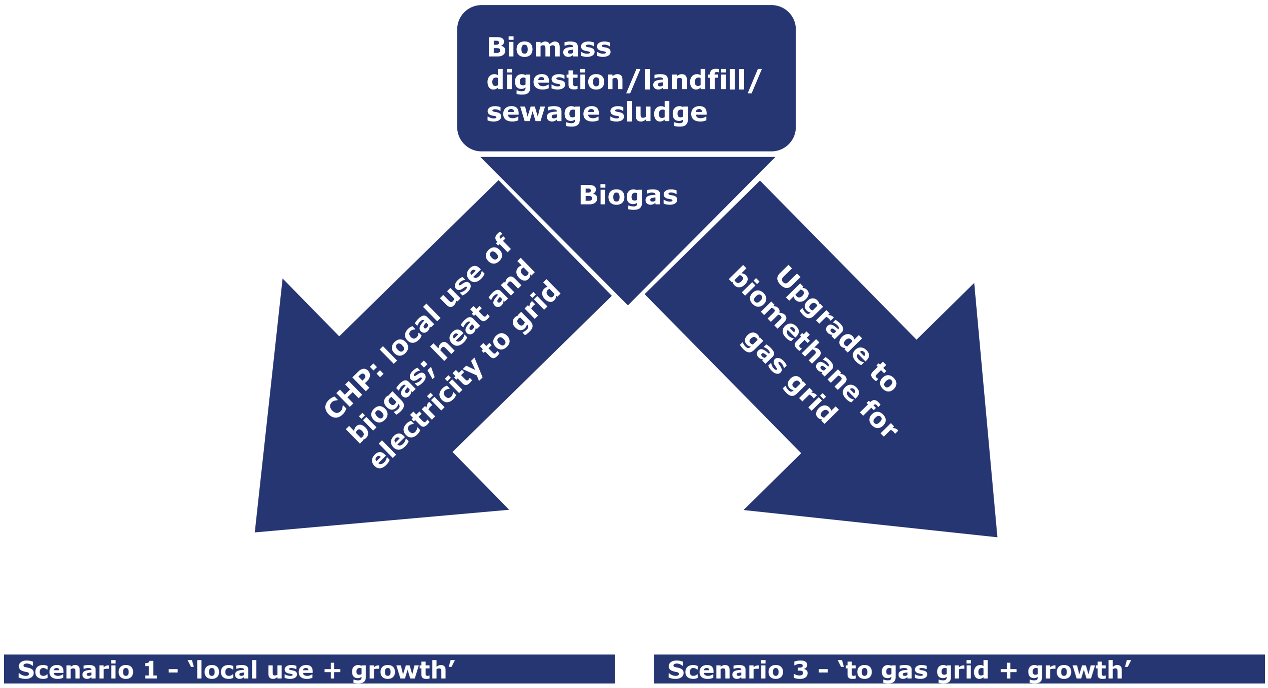
4.2.1 Main parameters to vary

The main parameters of the four scenarios are embedded in the story lines from which the scenarios are derived. The story lines of the scenarios are developed around two main potential market developments.

Firstly, the local production of biogas will in most cases be more than the local demand for biogas (or heat) at or near the production site. This results in a need to value the local excess biogas, either by producing electricity and heat with a CHP locally ('local use') or by upgrading to biomethane at natural gas quality ('to gas grid'). In the first case, the produced electricity can be fed into the electricity grid and the heat can be used in the production process (for example), in the second case biomethane can be fed into the natural gas grid. These possible value chains – around local use of biogas in a CHP and around production of biomethane – serve as one axis for the scenarios.

The other axis is the pace of deployment of biogas production together with the pace of innovation. Here, we have defined a 'growth' trajectory and an 'accelerated' growth development pace.

The developments along both axes are to a large extent driven by government policies. The axes and the scenarios are illustrated by the figure below.



Focus on value chain of *local use* of biogas: production of *electricity and heat* + *regular deployment* pace and *regular learning curve*	Focus on value chain of *replacement of natural gas* + *regular deployment* pace and *regular learning curve*
Scenario 2 - 'local use + accelerated'	**Scenario 4 - 'to gas grid + accelerated'**
Focus on value chain of *local use* of biogas: production of *electricity and heat* + *accelerated deployment* pace and *accelerated learning curve*	Focus on value chain of *replacement of natural gas* + *accelerated deployment* pace and *accelerated learning curve*

Clearly, Scenarios 1 and 2 are related, as are 3 and 4. Each scenario pair varies in deployment pace and technology development (learning curve) but not in biogas/biomethane usage types, allowing us to explore the potential benefits of future innovation in the biogas sector. Similarly, this approach allows us to explore the impact of different choices in end-use of the biogas, by comparing Scenario 1 with 3, and 2 with 4.

A number of key parameters follow from the axes of the scenarios, such as:

- the feedstock deployment pace, related to the improved collection and use of available organic waste streams suitable for digestion (growth or accelerated growth), based on the 'Reference 2030' potential presented in Section 4.3.1 for growth and the 'Accelerated deployment 2030' potential for accelerated growth;
- technological development or innovation, described by a learning curve (regular or accelerated learning curve);
- end-use of the biogas, including the share of biogas that is upgraded to biomethane.

These will vary between the scenarios, and are described in more detail in the following section.

A number of other important parameters are kept the same for all scenarios:

- Feedstock deployment per digestion or conversion technology. For example, manure can be digested in a mono-digester or together with energy maize in a co-digester. This will affect the production costs of biogas, since mono-digestion is currently more expensive then co-digestion, as well as GHG emissions. Assumptions on the technology deployment per feedstock were made, which were the same for all scenarios.
- The ratio maize versus manure in co-digesters is also not varied between scenarios. The impacts of variation of this specific ratio are, however, explored in a sensitivity analysis.

Appendix B provides an overview of the assumptions for the key variables in the model, including details on the assumptions mentioned above.

Table 2 Overview of the key scenario features

	1: local use, growth	2: local use, accelerated	3: to grid, growth	4: to grid, accelerated
Biogas volume	+	++	+	++
Biomethane volume	=	=	+	++
Costs biogas/biomethane	=	Accelerated learning curve	=	Accelerated learning curve
Feedstock use				
Wastes	Enhanced	Strongly enhanced	Enhanced	Strongly enhanced
Manure	Enhanced	Strongly enhanced	Enhanced	Strongly enhanced
Energy crops	Use in 2014, plus max 20% in co-digestion	Use in 2014, plus max 20% in co-digestion	Use in 2014, plus max 20% in co-digestion	Use in 2014, plus max 20% in co-digestion
Landfill	Enhanced, and according to landfill directive	Enhanced, and according to landfill directive	Enhanced, and according to landfill directive	Enhanced, and according to landfill directive
End-use	▪ renewable electricity ▪ local use of bio-heat	▪ renewable electricity ▪ local use of bio-heat	Use of biomethane as replacement of natural gas e.g. in: ▪ built environment (heat) ▪ transport sector (bio-CNG, bio-LNG)	Use of biomethane as replacement of natural gas e.g. in: ▪ built environment (heat) ▪ transport sector (bio-CNG, bio-LNG)
Policy focus	Stimulation of: ▪ biogas production ▪ GHG-reduction ▪ local use	Enhanced stimulation of: ▪ biogas production ▪ GHG-reduction ▪ local use Combined with strong innovation policies for biogas production	Stimulation of: ▪ biogas production ▪ GHG-reduction ▪ upgrading to biomethane Focus on replacement of natural gas	Enhanced stimulation of: ▪ biogas production ▪ GHG-reduction ▪ upgrading to biomethane Focus on replacement of natural gas and strong innovation policies for biogas & biomethane production

In the next sections, the storylines of the individual scenarios, the policy context and the main assumptions are presented.

4.2.2 Scenario 1: Local use + electricity

This scenario focusses on a value chain of local use of the produced biogas, by production of electricity and heat using cogeneration (CHP). The heat produced is used locally (if possible), the excess electricity is fed into the electricity grid. This local use maximises the production of renewable energy (heat and electricity) from the available biomass feedstock potentials against the lowest cost, because no extra investment steps and accompanying conversion losses are involved (e.g. for biogas upgrading, grid injection, etc.).

This implies that:

- renewable energy production from biogas will increase compared to 2014 levels;
- biogas use focusses on local use, for electricity and heat production;
- deployment of biogas production is assumed to grow, following the growth of feedstock used for biogas production;
- innovation rate is assumed to be regular.

In this scenario, it is assumed that the main driver for future biogas growth and support is the aim of Member States to use biogas locally in the electricity and heating sectors with high energy efficiency, optimizing the contribution of the available biogas to the renewable energy target.

Policy context

The developments of this scenario are driven by government policies (at different levels) throughout the EU.

- Member States and regional/local policies effectively drive the conversion of suitable biomass waste streams to digestion, and subsequently to the production of renewable energy (heat and electricity);
- the EU defines sustainability criteria for biogas which include, inter alia, a minimum level of GHG savings, and effectively prevents ILUC due to biogas production.

Key assumptions

- government policies effectively achieve that biogas production increases over time, until the full sustainable biogas production of the '2030 reference potential' is reached in 2030 (see Section 4.3.1), in all Member States;
- government policies focus on most cost-effective option for renewable energy production from biogas, from societal perspective;
- local use of biogas, with 100% application in CHP;
- on average 25% of the nett heat production (net heat production = heat production by the CHP minus the heat demand of the digester) is effectively used as replacement of heat production by boilers using natural gas;
- 'regular' innovation rates on investment costs and feedstock to biogas yield (see Section 4.3.4).

4.2.3 Scenario 2: Local use + electricity, with accelerated deployment and innovation

This scenario focusses, as Scenario 1 (Local use + electricity, see above), on a value chain of local use of the produced biogas, by production of electricity and heat using cogeneration (CHP). But in this scenario, accelerated deployment of the biogas production is assumed, together with accelerated innovation rates, both as a result of strong policies targeting biogas production and R&D for these specific technologies.

Compared to Scenario 1, this implies:

- Faster growth rates for the production of biogas.
- Steeper learning curves for existing technology both on efficiency and on cost, leading to lower cost and emissions per unit biogas.
- More feedstock can be deployed in the period to 2030 than in Scenario 1. The upper values for the feedstock potential are used.

The main driver/reasoning for this scenario is the same as in Scenario 1: to use biogas locally in the electricity and heating sectors with high energy efficiency, optimizing the contribution of the available biogas to the renewable energy target.

As in the first scenario, biogas production and use are assumed to be mainly local and regional scale projects, i.e. focus on local and regional feedstocks and local and regional use of the biogas.

Policy context

The developments of this scenario are driven by government policies (at different levels) throughout the EU similar to those in Scenario 1, but with additional or stronger policies and accompanied funding for faster deployment of biogas production, and stronger policy support for R&D.

Key assumptions

- government policies effectively achieve that biogas production increases over time, until the full sustainable biogas production of the '2030 accelerated deployment potential' is reached in 2030 (Section 4.3.1), in all Member States;
- strong policy support, with focus on most cost-effective option for renewable energy production from biogas, from societal perspective;
- local use of biogas, with 100% application in CHP;
- on average 25% of the nett heat production (net heat production = heat production by the CHP minus the heat demand of the digester) can be effectively used as replacement of heat production by boilers using natural gas;
- accelerated/enhanced innovation rates on investment costs and feedstock to biogas yield, compared to Scenario 1.

4.2.4 Scenario 3: Biomethane to grid

The main driver/reasoning for this scenario is the desire to use the biogas to replace fossil fuels in applications where other sustainable alternatives are scarce: for heating in the built environment and industry (via the natural gas grid) and use as a transport fuel, to replace diesel. This helps the EU and the Member States to reduce their dependence on fossil fuel also in those sectors and applications. It can also be seen as a step towards further developing and strengthening the biobased economy, replacing the industry feedstock natural gas by biomethane. In this scenario an increasing share of biogas is converted to biomethane of natural gas quality, for use elsewhere. This biomethane can be injected into the gas grid or distributed separately (e.g. via trucks) to be used for example in heavy-duty transport when converted to bio-CNG or bio-LNG, for heating in specific areas in the existing built environment or in high temperature processes in industry; three sectors with relatively few options for renewable energy. This could be the result of a targeted EU market mechanism to reach the EU-wide RES target in 2030, and/or of the Member State's individual policy strategies to implement the EU-wide target.

This scenario can also result in increasing cross-border trade of biomethane within the EU, since the share of biomethane in the natural gas grid increases.

Policy context

This scenario assumes the following policy strategy.

- Member State and regional/local policies support biomethane injection into the gas grid and/or biomethane consumption in the sectors listed above (for example by supporting its use in heavy-duty transport);
- strong EU renewable energy policy, driving this Member State policy (to achieve an EU-wide focus on these routes);
- strengthening of the EU's alternative fuels in transport policies, including support to the roll-out of a (bio-)CNG and/or LNG fuelling infrastructure;
- further alignment of the EU's renewable energy policy framework to biomethane injection into the grid, including harmonisation of cross-border trade regulations.

Key assumptions

- focus on upgrading of the produced biogas to natural gas quality and injection in the gas grid;
- biogas production increases over time, until the full sustainable biogas production of the '2030 reference feedstock potential' is reached in 2030 (see Section 4.3.1);
- driven by government policies on all levels;
- use of the biomethane for applications where other sustainable alternatives are scarce;
- enhanced roll-out of LNG fuelling infrastructure for heavy-duty vehicles (HDV), and increasing shares of LNG-fuelled HDV;
- innovation rates on investment costs and feedstock to biogas yield as regular;
- this scenario is in general modelled as 100% upgrading of biogas to biomethane for the gas grid. Variations on this scenario are 100% upgrading to bio-CNG or bio-LNG.

4.2.5 Scenario 4: Biomethane to grid, with accelerated deployment and innovation

This scenario focusses, as Scenario 3, on conversion to biomethane as means to replace natural gas in those applications for which sustainable alternatives are scarce. However, in this scenario, accelerated deployment of the biogas/biomethane production is assumed, together with accelerated innovation rates, both as a result of strong policies targeting biogas production and R&D for these specific technologies.

Compared to Scenario 3, this implies:

- Faster growth rates for the production of biogas and, thus, biomethane.
- Steeper learning curves for existing technology both on efficiency and on cost, leading to lower cost and emissions per unit biogas and biomethane.
- More feedstock can be deployed in the period to 2030 than in Scenario 3. The upper values for the feedstock potential (see Section 4.3.1) are used.

The main driver/reasoning for this scenario is the aim of Member States to use biomass and biomethane optimally to reduce their dependence on natural gas and diesel and to further develop and strengthen the biobased economy.

This scenario may also result in an increasing cross-border trade of biomethane within the EU, since the share of biomethane in the natural gas grid increases.

Policy context

The developments of this scenario are driven by government policies at different levels throughout the EU, as they are in Scenario 3, but with additional policies and accompanied funding for faster deployment of biogas/biomethane production, and strong policy support focused on R&D.

Key assumptions

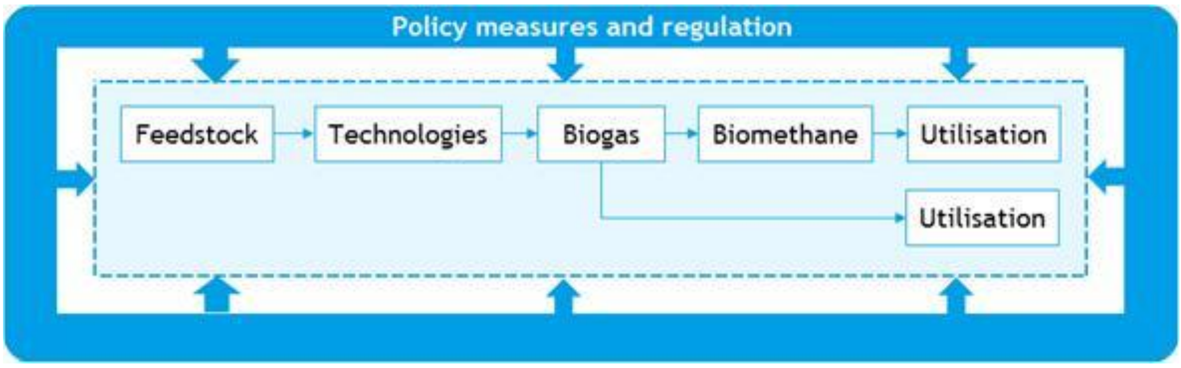
- focus on upgrading of the produced biogas to natural gas quality and injection in the gas grid;
- biogas production increases over time, until the full sustainable biogas production of the '2030 accelerated deployment potential' is reached in 2030 (see Section 4.3.1;
- driven by government policies on all levels;
- use of the biomethane for applications where other sustainable alternatives are scarce;
- enhanced roll-out of LNG fuelling infrastructure for heavy-duty vehicles, and increasing shares of LNG-fuelled HDV;
- accelerated/enhanced innovation rates on investment costs and feedstock to biogas yield, compared to Scenario 3;
- this scenario is in general modelled as 100% upgrading of biogas to biomethane for the gas grid. Variations on this scenario are 100% upgrading to bio-CNG or bio-LNG.

4.3 Biogas model and scenario implementation

The CE Biogas model is an Excel- and VBA-based calculation model to calculate the effects of biogas scenarios per feedstock, EU Member State and time period. The model uses a feedstock and technology database filled with the necessary data on feedstocks and technologies as discussed in the following Sections and Appendix B. Learning curves are implemented in the model to account for the effect of learning by innovation on investment costs, conversion efficiencies, electricity consumption and methane loss.

In the model calculations it is assumed that all new available feedstocks per Member State in a given period are digested or converted to biogas. The biogas is then upgraded to biomethane, or directly used in a biogas CHP. Figure 12 illustrates the model building blocks and calculation sequence on a schematic level. This results in a staged procedure, where the calculations concerning the production of the biogas are separated from the calculations concerning the biogas upgrading and utilisation.

Figure 12 Schematic view of the building blocks and calculation sequence of the model, from feedstock to utilisation of the biogas and biomethane



4.3.1 Feedstock potentials

The estimates of the feedstocks' potential availability for biogas production are sourced from the Biomass Policies project (Elbersen, 2016). In that project several scenarios have been presented, from which we selected the Reference and High bioenergy & global sustainability scenario. The first was assumed to be representative for the two 'Growth' scenarios of this project; the latter was used as a basis for the two 'Accelerated Deployment' scenarios. The high bioenergy global sustainability scenario builds on the Energy Roadmap 2050-Primes high RES scenario; it involves strict sustainability and resource efficiency criteria, in the EU and globally.

From the Biomass Policies database, 20 feedstocks types for anaerobic digestion have been identified to estimate biomass potential for biogas production for 2020 and 2030, which were summarised in six groups:

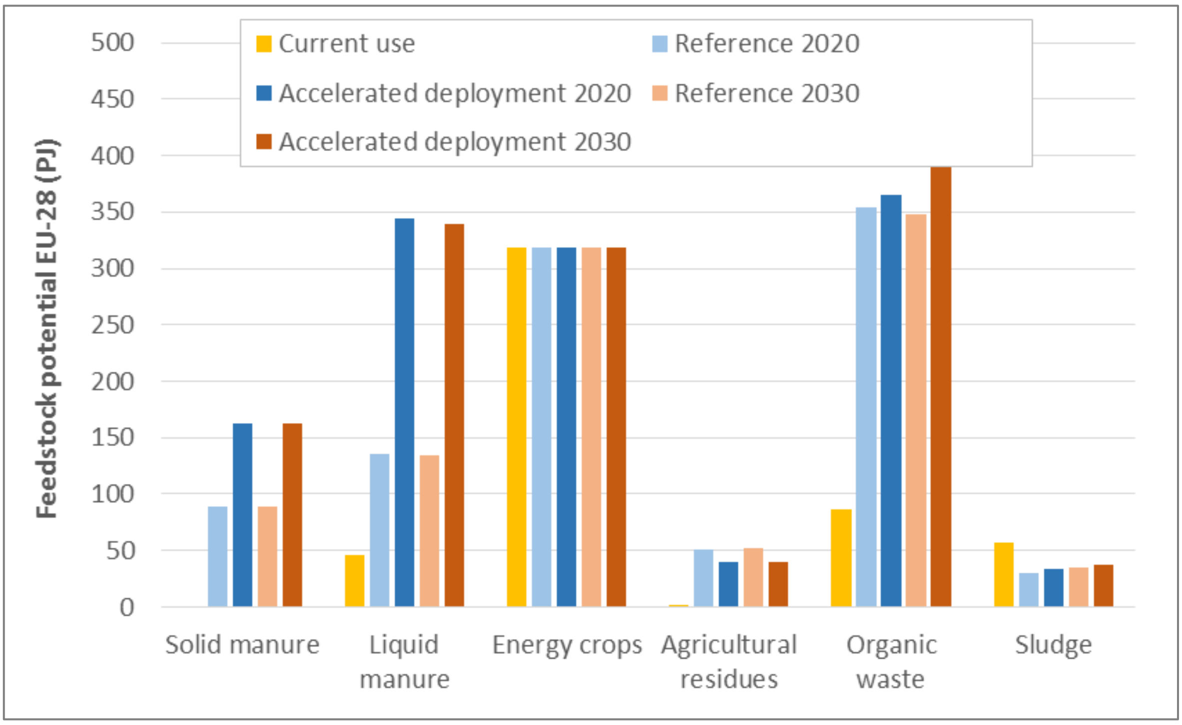
1. Energy crops (energy maize, and forage grass cuttings).
2. Solid manure (solid manure from poultry, cattle, pigs, goats and sheep).
3. Liquid manure (liquid manure from cattle and pigs).
4. Agricultural residue streams (residues from sunflower, rapeseed, sugar beet tops, and road-side verges).
5. Organic waste (from households: Animal & mixed food waste, vegetal waste, municipal solid waste; Other sources: Animal & mixed food waste, vegetal waste, municipal solid waste, and used animal fats and vegetal oils). And
6. Sludge.

For manure updated calculations were made of the potential, based on data from MITERRA-Europe model. In the Reference scenario all liquid manure and 50% of solid manure from farms with >200 livestock units is considered. In the High bioenergy & global sustainability scenario all liquid manure and 50% of solid manure from farms with >50 livestock units is considered.

Figure 13 shows the current feedstock use together with the feedstock potentials for 2020 and 2030 for these two feedstock scenarios. New potential feedstocks such as cover crops/intermediate crops, sea weed and algae were not included in the potentials, as EU-wide data is lacking and especially for sea weed and algae it is still very uncertain whether these feedstocks can be produced at a cost-effective large scale manner.

As discussed in Section 4.1, the amount of maize was assumed to be limited in scenario calculations, due to future sustainability constraints. The feedstock potentials are calculated based on the assumption that maize is only used in co-digestion with manure in at least a mass ratio of 80% manure and 20% maize. The level of maize in the feedstock potential is thus determined by the assumptions regarding the amount of manure used for co-digestion (i.e. following the feedstock potentials).

Figure 13 Current feedstock use and potentials for 2020 and 2030 based on two scenarios (PJ)

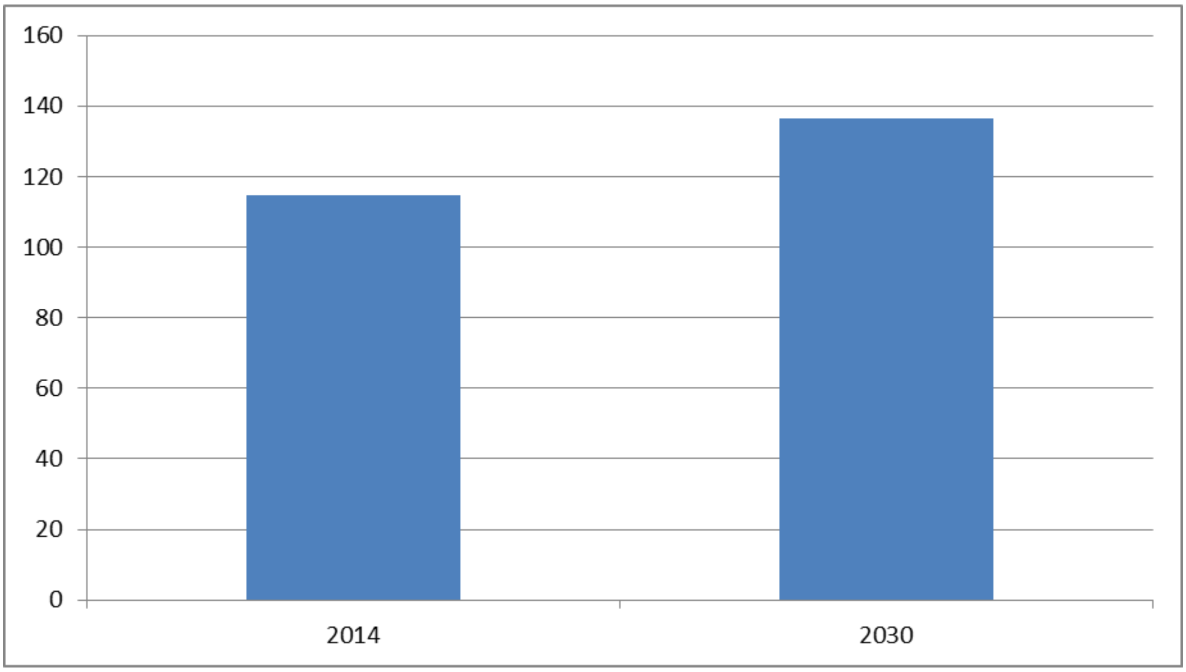


For solid and liquid manure and organic waste still a large potential for biogas production is available, whereas for sludges the current use is already estimated to be higher than the future potential. This might be due to uncertainties in the data, assumptions on better use of wastes over time which will reduce sludge volumes, or differing assumptions in the biogas yield. In any case, it indicates that there is no large feedstock potential for increase in biogas production from sewage sludge (and using current technologies).

The total additional feedstock potential in 2030, excluding energy crops and landfill, is estimated at 470 PJ in the 'Reference' scenario and 890 PJ in the 'Accelerated Deployment' scenario. This potential might increase in the future if new feedstock sources such as cover crops and sea weed are included, but it is very uncertain whether these feedstocks can be used for biogas in a cost-effective manner in the time period to 2030.

The landfill gas potential for 2030 per Member State is taken from SERPECC (SERPECCC, 2009) and shown in Figure 14. For the landfill gas production in 2014 we used the data of EurObserv'ER 2015 (EurObserv'ER, 2015). The methane emissions from landfill reported by SERPECC are the theoretical maximum, it is not sure whether these can be fully recovered and used as biogas. At least it is hard to do this economically in all cases. In the model calculations we therefore assumed a 95% utilization.

Figure 14 Landfill gas potentials in 2014 and 2030 for EU 28 (PJ)



SERPECC used a business as usual baseline scenario, based on projection of municipal solid waste and biodegradable waste to landfill by EEA Topic Center on Waste and Resources (based on economic and demographic assumptions in the PRIMES baseline). Furthermore, they assumed implementation of the Landfill Directive in all Member States (Council Directive 1999/31/EC of 26 April 1999). This directive requires a reduction of the biodegradable municipal solid waste (BMSW) landfilled by Member States (35% in 2016 compared to 1995 levels). Note that this does not necessarily mean no new landfill sites.

The emissions of BMSW show an exponential decay of biomethane production as a function of time, so waste landfilled in previous years, still result in emissions in future years (emissions are released over a period up to 30 years). This is the reason why, even when landfilling of BMSW is highly reduced, methane production from landfill sites is still possible in 2030. In case this production is not utilized as biogas, it will be released into the air. In 2014 not all landfill gas is extracted and converted to biogas, so also on already existing landfill sites there is a future potential for biogas utilization.

The feedstock potentials for digestion presented above are the leading parameters of the scenario assessment; these determine the new investments, production costs and productions volumes in the period 2014-2030. The feedstock potentials are different for the deployment of the 'growth' and 'accelerated' growth scenarios: 'Reference 2030' potential is used for 'growth" and the 'Accelerated deployment 2030' potential for 'accelerated' growth. It is assumed that in 2030, the full feedstock potentials are used in each scenario. A linear interpolation of the potentials between 2014 and 2030 is used to calculate the new capacity that is installed each year.

4.3.2 Technologies

As was described in Section 2.6, a range of biogas production systems are in use throughout the EU. In the scenario and model calculations the following technologies are included:

- non-specific digestion;
- mono-digestion;
- co-digestion;
- sewage sludge digestion;
- landfill gas cleaning.

Other technologies incorporated in the model are:

- upgrading of biogas to biomethane;
- compression of biomethane to bio-CNG;
- liquefaction of biomethane to bio-LNG;
- biogas and clean landfill gas CHP.

These technologies all have their own process characteristics (e.g. energy input, efficiencies) and cost associated with them. Details about the main technological assumptions can be found in Appendix A. This Appendix also includes a number of key assumptions on feedstock deployment per technology.

4.3.3 Cost and GHG reduction calculations

Costs are calculated over the production chain, taking into account the investments in new capacity, substrate costs where relevant, annual O&M costs and electricity costs where relevant (e.g. electricity used for gas compression)[13]. GHG emissions are also calculated 'from well-to-wheel', i.e. using a life cycle approach.

For each two-year period, the production costs of new invested capacities are calculated, as are the GHG emission effects of the added production. In case of decreasing feedstock potentials, the model calculations account for decreasing biogas production volumes, GHG emissions and operational costs (excluding O&M costs since existing investments have to be maintained). This occurs in some specific countries, for example due to changing demographics. The total production volumes of biogas or biomethane in a specific year are then calculated by adding this new production to the existing volumes of 2014. Production costs of existing capacities are not included, since details of the historic investments are unknown. Moreover, the aim of this study is to provide policy recommendations. Since the costs of already existing production facilities are in fact sunken costs, we concentrated on the costs of new production facilities in the scenario evaluations.

The GHG emission effects are then calculated for the feedstocks and chain emissions, mainly due to electricity consumption and methane slip. For maize we used the emission factors determined by JEC[14] (whole maize plant) excluding compression to bio-CNG (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014), to ensure alignment with other EU calculations. For the other feedstocks, where no JEC emission factors were available, the emission calculations were based on the data in our feedstock and technology database.

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[13] Cost of grid expansion or biomethane road transport are not included, these differ significantly between projects, depending on the local and regional circumstances, and average cost factors are unknown.

[14] We assumed that all manure feedstocks have the same emission factor equal to the JEC emission factor for wet manure.

In the specific situation when the biogas is used in a CHP, part of the heat produced by CHP is used for heating the digester tank. Nevertheless, there is a net heat production from the combined installation (digester + CHP). In determining the electricity production costs by CHP it is assumed that 25% of the nett heat produced can be put on the market, and the other 75% of the net heat is lost. This may be a pessimistic assumption for specific cases or countries where much more of the net heat can be used, but might be very optimistic when looking at the (average) EU level, taking into account the large volumes of biogas that are produced in the scenarios, often at remote locations where there is not a large heat demand.

In the scenarios, it is assumed that the heat is sold at the price of producing the same amount of heat produced with a natural gas boiler. The heat which is sold on the market is accounted as a revenue to the costs of producing electricity by the CHP installation. The nett costs of the whole chain – digestion and the generation of electricity by cogeneration – is used to calculate the production costs of electricity.

4.3.4 Learning curve: cost reduce over time, and process efficiencies increase

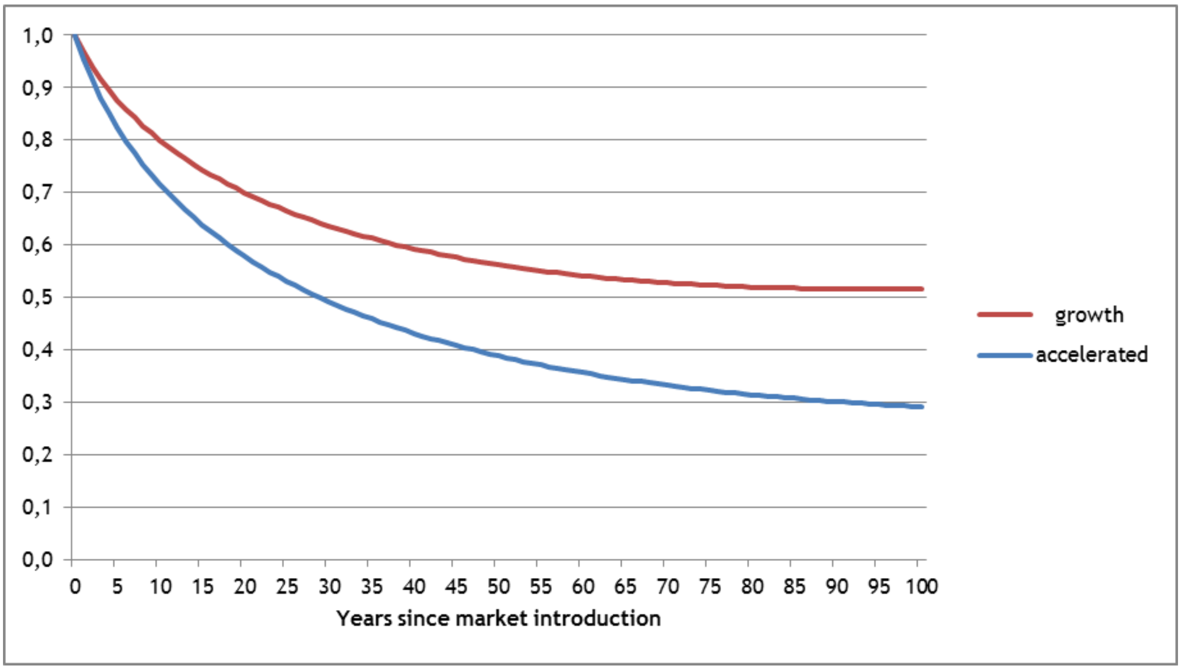
Learning curves represent the effect that technology costs per unit capacity or unit energy decrease as a function of time, as the market grows. In a strict theoretical approach, the costs per unit are represented as a function of market volume. In the calculations for this biogas study, we used cost curves as a function of time, using typical cost curve shape adopted from well documented wind farm investment cost reductions (Junginger, 2005). For the biogas 'growth' and 'accelerated growth' scenarios, different initial slopes of the learning curve were assumed; representing different innovation rates, see Figure 15.

The learning curves provides the cost reduction as a function of time. To the right end side, the technology gets more mature and the curve flattens out, whereas at the left end side, the curve is steep. In the model, the cost reduction as a function of time of each specific technology is calculated by placing each technology on its own starting point on the curve in the year 2014, based on the amount of years from the market introduction of the technology. Relatively young technologies, with large cost reduction potentials, are thus placed on the steep left part of the curve, whereas mature technologies, with small cost reduction potentials, are placed on the flat right part of the curve. The same approach is used to calculate improvements of the conversion efficiency and reduction of electricity consumption and methane loss over time.

The learning curve was furthermore used for digestion, resulting in the assumption that the biogas yield[15] per feedstock will increase to 110% of the 2014 yield in 2030 in the 'growth' scenarios and to 120% in the 'accelerated growth' scenarios. For other technologies we assume about 20% reduction in the cost, conversion efficiency and electricity consumption between 2014 and 2030.

[15] The biogas yield of a feedstock indicates the amount of biogas that can be generated from a certain amount of feedstock. New processes or technologies, e.g. pre-treatment, might be able to extract more biogas from the same amount of feedstock, thus increasing the yield.

Figure 15 General learning curves used in the model



4.3.5 Fuels replaced

In all scenarios, it is assumed that biogas/biomethane replaces a fossil fuel, which depends on the end-use application of the biogas/biomethane. The GHG emissions avoided by replacing these fuels are subtracted from the life cycle GHG emissions calculated for the biogas-based fuels in the model, and cost of the replaced fuels are subtracted from the biogas or biomethane cost.

In the GHG calculations, we assumed that biomethane replaces natural gas in the gas grid if used for heating, while electricity replaces the average production mix of electricity of a Member State as forecast in the EU reference scenario 2016 (EU PRIMES, 2016). The average mix is chosen here rather than a specific energy source because in these scenarios the electricity is produced in CHP units that run on continuous basis, in line with the operation of the digesters. No biogas storage is assumed. CHP units therefore replace whichever type of power production has marginal cost at a given point in time, and can be ramped down or curtailed. This could be any type of power production, including renewable energy sources if RES-E production is high. Since this varies over time and per Member State, it was decided that the electricity mix would be the best choice in our calculations. We also performed the GHG reduction calculations using the fossil electricity production mix in every Member State (taken from PRIMES, 2016), to show the effect of the assumption.

Biomethane consumption in transport, as bio-CNG and bio-LNG, are assumed to be used in road transport and replace diesel (taking into account different efficiency factors for the different types of vehicle engines).

In the case of CHP, it is assumed that 25% of the net heat produced can be put on the market; the other 75% of the net heat is lost[16]. The heat is sold at the price of producing the same amount of heat with a natural gas boiler with an efficiency of 97%. GHG emission reductions take into account the replaced electricity in the

[16] Nett heat is the gross heat production minus the heat consumed in the digestion process.

Member States electricity mix (again based on Primes 2016 Reference scenario), and the reduced GHG emissions of avoided natural gas consumption of the heat sold (50.81 $gCO_{2\text{-}eq}/MJ_{heat}$).

An overview of the key assumptions is provided in Table 3.

Table 3 Replaced fossil fuels and the emission factors used

Sector/application	Fuel assumed to be replaced by biogas/biomethane	Emission factor of the replaced fuel (gCO_2-eq/MJ)
Transport (bio-CNG, bio-LNG)	Diesel, using an efficiency factor to compare fuel efficiency of diesel with CNG (0.91 MJ_{diesel}/MJ_{CNG}) and LNG (1.11 MJ_{diesel}/MJ_{LNG}) (CE Delft, ECN and TNO, 2013)	95.10 (Council of the European Union, 2015)
Biomethane at natural gas quality in gas grid	Natural gas	49.36
CHP (cogeneration of electricity and heat)	Natural gas Electricity (production mix)	49.36 Variable (EU PRIMES, 2016)

In view of the large uncertainties in the future cost development of these energy sources, the 2014 EU-average prices are used in the cost calculations, based on 2014 Eurostat data: 9.5 €/GJ is used for the average EU natural gas price; 27.78 €/GJ for electricity and 15.70 €/GJ for diesel (average prices of Q3 and Q4 of 2014).

Alternatively, it might be argued that biogas/biomethane replaces a renewable energy source (wind, solar, biofuel, etc.), taking the viewpoint that Member States aim for an overall renewable energy target: more investments in biogas then result in less investments in other RES. However, this approach has not been chosen here: in this study the biogas/biomethane routes are assessed based on their own merit, the study does not aim to provide a direct comparison with other RES options.

Note that these assumptions are quite crucial to the calculations of the effects of the various scenarios and biogas-to-end-use routes.

4.4 Key output from the modelling

For each scenario, a range of output data is calculated per two-years interval. Data is calculated at Member State level, and aggregated to EU28-level. The outputs are:

- biogas production volume per feedstock and digestion technology (ktoe);
- biomethane production volume (ktoe);
- CHP heat and electricity generation (ktoe);
- life cycle GHG emissions (tCO_2-eq) and emission reduction (reduction %);
- biogas, biomethane, bio-CNG and bio-LBG production costs per technology, excluding taxes and levies (€/ktoe).

These results are presented in the next Chapter.

5 Scenario evaluation

In this chapter the main results of the scenario calculations discussed in Chapter 4 are provided and evaluated. For each scenario, a number of key parameters are assessed:

- biogas production volume potential;
- production costs of biogas;
- production costs of bio-electricity (from CHP) and of biomethane;
- greenhouse gas emission reduction potentials;
- fossil fuels replaced;
- biogas contribution to RES deployment in the EU.

In addition, in Section 5.8 we briefly discuss the impact of maize/manure ratio in co-digestion on GHG emissions of the produced biogas.

The results of these calculations indicate what would happen if the feedstock potentials that were identified are fully utilized, exploring 'the corners of the playing field'.

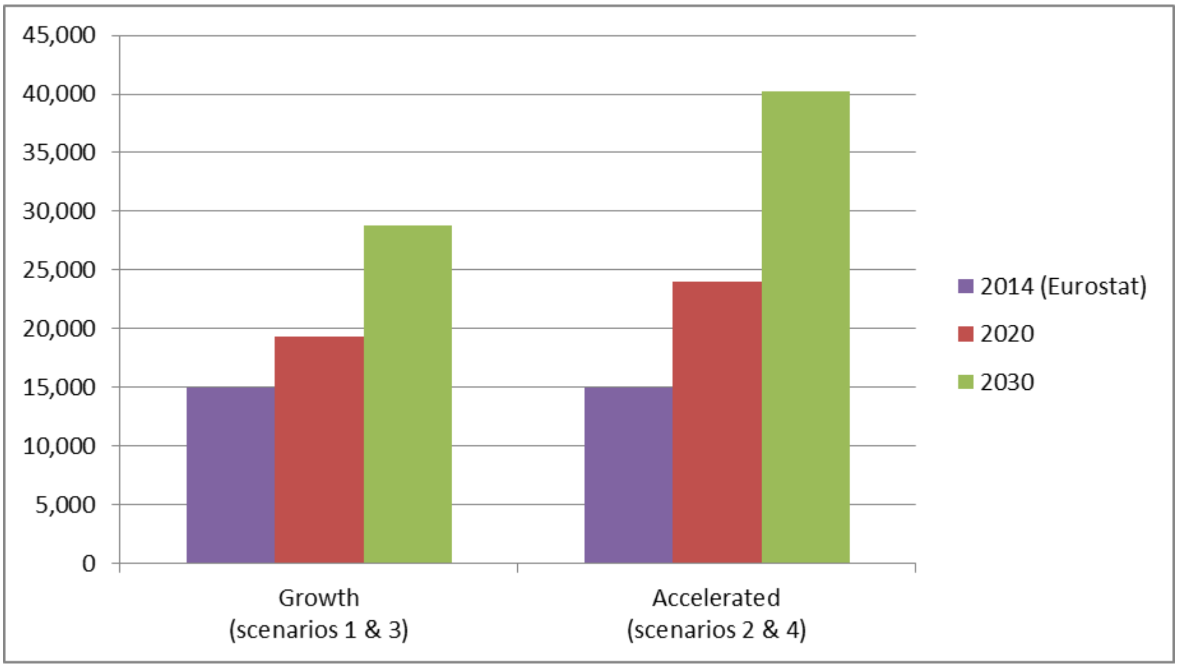
5.1 Biogas production volume potential

As was discussed in the previous chapter, the feedstock potential in 2030 of the accelerated scenarios (Scenarios 2 & 4) is larger than the feedstock potential of the growth scenarios (Scenarios 1 & 3). Together with different assumptions on how fast this potential can be deployed and the learning effects (i.e. cost reductions and conversion efficiencies) that can be achieved, this results in two different growth rates and a higher biogas production in the accelerated scenarios, as shown in Figure 16.

The potential biogas production for the EU28 in 2030 is calculated to be 28.8 and 40.2 Mtoe (of 1,436 Mtoe total primary EU energy consumption, as forecast in the 2016 EC Reference scenario to 2050) in the growth and accelerated growth scenarios respectively. This is about 1.9 and 2.7 times larger than the biogas production in 2014 (Eurostat data). Clearly, these results show that there is a considerable growth potential of biogas from digestion of waste streams, if the right policies and regulations are put in place.

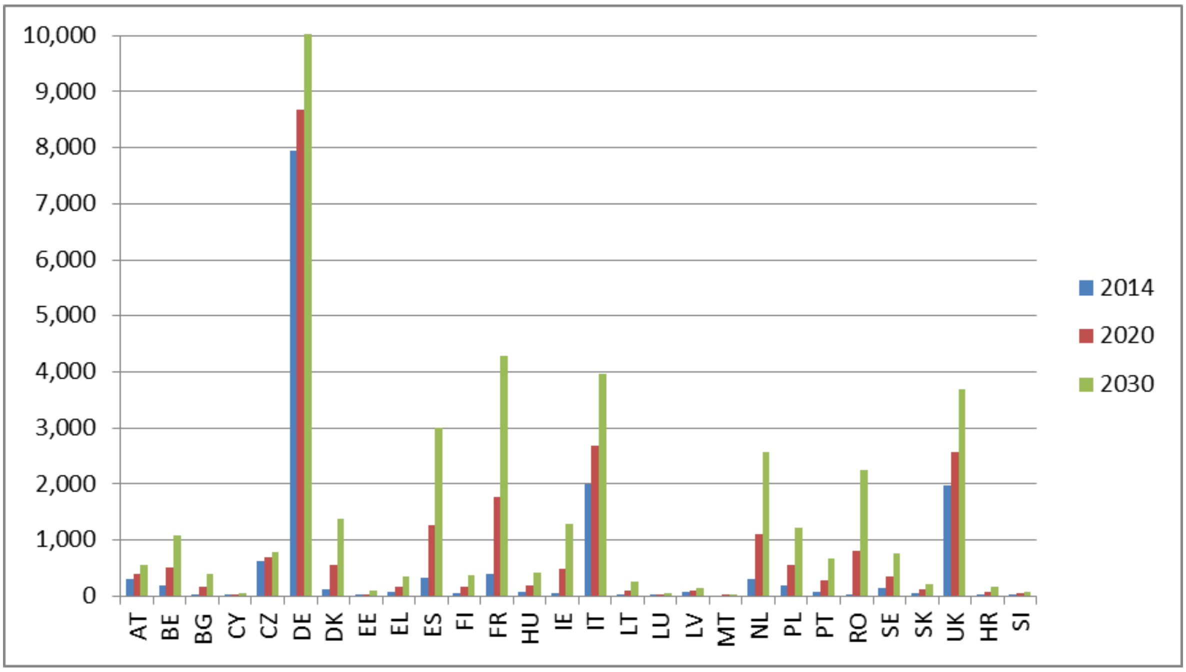
The results also show that with the linear growth rate that is assumed in these scenarios between 2014 and 2030, biogas production in the EU28 would increase between now and 2020: 2020 production levels are in these scenarios 1.3 and 1.6 times higher than 2014 production levels, respectively. It should be noted that the calculated 2020 production levels might be an underestimate in some countries, due to the assumption of linear growth rate between 2014 and 2030.

Figure 16 Growth of biogas production in EU28 in the scenarios in ktoe



Biogas production was modelled on Member State level, for both scenarios, based on the feedstock shares for the biogas production in 2030 that were provided in Section 4.3.1. To illustrate this, Member State results for the biogas production in Scenarios 2 and 4 (i.e. with accelerated growth) are provided in Figure 17.

Figure 17 Growth of biogas production per Member State in Scenarios 2 and 4 (accelerated growth) in ktoe



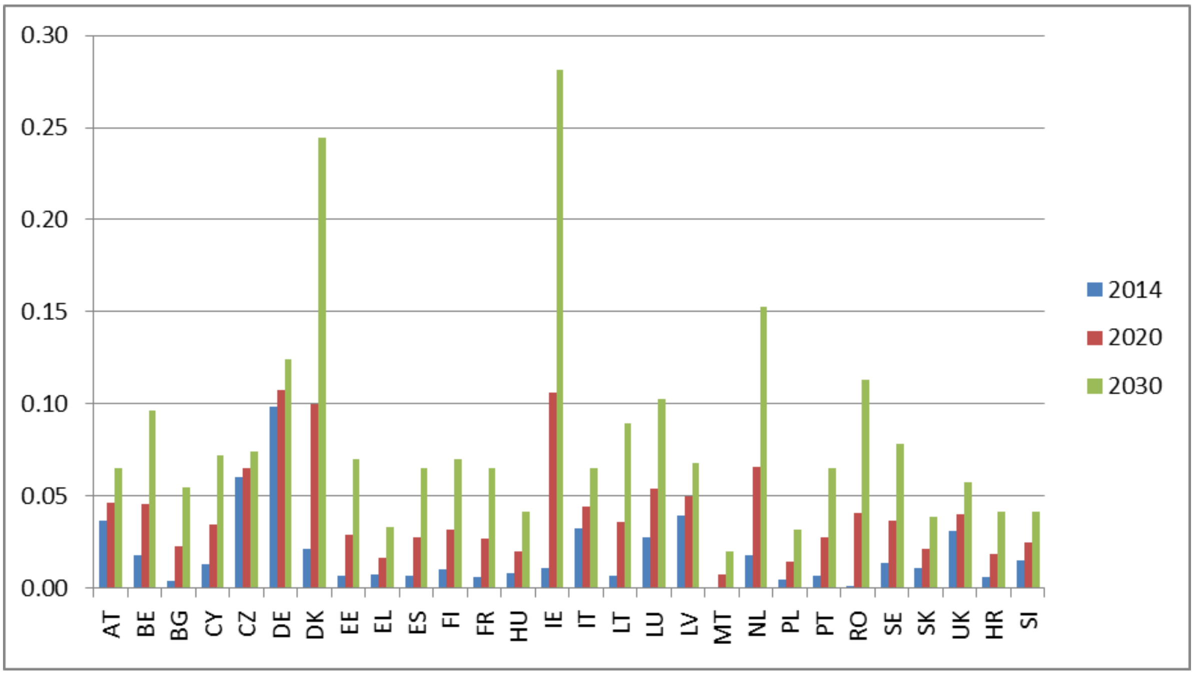
Clearly visible in the figure are the large differences between Member States in biogas production volumes in 2014, as well as the difference in feedstock potentials for 2030. In these scenarios, the largest markets in 2030, with more than 2,000 ktoe biogas production, are in Germany, Spain, France, Italy, the Netherlands, Romania and the

United Kingdom. The feedstock potentials, and thus the potential biogas production, correlates with the size of the country but also with the structure of the agricultural sector, especially concerning the amount of manure.

The Member States with the largest potential growth of biogas production between 2014 and 2030 are Ireland and Romania, with potential growth factors of 26 and 80, respectively. Most of the mature markets as determined in Chapter 2.4, Figure 8, show relatively small potential for growth of biogas production between 2014 and 2030, with growth factors smaller than 5, the exceptions being France and Sweden with potential growth factors of 11 and 5.6 respectively. There is no clear correlation between potential growth factor and market maturity for the two other groups of Member States, with moderate or immature current markets.

Figure 18 shows the biogas production per Member State in terms of production per inhabitant, to put the biogas production in perspective and facilitate comparison between the smaller and larger countries in the EU. It illustrates clearly that small Member States also have a large potential to increase their domestic biogas production (in terms of production per inhabitant). In particular relatively small Member States as Ireland, Denmark and the Netherlands still have large potentials to increase the biogas production per inhabitant.

Figure 18 Growth of biogas production per Member State in Scenarios 2 and 4 (accelerated growth) in ktoe/1,000 inhabitants



5.2 Production costs of biogas

Costs are presented in this section for biogas production from new production installations, i.e. from installations that were built after 2014 to accommodate the production increases of the various scenarios. As was discussed in Section 4.3.3, the investment and production costs of already *existing* installations are not known in sufficient detail to be included in the modelling. Due to the assumed learning curves (see Chapter 4), the costs depend on the specific year the installation is 'build' in the model. Cost estimates and forecasts were only available on EU level, not on Member State level, so any local, regional or cost and price differences could not be included.

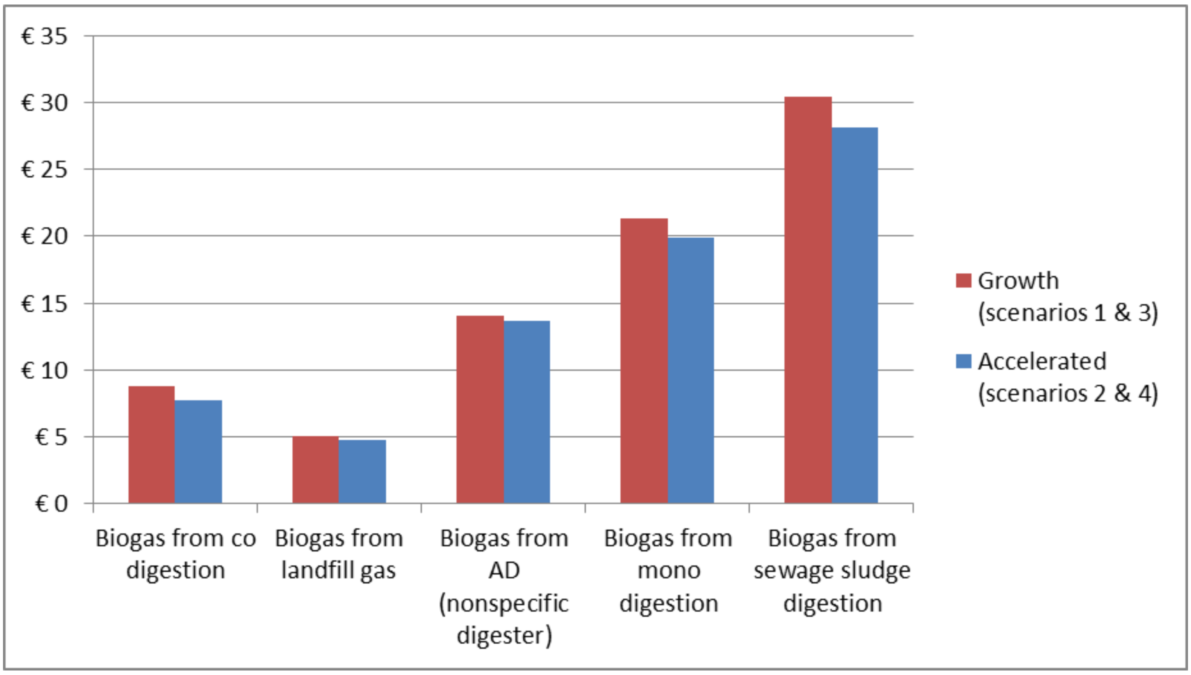
First, Figure 19 shows EU28 average biogas production cost for different digester and conversion types. Costs vary considerably, with the lowest cost values from landfill gas with production costs around 5 €/GJ[17]: since landfill gas comes for free and must only be cleaned. The highest values are for biogas production from sewage sludge digestion (around 30 €/GJ), with the important comment that the accompanying cost reduction for sewage sludge treatment – costs that are avoided when biogas is produced – could not be taken into account due to lack of specific information (the situation varies from Member State to Member State).

The various cost components of biogas production are further detailed in

Figure 20 for Scenario 3 (as an illustrative example). Clearly, mono-digestion and sewage sludge digestion have relatively high investment costs, compared to the other routes. In the case of mono-digestion, this is due to the fact that it is a relatively new technique (where cost reduction can be expected in the future), but also because the scale of the installations is relatively small. However, it should be kept in mind that in the biogas production totals (EU28), these two relatively expensive techniques account for only 13% (mono-digestion) and 3% (sewage sludge) of total biogas production, whereas for example co-digestion accounts for 35%.

On average, the calculated biogas production costs are 14 €/GJ in the growth scenarios and 12 €/GJ in the accelerated development scenarios.

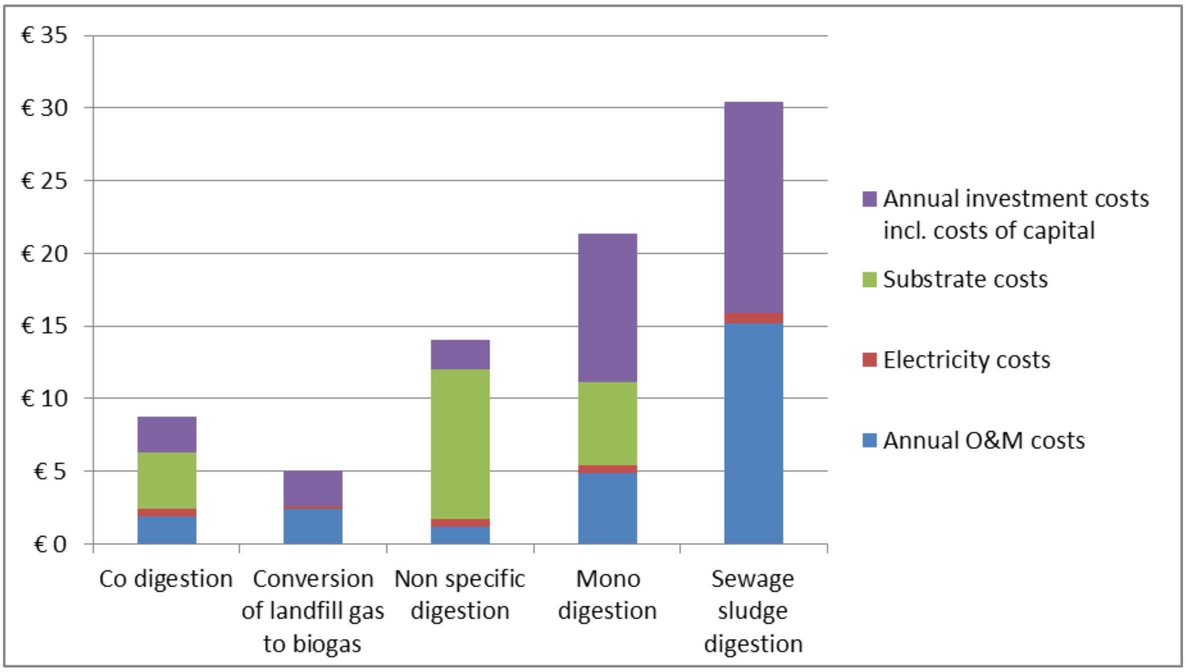
Figure 19 Average production costs in 2030 of biogas (incl. investments) of new capacity over period 2015-2030 in €/GJ



NB. The costs of biogas from sewage sludge do not take into account the cost reduction for sewage sludge treatment – costs that are avoided when biogas is produced.

[17] 1 GJ = 0.024 toe.

Figure 20 Scenario 3: break down of EU28 average production costs in 2030 of biogas (incl. investments) over period 2015-2030 in €/GJ



NB. The cost of biogas from sewage sludge do not take into account the cost reduction for sewage sludge treatment – costs that are avoided when biogas is produced.

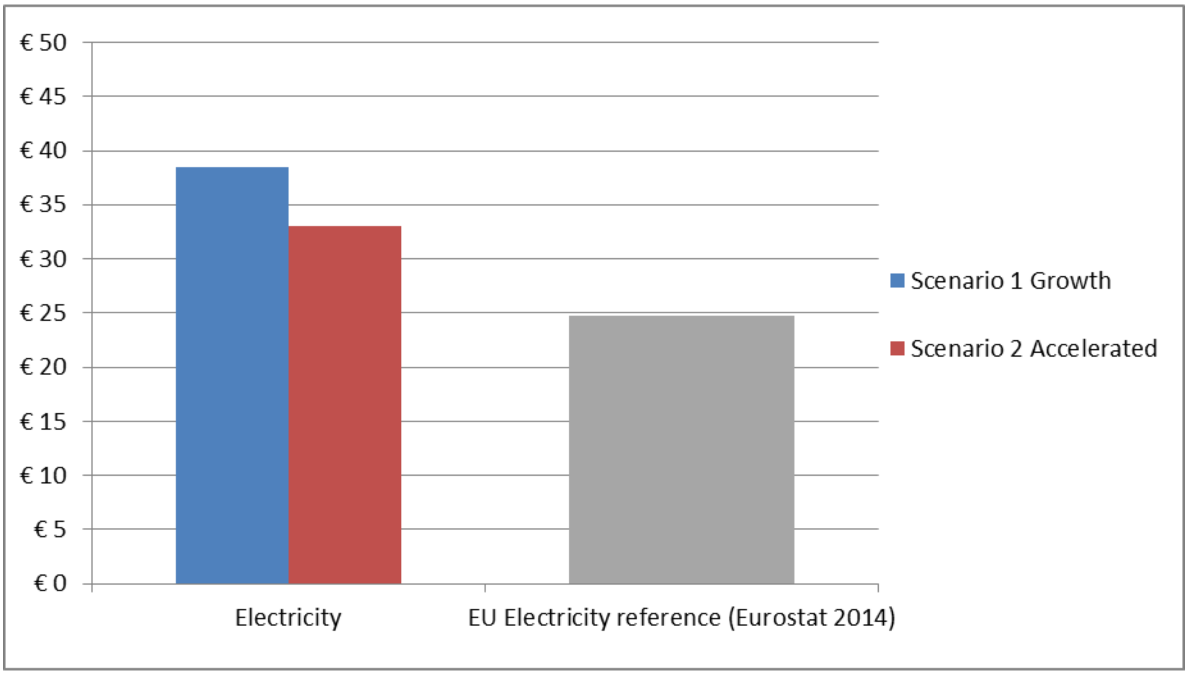
5.3 Production costs of bio-electricity (from CHP) and of biomethane

In case the biogas is used locally in a CHP unit to produce electricity and heat, we can calculate the production costs of the produced bio-electricity by treating the produced heat as a co-product, see Section 4.3.3. The resulting electricity production costs are shown in Figure 21. The figure shows electricity production costs of about 1.5 times the 2014 reference EU electricity price, implying that realisation of that volume needs active support policies. Since the heat from the CHP is treated as a co-product in the calculations, an increased utilization of the nett heat from the CHP will reduce the resulting electricity production costs. For example, in case the heat utilization is assumed to be 35% instead of 25%, the resulting electricity production costs reduce from 33.1 to 32.0 €/GJ in scenario 2, i.e. a cost reduction of 3.3%.

The electricity price in the accelerated scenarios is 5,4 €/GJ lower than in the growth scenarios, see Figure 21, due to cost reductions as a result from innovation and market stimulation.

The total of the extra costs of the produced bio-electricity in Scenarios 1 and 2 is 3.4 to 3.5 billion euro, when compared to the average (i.e. fossil dominated) market price of electricity in 2014 in the EU (Eurostat data). This is the cost for bio-electricity produced in 2030 by new installations build in the period 2015-2030.

Figure 21 Average production costs of electricity from biogas CHP in 2030 of new capacity over period 2015-2030 in €/GJ

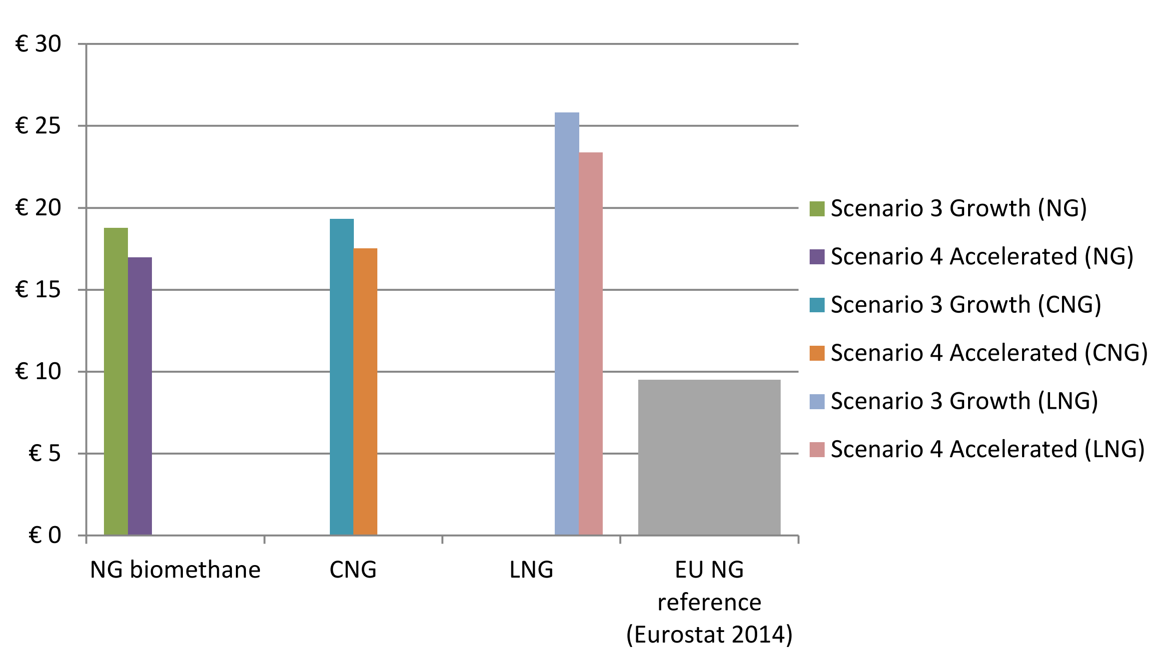


In Figure 22 the average specific production costs are shown for Scenarios 3 and 4, in case the biogas is upgraded to biomethane, bio-CNG or bio-LNG. For comparison, the reference EU natural gas price is also provided (Eurostat, 2014). As can be seen from the figure, the production costs of biomethane are 1.8 to 2.0 times higher than the current (2014) average EU price for natural gas. The costs for bio-CNG and bio-LNG are higher than biomethane cost because extra investments are needed for compression and liquefaction of the biomethane.

Clearly, also in these scenarios realisation needs effective support policies. The difference between the production costs in the growth and the accelerated scenario is 10%, due to the effect of cost reduction potentials (as a result from innovation and market stimulation).

The total of the extra costs of the produced biomethane in Scenarios 3 and 4, as compared to the reference (i.e. fossil dominated) natural gas market price in 2014 in the EU according to Eurostat is 5.7 to 7.7 billion euro. This is biomethane produced in 2030 by new installations build in the period 2015-2030, without further processing to bio-BNG or bio-LNG.

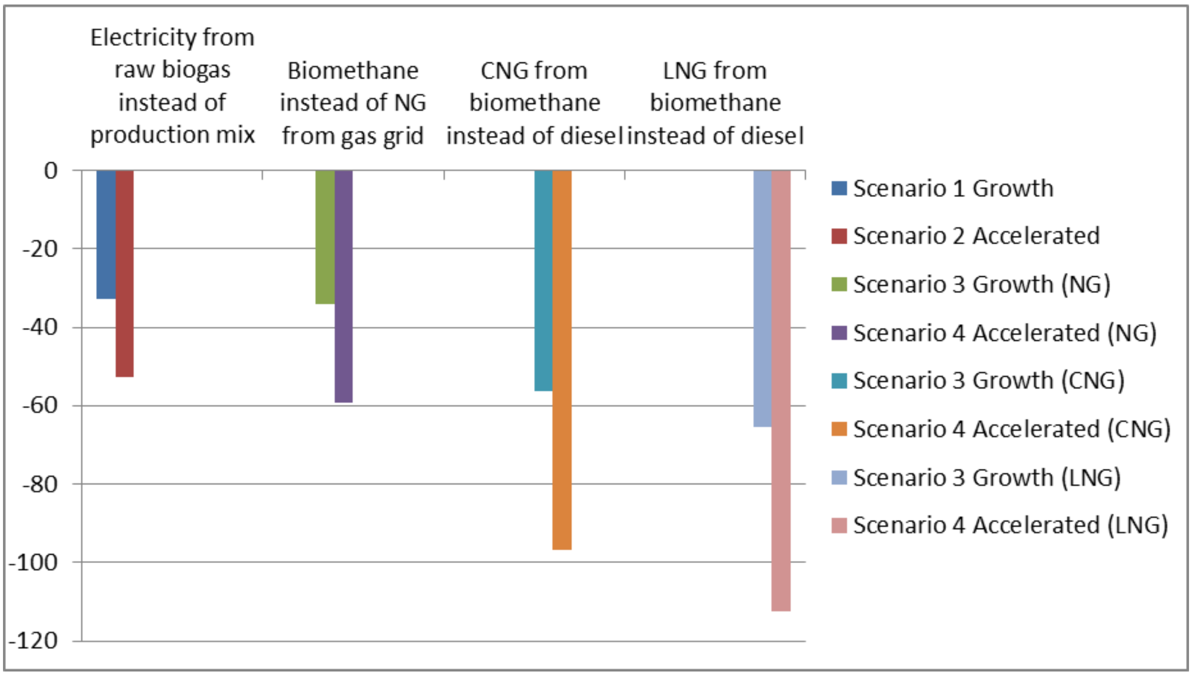
Figure 22 Average production costs of biomethane, bio-CNG and bio-LNG in 2030 (incl. investments) of new capacity over period 2015-2030 in €/GJ



5.4 Greenhouse gas emission reduction potentials

In the calculation of GHG emission reductions, the emission (reduction) of the feedstock, the chain emissions (in particular electricity consumption and methane slip) and the prevented emissions from the replaced fossil fuel are included. In Scenarios 1 and 2, in which electricity is produced in a CHP from raw biogas, also the replacement of natural gas by the heat from the CHP is accounted for in the GHG reduction calculations. The outcome of the calculations on GHG emission reductions is provided in Figure 23.

Figure 23 Absolute emission reductions of each scenario and end-use in 2030 (of new capacity between 2014 and 2030) in $MtCO_2$-eq



These findings show that the largest GHG emission reductions result from the use as biomethane in the transport sector. The use of biomethane as replacement of natural gas in the built environment shows a lower effect, mainly because the emission factor of the replaced energy source, natural gas, is lower than that of the diesel that is replaced in the transport scenarios.

The smallest effect arises when the biogas is used in a CHP. This may be surprising because of the high efficiency of CHP, but this is mainly due to the fact that emission factors for electricity are rapidly declining towards 2030, and because on average only 25% of the net heat production from the CHP is assumed to be effectively used (to replace natural gas heating). In case the net heat utilization from 25% can be increased, e.g. due to policy incentives, the GHG reduction in that scenario will increase also. For example, in case the heat utilization is assumed to be 35% instead of 25%, the resulting GHG emission reduction in Scenario 2 changes from 52.8 to 55.2 Mton in 2030, an increase of 4.5%.

GHG reduction could also be increased by ensuring that the biogas electricity does not replace the electricity mix but fossil power production only. In the short-term, this will typically be the case in most Member States since RES production is still limited, and wind and solar production are not likely to be curtailed on a significant scale. In the longer term, however, this situation may change, and GHG savings of biogas electricity production (i.e. the CHP operation) can be optimised to periods of low wind and solar generation. This would ensure that the biogas electricity production does not compete with other RES-E production. However, in many cases the CHP production is must run, since it follows the biogas production from the digester. This kind of optimisation therefore requires biogas storage (adding extra costs) and it might reduce the share of heat utilisation rather than increase heat use as was recommended above.

To illustrate this effect, we have also performed the GHG reduction calculations assuming that biogas electricity production from CHP replaces the 2030 fossil mix in each country (based on PRIMES, 2016) instead of the overall production mix. The GHG reduction of 53 $MtCO_2$-eq of Scenario 2 then increases to 92 $MtCO_2$-eq, i.e. almost the same value as the savings achieved in scenario 4 with replacement of diesel by biomethane (bio-CNG) in the transport sector. This clearly shows the large potential benefits from implementing policies that ensure that fossil electricity sources are replaced by electricity from the bio-CHP, rather than the average mix.

Furthermore, the effect of the acceleration scenarios is clearly visible in these results, more feedstock use and improved efficiencies result in more biogas production and more GHG reduction.

5.5 Cost-effectiveness

The cost per ton CO_2-eq reduction, as calculated for the various scenarios, is shown in Figure 24 for 2030. These results show that the most cost-effective route to reduce GHG emissions is upgrading of the biogas to biomethane and then using it as bio-CNG or bio-LNG, in both cases replacing diesel. If accelerated growth is assumed, electricity form CHP is somewhat more cost-effective than bio-LNG (66 €/tCO_2-eq instead of 70 €/tCO_2-eq). The use as biomethane replacing natural gas in the built environment shows the highest costs per unit GHG reduction. Better utilization of the heat from the CHP will result in a better cost-effectiveness. For example, in case the heat utilization is set in the model to 35% instead of 25%, the resulting cost-effectiveness of Scenario 2 changes from 66.4 to 55.0 €/tCO_2-eq, a reduction of 17%.

As explained above, the assumption that electricity from the bio-CHP replaces the total electricity production mix in each country also has a profound effect on the outcome of the GHG reduction calculations. When we perform the GHG reduction calculations using the fossil mix in each country in 2030 instead of the overall production mix, the GHG reduction of 66.4 €/tCO_2-eq of Scenario 2 decreases to 38.1 €/tCO_2-eq, as shown in Figure 25. This shows again the large effects of the assumption which electricity sources are replaced by electricity from the bio-CHP.

Again, the positive effect of the accelerated learning curves is clear in all cases, as cost-effectiveness improves with the accelerated learning curves.

It should be noted that even though these overall conclusions on cost-effectiveness are relatively robust, the exact values are highly uncertain since they depend on both the cost of the biogas/biomethane and their fossil counterparts, as well as on the GHG emissions of these energy sources – all having their own uncertainties.

Figure 24 GHG emission reduction cost-effectiveness of each scenario and end-use in 2030, in €/tCO$_2$-eq

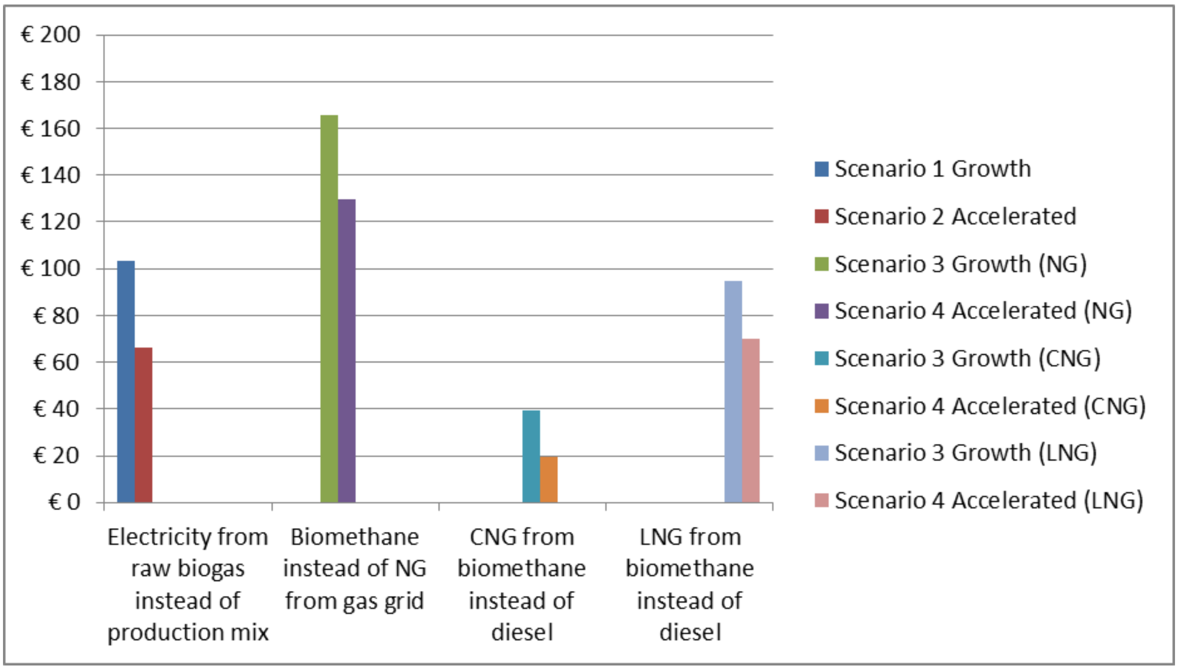
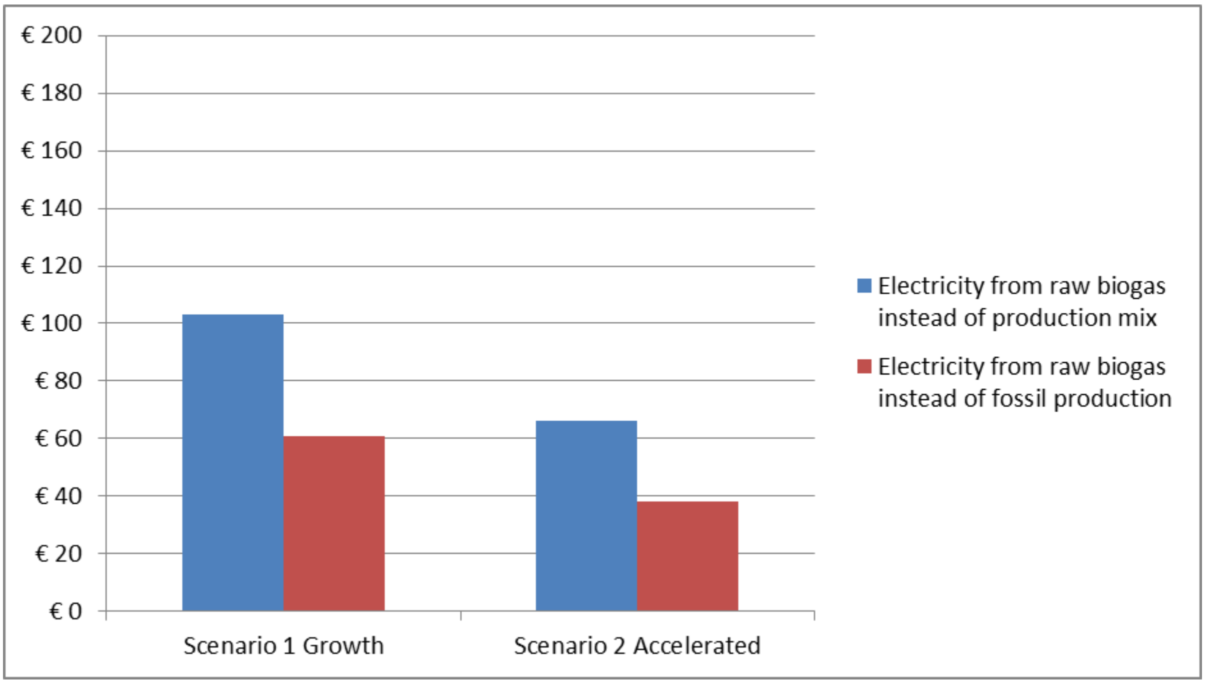


Figure 25 GHG emission reduction cost-effectiveness of Scenario 1 and 2 and end-use in 2030 (€/tCO$_2$-eq), replacing the average electricity mix or fossil electricity only



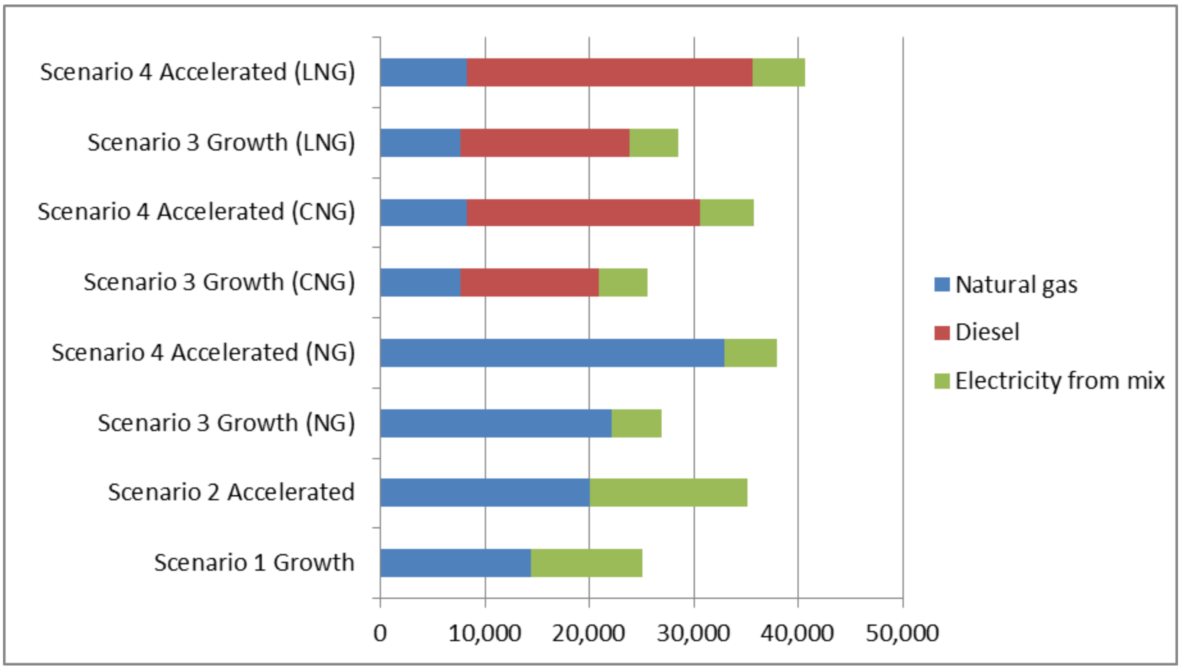
5.6 Fossil fuels and electricity production replaced

The total volumes of fossil fuels and electricity production replaced by the biogas and biomethane in the various scenarios are shown in Figure 26. Important to note is that in the model calculations is it assumed that the already existing production and use of biogas/biomethane in 2014 does not change, as is explained in the model description. The scenario storylines about the different uses of biogas and biomethane deal with the additional feedstock use, biogas and biomethane production and -use, above the production that already exists in 2014.

Where Scenario 1 replaces about 15 Mtoe of natural gas consumption for heating and 10 Mtoe of electricity production (from a mix of energy sources), the accelerated developments in Scenario 2 replace about 50% more. Scenarios 3 and 4 replace much less electricity than these 'local use' scenarios, but contribute significantly more to the reduction of natural gas consumption (if the biomethane is used for heat production in the built environment or industry) or to the reduction of diesel consumption (if used in heavy-duty transport).

As mentioned before, the type of fuels that are replaced by the biogas and biomethane depend on the national circumstances and policy measures in place. The same holds for the primary energy sources that are reduced under the 'electricity consumption' category in the figure. Depending on the Member State energy mix and marginal power production at any given time, the electricity production from biogas CHP can replace power production from natural gas, coal, nuclear or renewable energy sources.

Figure 26 Total reduction of fuel and electricity consumption from other sources in the various scenarios in 2030 (in ktoe)[18]



[18] 1 ktoe = 41,868 GJ.

5.7 Biogas contribution to RES deployment in the EU

The adopted targets for renewable energy production in the EU28 are 20% in 2020 and a minimum of 27% in 2030 (to be decided on in the coming years), in percentages of final energy consumption. Following the projections in the EU Reference Scenario 2016, the final energy demand in the EU28 will be about 1,134 Mtoe in 2020 and 1,081 Mtoe in 2030, resulting in values for renewable energy production of 227 Mtoe in 2020 and 292 Mtoe in 2030.

When comparing these values to the biogas production in the EU28 in the various scenarios, Figure 16, we find for the two accelerated growth scenario 24.0 Mtoe biogas in 2020 and 40.2 Mtoe in 2030 (primary energy production). This represents 10.6% and 13.8% of the EU28 renewable energy targets in 2020 and 2030 respectively, or 3.7% of the EU28 Reference Scenario energy consumption in 2030.

When comparing the 'local use' and 'grid injection' scenarios, the latter are likely to contribute more to national and EU RES targets of the RED than the former, due to the methodology used to calculate the contribution of RES to the target (Article 5 of the RED).

- When biomethane is used in transport, its full (primary) energy content can count towards the target.
- When it is used for electricity production, the gross final consumption of electricity counts towards the target. The efficiency of the electricity production (in our scenarios, of the CHPs) then has to be taken into account.
- The same holds for heating via CHP: the quantity of district heating and cooling from renewable sources counts towards the target, not the primary energy consumption.

The contribution of the various scenarios toward a RES target in 2030 therefore depends strongly on the conversion efficiency of the CHP used.

A different kind of contribution to RES deployment is that in contrast to wind and solar, renewable power production from biogas is non-intermittent, and it can even facilitate integration of these variable renewable energy sources when some form of biogas storage is in place.

As RES deployment increases throughout the EU, the electricity market will change quite fundamentally. Growth of intermittent sources (onshore and offshore wind, solar PV) will have a number of effects[19].

- Depending on weather conditions and demand, there will be either a surplus or a deficit of output from renewables.
- Frequent simultaneity of wind/solar leads to a substantial decrease in market value of renewably sourced power.

These effects will have a negative impact on business cases of both RES and conventional power generation capacities, and create risks for security of delivery as can already be observed in some parts of the EU. These effects are likely to increase as RES deployment grows, unless the underlying drivers are resolved adequately.

[19] CE Delft, 2014, Energy market on the move and CE Delft, 2014, Structural changes in the energy market. See http://www.cedelft.eu/publicatie/energy_market_on_the_move_-_thinktank_on_energy_market_reform/1623
See http://www.cedelft.eu/publicatie/energy_market_on_the_move_-_thinktank_on_energy_market_reform/1623

Potential solutions can be technical, for example by implementing 'smart' technologies and services, demand response services and energy storage, by expanding grid capacity to the level needed to accommodate the new generation and demand requirements, by integrating regional European power systems[20], etc. To ensure that these opportunities are developed and used, however, the electricity market design also needs to be adapted, as acknowledged, for example, in the recent launch of a public consultation process on a new energy market design by the Commission (SWD(2015) 142) and the 2015 publication 'Regulatory Recommendations for the Deployment of Flexibility' by DG Energy's Smart Grids Task Force.

In this future high-RES electricity system, electricity production from biogas (and bioenergy in general) can play an important role in complementing wind and solar electricity generation, especially in times of low output from these sources. Electricity production from biogas and biomass has the advantage that it is demand driven: it can be stored, and used for electricity (and/or heat) generation when needed. Furthermore, electricity production from biogas is very flexible, and can be ramped up and down quickly, when needed. It can thus have quite a number of benefits to the future electricity system and market:

- Biogas can reduce the need for fossil power backup. This will contribute to increasing the share of RES and reducing GHG emissions of power supply, and reduce the EU's dependency on energy imports (notably natural gas).
- As it can be stored and used when needed, biogas power generation can contribute to mitigation of the price fluctuations caused by supply-driven and variable RES technologies.
- Electricity production from biogas can respond quickly in times of large variation of wind and solar output, which can contribute to balancing the market and ensure security of delivery.

When comparing the four scenarios on these aspects, the 'local use' scenarios clearly have the most potential to contribute to the future electricity system, since more electricity is produced in these scenarios than in the 'to grid' scenarios. Flexibility of power production in these scenarios may be limited by heat demand, though, which is of course determined by other factors. Optimizing the CHP towards the electricity system demands is likely to have negative impacts on heat use, reducing overall energy efficiencies and GHG savings. Quantification of the benefits to the electricity system and market is not possible at this stage of developments within the scope of this project, as the future price fluctuations due to RES production are uncertain, as is the demand for flexible power production.

5.8 Variation of maize/manure ratio in co-digestion

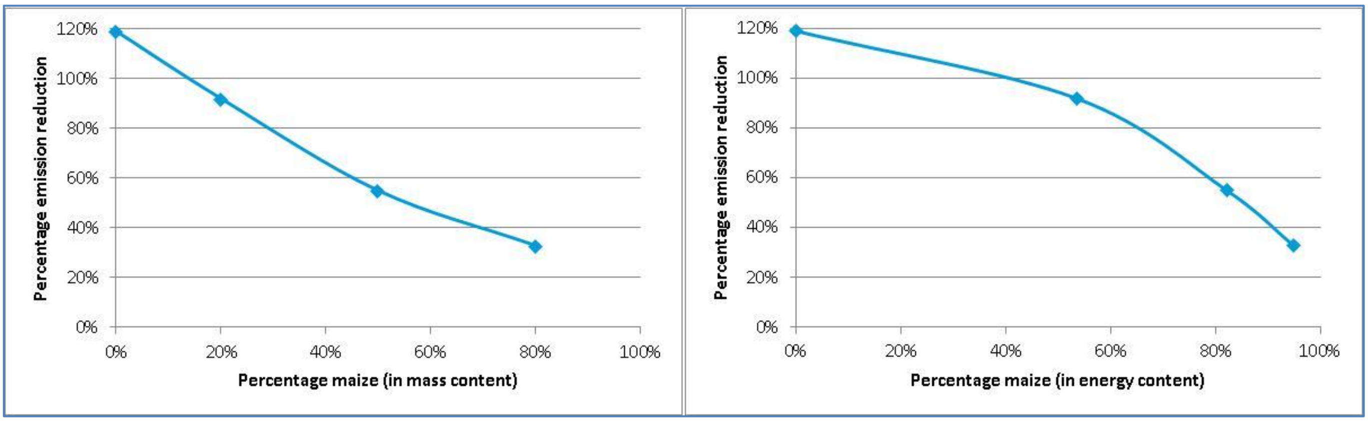
One of the specific issues that can be addressed with the model, is the question how the GHG savings of co-digestion depend on the share of maize in manure co-digesters. This is relevant for policy support measures and regulations, since higher shares of maize (or any other crop as co-substrate) can increase the scale of the digesters and biogas production, thus reducing cost, but at the same time increase GHG emissions and create a risk of indirect land use change[21]. Some Member States, e.g. Germany, use such a cap in their subsidy regimes for co-digesters.

[20] See, for example, Agora (2015) The European Power System in 2030: Flexibility Challenges and Integration Benefits.

[21] In the ILUC directive, maize falls under the cap of 7% maximal share of biofuels from crops grown on agricultural land that can be counted towards the 2020 renewable energy targets.

In Figure 27, the effect of the variation of the percentage of maize in the co-digester on the GHG emission reduction is depicted, assuming that the biogas replaces natural gas. The left picture shows results with the percentage of maize in *mass* content on the horizontal axis, the right picture with the percentage of maize in the *energy* content. The difference between the two pictures arises from the fact that the energy density of maize is much higher than that of manure: 20% of maize in mass content corresponds with about 50% of energy content. As can be seen, the GHG emission reduction declines with an increasing percentage of maize in the mix. For example, 50% GHG emission reduction is achieved with circa 50% maize mass content or 80% of energy content, a 70% reduction is achieved with about 35% maize mass content.

Figure 27 Effect on GHG emission reduction of the variation of manure/maize ratios in co-digesters[22]. The left figure with the percentage of maize in mass content on the horizontal axis, the right figure with the percentages expressed as energy content



5.9 Other effects

Apart from the impacts listed above, a number of other effects of the scenarios may be worth considering, such as impacts on:

- other sectors;
- resource efficiency incl. energy efficiency and land use;
- air quality.

These topics will be briefly discussed in the following.

5.9.1 Impacts on other sectors

As shown in the analysis above, the biogas scenarios have a direct impact on a number of sectors. Most notably the sectors and industries that provide the feedstock (agriculture, the food and waste industry) and the end-users of the biogas or biomethane (the electricity, heating and transport sectors). Other sectors may be affected indirectly, most notably due to competition for the feedstock. In view of the scope of the study, these indirect impacts are, however, expected to be limited. The feedstock types that were included are mostly waste streams that have limited other uses. There is currently mainly competition with the composting sector, which will be faced with higher cost and more limited availability of suitable biomass (unless they convert to biogas production.

22 In the JEC GHG emission data that were used in the GHG calculations, no ILUC factors for maize were taken into account.

In addition, the increasing demand for maize as co-substrate for manure in co-digestion might increase prices and thus impact the food and feed industry. However, the share of maize was kept at a relatively low level of 20%, and volumes are limited compared to the EU level of maize production and demand. However, for individual countries with a large volume of manure, this still might be a significant increase in maize demand.

In addition, there will be a financial impact due to the increased energy cost of the biogas scenarios. Depending on the support policies, these would have to be paid for by society as a whole, e.g. with a general tax increase, or by (a part of the) energy users, e.g. with an energy tax or RES premium increase or an increase of the energy price.

5.9.2 Resource efficiency incl. energy efficiency and land use

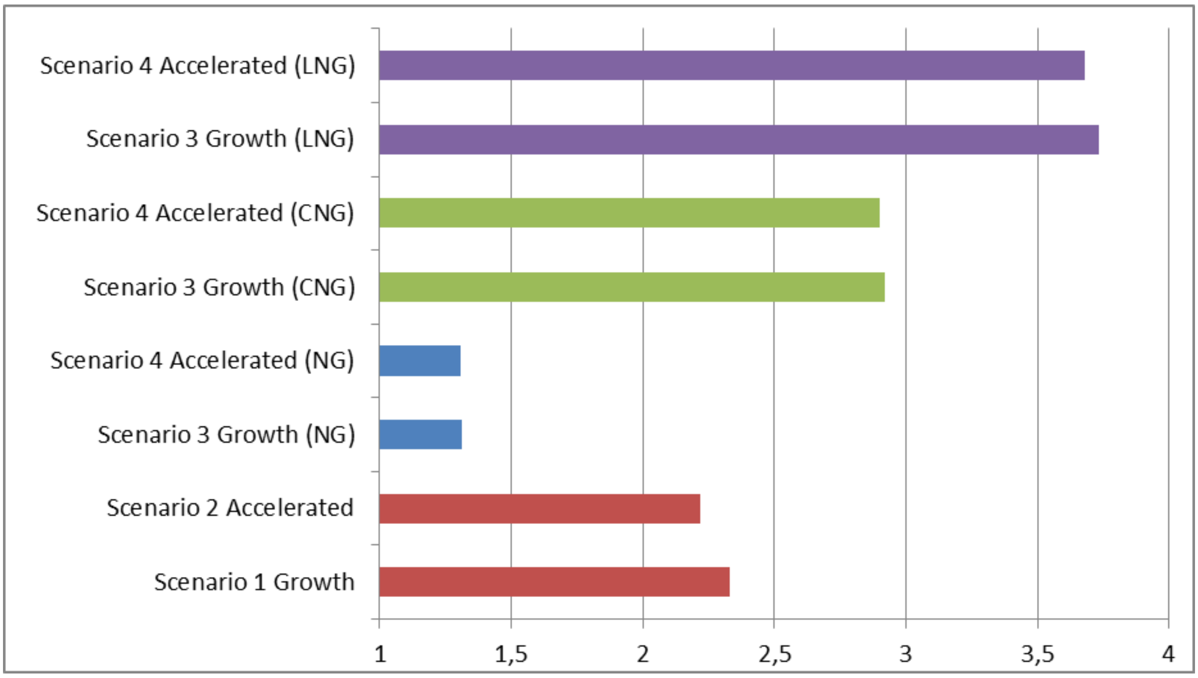
Biogas production from waste streams that cannot be re-used or recycled and have no other applications is well in line with current circular economy and resource efficiency efforts in the EU (see Section 3.2 for an overview).

In addition, from a resource efficiency perspective, the biogas should be used in routes with high energy efficiency, i.e. with limited energy input and limited energy losses. The average energy efficiency of the various scenarios is shown in Figure 28. These energy efficiencies are defined as the final energy consumption (i.e. power, electricity and heat) over all energy consumed during the process, including feedstock, heat and electricity. For biomethane use in the built environment we assumed heat production by a domestic condensing boiler with an efficiency of 94%. For biomethane use in transport, engine efficiencies of 35.2 and 43.0% were used for bio-LNG and bio-CNG, respectively[23]. This graph clearly combines a number of very different energy carriers (electricity, heat, power supplied to vehicle drive shafts) and should thus be used with caution, but it does provide a uniform 'well-to-wheel' comparison of all different applications.

The most efficient process is biomethane production and utilisation in a domestic condensing boiler, the least energy efficient process is bio-LNG utilization in a truck. The difference between bio-CNG and bio-LNG is partly due to the lower vehicle efficiency of the LNG truck, but also due to the relatively high energy consumption for liquefaction of the biomethane. CHPs could be more efficient if more than the assumed 25% of the produced heat can be sold and used.

[23] The vehicle efficiencies are calculated using a diesel engine efficiency of 39.1% (CAFEE, 2014) and the relative energy efficiencies of an LNG truck (8.46 MJ/km) and CNG passenger car (2.09 MJ/km) with respect to the same vehicle with a diesel engine (9.4 MJ/km and 1.9 MJ/km respectively) (CE Delft, ECN and TNO, 2013).

Figure 28 Final energy consumption process efficiencies of the scenarios for the new capacity of the year 2030 in GJ_{in}/GJ_{out} (including all produced heat of CHP)



Zooming in on land use, this is limited in all scenarios by the focus on waste streams as input for the biogas production and the 20% cap on the share of maize in co-digesters. Mono-digestion of crops was not included. The 'advanced deployment' scenarios (Scenario 2 and 4) can be seen to require more land than the 'growth' scenario, as they are based on a significantly higher manure potential, resulting in higher volumes of maize for co-digestion: 80.5 Mton maize in the 'advanced deployment scenarios, compared to 44.5 Mton in the 'growth' scenarios.

5.9.3 Air quality

Digestion of manure reduces most methane and nitrous oxide emissions compared to emissions from conventional manure storages. Odour from digested manure is in general lower compared to non-digested manure. However, as more organic nitrogen becomes available, the ammonia (NH_3) emission during application of digestate on the land might be higher compared to conventional manure. Therefore, it is recommended to apply digestate with low-emission techniques, i.e. injection in the soil, to reduce NH3 emissions (Hou, 2015). In case digestate is used to replace the use of artificial fertilizer, the emissions related to the production of the fertilizer might be reduced. In general, the accelerated deployment scenarios (S2 and S4) will have higher GHG reduction from manure storages.

5.10 Beyond current technologies

The scenario storylines and model calculations focus on 2020 and 2030, using information on feedstocks (i.e. suitable waste streams) and technologies from recent studies. In the model calculations, learning curves are assumed for investment costs and on efficiencies, anticipating the empirical fact that technologies have a tendency in time to gradually show lower costs and better efficiencies due to innovations and market scale effects.

Model calculations also have inherent limitations. For this study, the model and the input figures are used to calculate output values with a relatively high degree of possibility (albeit strongly depending on the design of the relevant policies). The calculations do not take into account new disruptive innovations, nor in feedstock technologies, nor in conversion technologies, nor in the markets.

For example, in the section on feedstock potentials (see Section 4.3.1), it was already mentioned that in the future, beyond 2030, there might be substantial contributions from new feedstocks for digesters like cover crops or sea weed. These are not likely to have large impacts before 2030 and are therefore not taken into account in the feedstock scenarios that are used in this study. It should be noted that also the volumes of feedstocks for digestion like manure and organic wastes may change after 2030.

In the longer term, power to gas (P2G) developments may lead to an increased availability of 'renewable gas'. The same may be true for syngas production from gasification processes, although that technology competes with other bioenergy routes as it requires significant amounts of sustainable biomass (mostly dry streams, e.g. wood) as feedstock that can also be used in other applications such as direct electricity production, bio-refineries or pyrolysis which directly produces a liquid biofuel that can be used as feedstock for the chemical or other industries (replacing mineral oil) or as transport fuel.

This short analysis does by no means disqualify the scenarios and model calculations presented here, but aim to stress that one should keep in mind that things might change over time.

The following provides a brief overview of a few innovative techniques that may influence the availability and costs of 'renewable gas' in the future. This is purely meant as an illustration of possible future developments, and does *not* serve as complete overview, that would be outside the scope of this study.

5.10.1 Examples of innovations in biogas/biomethane production[24]

BIOMASTER

The BIOMASTER Project (supported by Intelligent Energy Europe) aims to engage with people and processes to enable a significant breakthrough in the uptake of biomethane for transport. The four participating regions in BIOMASTER, Malopolska Region (Poland), Norfolk County (United Kingdom), Skåne Region (Sweden) and Trentino Province (Italy), are working together to promote biomethane production, its grid injection and use for transport. They are undertaking a joint initiative involving all these key components of the biomethane chain, stimulating investment, lobbying to remove non-technological barriers and mobilising action for uptake.

More information: http://biomaster-project.eu/index.php?ID1=8&id=8

BioWALK4Biofuels: Use of macroalgae for biogas production

The FP7 project BioWALK4Biofuels aims to develop an innovative system for the treatment of biowaste and use of GHG emissions to produce biofuels, through the use of macroalgae.

More information: www.biowalk4biofuels.eu

[24] Information is partly taken from www.biofuelstp.eu/biogas.html

AHPD (Autogenerative High Pressure Digestion)

AHPD produces almost pure biomethane with 90% CH_4-concentration directly from biomass or waste water. The high pressure (20 bar) in the digester is autogeneratively build up by specific micro-organisms. The pressure is used to concentrate carbon dioxide in the water phase, comparable with e.g. the process in a beer brewery. The AHPD technology can be used in various processes in which biomass wastes have to be processed, like waste water, sewage sludge and waste streams from agriculture and food industries. AHPD is assessed to be at Technology Readiness Level 8. The financial feasibility of AHPD is high: based on a green gas cost level of 0.44 euro/Nm^3 and a solid waste (substrate) gate fee of 330 euro/ton TSS, a pay-back time of 5-8 years is obtained.

An interesting feature of AHPD as sewage cleaning technique is that conventional sewage cleaning installations treat the settled sewage liquor using aerobic biological processes. To be effective, the biota requires both oxygen and food to live. The bacteria consume biodegradable soluble organic contaminants (e.g. sugars, fats, organic short-chain carbon molecules, etc.) and bind much of the less soluble fractions into floc. This conventional process results in large emissions of CO_2 into the air. However, in the AHPD process the CO_2 is used to produce biomethane. As a result, the biomethane production from sewage using AHPD is up to 50% higher than with conventional techniques and at the same time emission of the CO_2 to air is prevented.

A future development is the use of additional hydrogen to enhance the concentration of biomethane to 99%. The hydrogen can e.g. be produced from temporary surpluses of electricity from wind or solar power.

More information: www.bareau.nl

BIOGASFUEL

The Eureka BIOGASFUEL project is developing a dual-fuel supply system for diesel engines using alternative fuel. The research programme on fuel will assess the possibility of using biogas as a fuel for compression ignition engines of non-road vehicles and machines used in agriculture.

More information: www.eurekanetwork.org/project/id/5030

FaBbiogas

The objective of the IEE project FaBbiogas is to elaborate a solid information base on FaB (Food and Beverage) waste utilisation for biogas production and to prove the efficiency and feasibility of FaB waste-based biogas implementation projects. The EU project FABbiogas (Intelligent Energy Europe) project aspires to change the mindsets of all stakeholders in the waste-to-energy chain by promoting use of residue streams from FAB industry as a new and renewable energy source for biogas production. Project outputs will support the diversification of energy sources within FAB companies, leading to wide-spread valorization and efficient integration of FAB residue streams into energy systems and boosting the realization of a growing number of biogas projects in Austria, Czech Republic, France, Germany, Italy and Poland.

More information: www.fabbiogas.eu/en/home/

5.10.2 Gasification[25]

Gasification is a process that converts organic or fossil fuel-based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700°C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas and is itself a fuel.

The advantage of gasification is that using the syngas is potentially more efficient than direct combustion of the original fuel because it can be combusted at higher temperatures or even in fuel cells, so that the thermodynamic upper limit to the efficiency defined by Carnot's rule is higher or (in case of fuel cells) not applicable. Syngas may be burned directly in gas engines, used to produce methanol and hydrogen, or converted e.g. via the Fischer–Tropsch process into synthetic fuel. Gasification can also begin with material which would otherwise have been disposed of such as biodegradable waste. In addition, the high-temperature process refines out corrosive ash elements such as chloride and potassium, allowing clean gas production from otherwise problematic fuels. Gasification of fossil fuels is currently widely used on industrial scales to generate electricity. Gasification of biomass is a technology for production of renewable energy. One of the critical process parameters in case of gasification of biomass is a stable quality of the biomass, for which pretreatments like torrefication might be used.

Gasifiers can be categorized as follows:

- fluidised bed gasifiers (for dry streams), work at lower temperatures;
- entrained bed gasifiers (for dry streams), work at higher temperatures and at a larger scale than fluidised bed gasifiers;
- supercritical gasifier (for wet streams, like wet manure and sewage sludge), at supercritical condition in water (i.e. high pressure of 300 bar and temperature of 400°C);
- plasma gasifier (for both dry and wet streams) at atmospheric pressure and 600°C.

After a long lasting development, which dates back to the 18th century, the commercial implementation of biomass gasification is still problematic. Very few processes have yet proved economically viable, although the technology has progressed steadily.

One of the important features of gasifiers for future biogas/biomethane markets is the capability to produce biogas/biomethane on a large scale from domestic or important wood pellets, for example in harbour sites.

5.10.3 Power to gas

With increasing capacities of electricity production from domestic intermittent renewable sources (wind, solar), there comes a time when an increasing fraction of the additional power from solar and wind can no longer be directly used in the electricity markets, but will have to be stored or 'time-shifted' using some form of flexibility solutions. The situation depends on the specific country. Storage and large scale flex options, require investments and may also reduce energy efficiencies but add value to the renewable energy produced and are a crucial enabler for an energy system with large shares of fluctuating renewable energy sources.

[25] Information taken from, among other sources: Wikipedia, from Groen Gas Nederland "Innovatieve technieken en leveranciers voor biogas en groen gas", and from the European Biomass Industry Association (www.eubia.org/index.php/about-biomass/pyrolysis-and-gasification/gasification)

One of the potential options to make use of higher shares of RES production is power to gas, where the renewable electric power is used to produce hydrogen and/or methane. These can be stored and especially the renewable methane can also be transported over long distances (via pipelines or liquefied). If the Power-to-Methane technologies and routes are developed on a large scale in the future, they may result in significant additional volumes of renewable methane that can be injected into the natural gas grid or directly used as a fuel for transport, heating or electricity production.

6 Policy recommendations

The stock-taking exercise of this study clearly identified a number of best practices, as well as barriers to biogas deployment throughout the EU. The scenario assessment then provided more insight in the potential growth of biogas production and use in the EU until 2030, as well as the potential impacts of these developments.

Based on these results and a thorough review of recent biogas studies, position papers or other publications on biogas policies, a wide range of policy recommendations could be identified. They aim to further develop sustainable biogas and biomethane deployment in the EU, allowing biogas production projects to be developed and market demand to grow. These recommendations span the whole biogas value chain, and are aimed at both EU and national policy makers. As was also the case for the previous chapters, the recommendations focus on biogas and biomethane production from digestion of waste streams.

The national policy recommendations provided here focus on issues relevant to all or at least a significant share of Member States. Specific recommendations for specific countries were outside the scope of the study. While some Member States already have a large part of their potential biogas production in operation and have a mature market and policy framework in place, there is still significant room for growth in other countries. Depending on their current starting point and maturity of their markets, some policy recommendations may be more relevant for some Member States than for others.

6.1 General policy recommendations

Due to the additional cost of biogas and biomethane compared to natural gas and other fossil fuels, national support policies and an effective EU policy framework are key to increase biogas and biomethane production and use. There is still significant potential for growth of biogas and biomethane production and use throughout the EU, with only few exceptions, especially in the already mature markets (e.g. Germany). Any investments in this area strongly depend on an **attractive, reliable and stable policy support scheme**, and a positive long-term outlook. These are likely to be more important than the exact type of policy measure in place. Policy proposals should be validated against these requirements, taking into account that biogas and biomethane projects typically require high up-front investments and have long pay-back periods (around 15 years). The climate and renewable energy policies and regulations that are currently being developed for the timeframe until 2030 on both EU and Member State levels are considered key to achieving the growth rates and innovation scenarios presented in this report.

Increasing biogas and biomethane production and use can contribute to various EU and national policy aims, most notably to climate goals - reducing methane emissions of agriculture, land-fill sites or sewage plants, reducing fossil fuel emissions - and to renewable energy targets. However, these projects are typically affected by a much wider range of policy areas, including agricultural and waste policies, natural gas regulations, etc. It is therefore important to ensure adequate involvement of the various policy makers and stakeholders in the decision making process, to ensure a **consistent approach and alignment** of the policy developments.

In the following, EU level recommendations are provided first, followed by recommendations for national policies. This distinction was based on the authors' assessment, keeping the EU's key principles on subsidiarity[26] and internal market in mind. Some recommendations could arguably be implemented at either policy level based on political considerations. We have then included the recommendations in both sections, so that they can be read separately and independently, at the cost of having some duplication in the text.

6.2 EU policy recommendations

6.2.1 General

Biogas and biomethane deployment is affected by a wide range of EU regulations, including directives on renewable energy, natural gas and agriculture. However, in many of these regulations only a (very) limited number of provisions specifically focus on biogas or biomethane. For example, the RED is an important driver for biogas support in many Member States and biogas can contribute to the target in various sectors, but it is only included in the GHG calculation methodology for biofuels for transport. While the EU internal market rules for natural gas (Directive 2009/73/EC) are also applicable in a non-discriminatory way to biogas and other types of gas[27] and quality standards for natural gas also apply to biomethane, these EU regulations do not have any specific provisions on biomethane included. This is understandable, given the relatively limited share of biogas in total RES and a limited share of biomethane in the gas grid. It is important, however, to assess whether biogas needs **specific attention** when designing these policies, in view of the potential benefits that increased biogas and biomethane production and use can have, both in terms of GHG emission reduction and as a versatile renewable energy source that can play a valuable role in the future energy system.

Furthermore, since many relevant EU regulations are currently being drafted (e.g. 2030 energy policies and state aid guidelines) or under revision (e.g. the waste regulation), **coherence and interaction** between the various policies and regulations should be considered. For example, since biomethane can be exported to other Member States via the gas grid (a current practice in a limited number of Member States only, but this trade may increase in the future), the RED (or an alternative regulation) should regulate and facilitate cross-border administration of the biomethane as renewable energy with certain sustainability characteristics and grid regulations should address technical specifications of the injected biomethane.

It is also recommended to **improve data monitoring**, on both EU and Member State level. Biogas production is monitored by Eurostat, but data on the feedstock mix and on the end-use of biogas and biomethane is currently not monitored and reported in full throughout the EU. Especially data gathering and reporting on feedstocks (the various waste streams as well as any energy crops used), use of the heat in biogas CHP applications and cost of the various biogas chains could be improved.

More specific EU level policy recommendations are listed in the following Sections.

[26] See, for example, http://eur-lex.europa.eu/summary/glossary/subsidiarity.html
The principle of subsidiarity aims to ensure that decisions are taken as closely as possible to the citizen and that constant checks are made to verify that action at EU level is justified in light of the possibilities available at national, regional or local level.

[27] "…, in so far as such gases can technically and safely be injected into, and transported through, the natural gas system".

6.2.2 Renewable energy policies and targets

For many Member States, EU renewable targets and policies are arguably the strongest driver for biogas support measures. Agreeing on **stable and effective renewable energy targets and policies for 2030** on EU level can therefore be expected to increase investment security and lead to equally effective renewable energy targets and policies in the Member States. The overarching targets should preferably be accompanied by an effort sharing decision that translates the EU target to national RES targets or a strong encouragement to Member States to set their own binding targets. These would contribute to a clear and stable market outlook and thus increase investment security.

It is also recommended that the EU provides guidelines or benchmarks to further support decarbonisation efforts in all sectors and harmonise developments. Specific and long-term **sector targets** for RES (for electricity, heat, transport) have the potential to further increase investment security and thereby reduce the cost of capital for new installations. Sector (indicative) targets for heating and transport, in particular, can support increased biogas use in these sectors, where significant GHG savings can be achieved and alternative renewable energy options are currently scarce.

Member States should be encouraged to **develop an outlook** for biogas/biomethane production and use to replace natural gas. This outlook should be based on an assessment of the potential for biogas production, including identification of the various potential feedstocks and sources, and of the different options for its use. As a first step, biogas and biomethane could be explicitly included in the requirements for the Member State progress reports required by Article 22(1) of the RED.

In the transport sector, increasing the use of biomethane requires not only increasing the production of biomethane, but also an increasing market share of vehicles suitable for CNG or LNG, as well as sufficient filling stations. These issues are all addressed in a number of EU policies: the RED, the FQD and the Clean Power for Transport Directive[28]. Biomethane is likely to be key to increase the share of renewable energy in CNG and LNG, and **coherence of the various policies** is crucial to the effective development of biomethane use in transport.

The 2030 RES policies should include both direct application of (100%) biomethane (in the transport sector, for district heating, etc.) as well as injection in the grid. The latter route is often the most cost-effective means of transporting biomethane, but the first is sometimes preferred for reasons of cost, especially in areas with limited gas grid coverage, transparency or public perception. The mass balance method introduced in RED Article 18(1) can provide this flexibility on Member State level (see Section 6.2.7 for the topic of cross-border trade).

We furthermore recommend revisiting Article 17(1) of the RED and also allow Member States to apply an **energy balance system** to account for feedstock mixtures, as an alternative to the mass balance system. This is a detail of the legislation relevant to co-digestion, where the energy density of feedstocks can differ significantly: manure has a much lower yield (in terms of GJ biogas per tonne feedstock) than maize. For example, if co-digestion is applied with 80% manure and 20% maize (mass percent), the produced biogas and biomethane will be considered to be 20% from maize, i.e. from a crop that falls under the cap defined in the ILUC directive. 80% counts as being based on a waste and residue streams that does not fall under the cap and is eligible

[28] The first two support the deployment of biomethane in the sector, notably in road transport, the latter aims to ensure sufficient availability of CNG filling stations by 2020/2025, and of LNG for heavy-duty vehicles and shipping by 2025/2030.

for double counting if used in the transport sector. In reality, however, due to the difference in energy density, the maize will have contributed to about 60-70% of the resulting energy, depending on the characteristics of the manure. Energy allocation will thus provide a more realistic result than mass allocation in these cases. This issue is relevant for all biofuel and bioliquid production processes that have mixed feedstocks, but it is only relevant for use of the biomethane in transport and the transport target of the RED, not for use in heating or electricity production or for the overall RES target.

6.2.3 Sustainability criteria

It is recommended to agree on **clear, effective and robust sustainability criteria** for biogas feedstock and other biomass feedstock use at EU level for all applications, not only for transport as it is today. This is necessary for a number of reasons:

- to create a level playing field with other biomass routes;
- to enable and facilitate cross-border trade;
- to ensure public support; and
- safeguard that efforts focus on deployment of biogas routes that achieve high GHG savings.

These criteria should be **stable until 2030**, again to enhance investment security. They should put the necessary boundary conditions in place to be sufficiently robust for the next decade from an environmental point of view. This also requires that they **allow for new developments** and feedstock types to be included over time. Ambitious targets of minimum GHG savings over the whole production chain, for example, are likely to be more robust than specifications that define which feedstocks are allowed since they leave room for technological innovations.

EU level sustainability criteria should harmonise **criteria related to feedstocks** used for biogas production for all applications, comparable to the provisions of the ILUC directive that applies to biofuels (incl. biomethane) used in the transport sector. This is especially relevant for co-digestion of manure and mono-digestion of crops such as maize. In co-digesters, large shares of co-substrate will improve biogas yields and, depending on local conditions and cost, improve the business case for the biogas production. These feedstocks can have limited environmental benefits, though, and cause indirect land use change. Sustainability criteria should limit the environmental impact of these co-substrates, encouraging farmers to increase the level of manure in co-digestion.

Harmonisation of sustainability criteria in the EU can be considered a prerequisite for the proper functioning of the internal market, as it will facilitate cross-border trade.

6.2.4 Heat

Using biogas as a fuel in CHP-plants has the potential to achieve relatively high GHG savings, depending on whether or not the produced heat is used. Reliable EU-wide data on heat use from biogas electricity production are not available, but EBA estimates that about 25% of the heat is utilized. If a larger share of the rest-heat would be used, there would be significant potential to improve overall energy efficiency, replace more natural gas with a given amount of biogas and increase GHG savings. However, biogas production is not always close to heat users and heat demand typically varies significantly over the year. Heat demand from industry, as energy input for processes, can be more stable over time than demand from the built environment, depending on the type of industry and processes.

It is therefore recommended to **provide incentives to use the rest-heat** from biogas use. This can be done on Member State level (discussed below, Section 6.3.3), but there are also a number of EU level regulations and communications that could support these measures. This support would aim to encourage biogas producers and users to optimise local biogas end-use by choosing a location for CHP close to heat users, by optimising CHP operations (e.g. by combining CHP with biogas or thermal storage), by investing in infrastructure needed for heat use, etc.

EU heating and cooling policies should explicitly address the use of biogas and biomethane as a potential means for (locally produced) sustainable energy, particularly for heating. Heat utilisation warrants explicit support through the relevant policies, namely the Energy Efficiency Directive (EED; 2012/27/EU), RED and **Energy Performance of Buildings Directive** (EPBD; 2010/31/EU), and the future 2030 energy policies. These policies should encourage Member States to reduce and decarbonise energy demand for heating in line with the 2016 EU Strategy on Heating and Cooling (COM(2016) 51 final), and include provisions on the following topics:

- For example, by providing indicative targets for the share of RES in the heating sector, or by setting an ambitious overall RES target that would require increasing the share of RES in heating in order to meet the target efficiently.
- Encourage Member States to require heat utilisation plans for future CHP plants as well as for existing ones.
- Urge Member States to consider heat distribution as a sustainable alternative to other heating options in their energy network strategies.
- Share information on best available technologies for useful heat utilisation from CHP plants, including options such as district heating and cooling and on-site utilisation. This could be achieved, for example, through guidelines for practitioners and demonstration projects.

6.2.5 Agriculture

There are a number of key issues in EU level agricultural policies that directly affect biogas production and use, the following are recommendations for potential improvements of these policies.

The use of digestate as fertilizer and soil improver instead of waste should be stimulated, as long as the digestate is derived from clean feedstocks. The EU waste legislation[29] already regards anaerobic digestion, which result in the production of biogas and digestate, as a recycling operation. The EC proposal (COM(2016) 157) for a Regulation on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009, provides the legislative framework and limits for use of organic fertilizer products, such as digestate, which should lead to harmonisation.

However, in livestock dense areas, the use of digestate can be limited, since the Nitrates Directive (91/676/EEC) considers all digestate with a share of animal manure, as 100% animal manure for which a limit of 170 kg N/ha is included for Nitrate Vulnerable Zones. Whereas use of undigested manure in combination with compost would allow higher application. It is therefore recommended to **differentiate the requirements regarding the use of digestate** in agriculture, based on the share of manure in the feedstock and the nitrogen content of the digestate. This would increase

[29] Article 2 (6) of Commission Decision 2011/753/EU establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council. OJ L 310 of 25.11.2011.

the potential use of digestate and therefore promote biogas production from co-digestion.

EU-wide **harmonisation of the regulations regarding which co-substrates** are allowed in anaerobic digestion would be beneficial to the development of the EU internal market of biogas/biomethane. This would create a level playing field and would allow export of digestate to other Member States. This approach should allow for flexibility regarding co-substrates – an important issue as there are different co-substrates used in different Member States and developments and research may result in new types entering the market in the coming years and decades[30]. An option to achieve this is by defining EU-wide **sustainability criteria** for biogas and biomethane, as discussed above. This approach should allow for flexibility regarding co-substrates and ensure the sustainability of the overall end product. Large shares of co-substrate in co-digestion can improve biogas yields and therefore improve the business case for biogas production on farms. However, they may also reduce the average environmental benefits (GHG savings) of the biogas that is produced, depending on the GHG emissions of these co-substrates. Sustainability criteria can increase the GHG savings of the biogas produces, encouraging farmers to increase the level of manure in co-digestion and choose co-substrates with low environmental impact[31], e.g. by distinguishing between different levels of the use of maize in co-digestion.

Although the current **Common Agricultural Policy** (CAP) already provides options to stimulate anaerobic digestion of manure through provisions in the Second Pillar, e.g. investment subsidies, this could be strengthened in the next revision of the CAP, e.g. through rewarding the prevented emissions from manure storage and stimulating mono-digestion.

Removal of nitrogen rich crop residues (e.g. vegetables and sugar beet leaves) and use as biogas feedstock could decline nitrogen leaching and could lead to an improvement of the soil and surface water quality. The introduction of measures to **introduce residue removal practices** in zones that have high nitrate leaching could increase the availability of biomass feedstock available for digestion, improve compliance with the Nitrates Directive and bring down nitrate leaching levels.

6.2.6 Waste and circular economy

The main objective of the EU's Circular Economy Package published in 2015 is to 'close the loop' of product lifecycles through greater recycling and re-use, and to bring benefits to both the environment and the economy. 31% of the EU's municipal waste is still being landfilled, with very large variations between Member States (COM(2015) 595 final). Since a large proportion of municipal waste is biodegradable, this landfill potentially causes significant GHG emissions, as well as pollution of surface water, groundwater, soil and air. The 2015 proposal for a landfill directive includes a binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030 and a ban on landfilling of separately collected waste. These developments are likely to reduce biogas production from landfill, but increase the availability of organic waste for anaerobic digestion. When re-use is not feasible, for example when the waste cannot be used as food or feed, biogas production through anaerobic digestion can

30 An alternative approach with a list of allowed co-substrates (currently used in some Member States, for example in the Netherlands) would be less flexible in that respect.

31 The cost of co-substrates is also relatively high, therefore innovations aimed at improving business cases of mono-digestion would be beneficial, and research is ongoing.

then be a waste-to-energy route preferable to landfill[32]. Biogas production can thus contribute to the objectives and targets of both the current and the future (2030) EU level waste and circular economy policies.

It is therefore recommended to ensure **compliance with the waste and landfill directives** throughout the EU. This includes the provisions on applying the waste hierarchy (Article 4) and on bio-waste (Article 22). For example, some countries in the EU still lack economic and regulatory instruments to divert waste from landfill. Furthermore, in view of the significant potential for growth of biogas production from organic wastes that was identified in this study (see Section 4.3.1), Member States should be encouraged to implement separate collection systems for organic waste streams, if they do not yet have this in place. The various reporting provisions included in the proposals for the waste and landfill directives can be a useful starting point for this exercise.

The 2015 proposal for an EU waste and circular economy package also aims to improve harmonisation and simplify the legal framework on by-products. Digestate, the by-product of anaerobic digestion, is also affected by this legislation: Article 5 confirms that it is a by-product and not waste. This allows the digestate to be used as fertilizer and soil improver.

6.2.7 Biomethane: grid access and trade

To further develop biogas upgrading to biomethane, **access to the natural gas grids** becomes relevant and, albeit to a lesser extent, **biomethane trade** across borders. Biomethane trade is still very limited, mainly because biomethane volumes are limited and demand is often higher than supply, but this may change as biomethane demand and production increases in the EU[33]. Trade is currently based on bilateral agreements between countries. EU-wide harmonisation of quality standards, sustainability criteria as well as data transfer would remove the need for these bilateral agreements and facilitate the internal market for biomethane.

From a regulatory point of view, biomethane grid access is currently covered by the EU natural gas regulations, and recently approved **standards for biomethane** for injection into the natural gas network (EN 16723-1:2016). An automotive standard is currently under approval (prEN 16723-2), both under responsibility of CEN Working group TC408. These standards are considered to be an essential enabler of the biomethane market in the EU.

It is furthermore important to develop EU-wide common traceability and **sustainability standards** for biomethane for the use in national grids, as harmonisation of these standards can support the development of the internal market and cross-border trade, ensuring that sustainable biomethane that is injected into the grid in one Member State can be sold as sustainable biomethane in another Member State, where it can also be included in RES consumption targets and policies (depending on the policies in place).

It is, however, recommended to keep the approach for **trade of biomethane** in line with the situation in renewable electricity production, where the actual location of the RES production to the electricity grid determines which country may count the RES towards its RES target (RED, Article 5(3)). National policy support measures are

[32] The proposals also contain provisions on waste prevention (Article 9), which also reduces potential feedstock for biogas production but nevertheless will have a positive environmental impact.

[33] Biomethane Status and Factors Affecting Market Development and Trade, IEA Bioenergy, 2014.

typically also limited to this scope. This prevents double counting in EU statistics and double support. At the same time, EU level harmonisation of transfer of administrative data relevant to biomethane would facilitate trade within the EU. **An EU-wide system of Guarantees of Origin (GoO) for biomethane**, similar to GoOs for electricity that are governed by Article 15 of the RED, can then be used to facilitate administrative trade of the biomethane, for disclosure and transparency purposes.

An alternative approach would be the implementation of a system for an EU-wide mass balancing of biomethane in natural gas grids that could provide a flexible basis for biomethane trade. This could encourage end-users to use biomethane that is produced elsewhere, further contributing to an internal market for biomethane. The BIOSURF project recently concluded that EU-wide mass balancing is necessary to maintain the 'green' and 'renewable energy' value on the international market (BIOSURF, 2016) and ensure that any volume of biomethane injected into the grid can only be brought to the market once. These options would require cross-border harmonisation of biomethane support policies to prevent double support (e.g. eligibility for a feed-in tariff in our country and for lower tax levels for biomethane end-use in another country).

The data to be transferred through GoO or any other administrative system when trading biomethane should include all information relevant for national support schemes, transparency and RES reporting requirements, such as[34]:

- biogas producer details;
- biomethane upgrading details (plant name and address);
- period of injection and amount injected;
- proof of Injection by the distribution system operator (DSO) or transmission system operator (TSO);
- trader ID;
- origin (anaerobic digestion, landfill, sewage sludge, other);
- in case of anaerobic digestion: substrate(s) used. In case of co-digestion or other mixes: share of various substrates, based on energy content;
- sustainability certificate;
- whether the biogas producer, the biomethane upgrading or injection received any support, and if so, what kind;
- date, country of issue, unique ID.

As a first step, the use of Guarantees of Origin certification systems as a disclosure and transparency system for biomethane can be improved by encouraging more Member States to establish a national register for biogas GoOs. Currently, 7 Member States have such a register in place. These registries oversee the issuing, administration and cancellation of GoOs. This measure could be included in Article 15 of the RED, which contains similar provisions for GoO of electricity, heating and cooling produced from RES.

The EU can furthermore encourage Member States to invest in **grid development** relevant for biomethane projects: to connect remote biogas production locations to the natural gas grid as part of gas network strategy and planning, with a focus on rural grid development.

Biomethane can be injected into both the distribution and transmission gas grids, most of the recommendations above therefore apply to all gas grids. As far as the authors

[34] Partly based on BIOSURF Deliverable D3.3, with modifications.

of this study are aware, cross-border trade of biomethane, however, only involves transport via transmission grids.

6.2.8 Dissemination and Innovation

As the results of the scenario analysis illustrate, innovation of the biogas chain can have a range of benefits. Continued efforts into **R&D** of biogas production, conversion into biomethane and the application of biogas are therefore recommended. These efforts should be aimed at technology developments that reduce cost, improve efficiencies and reduce emissions, as well as at sustainable sourcing of co-substrates for co-digestion. Important issues to address are further developing innovations regarding manure mono-digestion and development of other innovative digestion techniques (e.g. high pressure digestion), but innovative research into other parts of the value chain, for example regarding methanisation processes, can also contribute to cost reductions and/or extra cash flows in the future. Innovations into the use of digestate as useful natural fertilizer, the use of fibres from digestates, and pre-treatment of sludges can also contribute to further driving biogas developments.

Provide a **platform for best practices** related to biogas production technologies, applications and policies, with dissemination targeted at farmers, economic actors, municipalities, policy decision makers and other stakeholders throughout the EU. The results of the stock-taking has shown that a large part of the biogas installations are deployed by semi-professional investors such as farmers, local cooperatives and private owners. Such groups often do not have the means to inform themselves on the fields relevant for an investment decision. They would therefore greatly benefit from a platform that gives them a first overview on the framework of biogas investments and helps them evaluating their own project ideas. A description of best practices would also help policy decision makers understand their own conditions and find new options to improve their respective national framework. It should be noted that, though, that there is already a large number of platforms that cover parts of the content of this platform. For that reasons, the main input of the proposed platform would be to assess the existing platforms and connect their input in a centrally available information database.

6.3 Member State recommendations

6.3.1 Strategy Development

As was concluded earlier, stable and effective Member State policy support is crucial for biogas projects and investments throughout the EU. There is significant potential for biogas production with significant potential benefits, but there are still many Member States with no or only limited support policies. Other Member States, including countries with mature markets and large scale biogas production in operation, are currently revising their renewable energy policies and support schemes, for various reasons: the revised state aid guidelines from the European Commission, concerns about high cost to consumers, the need to enhance efforts to achieve the 2020 RED targets or change in policy priorities. The current policy reviews as well as ongoing and future efforts to develop national RES targets and policies for 2020 and beyond can provide a good opportunity to further develop the national biogas strategy for the longer term.

Member States are therefore recommended to **develop national strategies on the role of biogas and biomethane to meet future renewable energy and climate goals**, in cooperation with the relevant biogas stakeholders. This should include an assessment of available suitable feedstocks and an outlook for biogas/biomethane production and use, indicating the potential for biogas production and assessing the different options for its use: is local use feasible and cost-effective, how does this compare to upgrading and grid injection or transport to end-user in heating or transport?

The strategies should **take into account related policy areas** that may benefit from increased biogas deployment such as agriculture, rural development, air and water quality, waste and circular economy. Environmental benefits of biogas production, including avoided methane emissions, should be included both in strategy development as well as in any support policies.

As part of this strategy, Member States should decide which **policy focus** would be optimal, given the national, regional and local objectives, opportunities and circumstances. Policies can focus on different areas: on integration of biogas sector as a part of sustainable agriculture, on maximising renewable energy production and/or GHG savings (national or regional), on developing a renewable and sustainable alternative to natural gas in the heating and/or transport sectors, etc. As part of the assessment, Member States can also compare **different applications**, i.e. options for end-use.

For example:

- Biogas can be used locally for sustainable electricity and heat production, typically as a replacement for natural gas in district heating systems (e.g. in high efficiency CHP).
- Biogas can also be used to provide flexible electricity production, and thus contribute to the uptake and growth of flexible RES from wind and solar energy in the energy system. The benefits of this application can be further enhanced by using the residual heat.
- If the biogas is upgraded to biomethane, it can be used as a renewable energy source for heating in the built environment or industry, or as a renewable transport fuels, notably in CNG and/or LNG vehicles. If the natural gas network allows, this can be achieved by injection into the grid, alternatively, dedicated biomethane transport by truck to the end-user or filling station may be an option. As the scenarios demonstrate, this route can result in relatively high GHG savings, assuming that the biomethane replaces diesel.

These choices can each have different impacts, pros and cons, and will result in different policy packages.

6.3.2 Biogas production and demand support policies

Irrespective of what overall strategy is chosen, **stable and effective renewable energy targets for 2030 and long-term, stable support policies** are considered to be a prerequisite to increase biogas production and demand to the levels identified in this study. These policies should include effective and stable minimum **sustainability criteria** that remain valid until at least 2030. These determine the environmental benefits from the policies as well as the future demand for specific feedstock-biogas/biomethane routes, important boundary conditions for investment decisions.

Specific RES targets and support policies for the various **sectors** (e.g. electricity, heat, transport) can further increase investment security as it reduces uncertainties regarding the future outlook for biogas demand. Support policies can take many forms, including feed-in tariffs or premiums, quota (e.g. for renewable heat in buildings, renewable energy in transport fuels, etc.), financial and fiscal incentives, etc.

A further **differentiation of policy incentives to the sustainability** of the renewable energy (e.g. GHG savings) can further ensure focus of efforts and investments towards the most sustainable options including many of the biogas routes from waste, use of waste heat and CHP, etc.

Biogas and biomethane support policies need to take into account that biogas installations have high upfront investment costs and therefore need long-term financing possibilities and return on investments. To realise biogas projects on small-scale farm-level, specific support policies for these actors may be necessary, the smaller scale operations typically lead to higher investment security requirements. Farmers have, for example, indicated to accept lower prices if those are guaranteed over time, and that this type of support would be preferred over investment subsidies.

The biogas sector can also be seen as a part of **sustainable agriculture**, not limiting policy considerations to energy production. The biogas sector can contribute to prevention of GHG emissions from manure storage and wastes, and the use of biogas co-products for improved soil management (high-quality bio-fertilisers). Policy support can include higher incentives for mono-digestion (at least 90 or 95% manure) than for co-digestion with lower shares of manure. As a matter of course, in case manure is used as feedstock in a digester, GHG emission reductions due to prevented methane emissions that would normally result from the manure should be taken into account in the GHG emission calculation methodologies.

To support and facilitate growth of demand for biogas or biomethane, different **policy packages** are needed for different applications of the biogas and biomethane. These typically require additional supporting policies and strategies on top of biogas policies, for example:

- support to district heating and CHP installations;
- an electricity market design that values flexible power production;
- investment support or supporting regulations to facilitate connections to the gas grid;
- support for the market uptake of CNG vehicles and filling stations, possibly targeted at specific transport modes such as city buses or regional goods transport.

It is recommended to assess and compare the various policy options in these areas, based on the more strategic choice of the preferred end-use options that was discussed in the previous section. Member States can then design and implement a **coherent and integrated policy package** that suits the national priorities and opportunities.

The largest potential for biogas growth is in making more use of existing agricultural waste streams such as manure. Member States that do not yet have sufficient support policies in place should therefore focus their efforts on the mobilization of these feedstocks. Care should also be taken that EU agro-environmental legislation such as the Nitrate directive is properly implemented (Elbersen, 2016).

As mentioned above, it may be useful to implement support policies specifically for small scale biogas production facilities (typically < 1 MW, but this can vary per Member State). These projects can be very effective in reducing GHG emissions and making use of waste streams that have no other applications. This applies to digesters, but also to biogas production from landfill and sewage sludge.

It is also recommended to assess whether the administrative procedures and technical rules for biogas and biomethane projects create unnecessary barriers and can be improved (related to permits, support policies, grid injection, etc.).

Member State implementation of future EU level regulations regarding biogas (and co-substrate) sustainability criteria, which are expected to be part of the 2030 renewable energy policy proposals by the European Commission, can be an important step towards harmonisation of biogas-related Member State policies. In the current situation, these policies differ significantly, as illustrated in Section 3.3.4.

6.3.3 Support use of residual heat

As was concluded in Section 6.2.4, using biogas as a fuel in CHP-plants has the potential to achieve relatively high GHG savings, if a large share of the produced heat is used. However, biogas production is not always close to heat users, and especially heat demand from the built environment (households, public buildings, utilities, offices, etc.) can vary significantly over the year. Heat demand from industry, as energy input for processes, can be more stable over time, depending on the type of industry and processes.

It is therefore recommended to provide **incentives to use of heat** from CHP, in order to increase both the GHG savings from the biogas and the share of RES in the heating sector. There are a number of options to achieve this on Member State level, such as:

- Include relevant requirements or incentives in financial support measures for renewable energy. For example, differentiate support to biogas according to GHG savings achieved or to the average share of rest-heat used, provide support to renewable heat production and use, or oblige gas grid operators to achieve a minimum share of RES in their heat production and supply or to purchase biogas at set prices and inject into the grid (as is the case in Lithuania, for example).
- Include relevant requirements or incentives in building regulations. Consider, for example, to take measures that oblige the use of RES-heat in buildings. In Germany, for example, the law 'EEWärmeG' regulates the obligation to use renewable energy in new buildings. Owners of new buildings must cover part of their heat supply with renewable energies.
- Promote use of biogas in CHP installations close to end-users of the heat. For example, require heat utilisation plans for future CHP plants as well as for existing ones, or provide dedicated support to biogas project developers, such as heat mapping, technical or contractual support (see, for example, the Heat Network Delivery Unit in the UK). Barriers related to heat grid connection and access should be addressed. Suitable locations could be near municipalities or residential areas with a district heating system, or an industrial area with heat-consumers. Financial support may be necessary to develop a sound business case for all parties involved, for example due to additional transport and distribution cost if these locations are at a distance to biogas feedstock or production facilities.
- Encourage investments in heat infrastructure, for example by providing financial support, by implementing requirements in industrial development areas or (new) residential areas, etc.

Note that most of these measures are not only relevant for biogas but also for the decarbonisation of heat in general. They should therefore be an integral part of the sustainable heating and cooling strategies of Member States, regions and municipalities, especially related to existing buildings were there are often only few renewable and cost-effective alternatives for decarbonisation.

6.3.4 Agriculture

Agricultural policies are very relevant to biogas developments, and Member States could focus stronger on integration of **the biogas sector as a part of sustainable agriculture**, not limiting policy considerations to energy production. For example, by optimising the biogas sector's contribution to prevention of GHG emissions from manure storage and wastes, and the use of biogas co-products for improved soil management (high-quality bio-fertilisers). Member States should value GHG emission reduction in their support policies and regulation in case manure is used as feedstock in a digester, thereby reducing the methane emissions that would normally result from the manure.

6.3.5 Waste and circular economy policies

In line with the EU level recommendations on waste and circular economy, each Member State should ensure **compliance with the waste and landfill directives**. This includes the provisions on applying the waste hierarchy (Article 4) and on bio-waste (Article 22). Many countries have these policies implemented and some have effectively prohibited landfill of organic wastes altogether, for example the Netherlands, but some countries in the EU still lack economic and regulatory instruments to divert waste from landfill.

Furthermore, in view of the significant potential for growth of biogas production from organic wastes that was identified in this study, Member States should assess **their organic waste streams**, identify their sources, determine the potentials for biogas production and ensure separate collection of these waste streams.

6.3.6 Biomethane: grid access and trade

A number of Member States have chosen to support biomethane as a renewable alternative to natural gas for heating or for use in the transport sector, typically to increase the share of renewables in these sectors and to increase demand for biogas. The latter can improve the business case for biogas projects, especially in cases where the biogas is produced at locations with limited electricity and heat demand. The biomethane is then either transported directly to the end-user (typically via dedicated trucks[35]) or injected into the gas grid where it is then mixed with natural gas. The first route is applied by some Member States (e.g. Sweden), the latter route in others (e.g. Italy, the Netherlands). The type of distribution is mainly based on cost considerations, which depend strongly on the gas grid coverage near the biogas and biomethane production site.

If a Member State has a well-developed gas grid, distribution cost will be lower than in countries with a less developed grid, but even then, additional pipelines are often necessary to **connect biomethane plants to the grid** due to the often remote location of biogas production plants.

Since **grid expansion** typically requires significant investments, Member States can thus support biomethane development by providing investment support, or by implementing relevant grid expansion requirements for national gas grid operators. The investments needed in grid expansion, and the overall cost of bringing the biomethane to the market depend strongly on the local conditions, and need to be determined on a project-by-project basis. Any assessment of options to enhance biomethane grid access should then be part of a broader national gas strategy and grid development plan, to identify projects where grid expansion would be cost-effective.

Facilitating biomethane cross-border trade requires a number of EU level actions (see the recommendations in Section 6.2.7), but Member States can contribute to these developments by setting up a national registry for biogas Guarantees of Origin that oversee the issuing, administration and cancellation of GoOs.

[35] Either as compressed biomethane or as liquid (bio-LNG), depending on transport distance.

6.3.7 Regional opportunities

Regions and municipalities are also recommended to **assess their potential biogas sources** as well as **options to develop these opportunities**. These can contribute to their energy independence and rural development, increase the share of locally produced renewable energy, and, at the same time, reduce environmental impact of waste streams. These include agricultural waste (incl. manure), food waste, sewage sludge and landfill.

A broader view on biogas and RES-related regional and rural development can then be useful to identify options to optimise investments, support and energy related opportunities. Examples of policies that can support biogas and biomethane projects are financing of demonstration or pilot projects of rural intelligent grids with high share of renewable energy (RE) on farms, and the development of micro-credit schemes at the national level (possibly guaranteed by EU funds) for RE installed on farms. Connection of remote biogas production locations to the natural gas grid typically requires a broader view on rural natural grid developments. Developing biogas projects in conjunction with district heating can optimise heat use.

6.3.8 Dissemination and information

Specific attention should be given to **raising awareness of potential stakeholders and investors** regarding the available benefits of biogas production and usage, especially in Member States where biogas markets are still immature and there is significant potential to increase biogas production. Potential producers and users can be informed directly, best practices can be advertised, training courses and workshops can be organized, etc.

Organise adequate **communication with the public and national or local NGOs**, to ensure that they are well informed about ongoing and planned biogas projects in their neighbourhood, the environmental benefits and safety and sustainability safeguards in place, etc. This could include local and regional information campaigns, web-based communication and a central point to turn to in case of questions.

7 Conclusions and recommendations

This final chapter provides and overview of the key conclusions and recommendations of this study.

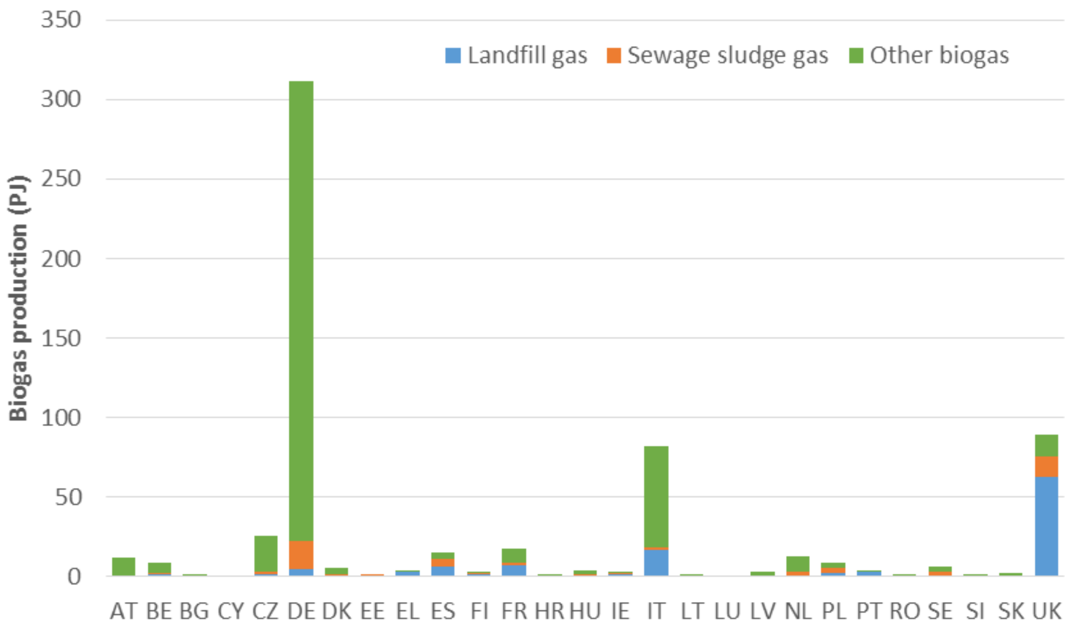
7.1 Main conclusions

7.1.1 Current status of biogas in the EU

Biogas production and use

Biogas production in the EU is currently 625 PJ (2014 data), accounting for 7.6% of the total primary production from RES. All EU Member States have at least some biogas production, but, as shown in Figure 29, Germany is by far the largest producer - responsible for half of the total annual production in the EU28 - followed by Italy and the United Kingdom. 72% of the biogas is produced in anaerobic digesters, mainly farm-based plants and some industrial organic waste digesters. In addition, landfill had a share of 18% of the total, and sewage sludge 9%. This biogas is mainly used for electricity production (62%), followed by heat production (27%). About 11% is upgraded to biomethane and then either used directly as a transport fuel or injected into the natural gas grid.

Figure 29 Biogas production per Member State in 2014, differentiated by source (EurObserv'ER, 2015)[36]



Information on feedstock use for biogas production in the EU is not easy to obtain, but it is estimated that energy crops (maize mainly) provide about half of the biogas production (318 PJ) in the EU, followed by landfill (114 PJ), organic waste (86 PJ), sewage sludge (57 PJ) and manure (46 PJ).

Based on the number of biogas plants installed, the Member States were divided into 'mature', 'moderate' or 'immature' market categories. This division was then used to

[36] In PJ, with 1 PJ = 23.88 ktoe.

explore whether specific drivers or barriers could be identified depending on the market maturity of a country.

Drivers for biogas developments

Existence, stability and reliability of the policy framework and support scheme(s) is the number one driver in all countries, independent of whether they already have a mature biogas market in place or not. This demonstrates how important it is to have a stable and reliable political and legal framework providing long-term visibility and certainty for project developers and investors. Along with attractive and well-functioning support schemes it helps technologies to enter the market and compete with conventional energy.

National targets and goals also play an important role in all three markets, leading to the conclusion that ambitious GHG reduction, renewable energy or biogas/biomethane specific targets at national level can be seen as a good example also for the remaining Member States that opt to increase biogas/biomethane production and use.

Furthermore, feedstock potential or availability of feedstock is a driving force in all three markets; highlighted in Poland, Belgium, Portugal, Spain, Ireland, and Croatia. Stakeholder effort is seen as an important driver in mature markets and immature markets; it is not mentioned as a driver in moderate markets.

Other identified drivers are difficult to compare since they vary a lot not only among the three markets but also in the respective market itself. Examples of other drivers mentioned are growing confidence in biomethane technology (the United Kingdom), regions with poor electricity and high unemployment rate (France), and large customer demand for green gas (Ireland).

Barriers

The number one barrier in all three sectors and in all three markets is opposite of the main driver mentioned above: the lack of existence, stability and reliability of the framework and support scheme(s). This barrier is a result of the current revision of the existing support schemes in some Member States and lack of support schemes, especially in heat and transport sectors, in a variety of Member States.

Besides this main issue, there is a great variety of barriers across EU Member States. Access to finance is a barrier in electricity sector in all three markets, more severe in immature and moderate markets. In the heating sector access to finance is more severe in mature markets than in immature markets (and not detected in moderate markets).

In the transport sector, other problems are deemed more relevant, such as lack of EU and/or national goals, lack of supporting taxing regimes, mass balancing rules related issues as well as a negative perception of biogas/biomethane technologies and low public awareness, which was found to be the second biggest barrier in mature markets.

ILUC and sustainability issues have mainly been reported by the Member States with mature markets (the United Kingdom and Sweden in all three sectors). For the transport sector ILUC related problems have been communicated also by Poland. These issues typically relate to policy uncertainties.

Barriers related to the treatment of biogas by-products as well as the access to the suitable waste streams appeared in mature and moderate markets, whereas lack of expertise and stakeholder efforts constitute a barrier in immature markets (Croatia, Romania and Bulgaria). Some barriers appeared only in one of the Member States, like e.g. certification issues in Italy or cost of feedstock in Portugal.

Cost of biogas production

Biogas production cost differs significantly, depending on the substrate used, the technology applied, investments needed and the possibilities to distribute the resulting digestate in the surrounding agricultural area. In case the biogas is upgraded to biomethane, additional investment and operational cost result.

Infrastructure

Almost all EU Member States currently have gas infrastructure and storage in place, as well as a natural gas infrastructure for transport and gas quality regulations, important prerequisites for biomethane deployment and growth (unless biomethane is transported with dedicated trucks, as is common practice in Sweden).

To apply the biomethane in transport, the necessary infrastructure and sufficient filling stations for CNG or LNG need to be available, and typically also support policies to make the bio-CNG or -LNG attractive to vehicle owners. The EU-countries with the highest number of CNG filling stations are Italy and Germany, but Austria, Sweden and Finland also have an extensive network of CNG stations. Other EU Member States are clearly lagging behind these countries in this area, as many of them have only initiated the process of creating the necessary infrastructure.

Inter-EU trade

Initially, biomethane has been traded at a national level only, but gradually it becomes a cross-border commodity that is traded between EU Member States. Nevertheless, cross-border biomethane trade is still very limited. The main problems identified concern the traceability requirements and in particular the mass balancing system that is implemented on national level but does not include trading of biomethane across borders via the natural gas grid. Moreover, cross-border trade in biomethane is more difficult if there are country specific quality requirements additional to those set by the EU (e.g. regarding noise or odour emissions of production plants). EU-wide harmonisation and mandatory sustainability criteria for gaseous biomass, especially used in the heat and power sector, are seen as an important prerequisite to resolve this issue.

7.1.2 Biogas polices in the EU and Member States

EU policies

A large number of EU policies is relevant to biogas and biomethane developments, ranging from renewable energy and climate change policies, state aid guidelines, regulations on transport, agriculture and waste to natural gas regulations. Many of these are currently being revised or further developed, most notably the renewable energy and climate policies beyond 2020, and waste and recycling policies related to the EU's Circular Economy Package. In view of the dependence of biogas deployment and investments on effective and stable policy support, these new regulations and communications for the period after 2020 are expected to be crucial to the longer term developments of biogas in the EU.

Member State support schemes

The EU-wide overview of biogas support schemes demonstrates that biogas across EU Member States is mainly supported in the electricity sector, while support for biomethane has its focus on the transport sector. As the significant gap between current biogas production and technical potential illustrates, there is still a lack of effective support schemes in many Member States. Biogas and biomethane for electricity generation is supported in 26, for heat generation in 18, biomethane in the transport sector in 16 Member States. A greater focus in the future national policies on the biogas and biomethane supporting incentives in the heat and transport sector could further increase biogas demand and thus support future investments and growth of biogas production.

Moreover, the survey indicated a clear correlation between the financial incentives in place and the way biogas is deployed in the Member States. As described in Section 3.2 on drivers, the deployment of biogas and biomethane is a clear result of support schemes with beneficial conditions in the Member States with mature markets, including Germany, the United Kingdom, Italy, Sweden, etc.

7.1.3 Scenarios for biogas development beyond 2020

Four scenarios covering the playing field of possible biogas development in 2030 were designed and quantified, based on the presumption that digestion of local biomass waste streams increases throughout the EU towards the total biogas potential that was identified. These scenarios show what *might* be possible, and are not predictions of what *will* be possible.

One axis of the scenarios considers the use of the biogas: either locally in a cogeneration unit, where the excess electricity is fed to the electricity grid and the heat is used locally, or in the gas market via upgrading of the biogas to biomethane and subsequent feeding into the gas grid. The other axis of the scenarios considers the rate of deployment of the feedstock potentials (i.e. the improved collection and use of organic waste streams) and the rate of innovation.

The four scenarios are:

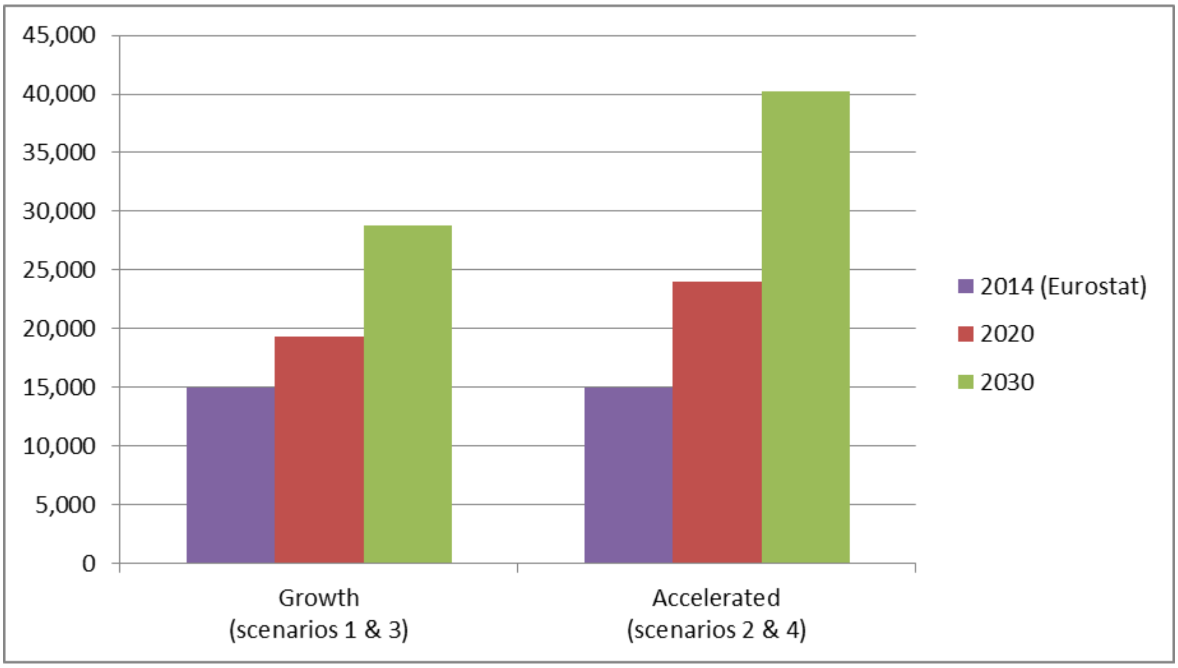
1	Local use & growth	Local use of the biogas in CHP, with electricity fed to the grid and local use of the heat Growth of feedstock deployment, regular development of investment costs and conversion efficiencies
2	Local use & accelerated growth	Local use of the biogas in CHP, with electricity fed to the grid and local use of the heat Accelerated growth of feedstock deployment, accelerated development of investment costs and conversion efficiencies
3	To gas grid & growth	Upgrading of the biogas to biomethane, fed into the gas grid. Use in built environment or in transport sector. Growth of feedstock deployment, regular development of investment costs and conversion efficiencies
4	To gas grid & accelerated growth	Upgrading of the biogas to biomethane, fed into the gas grid. Use in built environment or in transport sector. Accelerated growth of feedstock deployment, accelerated development of investment costs and conversion efficiencies

The potentials of the biomass waste streams suitable for digestion, were derived from two feedstock scenarios in the Biomass Policies project (Elbersen, 2016), completed with information on the potential of biogas capture from landfill sites. The feedstock scenarios show that the largest growth potentials are in liquid and solid manure, and in organic wastes.

As shown in Figure 30, the scenario assessment shows that biogas production in the EU in 2030 could increase to 28.8 to 40.2 Mtoe, depending on the amount of feedstock deployed and the learning effects attainable until 2030. The higher value corresponds to a factor of 2.7 times the 2014 biogas production levels. For 2020, this factor is 1.6. The biogas contribution to the EU renewable energy goals in 2020 and

2030 can be 10.6% and 13.8%, where the target volumes in these years are expressed as 100% and assuming that a 27% RES target is set for 2030.

Figure 30 Growth of biogas production in EU28 in the scenarios in ktoe[37]



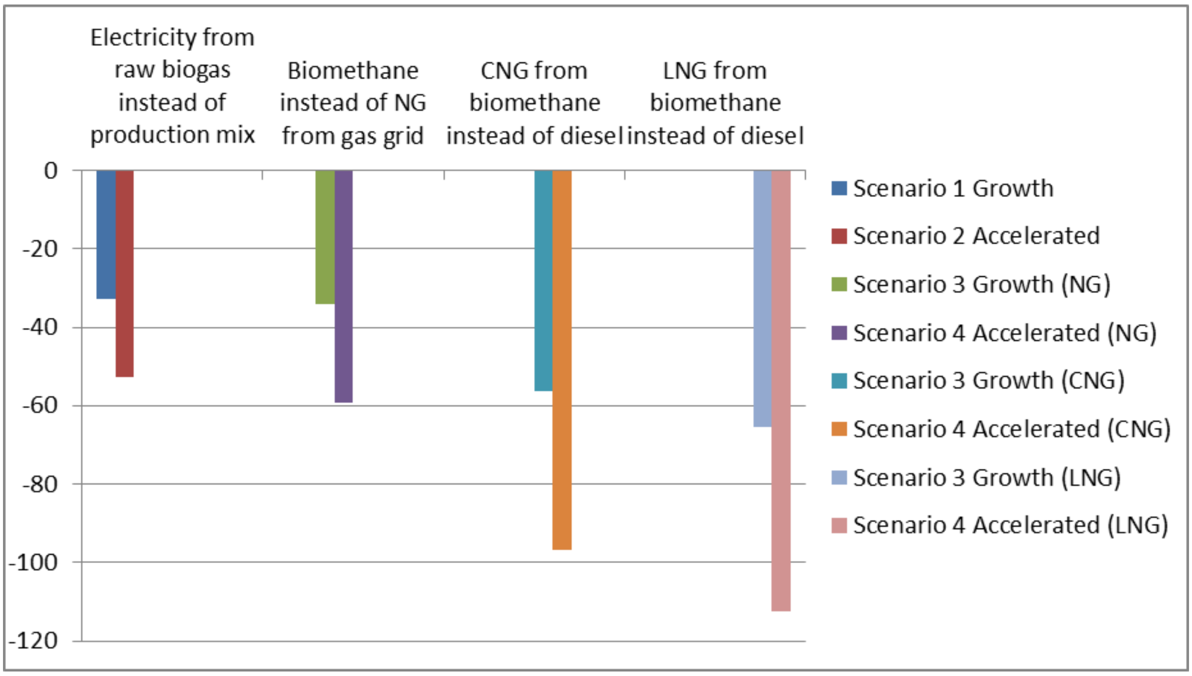
The costs per GJ biogas depend on the feedstocks and the corresponding digester technology and scale used. The range is between 5 €/GJ for landfill gas to around 30 €/GJ for sewage sludge digestion, with the comment that in the last number, the reduction of sewage sludge treatment costs is not taken into account in the calculations due to lack of data. On average, the calculated EU-wide biogas production costs are 14 €/GJ in the growth scenarios and 12 €/GJ in the accelerated growth scenarios.

In case all the produced biogas is upgraded to biomethane at natural gas quality or all production is converted to electricity in a cogeneration unit (CHP), the resulting cost levels are 1.8 to 2.5 times the current EU reference prices in the EU for natural gas and electricity, respectively. A cost reduction effect can be seen from accelerating learning curves due to market stimulation and innovation stimulation, but this is insufficient to become competitive with natural gas at the current price level.

As shown in Figure 31, the largest GHG emission reductions result from the use as biomethane in the transport sector, when the biomethane replaces diesel. The smallest GHG effect arises when the biogas is used in a CHP, due to the fact that emission factors for electricity are rapidly declining towards 2030 (resulting in relatively low-carbon electricity to be replaced), and because on average only 25% of the net heat production from the CHP is effectively used in the scenarios. Optimisation of electricity production to ensure that only fossil power production is replaced and increasing heat utilization could therefore both contribute to increasing the GHG reduction in that scenario. In fact, if the electricity produced by the CHP in Scenarios 1 and 2 replace fossil fuels only instead of the 2030 electricity mix, the GHG savings in these scenarios could increase by more than 70%.

[37] 1 ktoe = 41,868 GJ.

Figure 31 Absolute emission reductions of each scenario and end-use in 2030 (of new capacity between 2014 and 2030) in $MtCO_2$-eq



The best cost-effectiveness is achieved in the scenarios where the biogas is upgraded to biomethane and used as bio-CNG or bio-LNG, replacing diesel. If accelerated growth is assumed, electricity form CHP is somewhat more cost-effective than bio-LNG (66 €/tCO_2-eq instead of 70 €/tCO_2-eq). The use as biomethane replacing natural gas in the built environment shows the highest costs per unit GHG reduction. Accelerated innovation rates were found to improve cost-effectiveness significantly, since innovation can be expected to both reduce cost and improve GHG savings.

Looking at the contribution of biogas to the reduction of fossil fuel consumption large variations can be seen in the scenarios, mostly depending on the end-us application of the biogas: using the biogas locally in CHP or injecting it into the gas grid and then using it for heating reduces mostly natural gas consumption, whereas using it in transport will reduce diesel consumption mainly.

7.2 Main policy recommendations

To ensure further growth of biogas and biomethane production and use in the EU, it is strongly recommended to implement an **attractive, reliable and stable policy support scheme and a positive long-term outlook** for the various stakeholders involved, both on EU and on Member State level. This includes ambitious climate and renewable energy targets for 2030 (and beyond).

7.3 EU level recommendations

Developments in biogas and biomethane production and demand are affected by a range of EU policies and regulations, on climate, renewable energy, waste and circular economy, on nitrate and natural gas infrastructure. Many of these are currently being drafted or under revision and coherence and interaction between the various policies and regulations should be considered to ensure **EU-wide harmonisation of developments and enable biomethane cross-border trade**. It is also recommended to improve monitoring of relevant data on Member State and EU level, such as data on feedstock for biogas production and end-use of the biogas and biomethane.

In line with the general recommendation above, **stable and effective renewable energy targets and policies for 2030** on EU level can increase investment security, which can be further enhanced by EU level policies that achieve equally effective renewable energy targets and policies in the Member States, preferably in the form of specific and long-term sector targets for renewable energy (for electricity, heat and transport). Member States should also be encouraged to develop an **outlook for biogas/biomethane production and use** to replace natural gas, based on an assessment of the potential for biogas production and of the different options for its use. These targets and efforts would contribute to a clear and stable market outlook and thus increase investment security.

Increasing the use of biomethane as a means to decarbonise the EU transport sector not only requires increased production but also increased shares of (natural) gas vehicles and a network of CNG and/or LNG filling stations. This requires **coherence** of a range of EU level policies, including the RED, the FQD and the Clean Power for Transport Directive.

It is furthermore recommended to use an **energy balance method** to account for different feedstocks rather than the mass balance method currently used in the RED (Article (17(1)). This is relevant to properly account for co-digestion of manure and an energy crop such as maize, two feedstocks with very different energy densities.

Agreement and implementation of EU-wide **clear, effective and robust sustainability criteria** for biogas and biomethane is key to create a level playing field with other biomass routes, to enable and facilitate cross-border trade, to ensure public support and to safeguard that efforts focus on deployment of biogas routes that achieve high GHG savings. They need to be stable until 2030 to enhance investment security, and should be technology and feedstock neutral, to allow for new development and feedstock types to be included over time. They should furthermore harmonise criteria for feedstocks used for biogas production for all applications, comparable to the provisions of the RED and ILUC directive for biofuels (incl. biomethane) used in the transport sector.

It is recommended to provide **incentives to use the heat** from biogas use in a CHP, since this can significantly increase GHG savings and energy efficiency. This can be done on Member State level (discussed below), but heat utilisation also warrants explicit support through the relevant EU policies, namely the EED, the RED, the EPBD, and the future 2030 energy policies. These policies should encourage Member States to reduce and decarbonise energy demand for heating, for example with provisions on indicative targets for the share of RES in heating, a requirement for Member States to demand heat utilisation plans for CHP plants, etc.

Looking at agricultural policies, it is recommended to **differentiate the requirements regarding the use of digestate** in the Nitrates Directive (91/676/EEC), based on the share of manure in the feedstock and the nitrogen content of the digestate. This increases the potential to the use the digestate and therefore promote biogas production from co-digestion. In addition, EU-wide **harmonisation of the regulations regarding which co-substrates** are allowed in anaerobic digestion would be beneficial to the development of the EU internal market of biogas/biomethane. This could be achieved with a list of allowed co-substrate (where new co-substrates can be added over time) or via EU-wide **sustainability criteria** for biogas and biomethane, as discussed above.

It is also recommended to ensure **compliance with the waste and landfill directives** throughout the EU, and to encourage Member States to implement separate collection systems for organic waste streams, if they do not yet have this in place. This is an important step towards developing the significant potential for growth of biogas production from organic wastes that was identified in this study.

To further develop biogas upgrading to biomethane, **access to the natural gas grids** becomes relevant as does **biomethane trade** across borders. EU-wide standards for biomethane injected into the grid have been recently agreed on. In addition, EU-wide sustainability criteria as well as harmonisation of (administrative) data transfer can be considered key to facilitate the internal market for biomethane. An EU-wide system of **Guarantees of Origin** (GoO) for biomethane, similar to GoOs for electricity that are governed by Article 15 of the RED, can be implemented to facilitate administrative trade of the biomethane for disclosure and transparency purposes. The EU can furthermore encourage Member States to invest in grid development relevant for biomethane projects: to connect remote biogas production locations to the natural gas grid as part of gas network strategy and planning.

Innovation of the biogas chain can have a range of benefits (e.g. cost reduction, increased GHG savings) and many projects are currently ongoing. Continued efforts into **R&D** of biogas production, conversion into biomethane and the application of biogas are therefore recommended.

To improve dissemination of biogas-related knowledge and expertise, it is recommended to set up a **platform for best practices** related to biogas production technologies, applications and policies. EU dissemination efforts should be targeted at farmers, economic actors, municipalities, policy decision makers and other stakeholders throughout the EU.

7.4 National recommendations

Because of the importance of stable and effective Member State policy support for biogas projects and investments, Member States are recommended to develop **national strategies on the role of biogas and biomethane** to meet future renewable energy and climate goals, in cooperation with the relevant biogas stakeholders. This should include an assessment of available suitable feedstocks and an outlook for biogas/biomethane production and use, indicating the potential for biogas production and assessing the different options for its use (local use in CHP or injection into the natural gas grid, use in transport or in other sectors, etc.). The strategies should take into account related policy areas that may benefit from increased biogas deployment such as agriculture, rural development, air and water quality, waste and circular economy.

Based on the results of this strategy development, **stable and effective renewable energy targets** for 2030 and long-term, stable **support policies** should be implemented, a prerequisite to increase biogas production and demand to the levels identified in this study. These policies should include effective and stable minimum sustainability criteria that remain valid until at least 2030, in line with the EU criteria that will be decided on in the coming years. Specific RES targets and support policies for the various sectors can increase investment security, a further differentiation of policy incentives to the sustainability of the renewable energy (e.g. GHG savings) can enhance focus of efforts and investments towards the most sustainable options. Policies should take into account that biogas installations have high upfront investment costs and therefore need long-term financing possibilities and return on investments.

It is furthermore important to realise that different **policy packages** are needed for different applications of the biogas and biomethane. This could entail, for example, support to district heating and CHP installations, an electricity market design that values flexible power production or support for the market uptake of CNG vehicles and filling stations. Member States can then design and implement a coherent and integrated policy package that suits the national priorities and opportunities.

Since the largest potential for biogas growth is in **making more use of existing agricultural waste streams** such as manure, Member States that do not yet have sufficient support policies in place should focus their efforts on the mobilization of these feedstocks (whilst ensuring adequate implementation of the Nitrate directive). It is also recommended to assess whether the administrative procedures and technical rules for biogas and biomethane projects create unnecessary barriers and can be improved (related to permits, support policies, grid injection, etc.).

It is also recommended to **provide incentives to use of heat from CHP**, in order to increase both the GHG savings from the biogas and the share of RES in the heating sector. A range of policy options was identified, such as including requirements or incentives in relevant support schemes or building regulations and providing technical or contractual support to biogas project developers.

Member States could focus stronger on integration of **the biogas sector as a part of sustainable agriculture**, for example by optimising the biogas sector's contribution to prevention of GHG emissions from manure storage and wastes and the use of biogas co-products for improved soil management (high-quality bio-fertilisers).

Member State should furthermore ensure **compliance with the waste and landfill directives**, including the provisions on applying the waste hierarchy and on bio-waste.

If a Member States chooses to support biomethane as a renewable alternative to natural gas for heating or for use in the transport sector, to increase the share of renewables in these sectors and/or increase demand for biogas, distribution cost may be a significant barrier for project developers. This may require **financial (investment) support to connect biomethane plants to the grid**. If significant grid expansion is required, an assessment of options should be part of a broader national gas strategy and grid development plan, to identify projects where grid expansion would be cost-effective. To facilitate transparency and cross-border trade, Member States can set up a national registry for biogas Guarantees of Origin that oversee the issuing, administration and cancellation of GoOs if they do not yet have this in place.

Regions and municipalities are also recommended to assess opportunities for biogas production and use. These can contribute to their energy independence and rural development, increase the share of locally produced renewable energy and reduce environmental impact of waste streams.

On both national and regional level, knowledge transfer and awareness raising can be improved, especially in Member States where biogas markets are still immature. This includes providing information for potential producers and users, advertising best practices, etc. Adequate communication with the public and national or local NGOs should be organised to ensure that they are well informed about ongoing and planned biogas projects in their neighbourhood, the environmental benefits, safety and sustainability safeguards, etc.

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Appendix A Country factsheets

Appendix A.1 Austria

Current production and consumption of biogas and biomethane

In Austria, biogas is deployed in 436 plants in total, with the highest number of 201 plants in the agricultural sector followed by the bio and industrial waste sector (125 plants), the sewage sector (95 plants) and the landfill sector (15 plants). In general, Austria has maintained its number of biogas plants in the recent years and is considered one of the leaders in the EU when it comes to plants running on industrial waste and bio waste. Due to investments into heat use technologies, the fuel efficiency of the biogas plants has been constantly raised up to 60%. Following Austrian legislation, this has been obligatory in order to become eligible for a potential successive feed-in tariff after the original eligibility period of 15 years has ended. Concerning the biomethane sector, 14 plants were operating in Austria as of 2015, from which 3 were not connected to the natural gas grid and 8 were linked to CHP plants. The installed capacity of biomethane production amounted up to approx. 100 GWh in 2015, whereas its potential performance sums up to 7.6 million Nm³.

The actual focus lies on the refurbishment of the existing plants with the objective of increasing capacities or building biomethane upgrading units with grid injection. Further, the current trend is moving toward improving efficiency and diversifying/adapting feedstock use.

There is a clear upwards trend for biomethane production in Austria. Also the research will give greater attention to biomethane deployment. It is expected that the research focus will lie inter alia on the conversion of the separated carbon dioxide into biomethane.

Biogas and biomethane supporting schemes

Both biogas and biomethane for **electricity generation** are mainly supported through a feed-in tariff, regardless of the plant's capacity. The plant operators are entitled to the conclusion of a contract for the purchase of and payment for electricity as long as funds set by the government are available. There are several preconditions in order to receive the tariff. First, the plant's efficiency shall reach at least 60%. Second, the share of pure agricultural substrates and animal manure deployed shall be greater than 30%. If other feedstocks are used, the tariff will be cut by 20%. The tariff rates are differentiated by technology, mainly biogas, landfill and sewage gas as well as biomethane. The guaranteed tariff is granted for 15 years.

In Austria, **CHP** is an outstandingly fostered technology, which is reflected through a supplementary premium to the basic feed-in tariff (CHP bonus). In addition to the tariff, investment subsidies may be granted for the construction or revitalisation of a CHP-plant with a capacity >100 kW which deploys sewage or waste and contributes to the district heating supply. Companies, other entrepreneurial organisations, confessional facilities and associations can profit from investment subsidies granted for the installation of CHP off-grid power installations for the purpose of self-supply.

Where biomethane is not used for electricity generation and does not receive a feed-in tariff, it becomes eligible for support reimbursing the eligible environmental investments up to 30% compared to fossil fuel production. According to the expert, the eligibility criteria for this type of support are often unclear. Therefore, the system installer can barely rely on it when an investment is planned.

In **the transport sector**, emission-reduction measures are fostered under the scheme of 'klimaaktiv mobil', providing investment grants or operating grants for environmental friendly refurbishment of vehicle fleets. Projects are eligible for support if upgraded biogas/biomethane with a minimum share of 50% is deployed.

Finally, there are several research programmes in Austria which foster the optimal use of biogas and biomethane, such as the project 'Virtual Biogas', analysing the whole value-added chain of biogas utilisation since 2007 in a pilot plant situated near Bruck/Leitha which has been finalised successfully. Research funds are constantly available within the Energy Research Programme.

Key drivers for biogas and biomethane developments

In Austria, a successful development of the biogas sector has been achieved through cooperation of relevant stakeholders such as energy supply companies, industrial businesses and private individuals. Concerning biomethane, the establishment of the biomethane register with a data platform (offers inter alia marketing and international networking possibilities) fosters the development of the sector. Furthermore, a consortium within the framework of the EU-project 'BIOSURF' aims to foster the deployment of biomethane and to enable its cross-border trade. Since June 2016, there is a bilateral agreement in place between the Austrian biomethane register and the German DENA which should support the latter and foster the recognition of related certificates between participating states.

Key barriers to biogas & biomethane growth

In general, the experts criticize that renewable energy sources have not been recognized within the Act on Energy Efficiency which foresees the reduction of energy consumption. The deployment of RES as a carbon dioxide free alternative has not been taken into account at all within the legislation.

In the electricity sector, **inefficient support schemes and follow-up regulations** have been identified as barriers to further developments in the biogas sector**.** Interest groups urge the implementation of efficient follow-up regulations within the upcoming amendment (expected by the end of 2016) of the Green Electricity Act in order to avoid the shut-down of further biogas plants in Austria. First plants commissioned under the Feed-in Tariff scheme will receive no support anymore and operators might be forced to make new investments to amortize the costs of maintaining a biogas plant. This development also reflects the fact that there have not been enough incentives for efficiency measures in the past years. Furthermore, **the existing disagreements on the successive feed-in tariff rate** have led to planning uncertainty and loss of credibility for the renewable energy objectives.

Within the heat sector, **complications with the grid connection** might occur. Most of the Austrian biogas plants are not situated in the area of the natural gas grid making grid extensions inevitable in the near future. This might require additional financial support from the Government.

In the transport sector, a **lack of official recognition for biomethane as a renewable fuel** has been identified as a barrier. This has a noticeable impact for example on taxation policy and administrative processes, where biomethane is treated like a fossil fuel at the moment. In the view of plant operators, the focus of current policies on electricity generation from biogas impedes the development of the biomethane sector.

Key policy amendments planned

In Austria, ongoing negotiations about the successive rate of the feed-in tariff or even a scrapping bonus for non-efficient operations have resulted in huge uncertainties in recent years. However, the respective amendment of the Green Electricity Act should be passed by the end of 2016, and negotiations with relevant stakeholders will be launched in mid-2016. According to the industry, it is time to modify the current feed-in tariff system or elaborate a green electricity model for Austria, which is foreseen by the EU for the long-term perspective. However, the industry is concerned that the planned amendments might lead to a decrease in the number of the domestic biogas plants.

Appendix A.2 Belgium

Current production and consumption of biogas and biomethane

In 2014, the total primary energy production from biogas in Belgium amounted to 8,637 TJ, among which 6,598 TJ was produced from anaerobic digestion. Landfill gas represented 1,122 TJ, whereas sewage sludge gas amounted to almost 917 TJ. Over 85% of the gross electricity production from biogas was covered by cogeneration plants in 2013.

In total, there are currently 1 biogas installation in Brussels-Capital, 40 in Flanders and 43 in Wallonia. In this regard, Flanders and the Walloon Region have different biogas production profiles: In Flanders, biogas is produced in large industrial facilities, whereas the Walloon biogas production rather comes from agricultural plants, using mainly food waste and agricultural residue streams. Regarding the production purposes: the biogas plants cogenerate electricity and heat (sometimes they produce only electricity). Most of the time, electricity is fed into the grid; sometimes it is used on site for self-consumption. Heat is used on site or sold to houses, plants, municipal buildings, etc.

Biogas and biomethane supporting schemes

In all 3 regions, biogas plants producing **electricity** may benefit from green certificates (GC). In the Walloon region, the total amount of GC available per technology is determined on a yearly basis by the Walloon Government, according to a trajectory aiming at reaching a total electricity production from renewable energies of 8,000 GWh by 2020. In Brussels-Capital, the number of GC depends on the amount of electricity generated in proportion with the CO_2 saved: 1 certificate is issued for every 217 kg of CO_2 saved. In Flanders, the amount of electricity to be produced for 1 certificate is calculated by multiplying 1 MWh with a technology-specific 'banding factor', ranging between 0 and 1 and depending on the feedstock used.

In addition, the Walloon and the Flanders region provide financial support to companies willing to develop R&D projects. In Flanders, funding is granted through the Environment and Energy Technology Innovation Platform for interdisciplinary cooperative research and feasibility studies. In Wallonia, companies can benefit from an advance amounting to up to 70% of their investment costs for projects of applied research or technological development.

In the **electricity and heating sectors**, all regions provide investment subsidies for companies willing to invest in renewable energy projects. In Wallonia the support corresponds to 20% to 40% of the investment costs, depending on the company size. The investment shall amount to at least € 25,000. In Brussels-Capital, biogas CHP and trigeneration plants may be supported in the amount of 20% to 40% of the investment costs. In Flanders, the amount of subsidy depends on the company size and the ecological performance of the relevant technology.

Finally, in the **transport sector** a bonus of € 1,000 is in place in Belgium for the purchase of cars running on CNG.

Key drivers for biogas and biomethane developments

In the **Walloon region**, the GC system as well as the investment subsidies are currently considered as quite efficient by stakeholders. The amendments to the GC implemented in 2014 have provided for a greater visibility regarding the amount of expected support as well as a greater stability of the GC market. In addition, the investment subsidies provide an interesting financial support when coupled with green certificates. Thanks to their stability, visibility and financial arguments, both support schemes encourage producers to invest in biogas plants and are therefore important drivers for biogas.

In **Brussels-Capital**, the high share of natural gas in primary energy consumption is a non-negligible opportunity for the development of biogas and biomethane production. From 22,3 TWh primary energy consumed in 2013, 43% came from natural gas, 25% from electricity and 21% from fossil fuels.

In **Flanders**, the availability of technical know-how ensures a profitable management of biogas production. Moreover, the excess of animal manure and its related energy potential also represents a driver for further biogas deployment.

Since January 2016, the Belgian royal federation of natural gas (ARGB), has launched a campaign for the support of CNG. The support consists in a bonus in the amount of € 1,000 for the purchase of cars running on CNG. In 2014 and 2015, a similar campaign had already been launched by the ARGB, with a bonus respectively amounting to € 2,000 and € 1,000. This campaign seems to be bearing fruits, since over 1,000 NGV were ordered in Belgium in January and February 2016. Such measures represent a non-negligible driver for the production and consumption of biomethane as a biofuel, since biomethane has the same properties as natural gas and could be therefore used in NGV.

Key barriers to biogas & biomethane growth

In all regions, the crisis following the excess of green certificates for PV on the market, as well as the temporary lack of visibility regarding the support conditions have resulted into a **lack of confidence** towards renewable energies**, especially in the banking sector**. In 2014, changes to the green certificate system have provided for a greater certainty as to the expected support. Moreover, legislative amendments regarding the allocation of the building permit allow an easier installation of biogas units. Despite these positive regulatory changes since 2014, banks are still reluctant to participate in biogas projects. The persistent lack of confidence of banks may be due to a lack of targeted communication, which results into a lack of knowledge about the technologies and prospects of biogas.

Another barrier concerns the **legal status of digestate**, which represents no less than 90% of the output of an anaerobic digestion plant (the remaining 10% being biogas). The status of the digestate depends on the nature of the feedstock used in the biogas unit, whether it is waste or not. Therefore, only the production of biogas currently contributes to the profitability of a biogas project, while the economic potential of digestate remains untapped.

Finally, **only a few service stations in Belgium are equipped with a CNG pump.** As of January 2016, there were approximately 40 service stations in Flanders and 6 in Wallonia. Currently, there are no service stations offering CNG in the Brussels-Capital Region. The further deployment of CNG service stations is strongly correlated with the deployment of vehicles fuelled with CNG. In order to stimulate the demand for CNG vehicles, it is required that a certain number of gas stations offering CNG already exist. The lack of CNG fuelling stations is probably due to the fact that the legislative framework for on-site sale is not defined yet. In this regard, difficulties relating to jurisdictional matters may arise when elaborating regulations, considering that the federal level is responsible for the transport policy, whereas regions are responsible for the energy policy.

Key policy amendments planned

No major new policies or policy amendments are currently being planned in Flanders. This is partly due to the fact that that the green certificate policy was amended recently, in 2013. As far as Wallonia is concerned, the regional government is currently examining the introduction of support instruments to address the lack of incentives for the injection of biomethane into the gas grid. The reflection on this matter should lead to concrete measures in the coming months. At present, projects involving the injection of biomethane in the gas grid are still at the stage of feasibility study. Although technically feasible and legally possible, the lack of financial support makes the execution of such projects difficult.

Appendix A.3 Bulgaria

Current production and consumption of biogas and biomethane

Bulgaria is one of the countries with the lowest biogas production in the EU. The total number of biogas plants in Bulgaria in 2013 and in 2014 amounted to 11: 8 biogas plants produced biogas from agricultural waste, 2 from biodegradable waste and 1 from sewage. The total installed capacity of all these plants in 2014 amounted to 13.6 MW and in 2015 to 20 MW, which is equivalent to 160 GWh/a electricity and approx. 180 GWh/a heat.

As of January 2015, the number of working plants reached 21, including 18 agriculture, 2 co-fermentation and 1 sewage biogas plants. Currently, there is no biomethane production in Bulgaria.

Biogas and biomethane supporting schemes

In the **electricity sector**, new biogas plants are not eligible under the Feed-in Tariff scheme from January 2016. The existing CHP plants working with thermal gasification of timber biomass or biodegradable fraction of industrial and municipal waste and having a capacity up to 5 MW may still receive the feed-in tariff. The National Long-Term Programme to Encourage the Use of Biomass (2008–2020) indicates a huge potential for energy production from solid agricultural by-products – up to 2.9% of the gross domestic consumption in Bulgaria.

In the **heat sector**, the use of renewable energy is promoted through loans from the Bulgarian Energy Efficiency Fund and through an exemption for building owners from property tax. Eligible for loans are also biogas and biomass installations with an installed capacity of less than 5 MW electric output (for biomass heat only boilers with a thermal input higher than 10 MWh). Buildings using renewable energy technologies (covers also biogas) with ‘A’ certificates for energy performance are exempted from tax for 10 years, and buildings with ‘B’ certificates for 5 years.

There are no direct biogas supporting schemes in the **transport sector** in Bulgaria. Biofuels are supported under the quota system, however, it is not clear if the definition of biofuels covers also biogas. It has to be highlighted that Bulgaria has a potential for the production of biofuels from raw materials without causing any negative impact on the food and beverage industry. According to the forecast for biofuel production, the needed area to grow energy crops in order to achieve the target of 10% biofuels by 2020 corresponds to 509,001 ha, which accounts for 16.3% of the arable land in Bulgaria (3,128,210 ha).

According to the industry, the Bulgarian government has recently been sending rather negative signals to the biogas sector. To mention in this context is the termination of feed-in tariffs for electricity from biogas producing installations from January 2016. Another example refers to the Operational Programme "Environment 2014-2020", approved by the European Commission on 15 June 2015. The Programme envisages the funding of biogas production in wastewater treatment plants and grants for the construction of biogas plants in the agriculture sector. Grants amount to 50-70% of the construction cost, depending on the region and certain other conditions. The programme envisages strong restrictions for substrates from stockbreeding and agriculture waste. Moreover, there is no possibility to use biodegradable waste e.g. slaughterhouse waste. Finally, the whole produced energy should be used only for own purposes. However, there is currently no information as to when such projects will be financed.

Key drivers for biogas and biomethane developments

The implementing measures of the Operational Programme "Environment 2014-2020" cover the construction of installations for the preliminary treatment of municipal waste, as well as composting facilities for the separate collection of biodegradable and green waste. The programme aims to reduce the amount of waste going to landfills in the less developed regions from 2,323,000 to 2,038,000 tonnes by 2023. In July 2015, the Ministry of Environment and Water published a tender for the design and construction of composting facilities for separately collected green and/or biodegradable waste. Such tenders represent a significant driver for the deployment of biogas producing technologies, since the production of biogas could be easily combined with the construction of composting facilities. However, it has to be noted that the announced measures of the Operational Programme "Environment 2014-2020" have their focus on the improvement of waste and water management in Bulgaria, without putting an emphasis on biogas production.

Key barriers to biogas & biomethane growth

There is a **lack of incentives for biogas** in Bulgaria. After the abolition of the preferential prices for electricity from biogas, no other support mechanism has been introduced in order to stabilize the development of the sector. The current situation makes it difficult, if not nearly impossible, for biogas projects to receive any financing. The future development of the biogas sector is highly dependent on the Government responsible for introducing an appropriate legislative framework.

In addition, **no funds** under the current Bulgarian Rural Development Programme (RDP) are envisaged **for biogas production**.

Furthermore, the **information on the actual situation in the biogas sector** in the current National Renewable Energy Action Plan (NREAP) **is not accurate**. In line with the RED (2009/28/EC) the Ministry of Economy and Energy has sent to the European Commission its "Second National Report on Bulgaria's Progress in the promotion and use from renewable energy sources-2013". The report states that Bulgaria has reached its binding national target of 16% renewable energy in the final energy consumption in 2012. However, according to the report published by the Association of Producers of Ecological Energy in 2013, Bulgaria has only reached a RES-share of 14.7% in the gross final energy consumption by 2012.

Further barrier for the biogas project developers is the **local opposition**. The lack of awareness among the people living near the planned biogas plants leads to an incomprehension, scepticism and resistance. As an example, the road between the towns of Strelcha and Hisar was blocked by protesters in 2013, who believed that the planned biogas plant would pollute the air in the region. This happened despite investors' prior explanations that the installations will cause no odour or noise and that the newly created jobs will have a beneficial impact on the local employment in the region.

Key policy amendments planned

The Operational Programme "Environment 2014-2020", approved by the European Commission on 15 June 2015, envisages the funding of biogas installations in wastewater treatment plants. There are ongoing discussions on the construction of such installations among the Bulgarian authorities. However, there is currently no information as to when such projects will be developed.

Appendix A.4 Croatia

Current production and consumption of biogas and biomethane

In Croatia, the production of biogas from anaerobic digestion is predominantly used for the operation of electric power plants. By June 2016, there are 11 registered biogas installations with a total capacity of at least 29,62 MW in Croatia. These biogas installations predominantly use waste from livestock production (manure), animal slaughter, agricultural industries (e.g. maize silage) and the food industry.

The processing of biogas to biomethane quality is planned, but not yet realised. By now, LNG filling stations do not exist and there are only three CNG filling stations for the estimated 200 gas-driven vehicles in Croatia.

Biogas and biomethane supporting schemes

In the **electricity sector**, power plants using biogas are supported with a feed-in premium since January 2016. Although the new Act on Renewable Energies and High-efficiency Combined Heat and Power (RES Act) does not mention explicitly biogas or other renewable energy sources as eligible technologies, it is virtually certain that biogas installations are eligible, which use agricultural crops and organic residues, wastes of plant and animal origin, biodegradable waste, including landfill gas and sewage gas for the electricity production. The exact form and further details of this support mechanism will be regulated in a special Rulebook on Renewable Energies and High-efficiency CHP.

Both for the **electricity and the heating sector**, the Environmental Protection and Energy Efficiency Fund (EPEEF) invites to tender for interest-free loans and financial subsidies for projects (invitation to tender is dependent on the Fund's Annual work program), which generate electricity or heat or combination of both from renewable energy projects including biogas.

In addition, the Croatian Bank for Reconstruction and Development (HBOR) has launched the Loan Programme for Environmental Protection, Energy Efficiency and Renewable Energy, which, among others, offers low-interest loans for renewable energy projects. This also includes the construction of biogas installations. Finally, the Rural Development Programme of the Republic of Croatia for the period 2014-2020 has implemented subsidy measures in 2016 aimed at the use of renewable energies in the agricultural sector, which also encompasses biogas power plants.

Regarding the **transport sector**, there are measures to encourage the use of biofuels. Firstly, biofuels are exempt from excise tax. Biofuels in terms of the Excise Tax Act are liquid or gaseous fuels for transportation purposes produced from biomass, which also comprises biogas, as long as it was purified to natural gas quality. Secondly, the National Action Plan to promote the Production and Use of Biofuels in Transport for the Period 2011-2020 sets the goal of 9.18% of biofuels, which the distributors (i.e. traders) of fuel are obliged to place on the market by the year 2020. The total goal of 9.18% shall mainly be achieved with biodiesel (7.53%) and only to a lesser degree with bioethanol (1.03%) and biogas (0.62%). So far, subsidizing system does not cover CBM.

Key drivers for biogas and biomethane developments

Croatia has a significant agricultural sector and therefore farmers mostly can use potentials from agricultural waste for the energy production. Croatia has half of its agricultural land out of function which could be an opportunity for utilizing it for growing biomass (either as energy crops, perennial grasses or SRC). Yet, a clear strategy towards biofuels and achieving 2020 goal is still missing. Livestock sector cannot cope with the EU standards and prices which is reflected in shrinkage of total number of pig and dairy farms.

Compared to neighbouring countries, Croatia offered relatively high incentive prices for electricity from biogas installations, which led to a steady growth in this area. It is not clear yet, how the new support scheme (premium tariff) will affect the further implementation.

Key barriers to biogas & biomethane growth

At the present, it is **difficult to predict the concrete content of the future sub-statutory provisions of the RES Act**, which will specify and regulate the premium tariff support scheme. Moreover, the newest political events led to a collapse of the government under Tihomir Orešković and new parliamentary elections will be held in autumn 2016. Energy experts estimate that the first tenders for the premium tariff will not be launched before 2017. The delays of the awaited regulatory provisions cause insecurities for potential investors. Additionally, the premium tariff will probably not be a serious driving force for the biogas sector, since the existing approx. 7-8 MW of the quota of 70 MW for biogas should be exhausted after the first tendering process.

One of the greatest obstacles for the development of biogas projects in Croatia is that potential investors and plant operators often have **no awareness of the economic (and environmental) benefits of the use of biodegradable waste**. Especially in the traditionally important agricultural sector, farmers tend to shy away from considering the construction of (even smaller) biogas installations. The main reason for that is a missing technical and commercial understanding of the potentials of biogas usage. Although Croatian biogas plant supplier have achieved considerable success with the construction of several biogas installations, these very recent success stories are not well known yet and could not have proven their profitability by now.

Considering the low amount of only two CNG filling stations, the **infrastructure for biogas/biomethane in the transport sector** might be described as **almost non-existing**. Furthermore, in Croatia there is no production and no selling of LNG and (political) efforts to change this situation are not in sight at the moment.

The existing support schemes for the use of RES in the transport predominantly **focus on electric cars** and only marginally incentivize the purchase of gas powered vehicles. Private investors of gas filling stations will be reluctant to expand the infrastructure as long as a sufficient number of gas station consumers hold out the prospect of a profitable operation.

Key policy amendments planned

Given that the new RES Act only represents the basis for the regulation of renewables in Croatia, more specifying sub-statutory provisions will have to be adopted. The above-mentioned Rulebook on Renewable Energies and High-efficiency Combined Heat and Power will determine the specific conditions for public tendering, the eligible technologies, details on the Register of renewable energy producers, the conditions of acquiring the status of privileged producer and the support scheme of premium tariffs as such. A public discussion on the first draft with the experts in the field of energetics and the interested public is ongoing. Moreover, pursuant to the RES Act the government will issue a special Decree on the Determination of Quotas for the Promotion of Electricity Production from Renewable Energy Sources for the period of 2016 to 2020.

Appendix A.5 Cyprus

Current production and consumption of biogas and biomethane

Cyprus has shown a moderate improvement as far as biogas deployment is concerned, mainly during the period 2010-2014. Currently, there are 13 biomass/biogas plants on the island. Their installed capacity remained stable since 2015 (9,714 kW). However, the number of plants almost doubled during the period 2010-2014, while their installed capacity almost tripled during that period (3,555 kW in 2010, additional 6,159 kW during 2010-2014). Concerning the feedstock used, manure accounts for 50%, while slaughter house material and other biowaste account for 30% and 20% respectively.

There is currently no biomethane production in Cyprus.

Biogas and biomethane supporting schemes

There are currently no specific support schemes for biogas/biomethane in Cyprus in all three sectors - electricity, heating and cooling, transport. The existing support schemes 'Energy Upgrading of Enterprises Scheme 2014-2020' and 'Energy Upgrading of Residential Buildings Scheme 2014-2020' support solely the purchase of biomass installations for heating.

The Cyprus Energy Regulatory Authority (CERA) Decision 913/2013 could be seen as the last indirect support for biomass/biogas installations in the electricity sector. According to the Decision, CERA implemented a scheme for the autonomous production of electricity from PV and biomass/biogas plants. Electricity production from those autonomous producers was destined exclusively for their own consumption purposes i.e. plant operators would not be compensated in any way for electricity fed into the grid. The net electricity consumption by those plants had to be measured and the electricity supplier (Electricity Authority of Cyprus - EAC) had to impose the respective charges such as charges for ancillary services, for the stability of the transmission system and distribution network. In contrast with PV, biomass/biogas plants had no cap as far as the maximum installation capacity was concerned. The scheme was in place until 20 December 2013.

Key drivers for biogas and biomethane developments

Despite the slowdown of biogas deployment since 2015, there is a number of crucial factors that could facilitate the further development of biogas sector in Cyprus. The first driver that could boost the deployment of biogas on the island is the supply of feedstock that is currently available. Currently, only <20% of pastoral feedstock is processed in biogas plants. This signifies a great potential, as that feedstock can be exploited in a cost-efficient and environmental friendly manner. Apart from feedstock from animal farms that currently supply biogas plants in Cyprus, a potential biogas source may come from landfills. Despite the fact, that landfills promote the sorting/separate collection of organic residues, this potential remains unexploited. More specifically, almost 150,000 tonnes of organic residue streams are collected by landfills every year and are processed with € 40/tonne. This equals to many additional MW of biogas plants on Cyprus.

Key barriers to biogas & biomethane growth

Lack of support scheme. There is currently no support scheme for the promotion of biogas in the electricity sector in Cyprus. Moreover, there seems to be no intentions for the introduction of such a scheme in the future. The same applies to the heating sector, despite the fact that the existing biogas plants have a great heat potential. Currently, only 60% of the produced heat is used for the heating needs of the plants, while the 40% remain unexploited.

Unreliable policy framework. The previous government planned to revise its NREAP projection for 2020 and to foresee in the new plan an increase in the capacity of biomass/biogas plants (from the currently envisaged in the NREAP 10MW to 14 MW). For that reason, a Ministerial Decree was issued and a respective support scheme was designed. However, as the government changed, the Ministerial Decree was not implemented and no support scheme was announced, leaving the capacity of biogas plants stable. It can also be said that Cyprus lacks an ambitious policy with regards to biogas. It is viewed as one of the renewable energy technologies without taking into consideration its additional environmental advantages. Apart from that, there has been no holistic study concerning the biomass/biogas potential on the island.

Grid parity. Grid parity for biogas cannot be currently implemented in Cyprus. Without the premium provided within the previous support schemes, the EAC remunerates the electricity fed into the grid with the market price (so-called avoidance cost). As the electricity market price in Cyprus is correlated with the price of fossil fuels, avoidance cost is low (approx. €ct 6). Such a low price discourages potential investors to invest in that sector. To mention is that only maintenance cost amounts to €ct 2.1.

Key policy amendments planned

It is not clear whether there will be amendments concerning the support for biogas/biomethane in Cyprus. It is obvious that there will be further calls under the existing support schemes, i.e. 'Energy Upgrading of Enterprises Scheme 2014-2020' and 'Energy Upgrading of Residential Buildings Scheme 2014-2020'. However, it is uncertain if biogas/biomethane will be offered the necessary incentives.

Appendix A.6 Czech Republic

Current production and consumption of biogas and biomethane

In the Czech Republic, biogas is mostly produced by anaerobic digestion. The number of biogas plants in the Czech Republic in 2014 was 554, where 383 were agricultural biogas plants, 98 were waste water treatment plants, 55 plants in landfills and 17 biowaste and industrial waste biogas plants. Biogas production in the Czech Republic in 2014 in electricity and heat amounted to 6,642 GWh, with 2,566 GWh of generated electricity and 134.9 GWh generated heat.

There is currently no biomethane production in Czech Republic.

Biogas and biomethane supporting schemes

The only supporting policy applying to new biogas plants in the **electricity and heat sector** are the subsidies from the Operational Plan "Enterprise and Innovation for Competitiveness for 2014-2020". The remaining support schemes, namely the Feed-in Tariff and the Green Bonus, apply to the already existing installations. The conditions for the feed-in tariffs were amended for the existing installations from January 2016. According to these amendments, supported are only CHP plants put into operation between 1 January 2013 and 31 December 2015, and that generate electricity using biogas from no more than 30% energy crops and secure the efficient use of at least

50% of the primary energy generated by the biomass from which the biogas is produced. In addition, the Green Bonus was abolished for renewable energy installations including biogas installations put into operation from 2014 onwards.

Concerning the **transport sector**, there is currently no supporting measure for the production or the consumption of biogas and biomethane as a biofuel in the Czech Republic.

Key drivers for biogas and biomethane developments

Since the political climate in the Czech Republic is not in favour of renewable energy, but rather supports the deployment of nuclear power, no political drivers have been communicated for biogas and biomethane production by the relevant stakeholders interviewed.

Key barriers to biogas & biomethane growth

Unavailability of information. Information regarding biogas and/or biomethane (e.g. feedstock availability) is not sufficient. Only the Energy regulatory office conducted a large survey regarding the biogas plants in the Czech Republic in 2014. However, the information was not disclosed to the public, with one exception - energy consumption. Therefore, the information about biogas plants in the Czech Republic is mainly based on estimations.

Technological barriers. The Czech biofuel market is unexperienced in dealing with advanced biofuels. One of the main problems is the lack of flexifuel vehicles and the presence of too much old vehicles. The flexifuel vehicles, which are able to run on E85, were produced only between 2012 and 2014. Due to the old fleet of vehicles, trade with another biofuel E10 is very limited. This type of biofuel can only be used by vehicles produced after the year 2000. Furthermore, the distribution from biofuel producers to gas stations is not well developed yet. Moreover, the quality of biomethane does not reach the quality of natural gas and there is no infrastructure to upgrade biogas into biomethane with natural gas quality.

Another barrier concerning all three sectors is that the Czech media do not create a positive image of renewable energy sources. Moreover, Czech politics focuses rather on other energy carriers. President Miloš Zeman claimed in 2014 that renewable energy is just a burden on the state budget and that an emphasis should be put on nuclear energy.

Key policy amendments planned

There seems to be no planned policy amendments.

Appendix A.7 Denmark

Current production and consumption of biogas and biomethane

In 2013, biogas was produced in a total of 154 plants with an overall production of 1,218 GWh, with the highest number of facilities and production level in the agricultural sector (67 plants producing 861 GWh) followed by sewage sludge (57 plants/250 GWh), landfills (25 plants/56 GWh) and the industrial sector (5 plants/ 51 GWh). In the same year, biogas provided 1.1% of the energy consumption in Denmark. An amount of 1,400 GWh was used for electricity purposes, representing a share of 79% of the total biogas production, followed by 250 GWh for the heating sector (20%).

An increasing political and public interest in using biogas as a transport fuel can be stated, especially concerning the use in public transport and heavy-duty vehicles.

A total number of 6 biogas upgrading plants with a capacity of 18 million Nm³ was operated and fed into the grid in Denmark in 2013.

Biogas and biomethane supporting schemes

Already since 2008, **Electricity production** from biogas is mainly promoted through a feed-in premium, which currently amounts to a fixed tariff of 11 €ct per KWh or to 5.4 €ct per KWh paid as a premium in addition to the current market price of electricity. The tariff is net-price indexed and calculated every year on 1 January and based on 60% of the increase in the net price index of the previous year as compared to 2007.

In the **heating sector**, the use of biogas is indirectly subsidised by an exemption of taxes, which are normally levied on the production, processing, possession, receipt and dispatch of fossil fuels for heating purposes, for example the energy tax on mineral oil products, taxes on coal, lignite and coke or the carbon dioxide tax on certain energy products.

Denmark supports the use of biogas in the **transport sector** through a direct premium tariff granted to sellers of biogas to end consumers for transport purposes. The funding consists of the sum of three tariffs DKK 39 (approx. € 5.23), DKK 26 (approx. € 3.5) and DKK 10 (approx. € 1.34). As of 1 January 2016, the tariff amounting to DKK 10 (approx. € 1.34) per GJ biogas will be annually decreased by DKK 2 (approx. € 0.27) and will cease by the end of 2019.

Key drivers for biogas and biomethane developments

As an important driver for the deployment of biogas in Denmark, the 2012 Energy Agreement's increased operating support for the use of biogas for electricity generation and upgrading can be identified. Furthermore, the investment support scheme, being established in 2009 as a part of the "Green Growth" strategy, should be mentioned. However, final decisions have been made so far only for a limited number of projects, as the production expansion is 1.5 PJ. According to the biogas taskforce initiated by the Danish Energy Agency, the biogas production is expected to more than double until 2020 under the current framework conditions (from 4.3 PJ to approx. 10 PJ).

Ambitious biogas targets have been formulated in the "Green Growth" strategy, stating the objective that 50% of the livestock manure is to be used for green energy in 2020. In addition, the Energy Agreement 2012's aim was to have 35% of the energy supply renewable by 2020 as well as to make Denmark fossil fuels-free by 2050.

Key barriers to biogas & biomethane growth

Insufficient financial incentives for the establishment and operation of biogas plants. Linked to the fact that several new subsidies are being phased out and probably disappear completely after 2020 if the natural gas price's development is as expected, the financial situation for biogas plants remains uncertain. Also contributing to the financial burden, biogas plants have to deal with are the high costs occurring from upgrading and grid connection. In addition, it is difficult for the plants to obtain a sufficiently high price when selling their biogas for CHP, which leads to the fact that the full value of indirect subsidies is rarely achieved.

Limited access to suitable biomass feedstock. Difficulties regarding the expansion of biogas could occur because of the problems in finding suitable biomass for supplementing slurry in order to achieve adequate gas production. Biomass consisting of deep litter and straw is available for the replacement of energy crops and industrial waste as the basis for the biogas expansion, however, there is a lack of specific long-term experience and documentation regarding the economic durability of these raw materials.

Missing competitiveness of biogas. Compared to alternatives such as heat pumps, solar heating, wood chip-fired boilers and geothermal energy, biogas is not yet a financially competitive technology for enterprises, as the average production costs amount to € 17.5 per GJ and € 20.7–22.3 per GJ in upgraded form. According to the biogas taskforce, it is estimated that the current biogas framework conditions will not be sufficient for a continuous expansion.

Key policy amendments planned

After 2020, some of the subsidies will phase out. Even though there is no expiration date defined by law, the aid approval is only valid for a period of 10 years (except electricity and upgrading valid until 2023), according to the European Commission. Thereafter, the aid is going to be renotified to the Commission, which could involve changes. Also to the power generation accompanying the generation of heat, the given subsidies for electricity cannot be granted.

Appendix A.8 Estonia

Current production and consumption of biogas and biomethane

Currently, there are 18 biogas plants in Estonia. All of them produce heat and/or electricity: 5 plants running on agricultural input, 4 plants running on sewage treatment, 3 plants running on industrial wastewater treatment, 6 plants running on landfill gas.

Biomethane is currently not produced in Estonia. However, there are five operational CNG stations at the moment and an additional three under construction. The development plan of AS Eesti Gaas anticipates further construction of natural gas filling stations and the launch of specialised filling stations for transport enterprises if necessary.

Biogas and biomethane supporting schemes

In Estonia, renewable energy sources in the **electricity and heating sector** are mainly supported with the feed-in premium. The Electricity Market Act stipulates that where a renewable electricity producer sells renewable electricity on the free market and exports it to the electricity grid, the transmission grid operator shall pay a bonus on top of the selling price (a feed-in premium). Supported under this mechanism is also electricity from biomass in CHP plants, electricity from waste and other renewable electricity generated in an efficient CHP mode (for latter the maximum capacity is limited to 10 MW). From 31.12.2010, producers who have started generating electricity from biomass can only get the subsidy for electricity generated in efficient CHP mode.

The (re)construction of infrastructure and technology to enhance the building of CHP plants and to encourage the wider use of renewable energy sources is eligible for the investment support. Supported measures cover the construction CHPs, the reconstruction of boiler-houses to enable their operation on renewable energy sources and for the reconstruction of the district heating network to improve the energy efficiency.

In the **transport sector**, biomethane is eligible for subsidies. This financial measure is the first of its kind that Estonia has adopted to promote the production and the consumption of biomethane in this sector. One of the sub-targets is to support the use of buses in the public transport systems that are fuelled by biomethane. The support is available on first come first served basis.

It has to be noted that the support mechanisms currently in place in Estonia will not allow the biogas to enter the market at a competitive price, not to mention the biomethane. The country should follow the model of other Member States applying a differentiated support for renewable technologies. The possible criteria could be the source of the renewable energy, the raw material used, the size of the installation, and its location.

A stronger effort is necessary in the transport sector, where the measures for the significant increase in biomethane do not exist at the moment.

Key drivers for biogas and biomethane developments

The key driver for the production and consumption of biogas in the electricity and heat sector is the feed-in premium envisaged in the Electricity Market Act. The supporting measure for the promotion of biomethane in public transport is too recent to assess its effectiveness in the increase of biomethane deployment in the transport sector.

Key barriers to biogas & biomethane growth

The key barrier negatively affecting biogas/biomethane in Estonia is **the low price of natural gas** imported from Russia, Latvia and Lithuania (the share of Russian imports should decrease to around 30% in the end of this year). At the moment there are no measures in place that would help to overcome this price gap. The low price of natural gas especially hinders the use of biomethane in pipelines and selling it to consumers at a reasonable price. In addition, despite the newly launched subsidy scheme for biomethane in the public transport is a positive development, it might not have an expected impact in the sector. Therefore, to achieve the 10% RES-share in the transport sector by 2020 extra measures are currently being developed in Estonia.

In the electricity sector, a **complex authorisation process** is a severe barrier. The preparatory work to obtain a grid connection permit and to be eligible for the support scheme is extremely difficult (micro-operators (<100 kW and <15 kW) get several exceptions). The process foresees several tests that are unique and not required in any other EU Member State. Also the length of the procedure is unpredictable, as it is not very well regulated.

In the heating sector, smaller heat producers have problems with the **access to finances**. Banks are reluctant to provide financing because heat consumption in some networks is relatively low and therefore the risks are too high.

Public perception constitutes a further barrier for biogas/biomethane project developers. The increasing share of renewable energy is a heavy burden for the energy consumers as the renewable energy fee is already very high. Consumers are very price sensitive and are not willing to pay for higher heating prices.

Key policy amendments planned

The Estonian support scheme for renewable energy sources is currently being amended. The fundamental change would be the dependence of renewable energy subsidies upon the stock exchange prices of electricity, the market prices for biomass, or the market prices for CO_2. However, the conditions on subsidising biogas production should remain the same.

A specific measure that is meant for the achievement of the 10% RES-share is the blending mandate for biofuels. When in force, this measure would require liquid fuel suppliers to provide fuels that include bio-components. A draft of this measure is in development since 2012 and is expected to come into force in 2018.

There are also plans to revise the excise duty policy to impose an excise duty on natural gas, which currently does not exist.

Appendix A.9 Finland

Current production and consumption of biogas and biomethane

In Finland, biogas has been produced since 1902 in demonstration plants and since 1910 in commercial plants. Biogas has been utilized for residential heating, industrial process heating, cooling, illumination and mechanical power production since 1932. Electricity production at CHP plants began in 1936. Since 1941 biogas has been utilized as vehicle fuel.

In 2015, 153 million Nm^3 (about 0.76 TWh) of biogas was produced at 84 commercial plants. Of these, 44 were reactor biogas plants (46% of production) and 40 were landfill gas plants (54% of production). Biogas is mainly used to generate heat and electricity in CHP plants that are located at the biogas production sites.

Thermal energy utilization was 483 GWh of which about 90% was low temperature use (heating) and the rest was high temperature use (industrial processes). All electricity production, 147 GWh, originated from CHP plants. Vehicles consumed 23 GWh that was delivered by 24 public CBG100 stations (100% Compressed BioGas). Final end-use of biogas totalled 653 GWh, of which 98 GWh was upgraded biogas originating from 9 commercial upgrading plants. Of upgraded biogas, 23% was consumed as vehicle fuel and the rest for thermal energy applications. Amount of unused biogas combusted by flares at production sites was 91 GWh.

Biogas and biomethane supporting schemes

In Finland, producers of electricity from biogas receive a premium tariff on top of the wholesale electricity price for a period of 12 years. The premium tariff comprises of the difference between the target and the market prices. A biogas plant is considered eligible for receiving the premium tariff if it is a new power plant, has a minimum nominal capacity of 0.1 MVA (no maximum nominal capacity is established), and has not received state subsidy before. Biogas plants with the minimum efficiency of 50% (75%, when nominal capacity of generator exceeds 1 MVA) may receive a heat premium on top of the basic feed-in premium of € 50 per MWh.

In addition, a state grant called "energy aid" is available for investments in biogas facilities as well as related research projects. "Energy aid" targets projects promoting the use or production of renewable energy, advance energy efficiency and reduce the environmental effects caused by energy production and use. Projects including innovative energy generating technologies are eligible for an aid against a fixed asset investment with eligible costs exceeding EUR 5 million. The incentive promotes among others also the generation of electricity or heat from biogas and investments of biogas upgrading plants and filling stations.

Biogas is exempt from excise duty in all applications, including electricity, heat and vehicle fuel.

Key drivers for biogas and biomethane developments

The existing support schemes might not have a very substantial effect on the biogas sector in Finland compared to other renewable technologies, nevertheless they have helped to promote the use and production of biogas/biomethane.

Energy aid, i.e. investment subsidy, has helped to realize many biogas plants and upgrading plants. But only 3 biogas plants, representing 20% of electricity production, received feed-in tariff in 2015. The tax exemption for biofuels that is in place in Finland can be seen as a good driver for biomethane development, because it alleviates the financial burden of biomethane operators. But since 2011 biogas vehicles have been subjected to an additional annual vehicle tax, of which gasoline vehicles are exempt.

Key barriers to biogas & biomethane growth

Inadequate support instrument. The RES in the national primary energy consumption is high in Finland. However, almost all of it is covered by the logging waste and old hydropower that are highly competitive even without any financial support from the state. The rest is mainly covered by the blending of liquid biofuels (gasoline and diesel) as required by the mandatory blending scheme. So far, diverse support instruments used have been inadequate to get any other renewable energy technology to play a significant role in Finland. However, even more important than the lack of support for renewables, are the **support schemes for fossil fuels**.

Another major issue is the **failure to address biogas-related issues** adequately **in municipal policies**. This can be seen as the most important barrier for a successful development of the biogas sector in Finland. Without addressing the role of local administrations (both municipal and provincial), the development of the sector will remain hindered.

Finally, **existing policies fail to simultaneously address the multiple benefits of biogas**. Biogas technology simultaneously addresses several core issues: waste management, health and public transport; recycling of digestate as fertilizer and production of energy in electricity, heating and transport sectors. To maximise the resource-efficiency, all of them should be addressed simultaneously in policies, but this is not the case. For example, one target of the Finnish National Renewable Energy Action Plan is to end utilization of biogas for transportation and to concentrate mainly on the use of biogas in heating. However, biogas utilization has been growing the most in the transport sector.

Key policy amendments planned

The main amendment currently in progress concerns the establishment of a new support scheme for the renewable energy sector. The keyword in the new scheme will be “technology-neutral”, meaning that no technology should be in a better position than others in receiving subsidies. The Ministry of Employment and Economy has put together a working group that will present its proposals by the end of April 2016. However, these changes in the support scheme will not have a strong impact on the biogas sector.

In November 2016, a national plan to implement the Directive on Clean Transport Infrastructure (2014/94/EU) will be released. It will contain support schemes for methane, hydrogen and electricity in the transport sector. This will also have a positive effect on biogas utilization in the transport sector. Finland is also working on a new energy and climate strategy. It is, however, hard to say what kind of impacts this document will have on the biogas and biomethane sector, since the new strategy is scheduled to be completed at the end of this year.

Appendix A.10 France

Current production and consumption of biogas and biomethane

Most of the biogas produced in France is produced through anaerobic digestion, where the biogas is used in CHP plants. In 2014, there were 502 biogas plants in the country, with a total installed capacity of 293 MW, producing approximately 1,500 GWh **electricity** and 1,600 GWh **heat**. As far as the feedstock is concerned, small biogas plants tend to use more livestock manure, whereas large biogas plants rather use organic waste. The annual production of biomethane amounted to 300 GWh by the end of 2015, among which 160 GWh were injected into the network. In October 2016, there were 24 sites injecting biomethane into the network. As stipulated in the energy transition law (law n°2015-992), 10% of all natural gas consumption shall be replaced by biomethane by 2030.

In the **transport** sector, the best way to currently upgrade biomethane for use as a fuel is by compressing it into BioCNG. Upgrading biogas to biomethane and then to bio-LNG is still experimental. There is currently one pilot plant called BioGNVAL, which produces and distributes liquified biomethane from a waste water treatment plant in the Val-de-Marne Region. This technology is aimed at long-distance heavy goods vehicles rather than for local fleets. Certain service stations, such as in Morsbach, already offer blended BioNGV and NGV or even 100% BioNGV.

Biogas and biomethane supporting schemes

The Act on Energy Transition for green growth from 17 August 2015 foresees a thorough reshaping of the existing support scheme for **electricity** from RES. According to this reform, the new support system for RES in France shall be composed of two main schemes: a feed-in tariff ("obligation d'achat"), and a premium tariff ("complément de remuneration").

On 29 May 2016, an implementation decree was published setting out the technologies eligible to the feed-in tariff and to the premium tariff. According to this decree, biogas plants producing electricity may be supported either through a premium tariff or through a feed-in tariff, depending on the plant size and location. Biogas plants with an installed capacity under 500 kWe located in metropolitan France as well as biogas plants with an installed capacity under 12 MWe located outside metropolitan France are eligible to benefit from the feed-in tariff. Biogas plants with an installed capacity between 500 kWe and 12 MWe located in metropolitan France are eligible to the premium tariff. However, pending the publication of bylaws determining the amount of support per technology, the current conditions for the feed-in tariff for biogas plants still apply.

Moreover, the purchase price of electricity produced by existing biogas cogeneration plants was revaluated in October 2015, in order to improve their profitability. This measure is mainly destined to support farmers in view of their operating and financial difficulties with biogas plants.

In addition, the support for biogas plants with an electric capacity over 500 kWe is allocated through a tender scheme allowing for a financial compensation guaranteed over 15 years. In this regard, a call for tenders was published in February 2016 for biogas plants, for a total capacity of 10 MWe.

For the **heating sector**, a Heat Fund (Fonds Chaleur) administered by the French Energy Agency (ADEME) is in place to support the production of heat through renewable energy plants. This fund was endowed with a budget of € 220 million for 2014, allocated through two subvention types: on the one hand a national call for tenders, which is published yearly only for large biomass plants, on the other hand the support of local RES projects including biogas.

Moreover, a feed-in tariff is in place for the injection of biomethane into the gas grid. The tariff varies between € 45 and € 95/MWh depending on the type of feedstock used and the maximum capacity of the installation. Moreover, producers may benefit from premiums depending on the type of feedstock used for their biomethane production. These measures currently span a period of 15 years.

Regarding the **transport sector**, there is currently no support scheme directly supporting the use of biomethane as a biofuel in France. However, there are numerous initiatives at regional level, which successfully encourage the use of biomethane in the transport sector. For example, the ADEME Rhônes-Alpes and the gas distribution operator GRDF jointly supported 50% to 70% of the additional costs induced by the purchase of 15 NGVs in the region. In 2014, GRDF also partnered with the city of Paris, the French Post and the Ile de France Region to develop alternative mobility concepts to diesel vehicles. The partnership consisted among others in equipping the vehicle fleets of Paris and the Post Offices with NVG and installing CNG fuelling stations across the region.

Key drivers for biogas and biomethane developments

Currently, some regions in France still suffer from a poor electricity supply resulting from an imbalance between electricity production and consumption. As those regions often have a strong agricultural profile and their farmers are facing economic difficulties, the deployment of biogas and biomethane plants in such regions represents a good opportunity for ensuring both a better electricity supply and additional revenues for farmers. It also allows a local production in line with the ambition of creating a truly circular economy, and enables a re-qualification of soils that could otherwise be mismanaged.

Moreover, the national climate ambitions enshrined in the energy transition law which states an objective of 10% renewable gas in the network by 2030, and the binding targets for greenhouse gas reductions at EU level also constitute important drivers for the development of biomethane.

Finally, experts estimated that a total amount of 16,000 direct and indirect jobs could be created in the biogas and biomethane sector by 2020. In view of the high unemployment rate France is currently facing, these figures represent a significant driver for the French government.

Key barriers to biogas & biomethane growth

There is a general **lack of knowledge about biogas and biomethane technologies among financial stakeholders**. As a result, the granting of loans is conditioned to high guarantee requirements of banks, which makes it very difficult for biogas project developers to obtain financing.

Lack of public acceptance. Biogas projects which are subject to authorisation by the regional prefect shall first undergo a public inquiry. In several cases, public inquiries issued a negative opinion, which prevented the projects from obtaining their building authorisation. Such negative opinions are often based on fears and received ideas regarding odour nuisance or explosion risks of biogas plants.

Lack of support schemes for the direct liquification or compression of biomethane. Biomethane used as a biofuel may be either liquified/compressed, or it may be first injected into the gas grid in order to supply fueling stations connected to the grid. Since only the injection into the gas grid benefits from a support in the form of a FIT, most producers prefer their biomethane to be injected into the grid.

Biomethane plants located too far from the gas grid. Around 40% of the applying biomethane projects do not benefit from feed-in tariff for technical reasons, mostly because the production plants are too far from the gas grid. Transporting biomethane by trucks over short distances may be an option for certain sites.

Key policy amendments planned

In France, the legal framework for biogas plants is sufficiently developed to enable their deployment. However, the current legislation regarding the agricultural use of digestate as a fertilizer is not enough elaborated. Regulatory changes shall be made in the near future to clarify the legal value of digestate, namely to recognize it as a valuable fertilizer instead of waste. This work is crucial to ensure that the whole production of anaerobic digestion is taken into account and valued for its true potential. In this regard, a decree of 4 June 2015 provides for an end-of-waste status for materials which either benefit from marketing authorization, or comply with the technical specifications defined by the Ministry of Agriculture. However, the bylaw defining these technical specifications has not been published yet.

Appendix A.11 Germany

Current production and consumption of biogas and biomethane

By the end of 2015, 8,928 biogas plants were installed in Germany. 190 of them have the capacity of upgrading the biogas to biomethane. The total capacity of biogas plants amounts to 4,177 MW_{el}. In 2015, about 200 new biogas plants were developed, which is a considerable decrease of new installations in comparison to the years 2009-2011 when over 1000 new plants were erected yearly. In 2014, the 185 biomethane plants have produced a volume of 688 million Nm^3 injected biomethane, the equivalent of 7,489 million kWh. These numbers increased by 37% in comparison to 2013.

The main feedstock used is energy crops (51%), followed by agricultural residue streams (46%), biowaste (2%) and industrial waste (1%). The main used energy crop is maize in form of silage, followed by cereals (grains and whole plants), and grass. From the 1.5 million ha agricultural land, on which feedstock for the production of biogas is grown on (approx. 10% of the overall German agricultural area), 1 million ha is dedicated to maize. This has fuelled a vivid public debate and a public protest has emerged against the rising use of maize and further food crops for energy production.

Biogas and biomethane supporting schemes

The utilization of biogas and biomethane is particularly supported in the **electricity** sector which was the key driver for development of biogas installations in recent years. The main support schemes, which are laid down in the Renewable Energy Sources Act 2014 (EEG), are Feed-in tariff for systems with a capacity of up to 100 kW and a premium tariff (Market Premium) for systems with a capacity of up to 20 MW. Until 2011, the old feed-in tariff scheme was the main reason for the robust development. Following changes of the structure of the tariff, however, led to the strong decrease of new installations. In addition to that support scheme, there are first experiences to reimburse electricity producers not for the production of electricity but for the provision of on-demand capacities (flexibility surcharge). Other support schemes are a loan program and a tax instrument.

In the **heating sector**, the main support scheme for biogas is a building obligation under the Renewable Energies Heat Act (**Erneuerbare-Energien-Wärmegesetz** - EEWärmeG): house owners have to use a particular share of energy for heating and cooling from renewable energy sources when constructing a new building or renovating an existing one. The installation of CHP biogas heating systems is only one of many options to fulfil this obligation and the obligation is not applicable to existing buildings.

The main instrument in the **transport sector** is a GHG quota that also covers the usage of biogas/biomethane, aside from other technologies and resources. The same holds true for the KfW Environmental Programme, a loan system that applies to the purchase of low-emissions cars that are powered by biogas/biomethane.

Key drivers for biogas and biomethane developments

The most efficient policy for the support and promotion of biogas and biomethane in the **electricity sector** by far is the EEG, even though the support tariffs have been gradually reduced in 2012 and 2014 and compared to the flourishing conditions of 2009 are not so attractive anymore.

Most relevant policy in the **heating sector** is the EEWärmeG. This regulation, however, concerns only biogas with CHP installations and applies only for new buildings or structural renovations. Therefore, its impact is difficult to assess.

The share of biogas/biomethane is almost insignificant for the **transport sector** because the existing support schemes do not function as effective drivers. There is no incentive to feed in biomethane into the natural gas grid. Since 1 January 2016 there is no tax exemption for biomethane anymore. By far the biggest incentive for biomethane in the transportation sector is the GHG quota system.

Key barriers to biogas & biomethane growth

Weak(-ened) political and economic framework. The main barrier to the further development of biogas in all three sectors (electricity, heat and transport) are the lack of support schemes that sufficiently promote the extended usage of biogas. Regarding the electricity sector, the reforms of the EEG in 2012 and 2014 drastically reduced the tariffs and introduced a cap of 100 MW/year. The same applies for the heating sector to the EEWärmeG and for the transport sector to the GHG quota which both have limited impact on biogas deployment.

Lack of grid access. The German biogas sector suffers from the difficulty to be connected to the existing energy infrastructure. Biogas plants are mainly located in the rural area; in some remote areas the infrastructure is underdeveloped making a connection to the grid harder. The current support scheme structure does not incentivize the upgrading of biogas to biomethane and to feed biomethane into the natural gas grid. In case of biogas upgrading plants, when connection to the natural gas grid is up to 1 km 75% of the connection cost are borne by the grid operators and the remaining 25% by the connectee (however no more than € 250,000).

Insufficient market structure. The third main set of barriers is connected to the structure of the biogas market in Germany. The development of feedstock prices is unpredictable and there are no sufficient regulatory provisions to mitigate this risk. The demand for biomethane especially as a fuel is very low. Stakeholders also mention that the connection of biogas heating units to local district heating networks is very difficult and too complex for most local authorities.

Lack of public support. Another barrier to the further development of biogas is its ambiguous reputation in the German society. The acceptance of biogas has decreased in the past years due to the fear of rising crop prices and land use change.

Key policy amendments planned

A new amendment of the EEG is planned to be published by the end of 2016, becoming effective as of 2017. According to the current plan, the support system is being transformed. In the future the level of the feed-in/market premium tariffs will be decided through an auctioning system. In particular operators of existing plants favour the introduction of an auctioning system because they hope for an increase of tariffs. Furthermore, an amendment to the EEWärmeG is also expected during this legislative period; the plan is to restructure and expand this law. However, further details are still pending.

Appendix A.12 Greece

Current production and consumption of biogas and biomethane

The total number of biogas plants in Greece in 2015 was 18. More specifically, 3 plants are operating at municipal waste landfills, 9 plants at municipal wastewater treatment facilities, 4 plants produce biogas from agricultural wastes, while there are 2 plants in food industries that produced only heat. Total installed capacity amounted to 52MWe and to almost 30MWe thermal capacity, amounting biogas production to 168 million m^3/year in 2015. The Regulatory Authority on Energy has issued 83 production licences for biogas plants above 1 MW (cumulative capacity 441.4 MW). Apart from that, in relation to grid connection, the Hellenic Distribution Network Operator (HEDNO) has already given priority to 127 applications (cumulative capacity 132 MW), while 21 plants (cumulative capacity 33 MW) have already signed a connection offer.

There is currently no biomethane production in Greece.

Biogas and biomethane supporting schemes

In the **electricity sector**, Greece introduced a coherent legislative framework for the development and implementation of renewable electricity projects in 2006. Four years later Law No. 3851/2010 transposed the majority of the provisions of the RED (2009/28/EC) into the Greek law and reaffirmed the Feed-in Tariff system as the basic support mechanism for the further development of RES in Greece. However, the tariff rates were reduced in 2014 as a result of liquidity problems of the financing mechanism managed by the Greek Electricity Market Operator (LAGIE). Biogas plants are basically promoted though the Feed-in Tariff scheme.

Furthermore, as far as the issue of production license, connection offer and approval of the Environmental Impact Assessment (EIA) is concerned, biogas/biomass plants that are managed by the solid waste management agencies have a priority over the RES plants that are managed by the land reclamation organisations.

In the **heating sector**, support for biogas plants may be provided under the provisions of the Investment Law (General Investment Plans). The law distinguishes between the following types of general investment plans: (1) General Entrepreneurship, (2) Technological Development and (3) Regional Convergence plans. RES projects are eligible for funding if they fall under one of these categories. There are three different subsidy types available: income tax relief, subsidised expenditure and leasing subsidy.

Key drivers for biogas and biomethane developments

One of the key and most crucial drivers for the deployment of biogas in Greece is the fact that it is considered a new market. In contrast with other RES technologies, biogas is a fairly new technology in Greece. It should be noted that during the "boom" of the RES market in 2010-2013, biogas was expected to take the lead from the PV sector. However, after the reform of the Feed-in Tariff scheme in 2014 ("New Deal on RES"), those projections were minimised. As Greece is currently introducing a new support scheme for RES in the electricity sector that is going to substitute the existing Feed-In Tariff with a sliding Feed-In Premium, it remains to be seen if with the new support scheme biogas will be further deployed. A positive sign is that the revised support scheme for RES that foresees a Feed- In Premium for all RES technologies provides the same level of support to biogas plants as within the Feed-in Tariff scheme.

Key barriers to biogas & biomethane growth

As far as the electricity sector is concerned, the main barrier for the deployment of biogas in Greece is the **lack of a relevant support scheme in the heating sector**. In contrast to the electricity sector, biogas in heating sector lacks the necessary incentives for its further deployment.

Lack of an efficient and reliable supply chain. This is the main problem that plagues the biogas sector in Greece. More specifically, feedstock as the primary input for biogas production is located in numerous places. However, their location is fragmented and in most of the cases almost unknown. Small animal farms are situated in places that are difficult to locate. In addition, the morphology of the country (many mountainous areas) renders the identification and location of feedstock sources almost impossible. Possible feedstock is always identified locally and regionally only after a potential investor expresses his interest to proceed with an investment for that kind of technology.

Lack of reliable information sources. This is a barrier that is directly correlated with the previous barrier. There are more than 100 Secretariats in charge of collecting data on available feedstock. Those different Secretariats do not cooperate and they are reluctant to exchange this data. Consequently, information remains fragmented, even on similar organic residue streams. This obstructs a comprehensive and holistic evaluation of the feedstock potential in the country, let alone their identification.

Lack of expertise. Another barrier that hinders the quality of information sources is the personnel at the respective Ministries and Secretariats. The majority of them do not have the necessary academic background so as to evaluate the quality of the information provided and process the information accordingly. The same is applicable also to the personnel of the administrative regions that are responsible for the authorisation of the construction of the installation and electricity production. Biogas plants are regarded just like another RES source, without considering additional environmental advantages that this technology brings.

Key policy amendments planned

Radical changes concerning the support for biogas/biomethane are expected to take place in Greece. Firstly, Greece is obliged to introduce a new support scheme for RES in the electricity sector. This new support scheme should be in line with the 'Guidelines on State aid for environmental protection and energy 2014-2020'. A first draft of the revised support scheme was open for public consultation until 14 March 2016. It foresees the introduction of a Feed-in Premium scheme, as far as renewable electricity is concerned. Secondly, the new investment law that will be approved in June 2016 foresees support for the development of biogas in the electricity and heating sector. The new investment law foresees a "bundle" of different support mechanisms that could be used alternatively such as income tax relief, subsidised expenditure, leasing subsidy, stabilisation of income tax coefficient or the subsidy of investment risk. In addition, a working group on biomass has been recently established by the Ministry of the Environment and Energy that is responsible for drafting a bill concerning solely provision concerning the deployment of biomass in Greece.

Appendix A.13 Hungary

Current production and consumption of biogas and biomethane

In Hungary, biogas is deployed in around 70 plants in total. Half of the plants operate within the agricultural sector with a capacity of 30 MW_{el}, followed by the landfill sector (20 plants) and the sewage sector (13 plants). The outstanding technologies used are anaerobic digestion (mesophilic and thermophilic) and sludge dewatering. The overall capacity amounts up to approx. 40 MW as of 2015. It is not expected that Hungary will reach the target of 100 MW installed capacity set in the National Renewable Energy Action Plan 2010-2020. However, higher capacities would be available to strengthen the biogas sector, especially in the field of waste from food processing with an estimated potential capacity of 25 MW_{el}, which is unused.

Taking all the currently available sources for biogas in Hungary into consideration, there is an annual potential production level of 121-177 million m^3 for biomethane. This amounts to 1.1-1.6% of the Hungarian natural gas consumption. However, the biomethane sector is considered a niche segment in the field of renewable energy in Hungary. It received no support recently and has barely any market, with less than 5% of the total estimated capacity for biomethane utilised. In 2015, only two upgraded biomethane plants were operating throughout the country.

Biogas and biomethane supporting schemes

In the **electricity sector**, biogas with the installed capacity greater than 50 kW is eligible for the feed-in tariff. The eligibility period and the maximum amount of eligible electricity are determined for each eligible electricity producer by the Hungarian Energy and Public Utility Regulatory Authority (HEA). For biogas (<5 MW) and landfill gas, there are benchmark feed-in periods which can be shortened if other investment schemes are used for the individual project. There are three different tariff rates depending on the time of the day. These time periods are defined by law, depend on the area the electricity is generated in and vary for weekdays and weekends/holidays as well as for summer and wintertime. The tariff level also depends on a plant's installed capacity and the generation technology employed. It is to be noted that the Hungarian feed-in tariff with an average amount of 99.5 €/MWh (in Germany: approx. 237.3 €/MWh) is the lowest in the EU.

A number of programmes under the main 'Széchenyi Plan 2020' may provide non-repayable financial means (subsidies) for the **electricity or heat** generation from biogas. To mention here are such programmes like the Environment and Energy Efficiency Operational Programme (EEEOP) or the Rural Development Programme (RDP). Both can provide subsidies through tenders to foster biogas deployment for electricity or heat generation.

In addition, within several sub-programmes of the EEEOP and the Economic Development and Investment Operational Programme (EDIOP) favourable loans are provided for the deployment of renewable energy sources, also for biogas both in the electricity and heating sector.

Theoretically, biogas/biomethane is eligible under the obligatory biofuel quota obligation of 4.9% in **the transport sector**. However, the biogas/biomethane deployment is given little importance in Hungary. The NREAP of 2010 for example prescribes only a share of 0.9% for biogas of all the renewable sources used in that segment.

Key drivers for biogas and biomethane developments

No drivers have been communicated by the industry with regards to the biogas deployment in Hungary. This is due to the lack of political will which is experienced by the actors on the free market.

Key barriers to biogas & biomethane growth

Concerning the electricity sector, the **feed-in tariff scheme is associated with a high administrative burden and disadvantages** for the plant operators in Hungary. Inter alia, there is an obligation for the producer to hand in an extensive prognosis of the plant's electricity generation and penalties have to be paid if it is missed. Furthermore, there is no defined cap of feed-in quantities and the eligibility period for the feed-in tariff is calculated on the individual basis. This might lead to the uncertainty with regards to the investment planning. In general, the Feed-in Tariff scheme sets not enough incentives to invest into the installation of biogas plants.

Moreover, **investments in CHP** are not supported in Hungary. The heat, which results during the electricity generation process in biogas plants, remains mainly unused due to a lack of financial incentives to invest into the efficient use of heat energy. Further, the **investment cost for biogas upgrading to produce biomethane is too high** for the plant operators. For the support under financial mechanisms other than the Feed-in Tariff, only new projects are eligible.

The **lack of political support** also negatively affects the biomethane sector which is underdeveloped in Hungary. The use of biomethane is allowed but not supported and the administrative burden is high. As of 2016, approx. 24-25 permits are required for the construction and operation of a plant. However, there are ongoing negotiations between interest groups and the relevant authorities. Since the Hungarian gas distribution system is well developed and provides a good basis to feed-in biomethane, the government might incentivise investments for upgrading of biogas in the future.

Key policy amendments planned

The implementation of the new mandatory renewable and alternative energy purchasing scheme (METÁR) was already planned for 2011. It is meant to replace the current feed-in tariff scheme. The new scheme should foster the greater deployment of renewable heat in Hungary, focusing on appealing tariffs for that sector and taking the waste disposal costs for the biogas plant operators into consideration. In general, support should only be granted through tendering procedures in the future. However, the long lasting discussions about the introduction of the new scheme have led to investment uncertainty in the entire renewable energy sector in Hungary. Furthermore, it remains unclear, who will bear the costs for the new system, since reduction of household energy bills is still one of the main priorities of the Hungarian government.

Appendix A.14 Ireland

Current production and consumption of biogas and biomethane

The total number of biogas plants in the Republic of Ireland in 2014 was 31. More specifically, there are 3 agricultural, 14 sewage plant facilities and 7 industrial landfills (18.4 MW) and 7 waste/industrial waste biogas plants. Their cumulative capacity amounted to 47 MW, generating 206 GWh of electricity in 2014, while 8.1 ktoe of thermal energy were generated respectively.

There is currently no biomethane production in the Republic of Ireland.

Biogas and biomethane supporting schemes

In Ireland, biogas in **electricity sector** is mainly promoted through a Feed-in Tariff scheme (Renewable Energy Feed-In Tariff - REFIT). More specifically, landfill gas is eligible under REFIT 2 and anaerobic digestion is eligible under REFIT 3. It should be noted that REFIT 2 and 3 has closed to new applications on 31 December 2015.

In addition, there is a grant scheme with a focus on the cultivation of willow as energy crop in place. The scheme is issued yearly and the aid consists of a once off capital grant based on a percentage of approved establishment costs. Grant is available for up to 40% of approved costs but not exceeding a maximum of € 1,040 per hectare. The minimum allowable area per applicant eligible for the establishment grant is 3 hectares and the maximum allowable area is 50 hectares.

There are currently no support schemes for biogas/biomethane in **heating and transport sectors** in Ireland.

Key drivers for biogas and biomethane developments

There is a number of drivers that might lead to a steady and constant increase of the biogas/biomethane sector in Ireland. Primarily, there is an adequate, reliable and sufficient feedstock supply that could be used as a primary output for the production of biogas in the country. Currently, due to a lack of biogas processing plants, almost 60% of the available feedstock is exported to the United Kingdom and Northern Ireland. A further factor that is mainly related to the promotion of biomethane, is the demand from the side of the costumers for the "green gas". Such demand may prove decisive for the deployment of biomethane in Ireland, as there are prospects for its promotion. A Renewable Heat Incentive (RHI) has been consulted on and is in development with the expectation it will be implemented in 2017.

Key barriers to biogas & biomethane growth

Concerning the electricity and heating sector, there has **been no recognition of additional carbon benefits of biogas/biomethane** by the authorities in charge, particularly with regard to the agriculture sector which is responsible for circa 33% of Ireland's emissions. **The full potential of both** technologies **is not fully recognised** in the Republic of Ireland. Such technologies bring about spillover effects, as they do not only produce clean energy but also have additional positive effects, such as reduction of GHGs and waste output. Nevertheless, those additional positive effects of those technologies are not properly recognised by the respective public administration authorities.

As far as the electricity sector is concerned the main barrier for the deployment of biogas is **the limited capacity for anaerobic digestion CHP within the REFIT 3 support scheme** and the **insufficient subsidy for non-gate fee feedstock for biogas production**. Other renewable electricity technologies such as onshore wind can be developed for a lower subsidy than anaerobic digestion CHP but these cannot effectively address the heat and transport sectors, whereas biomethane can be injected into the natural gas network decarbonising the heat sector and in time the transport sector through CNG vehicles. Biogas technologies were supported through a Feed-in Tariff (REFIT3) until the end of 2015. Currently, a public consultation on the new support scheme is pending and is expected in 2017. It is envisaged that the new electricity support scheme could support a biomethane CHP located and a natural gas end-user site remote from the biogas production facility. The CHP Directive is transposed to Irish Law and the requirements for high efficiency CHP render the certification of biomass CHP facilities extremely difficult as those requirements are mainly applicable to CHP from natural gas.

The heating sector is confronted with an even larger barrier, i.e. **the lack of a relevant support scheme.** Despite the fact that a support scheme for the promotion of biogas was foreseen as early as 2014, such a scheme is not yet introduced. Public consultation on the introduction of the Renewable Heat Incentive (RHI) was initiated in 2015. Although the consultation process was accelerated, the RHI could not be introduced at the beginning of 2016, as it was planned and is now due in 2017.

Key policy amendments planned

Two crucial policy developments are expected to take place in 2017. The first one relates to the introduction of the RHI. Ireland’s Draft Bioenergy Plan from 2014 foresaw the introduction of the RHI with the aim of boosting renewable energy sources, covering also biogas, in the heating sector. The Department of Communications, Climate Action and Environment (DCCAE) carried out an initial consultation in September 2015 so it is likely that the RHI will be introduced in 2017. However, the RHI is not yet in place. Apart from that, the existing support scheme for renewable electricity is expected to be revised. For that reason, it is likely that a public consultation on a new renewable electricity scheme will be launched in 2017.

Appendix A.15 Italy

Current production and consumption of biogas and biomethane

Italy is ranked very high in the EU in terms of the production of biogas. The intensive and large livestock and agriculture production in the north of Italy has contributed to a great extent to the deployment of biogas. Agro-industrial biogas dominates the biogas energy output. In 2013, there were about 410.8 ktoe of landfill biogas, 48.5 ktoe of sewage sludge biogas and 1,356.1 ktoe of biogas produced in decentralised agricultural plants, municipal solid waste methanisation and centralised co-digestion plants.

Biogas and biomethane supporting schemes

In the **electricity sector**, biogas is mainly supported through a Feed-in Tariff, the so-called Tariffa onnicomprensiva, and a Premium Tariff schemes. The Feed-in Tariff supports small-scale biogas plants with an installed capacity between 1 kW and 1 MW, which are entitled to choose between the feed-in tariff and the premium tariff. Biogas plants with an installed capacity between 1 MW and 5 MW (and those with a capacity below 1 MW not opting for the feed-in tariff) are supported by the premium tariff. The premium tariff is calculated from the difference between the basic feed-in tariff and the hourly zonal electricity price. On top of the basic feed-in tariff, bonuses may be granted to the plant. The digression rate for the basic feed-in tariff from 2014 onwards is set at 2%.

Under the Feed-in Tariff and Premium Tariff schemes, biogas plants with a capacity up to 100 kW can access the incentives directly, while plants with a capacity between 100 kW and 1 MW have to be listed in a register first. For biogas plants with a capacity above 5 MW, the described premium tariff is granted through a tendering process. The incentives range between € 85 and € 122 per MWh and are granted for 20 years.

It has to be noted that since 1 January 2016 the feed-in tariff and premium tariff regulation for biogas in the electricity sector is not in place anymore, and currently Italy is waiting for a new law on renewable energy sources.

In 2015, the Energy Regulatory Authority approved two incentive schemes for biomethane – Premium Tariff for biomethane injection into the grid and Certificates of Release for Consumption of Biofuels (CIC) for biomethane for vehicles (the value of the certificate has still to be issued). The premium tariff for biomethane is calculated based on the amount of biomethane injected into the grid and equals the difference between twice the annual average price of natural gas and the average monthly price of natural gas, in every month that biomethane is injected into the grid. The tariff is granted for 20 years. Biomethane use to produce electricity and heating in co-generation is also encouraged under the Premium Tariff scheme. It has to be noted that since 2013 it is already allowed to inject biomethane in natural gas transmission and distribution grids, as well as in methane distribution plants for natural gas vehicles. However, in practice it is still not possible to use biomethane for the injection into the gas grid and for natural gas vehicles, as the technical rules have not yet been issued. They are expected in 2016.

Key drivers for biogas and biomethane developments

The biogas development in Italy started with the approval of a national regulatory framework on the use of the digestate in the agriculture. The framework went beyond regional differences and confirmed the importance of the anaerobic digestion in the national agricultural sector. The use of digestate in agriculture allows companies to produce food, energy and biofuels as well as to give back important fertilizer value to the land. Still, the most significant driving force to promote biogas was the first Feed-in Tariff scheme that was launched in 2008 and expired in 2012. In fact, most of the biogas plants in Italy were installed in 2008-2012 and since then the number of new biogas plants installed decreased, as a result of the reduction of the feed-in tariffs.

Regarding biomethane, the possibility to inject biomethane into the natural gas grids, as well as in methane distribution plants for natural gas vehicles was initiated by the Fiat Chrysler Automobiles group that urged the government to promote the use of biomethane for cars and reduce natural gas imports.

Key barriers to biogas & biomethane growth

Lack of biomethane technical rules. In practice, the possibility to feed in biogas into the natural gas grids is still not operational. Although since 2013 biomethane producers are allowed to inject biomethane in natural gas transmission and distribution grids, as well as in methane distribution plants for natural gas vehicles and in 2015 a support scheme for the biomethane injected into the grid was approved, the technical rules have not yet been issued. Technical rules and conditions for the injection of biomethane are expected to be issued by the national government in 2016.

Lack of legal framework in the electricity sector. Since 1 January 2016, the feed-in tariff and premium tariff regulation for biogas is under revision. Therefore, currently there is no support scheme in place for new biogas plants. However, the decree launching the new Feed-in Tariff and Premium Tariff is supposed to come in force anytime this year.

Thermal biogas plants are still not well known by the general public. Thermal biogas plants are not well known among citizens. In addition, renewable energy installers have still little information on thermal biogas plants. Thus there is a need for increasing the general awareness and specific information on the opportunities of biogas in the heating and cooling sector.

Certification of installers is not yet very developed. Although there are some certification bodies that have launched their own certification mechanisms, the interest towards certification of biogas/biomethane installers is still very limited. In fact, the importance of installers' certification in the biogas/biomethane sector is not yet acknowledged.

Key policy amendments planned

Since 1 January 2016, the feed-in tariff and premium tariff regulation is not in place anymore. For new biogas plants, a new feed-in tariff and premium tariff decree will come into force this year. It is expected that the tariffs will be very similar to the previous ones.

In 2016, the technical rules to feed-in biomethane into the natural gas grid should come into effect. The government expects that after the issue of these rules the annual biomethane output will increase to 5-8 billion m^3. For the coming years, it is foreseen to use selective membrane separation to upgrade biogas into biomethane.

Appendix A.16 Latvia

Current production and consumption of biogas and biomethane

There were only minor developments in the Latvian biogas sector in the recent years. In 2014, there were 58 biogas plants across the country with an overall installed capacity of 54.92 MW and with a total biogas production of 765 GWh. 48 out of the 58 biogas plants were agricultural plants, 1 plant used sewage and 7 plants used landfill gas as a substrate. In 2014, these plants produced 333,1 GWh electricity; its share in total electricity production was 5,8%. In the same time, over 165 GWh of heat from biogas was generated for self-consumption or injection into the district heating network. Almost 80% of the feedstock used for biogas production in Latvia are energy crops.

Currently, there is no biomethane production in Latvia.

Biogas and biomethane supporting schemes

In Latvia, biogas generation in **electricity sector** is stimulated through investment grants for plant construction and a feed-in tariff, which is acquired through a mandatory procurement, as set in the Electricity Market Law. Under the latter support mechanism, the public trader purchase electricity from merchants, which have been granted the right to sell electricity produced from renewable energy resources within the scope of mandatory procurement for electricity prices determined in accordance with the price formulas set in Cabinet Regulations No. 221/2009 and No. 262/2010. The feed-in tariff for biogas plants is guaranteed for 10, 15 or 20 years. The eligibility period depends on the installed capacity of the plant.

It is to highlight that currently there is no possibility to receive a feed-in tariff in Latvia. The Feed-in Tariff scheme is under revision since 2011 due to concerns about corruption and a lack of transparency in the way it was carried out since 2007. No mandatory procurements will be organized for feed-in tariffs in Latvia for biogas and biomass until 2020. A new long-term renewable energy strategy and a new support scheme for RES is awaited. The latter is not expected earlier than the end of 2018.

No support schemes are currently in place for biogas/biomethane in **heating** and **transport sectors** in Latvia.

Key drivers for biogas and biomethane developments

As there is a high insecurity about the future of the Latvian biogas sector, caused by the lack of long-term predictability and availability of both financial and legislative support, it is very hard to identify the drivers for the biogas deployment within the country.

A potential driver for biogas/biomethane in the near future could be the currently being drafted regulations on "Requirements for the injection of biogas and gas from biomass, as well as liquefied natural gas into the natural gas transmission system" and the possibility to distribute biogas through the natural gas transmission system, if the requirements will be approved by the government.

Key barriers to biogas & biomethane growth

The key barrier affecting biogas/biomethane in the electricity, heat and transport sectors is the **absence of policy instruments** since 2011 **as well as a long-term RES strategy**. Lack of a long-term predictability leads to a barely no investments in renewable energies, also biogas, in Latvia.

In addition, a new tax - **Subsidised Energy Tax** - was introduced in Latvia as of January 2014. This tax effectively reduces remuneration for electricity fed into the electricity grid by renewable electricity producers. The following tax rates are applied: 10% for the electricity produced from renewable energy sources and a reduced tax rate of 5% for high efficiency CHP units. The Subsidised Energy Tax is a temporary one and is scheduled to be in place until 2018.

Regarding biomethane the main barriers to its deployment in gas market and transport sector is the **lack of market structure and infrastructure** and **technology issues**, such as lack of experience in biogas purification and compression/liquefaction as currently there are no such plants in Latvia.

Key policy amendments planned

According to the Latvian Ministry of Economy, a new support scheme for renewable energy sources is under discussion. The objective is to create a new support scheme which will be transparent and understandable for both energy users and producers will be able to respond to market signals, to reduce costs and avoid over-compensation of energy producers. More clarity and predictability of the planned support scheme for energy production from renewable energy sources will give investors a clear long-term vision. Taking into account that burden of the existing support costs for electricity consumers rises till 2018; initiation of a new support instrument till the end of 2018 is not expected.

Finally, a new long-term renewable energy strategy is expected in Latvia.

Appendix A.17 Lithuania

Current production and consumption of biogas and biomethane

The total number of biogas plants in Lithuania in 2013 and 2014 was 21: 1 biogas plant produced biogas from agricultural wastes, 8 plants from sewage, 9 plants from landfill gas; the remaining 3 plants included biowaste and industrial waste biogas plants. The total installed capacity of all these plants in 2014 amounted to 21.1 MW_{el}. They generated 32.7 GWh of electricity and 26.7 GWh of heat (data for 2013).

At the end of May 2016, the number of biogas plants reached 36. Their installed thermal capacity amounted to 9,481 MWth and installed electrical capacity to 30,218 MW_{el}.

Currently, there is no biomethane production in Lithuania.

Biogas and biomethane supporting schemes

In the **electricity sector**, power plants using biomass, biogas derived from anaerobic digestion or other biodegradable organic waste or substrates and power plants using landfill gas are supported with a feed-in premium. Power plant operators are eligible for a flexible bonus - the difference between a guaranteed tariff and the sale price for electricity generated from biogas or landfill gas. Different procedures are applicable according to the total installed capacity of a plant. While electricity generated by plants up to 10 kW is purchased at a guaranteed price set by the National Commission for Energy Control and Prices (NCC), operators of plants above 10 kW may acquire a guaranteed tariff by taking part in tenders organised by the NCC. The Law on Energy from Renewable Sources (RES Law) introduced a cap on feed-in premium payments for each eligible technology. For biofuel power plants, covering biomass and biogas, the cap is set at 105 MW until 2020. Currently, this cap is already reached.

Biogas projects (both for electricity and heat generation) are also eligible for subsidies and loans under the Climate Change Special Programme (if no feed-in premium is received). For applicants not engaged in economic/commercial activity a subsidy of max. € 1,450,000 is available and for applicant engaged in economic/commercial activity max. € 200,000 (max. 80% of eligible project cost). No budget is envisaged for biogas projects under this programme for 2016. In addition, electricity from biogas is exempt from the excise duty.

Biogas in the **heat sector** is promoted through several support schemes. The RES Law obliges gas system operators to purchase biogas and inject it into the natural gas system. The biogas produced is purchased at the tariffs set by the NCC. In addition, operators using biogas are exempt from environmental pollution tax for all emissions resulting from used liquid biomass. Finally, the National Heat Sector Development Programme has an objective of additional 43 MW of electric power from biomass and/or biogas cogeneration plants in district heating systems of Lithuanian cities by 2021.

In the **transport sector** biogas/biomethane is promoted through an exemption from environmental pollution tax and an exemption from excise duty. The latter is applicable only to biogas/biomethane used as a fuel in public transport.

Finally, the Rural Development Programme 2014-2020 supports production of biogas from agricultural waste and other waste, heat and electricity production in biogas plants, biomethane production and compression, as well as production of degassed substrate. Eligible for support are farmers as well as micro and small enterprises engaged in livestock or poultry operations. Supported installations may not exceed 1 MW.

Key drivers for biogas and biomethane developments

Biogas deployment in Lithuania has mainly been driven by the feed-in premium (previously feed-in tariff). However, since the 105 MW cap for biofuels has already been reached, no support for biogas is currently available under this scheme.

In the transport sector, inclusion of biomethane into the currently drafted Renewable Energy Resources Development Programme for 2016-2020 could drive its deployment forward. The current draft foresees that in order to achieve the 2020 target of 10% for the RES-share in the transport sector, biomethane shall account for at least 1%.

Finally, the Ministry of Environment sees a set of measures, which could incentivise the use of biogas/biomethane in the transport sector, e.g. introduction of a vehicle taxation based on CO_2 emissions, obligation to public institutions to use biomethane in their means of transport or subsidies for natural gas refuelling stations. According to the industry, the main driver for biogas and biomethane deployment would be EU regulation on mandatory use of waste.

Key barriers to biogas & biomethane growth

The key barrier affecting biogas/biomethane in electricity, heat and transport sectors is **lacking long-term national vision for RES**. There is no long-term strategic thinking in the policy-making. So far, Lithuania has no strategy for the development of renewable energy. According to the industry, a RES strategy should be developed in order to see how much of country’s energy demand can be covered by local renewable energy sources and what other energy sources should be used to meet the remaining energy demand.

In addition, **some incentives intended to support biogas/biomethane do not function (well) in practice**. For example, the requirement of the Lithuanian Rural Development Programme for 2014-2020 that 50% of the electricity generated from biogas has to be self-consumed makes the receipt of support under this programme difficult. Lithuanian farms are too small to meet this requirement.

Limitation of biogas/biomethane supply by consumer demand. In Lithuania, biogas/biomethane producers may connect either to the gas transmission or distribution network. If a plant is connected to the transmission network, all biomethane produced is purchased by the gas network operator, however, the connection to the gas grid is relatively expensive. If a plant is connected to the distribution grid, the connection is cheaper, however, biomethane supply may exceed the consumer demand. Thus during the warm season biogas/biomethane production is economically not viable.

Removal of the excise duty relief for biomethane for vehicles. Excise duty relief for biomethane used for vehicles, except in public transport, has been removed from January 2016. There are plans to remove this exemption also for biomethane used in public transport.

Key policy amendments planned

In Lithuania, the Public Service Obligation (PSO) Fund reimburses feed-in premiums paid to RES-producers by the energy suppliers. There are government plans to abandon the PSO system, having regard to the European Commission's 'Guidelines on State aid for environmental protection and energy 2014-2020'. Furthermore, there are ongoing discussions on the replacement of the Feed-in Premium scheme with financial support for investments.

Currently, a new Renewable Energy Resources Development Programme for 2016-2020 is being drafted. The current draft foresees that in order to reach the 10% RES-share in the transport sector by 2020, biomethane shall account for at least 1%. However, it is not clear if this provision will remain in the final version of the Programme.

Finally, there are ongoing discussions on removing the excise duty exemption for biomethane used as a fuel in public transport.

Appendix A.18 Luxembourg

Current production and consumption of biogas and biomethane

In Luxembourg, biogas was produced in a total number of 30 plants in 2014, whereof 26 facilities were located in the agricultural sector. A total biogas production of 149 GWh was achieved, with a major share of 55.3 GWh of generated electricity and a minor share of 12.8 GWh of generated heat.

The biomethane sector is emerging, as three plants were producing 26 GWh biomethane in 2014. Roughly 300 gas driven vehicles are registered in Luxembourg being fuelled in 7 petrol stations offering CNG.

Biogas and biomethane supporting schemes

In Luxembourg, **electricity** from biogas is mainly promoted through a feed-in tariff. The amount of the tariff depends on the size of the plant and amounts currently to €ct 15.3-19.2 per kWh (the lower the nominal capacity of a plant, the higher is the tariff). It is guaranteed for a period of 15 years starting on the day of the first electricity export. The tariff for new plants depends on the year of commissioning and is subject to a yearly degression rate, which is legally defined.

In addition to the feed-in tariff, two subsidies are in place in order to support companies in the field of environmental protection and the rational use of natural resources for **electricity and heating purposes**. The subsidies can be allocated in form of capital grants or of interest-rate subsidies and may cover up to 40% of the eligible investment costs.

Key drivers for biogas and biomethane developments

The goal of the Ministry of Economics is to have additional 100 biogas plants in Luxembourg until 2020. The Biogas Association (Biogas Vereenegung Asbl) and the "Mouvement Écologique", an environmental protection agency, who are involved in the enhanced biogas production in the country for years, can be named as important drivers of the biogas sector.

Key barriers to biogas & biomethane growth

Too severe requirements for obtaining investment aid. In 2011, the new Agriculture Act (Loi du 18 avril 2008 concernant le renouvellement du soutien au développement rural) entered into force, only entitling biogas plants to investment aid if they meet strict criteria, inter alia on the geographic origin of agro-industrial waste materials being used for the production of biogas as well as on the length of supply contracts for biomass. Due to this ministerial decision, the scope of action concerning the biomass subsidy is substantially limited. The average investment aid for agricultural biogas plants amounts to approx. 50%. Without this aid, an economically viable operation of the biogas plants is not possible.

Prices for substrates too high. The rising prices for animal food also let to a sharp rise of the substrate costs for biogas plant operators during recent years. For systems in which a specific target has to be achieved in order to meet their heat supply contracts, an additional acquisition of substrates is unavoidable. On average, the substrate inputs cause half of the total cost of the biogas operation.

Governmental support too low. The support from the Ministry of Agriculture is assessed too low. In particular, there is no specific premium for the use of manure. To this end, the Centrale Paysanne Luxembourgoise calls for a clear commitment of the Minister to the National Action Plan on Renewable Energy from 2007. The National Renewable Energy Action Plan generally foresees a significant expansion of the use of biomass with a potential of 10,000 ha energy crops.

Key policy amendments planned

Currently, no policy amendments influencing the deployment of biogas and biomethane are planned. However, the Biogas Association has recently published a list of recommendations on how to improve the enhancement of biogas.

Adjustment of the feed-in tariff rates for biogas. Tariffs between €ct 16.4 and 19.4 per kWh were recommended in order to guarantee an economical and cost-effective operation both with new and existing biogas plants.

Introduction of a liquid manure bonus. Due to the increased use of agricultural residues in biogas plants, the production costs increased significantly. Such additional costs result primarily from the lower energy content of liquid and solid manure. According to calculations made by the Biogas Association, the share of manure in biogas plants is approx. 50% (mass fraction). Therefore, the introduction of a liquid manure bonus between € 30 and 70 per MWh is recommended, depending on the share of manure and slurry. The bonus shall be paid in addition to the applicable rates of remuneration.

Appendix A.19 Malta

Current production and consumption of biogas and biomethane

In Malta, all renewable electricity and heat produced from biogas is generated through anaerobic digestion of the organic part of municipal waste. The renewable energy production from biogas in Malta in 2012 amounts to 0.7 ktoe.

Biogas and biomethane supporting schemes

Currently and historically, no support measures for the promotion of biogas have been in place in Malta. Due to a lack of space, the country has no indigenous resource of fossil fuels and the development of biomass energy crops as a renewable energy source cannot be considered suitable for Malta given existing technologies and resource potential. Malta's NREAP does not mention future policies regarding the deployment of biogas. However, Malta’s 2020 biogas aim is to generate approx. 50 GWh (4ktoe) of renewable electricity and 2 ktoe of renewable heat from biogas.

Biogas is only produced through the treatment of waste at Sant' Antnin Solid Waste Treatment Plant, which includes the Mechanical Biological Treatment Plants (MBT) producing biogas through anaerobic digestion of the organic part of municipal waste. The biogas produced in this facility is used for the generation of electricity by combustion in a CHP plant, while any excess electricity will be fed into the grid. The biological treatment plant was put into operation in 2010 and the project was funded through € 27 million, while € 16.7 million were secured through EU co-funding from the European Union Cohesion Fund. The CHP plant running on the biogas produced, generates enough electrical power for 1,400 Maltese households of four persons each, in addition to the heat required to run the plant.

Key drivers for biogas and biomethane developments

As renewable energy generated from biogas is not considered to contribute essentially to the renewable energy mix in 2020, no drivers can be named here.

Key barriers to biogas & biomethane growth

The main barrier for biogas development in Malta is the complete lack of drivers such as additional feedstock and support schemes.

Key policy amendments planned

No further amendments are currently planned.

Appendix A.20 The Netherlands

Current production and consumption of biogas and biomethane

The Netherlands dispose of a total of 252 biogas plants (agriculture: 105; sewage: 82; landfill: 41; bio waste/industrial waste 24) producing roughly 300 million m^3/of biogas a year. In addition, 25 installations (membrane separation: 11; water scrubbing: 5; pressure swing absorption: 2; chemical scrubbing: 6; cryogenic separation: 1) are upgrading biogas to biomethane with a total yearly production of roughly 100 million m^3.

In 2014, the total primary production of biogas amounted to 13,094 TJ. The transformation output, i.e. the conversion of biogas to another energy carrier such as electricity or heat, amounted to 8,121 TJ, while 4,973 TJ of biogas were available for the final energy consumption in the industry (1,056.0 TJ), the agricultural and forestry sector (2,014.0 TJ) as well as the service sector (1,903.0 TJ). There is currently no direct use of biogas in the transport sector in the Netherlands. Upgraded biogas in form of biomethane is fed into the gas grid and used in the transport sector for CNG vehicles.

The outlook on future developments, based on an estimation of the Green Gas Forum, of which the Dutch government forms part, indicates that by 2020 around 1.2 billion m³ or 0.75 billion m³ of natural gas equivalent shall be generated; by 2030, this number shall rise to 3.7 billion m³ of biogas or 2.2 billion m³ of natural gas equivalent.

Biogas and biomethane supporting schemes

In the Netherlands, the generation of biogas for the electricity and the heating sector as well as the generation of biomethane is promoted through a premium tariff in form of the SDE+ scheme (Stimulering Duurzame Energieproductie). The scheme grants a premium on top of the market price, which shall compensate the difference between the price of electricity from renewable sources (base amount) and the wholesale price for electricity from fossil sources (correction value). The premium is thus variable and annually corrected in dependency to the price developments of fossil energy. The support of the SDE+ is made available in two rounds with four bidding stages each. Support is made available on a first-come-first-serve-principle, resulting in conditions, where applicants at a later bidding stage may risk to be rejected due to a depletion of funds. Biogas projects may request support at all four support stages of the two bidding rounds. The overall SDE+ budget for 2016 is € 8 billion, which is an increase of the support scheme budget of more than 50% in relation to 2015 (€ 3.5 billion). The maximum budget for auxiliary and co-firing of biomass is € 4 billion.

For biogas and biomethane there are in addition two tax regulations in form of fiscal subsidies; namely, the EIA Energy Investment Allowance Scheme as well as the VAMIL Environmental Investment Allowance Scheme. Both schemes allow private companies to write off investments in biogas plants against their income tax, respectively to deduct an extra amount from the taxable profit for investments.

Furthermore, the Dutch government introduced the public-private support programmes Green Deal and Green Gas Foundation to further support the development of biogas projects, by providing financial support as well as expert advice throughout the realization phase. In the transport sector, a general quota obligation applies, not specifically addressing biogas as such. Companies importing or producing petrol, gas or diesel fuels are obligated to ensure that biofuels make up a defined percentage of the company's total annual sales. For 2016, the quota is set to 7%. As outlined above, there is currently no direct use of biogas in the transport sector; however, biomethane is used via the general gas grid for CNG vehicles.

Key drivers for biogas and biomethane developments

A driver for the development of biogas and biomethane projects in the Netherlands may be identified in the public-private support programmes Green Deal and the Green Gas Foundation. Both programmes aim at supporting entrepreneurs during the development phase of biogas project, through the provision of expertise and guidance as well as attractive financing options.

Key barriers to biogas & biomethane growth

A dominant barrier is the **reliability of the general RES strategy and the related support schemes**. In the past however, every new cabinet in the Netherlands introduced its own support scheme and strategy and adapted or stopped previous ones, resulting in conditions, where a long-term planning concerning the revenue stream was difficult for investors and developers in renewable technologies.

Furthermore, the **focus of the SDE+ scheme on the efficiency criteria** is a further distorting factor. The support approach of the SDE+ scheme focuses and awards predominantly higher efficiencies of projects. GHG reductions and resource use are no factors that are considered for the calculation of the subsidy amount. Considering the first-come-first-serve-principle of the SDE+ scheme, projects with a lower efficiency might be excluded though they would contribute to a high GHG emission avoidance.

The general **access to finance** is a dominant barrier for the RES projects in the Netherlands. Developers of large scale commercial biogas & biomass installations are confronted with high difficulties to realise financial closures with commercial banks. Credit institutions remain reluctant to finance renewable projects and show a high risk aversion towards new technologies and projects. The Dutch government addressed this barrier by introducing the public-private support programmes mentioned above. The effectiveness will have to be evaluated throughout the upcoming months.

For biomethane, a barrier is identified regarding the **different gas specifications existing in the different regions**. Around Groningen the calorific value is lower than in the South. Biomethane injectors in the South thus have a disadvantage. Increasing the calorific value of biomethane is very costly. In the upcoming years the gas in the distribution grids in the Netherlands will need to shift to high calorific gas due to the lower production level and eventual depletion of the Groningen gas field.

Key policy amendments planned

In the National Energy Survey (NES) 2015, the Dutch Minister of Economic Affairs outlined on future development for the RES sector: in regards to biogas/biomethane, the NES 2015 foresees an amendment regarding a special policy for mono-fermentation of animal manure. The new policy shall especially address the required high capital costs of this technology and the fact that currently such a support can only be acquired in the latest stage of the SDE+ premium tariff, which often is not available due to the depletion of the overall funds (first come, first serve principle). The Dutch government is focusing on the digestion of animal manure to address the very amounts of this feedstock as well as to drive down GHG emissions of this carrier. The new policy shall enable a public-private innovation programme for the mono-fermentation of animal manure.

In addition, there are also changes foreseen to the SDE+ application process. The foreseen amendment shall increase the flexibility of the procedure. To this end, an extra application around shall be introduced to shorten the waiting period for rejected projects. Furthermore, a free category will be added to each phase, wherein producers can apply for a subsidy in tenths of eurocents allowing them to make a more competitive business case; leading ultimately to a higher efficiency of the SDE+ scheme.

Appendix A.21 Poland

Current production and consumption of biogas and biomethane

In Poland, anaerobic fermentation is the main process used to produce biogas. Biogas is almost exclusively produced in the heating and electricity sectors. There is practically no biomethane production. In 2014, there were 277 biogas plants installed (an increase of about 30%) in comparison to 2013 with an overall capacity of 209.3 MW: 60 biogas plants produced biogas from agricultural wastes, 96 plants from sewage, 101 plants from landfill gas, and remaining 20 plants included biowaste and industrial waste biogas plants. Altogether these plants achieved a production of 3,758.4 TJ, most of it being generated electricity.

Biogas and biomethane supporting schemes

The main support scheme for the use of biogas in the **electricity sector** and in general is a quota scheme. The quota scheme is technology neutral in the sense that it does not offer a different amount of certificates depending on what technology has been used. Each technology is eligible for the same amount of certificates for the same amount of energy. On 1 July 2016, the quota scheme shall be replaced by an auctioning system. For small installations with the capacity between 3 kW and 10 kW, there will be a feed-in tariff. However, this reform is currently implemented by the new Polish government. The new amendment is not published yet.

Both for the **electricity and the heating sector** the loan program Priority Programme RES Stork applies, which provides a credit with a particular low interest rate. The overall budget of this program amounts to PLN 570 million (approx. EUR 130 million) for the timeframe 2015-2023. The loan is established through the National Fund for Environmental Protection and Water Management. Another program that is financed through the very same fund is the Priority Programme Prosumer, which grants low interest loans together with subsidies to support the purchase and installation of small and micro-RES-installations for the needs of residential single-family or multi-family houses in electricity and heating sectors. The overall budget of this program amounts to PLN 249.8 million (approx. EUR 56.87 million) for subsidies and PLN 467.2 million (approx. EUR 106.36 million) for loans for the timeframe 2015-2022.

There is no support scheme for biogas in the **transport sector**.

According to industry stakeholders, none of the above described policies were very effective. This is reflected by the gap between biogas objectives and actually developed biogas installations. The 'Polish Energy Policy until 2030', adopted by the Council of Ministers in 2009, establishes the long-term objectives of the energy policy. It assumes that there will be on average one biogas plant per community, which means at least 2,478 biogas plants in the whole country until 2020. Currently, there are only around 207 biogas plants in Poland.

Key drivers for biogas and biomethane developments

Despite its shortcomings, the main driver for the development of the sector was the support of biogas in the electricity sector through the quota system. According to the Council of Ministers, an important driver might be the amount of agricultural waste and the need to make the agriculture more rentable.

Key barriers to biogas & biomethane growth

Insecure investment conditions. The most predominant barrier is the current legal insecurity that is created by the amendments of the RES-Act (adopted in February 2015) in December 2015 and probably once again in the coming months. According to the RES-Act, the installations launched in the first half of 2016 should be covered by the new support system. However, the amendment postponed the entry into force of the law. The new government has announced further amendments that currently remain unknown. As a consequence, biogas investors struggle with a new and unknown situation.

Grid access issues. Another serious barrier is the tiresome grid connection process for biogas installations. The legal position of installers is weak, for example the connection is not sufficiently guaranteed and only the waiting time for the decision on the conditions of connecting the installation can amount to 150 days.

Lack of public support. In addition, the construction of biogas plants faces a lot of public protest and lack of acceptance. The main concern of people is how their everyday life is impacted through the increased usage of biogas, particularly the smell of biogas.

The **legal regulations** concerning the use of fermented mass from agricultural materials and of agricultural origin in fertilising is **excessively restrictive**. Post-fermentation mass from agricultural biogas plants is treated equally in terms of legal approach as the sludge mass and thus it may not be used directly for fertilisation. After the methane fermentation process, the mass becomes a waste.

Key policy amendments planned

The main announced amendment in the electricity sector is the introduction of the auction system on 1 July 2016. The subject of the auction will be the amount of electricity generated from renewable energy sources. Separate auctions will be held for RES installations with capacities up to and over 1 MW. There will be a feed-in tariff for small installations with the capacity between 3 kW and 10 kW. Within 15 years following the beginning of RES energy production, owners of RES installations will be able to choose between the old quota system and the new auction system. However, the substitution fee will be set at the level of 2014, i.e. PLN 300.03 (approx. EUR 70) per 1 MWh. In addition, on 19 February 2016, the Ministry of Energy announced a thorough amendment of the RES-Act. The regulation will differentiate the support for energy production for citizen’s own purposes and for energy production as a business activity. In the first case, the support will consist on refunding of investments. In the latter, the feed-in tariff is being weighed up. The draft of the amendment has not been published yet.

Appendix A.22 Portugal

Current production and consumption of biogas and biomethane

Portugal has still a large unexploited biogas potential. There is a total of 65 biogas (only 51 connected to the electric grid) plants with a total installed capacity of 83 MW, producing only electricity. This represents a production level of 3,432 TJ by the end of 2014. In Portugal, the most used technology is anaerobic digestion. Gasification for biogas production is only used in a pilot unit in Tondela and small units for research purposes. Biogas comes usually from landfills, sewage, industrial and agro-industrial digesters as well as from the digestion of municipal solid waste. Yet, Portugal could take advantage of still unexploited sources to produce biogas like residue streams from forests and certain industrial sectors such as paper and cork producers as well as dedicated crops.

In Portugal, biomethane has not been developed yet.

Biogas and biomethane supporting schemes

In the **electricity sector**, biogas has been mainly promoted through a feed-in tariff. However, the Feed-in Tariff regime ended in 2012 for large scale units, being applied currently only to the plants with permits issued before this year. For existing biogas plants, the following indicative average rates are in place:

- fermentation of solid municipal waste, sewage sludge from waste water treatment, waste water and waste from the agricultural as well as food industries: € 115-117 per MWh;
- landfill gas plants: € 102-104 per MWh.

The payment for existing biogas installations is for the first 15 years of operation.

A new regime for Small Production Units (UPP) and Self-consumption Units (UPAC) was approved in 2014 and enacted in 2015. UPPs can have an installed capacity of up to 250 kW, whereas UPACs can have an installed capacity of more than 1 MW. The most important changes of 2015 are that UPPs are based on a bidding scheme, while UPACs are able to have more capacity and are allowed to connect to the national grid. For biogas UPPs, the feed-in tariff consists of 90% of the reference tariff, as set by Ordinance 15/2015. The reference tariff for the year 2016 is € 95/MWh, thus the tariff for biogas UPPs amounts to € 85.5/MWh. In the case of UPACs, they are supposed to meet individual consumption needs. Nevertheless, UPACs that are connected to the grid and have a capacity of up to 1 MW can feed their excess of electricity into the national grid, receiving a remuneration tariff that is 10% less than the market price.

No support schemes for biogas in the **heat and transport sectors** are in place in Portugal.

Key drivers for biogas and biomethane developments

The biogas sector is not widespread in Portugal, yet there are some opportunities that could lead to a greater development of biogas in the future. One of the most important potential drivers is the national legislation, which transposes EU Directives, and the National Waste Management Plans (PERSU) I, II and 2020 that promote the treatment and valorisation of organic wastes. The legal framework governing waste management has been consolidated over the last few years with systems for managing certain specific flows of wastes and placing the onus on producers to pursue targets for energy recovery and other management systems.

In addition, the CO_2 emission-based taxes for conventional vehicles under the Reform of Green Taxation, the establishment of tax incentives in the use of less polluting vehicles, including natural gas/biomethane, and the existence of national projects for the production of fuels from biomass represent opportunities for a major deployment of biogas.

Last but not least, the large unexploited potential in the rural areas of Portugal represents a potential driver. The deployment of biogas and biomethane in the rural regions is a good opportunity for the improvement of the energy supply, especially heating and cooling, as well as make some other revenues for impoverished areas.

Key barriers to biogas & biomethane growth

Uncertainty regarding new support mechanisms. Decree-Law 215-B/2012 has set a moratorium for all large RES-E projects introduced by Decree-Law 25/2012. New biogas plants should from now on be paid according to wholesale electricity market price (MIBEL). Support schemes were therefore extinguished, and can only be envisaged via a specific power granting tender to be launched by the competent energy authority. However, an ordinance defining the details of these tenders is still to be published. This represents a severe barrier, considering the fact that renewable electricity projects are being pushed into a marginal market in which prices have been historically so low that makes it impossible to build any power plant under this general remuneration regime.

Lack of financing worsened by high capital costs. The country risk, due to the economic and financial crises, induced a lack of capital available to finance renewable energy projects and when available, implicates high cost.

Lack of effective heating strategy for renewable energy sources. The 2020 target set for renewables in the heating and cooling sector (RES-H&C) in the NREAP is very low (35.9%). Moreover, the share of renewable energy in the heating mix has been dropping in the last years. This shows that the RES-H&C sector has been abandoned lately and this has a negative impact on the development of biogas/biomethane in the heating sector. The drafting of a RES-H&C Strategy is necessary to boost the ambition and the deployment of the sector. Moreover, both the Green Growth Commitment and the Reform of Green Taxation have not proposed measures for the RES-H&C sector.

Legislative issues related to gas quality standards. Currently, in Portugal Decree-Law 231/2012 allows the injection of gas from unconventional sources (biogas and gas from biomass or other gases) in the natural gas grid if quality and safety standards as well as licencing procedures are guaranteed. However, the standards as well as the licencing procedures have not yet been published in the Portuguese legislation, so it is still not possible the injection of biomethane in the natural gas grid, which is considered an important barrier to the development of the biogas sector in Portugal.

Key policy amendments planned

There are no planned policies or amendments to support biogas/biomethane investments by 2020. New regulations and policies are required to stimulate and boost the sector. In fact, experts agree that the annual volume of gas as a fuel (biogas + syngas) that could be produced from biomass is estimated at approximately 900 million Nm^3. This could be doubled after introducing anaerobic digestion in the gasification process, thus reaching a production of 1,700 million Nm^3/year.

Appendix A.23 Romania

Current production and consumption of biogas and biomethane

Romania’s biogas sector is one of the most underdeveloped ones in Europe. While the environment for renewable energy sources is quite well established in Romania, with the target of 24% in gross final renewable energy consumption by 2020 having been already achieved (and even surpassed), the biogas sector is almost inexistent. While at the end of December 2015, the total installed capacity for **electricity** from RES was approx. 4,662 MW$_{el}$, the share of biogas was only 12 MW$_{el}$. Further 5 MW$_{el}$ represented the amount of further sludge gases and 89 MW$_{el}$ of installed capacity for (solid) biomass.

The installed capacity of 12 MW$_{el}$ is being divided according to the National Regulatory Energy Agency (ANRE) among 12 economic operators and 13 biogas plants, only three of these being bigger than 1 MW. Most of the biogas plants function with a mix of feedstocks: 5 employ among others also energy crops, while the majority utilize animal manure and slurry; one plant is based on municipal waste.

While some of the energy is being produced in high efficiency CHP plants, the heat is being used only for self-consumption.

Biogas/biomethane is not being used in the transport sector.

Biogas and biomethane supporting schemes

In Romania, renewable energy sources in the **electricity sector** are supported through a quota system based on quota obligations and tradable certificates. Electricity suppliers and producers are obliged to present a certain number (or quota) of green certificates. These tradable certificates are allocated to the producers of electricity from renewable sources. The share of electricity from renewable energy sources to be delivered is defined on an annual basis by the energy regulator ANRE. The annual quota for 2016 has been set at 12.15%. New plants put into operation from 2004 onwards are eligible for support for 15 years.

The operators of biogas plants are eligible for green certificates only if they present certificates of origin for the biogas used.

The number of green certificates issued depends on the technology used:

- **Biogas, biomass, liquid biofuels for energy generation:** 2 certificates per MWh of electricity generated. Highly efficient CHP and plants fuelled by energy crops are eligible for one additional certificate.
- **Gas produced from anaerobic digestion of waste and sewage sludge:** 1 certificate per MWh of electricity generated. Highly efficient CHP plants based on anaerobic digestion and plants based on anaerobic digestion that use biomass from energy crops or deadwood are also eligible for one additional certificate per MWh.

However, the quota system has proved detrimental to the development of the biogas sector in Romania. Firstly, with an expected surplus of 18 million green certificates at the end of 2016, their value has been nullified. Secondly, the quota system does not benefit biomass plants, since they have relatively small investment costs (approx. 20%) but high operational ones (approx. 80%) in comparison to wind and solar projects, for which the proportion is reversed.

The quota system ceases on 31 December 2016.

Additionally, the new National Rural Development Programme for 2014-2020 foresees the financial support for investments (subsidies) in installation for the production of **electricity and/or heat**, by using biomass (from waste and other secondary products resulting from own agricultural activity) as a secondary component, embedded into an investment project. The generated energy, both thermal and electricity, shall however be used for self-consumption only.

There are no support schemes for biogas/biomethane in the transport sector in Romania.

Key drivers for biogas and biomethane developments

Given the low numbers of biogas plants and the insignificant amount of MW installed, no drivers have been communicated by the stakeholders with regards to biogas/biomethane deployment in Romania.

However, the country has a huge potential for biogas. The country already had a strong biogas sector in the 80s. After the energy crisis of 1973, Romania had a national biogas programme and solid investments both in R&D and the erection of biogas plants. The number of rural installations for households and small collectives was estimated at around 5000 at the end of 1989.

Key barriers to biogas & biomethane growth

The barriers identified for Romania with regard to all sectors are usually accounted to the deficient (barely existing) legislative framework, the lengthy administrative procedures and the lack of coordination and information between ministries (Energy, Agriculture, Environment).

More specifically, there is **no legislative framework supporting the deployment of biogas in the heating sector**, including no quota for the use of biogas as part of the building regulations. However, it is expected, that a new heating law would address these shortages. Furthermore, there are **no support incentives** such as tax exemptions or technical norms for biomethane, which makes the production and injection of it highly unlikely.

In addition, both **heating and electricity grids are deficient** in Romania, with tens of thousands of households, especially in the rural area, having no access to it. While biogas plants might provide for a very good local power supply solution, especially in the rural areas, the **high costs of biogas plant construction** and the **lack of information** on the potentials, financing possibilities or technology itself are hampering the progress in the sector.

Key policy amendments planned

There are three key policy amendments planned, which are expected to have an impact on the biogas sector in Romania.

The National Energy Strategy 2016-2030, with a perspective up to 2050 is expected by the end of September 2016. In addition, a new Heating Law has been under debate in the Romanian Parliament. It aims at implementing the Energy Efficiency Directive (2012/27/EU) into the national legislation and is expected to provide the legal framework for granting a guaranteed access to the heat distribution network (currently there is no obligation of the network operators to accept the heat from renewable energy sources) and setting a quota for heat from renewable energy sources. The new law should also introduce a subsidy for heat from renewable sources.

Given that the main support scheme for renewable energy sources ceases at the end of 2016 and the 2020 RES-targets have already been achieved, the future of the RES-sector in Romania is highly uncertain. However, there seems to be a consensus that biomass (incl. biogas) will be further financially supported due to its huge potential and almost inexistent development. Discussions are currently ongoing on whether to extend the quota system beyond 2016 for biomass only or to introduce a feed-in tariff scheme.

Appendix A.24 Slovakia

Current production and consumption of biogas and biomethane

In Slovakia, the number of biogas plants in 2014 was 139; of these 110 were agricultural biogas plants, 16 waste water treatment plants, 11 plants in landfills and 2 biowaste and industrial waste biogas plants. The biomass used for biogas production comes mainly from agricultural sector (agricultural waste) or food processing (food waste). Biogas production in Slovakia in 2014 in electricity and heat amounted to 2,786 TJ, with 734.4 TJ of generated electricity and 121.3 TJ generated heat.

Currently there is no biomethane production in Slovakia.

Biogas and biomethane supporting schemes

Biogas in the **electricity sector** is mainly promoted by a Feed-in Tariff that consists of two components: the price of electricity for losses (market price) and a surcharge. The surcharge is billed by the plant operator for the electricity generated, less the internal technological consumption of electricity. Additionally, the legislative framework sets certain limitations for the support. First, the market price is paid for all electricity supplied from renewable energy facilities up to a support limit of 125 MW. Second, only plants whose total installed capacity does not exceed 5 MW are eligible for the surcharge. Plants whose total installed capacity exceeds 5 MW (15 MW in case of wind power) are eligible for a payment of the proportion of 5 (or 15) MW to the total installed capacity. All electricity produced above the maximum installed capacity of 5 or 15 MW will be purchased at the price for electricity to cover grid losses. Furthermore, there are CHP-specific regulations in place. The obligation period for all eligible renewable technologies is limited to 15 years and starts in the year in which a plant is put into operation or in the year of reconstruction or upgrade of a plant. In addition, the feed-in tariff will not be granted if the project is co-funded by the Government, except where Government grant was used for measures to achieve the required GHG emission goals at EU level.

Apart from that, the consumption of electricity from biogas is exempt from the excise duty.

Concerning the **heating and cooling sector**, the Operational Programme Environmental Quality for 2014-2020 allocates investment grants from the European Regional Development Fund (ERDF) for small, medium and large enterprises. Renewable energy projects including biogas are eligible under Priority Axis 4 'Energy efficient low-carbon economy in all sectors'. Eligible activities under this target include the replacement of inefficient solid fuel fired boilers with heat generating plants fired by biomass as well as the construction of biogas plants. The amount of the subsidy is to be determined in an individual call for applications.

There are no support schemes for biogas/biomethane in the transport sector in Slovakia.

Key drivers for biogas and biomethane developments

According to the industry, the Slovak government offers no drivers and incentives concerning biogas deployment within the country. One of the reasons is different priorities with regards to the energy sector, such as building of the 3 and 4 block of Nuclear power plant Mochovce. Government representatives, on the other hand, advocate that the Feed-in Tariff scheme might be seen as the only long-term driver for the production and use of biogas.

Key barriers to biogas & biomethane growth

Size of the country. The great majority of biogas plants in Slovakia (85%) use corn silage as a feedstock to produce biogas. This requires greater areas of land to be used for corn planting. Therefore, the potential number of biogas plants using corn silage is exhausted.

Grid connection limitations. The possibility to connect new renewable energy plants (covering also biogas plants) to the electricity grid is limited in Slovakia, as the capacities in the grid are not sufficient for electricity from renewable energy sources. So far, mainly photovoltaic installations are connected to the grid.

Potential negative impact on electricity prices. In contrast to the electricity from nuclear power plants, biogas power plants are dependent on state support such as feed-in tariffs. The additional financial support might lead to an increase in operational and maintenance cost of distribution network and therefore increase electricity prices to end consumers. Therefore, construction of new biogas plants might receive no support in the future.

Key policy amendments planned

Currently, no new policies or policy amendments with regards to biogas and biomethane are being planned in Slovakia. However, certain changes affecting biogas sector might be undertaken by the new Government formed in the beginning of 2016.

Appendix A.25 Slovenia

Current production and consumption of biogas and biomethane

The total number of biogas plants in Slovenia in 2013 was 31 and in 2014 - 26: 24 biogas plants produced biogas from agricultural wastes and 2 plants included biowaste and industrial waste biogas plants. The total installed capacity of all these plants in 2014 amounted to 27.2 MW_{el}. Altogether these plants achieved a production of 141.0 GWh, most of it being generated electricity.

Currently, there is no biomethane production in Slovenia.

Biogas and biomethane supporting schemes

In Slovenia, biogas/biomethane deployment is supported through a series of support policies. In the **electricity sector**, the main support mechanisms are the feed-in tariff for biogas installations up to 1 MW and feed-in premium for biogas installations exceeding 1 MW. The tariff and premium level is dependent on the total installed capacity of the plant and the type of fuel source. In 2014, both schemes were overhauled and are currently being revised in a tender process. Under the new tender system, the feed-in tariff and feed-in premium will be set on a case-by-case basis. This is still to be determined by the new regulations.

Due to insufficient funds no tender for feed-in tariff and feed-in premium was initiated in 2015. Thus no tariffs and premiums have been granted to plants, which were connected to the grid after 22 September 2014. For 2016 the overall tendered funds are capped at € 10 million. However, the tender is still waiting for the approval by the European Commission. The tendered funds shall favour biomass and wind energy.

Furthermore, the Eco Fund regularly publishes public calls/tenders offering financial incentives in form of subsidies and soft loans to renewable electricity and heat producers, covering also biogas producers. The calls subsidize the reconstruction and renovation of plants. Public calls usually target at natural and legal persons (residents of Slovenia and enterprises registered in Slovenia) as well as local communities (municipalities etc.). Details on the amount, method of payment, credit rate, maximum allocated funds, length of repayment period, etc. are specified in each respective public call.

Production of biogas and biomethane for **heat and electricity** from agricultural waste and other waste was supported through several programmes under the Rural Development Programme in the period 2007-2013 but most of them were ceased for the 2014-2020 period or are running out.

In the **transport sector**, the only support scheme in place is the quota obligation imposed by the Energy Act. The Act imposes obligations on fuel distributors to offer biofuels. The definition of biofuels covers also biogas/biomethane. The minimum percentage of biofuels in the Slovenian fuel market is set on a yearly basis. The obligation level for 2015 was set at 7.5%. The obligation level for 2016 has not yet been set.

Key drivers for biogas and biomethane developments

The key drivers for biogas deployment in Slovenia are the financial incentives described above - the Feed-in Tariff and Feed-in Premium schemes, subsidies and loans from the Eco Fund and the quota obligation. The installed capacity of biogas covered under the Feed-in Tariff and Feed-in Premium schemes capped in 2012 following a big increase in the years 2010-2012. The reason for this increase was the extra premium support for CHP installations.

Since biogas/biomethane is still economically not viable without state support, it is very important to have an effective and stable policy in place to encourage the deployment of both technologies. The recent suspension of the Feed-in Tariff scheme and the transition to a tendering scheme has shown that there is little to no interest for the technology without state support, especially in the heating and transport sectors.

Key barriers to biogas & biomethane growth

Biogas deployment in Slovenia is mainly hindered by difficult **planning procedures.** Under the aspect of environment protection certain landscapes such as Natura 2000 or landscapes with a "special environmental value" are deemed not suitable for the construction of plants. Even if a suitable site is selected an environmental impact assessment needs to be carried out, which can lead to considerable delays. Furthermore, a project developer needs to wait for the local municipality to change its local spatial plan and sometimes even the national state spatial plan needs to be amended respectively. Depending on the authorities involved in the planning process, the project development can take up to 10 years.

Furthermore, there is a **lack of political support** from the Government, which should clearly define the mid- and long-term goals for renewable technologies. According to the industry, the full potential and spectrum of renewable technologies is not being exploited; for instance, the potential of research in the field of renewable energy or the potential of new jobs and economic growth, etc.

The **new model for the support schemes** foresees the introduction of public tender rounds with which investors will be invited by public call to apply to the Energy Agency with their renewable electricity projects. The Agency will rank the applications according to the project's economic rentability, its contribution to environment protection, the available funds allocated for that year, etc. This will bring some uncertainty within the support scheme as not all projects that would formally qualify might be given the support. Moreover, it is nearly impossible to compare different RES technologies based on some pre given "objective" criteria.

Economic feasibility. A great deal of project developers in Slovenia opted or still opt for large biogas installations (>1 MWp) rather than smaller ones. Many plants produce not enough biomass to be used as an on-site energy generation source and therefore plant operators are forced to buy biomass (mainly maize silage) on the market. This makes the investments dependent on the market developments and therefore economically unpredictable.

Key policy amendments planned

In 2014, the Feed-in Tariff and Feed-in Premium schemes were overhauled and are currently being revised into a tender process. The tender scheme is currently waiting for the confirmation by the European Commission and is as such currently on hold.

No policy developments that might have an impact on the biogas/biomethane development in the heat and transport sector are currently being planned.

Appendix A.26 Spain

Current production and consumption of biogas and biomethane

Spain is a country with great potential for the production of biogas, as it has an intensive agriculture activity. Nevertheless, biogas production levels are still low accounting to about 14,791 TJ in 2014, coming mainly from landfills, through biogas digesters. The amount of agroindustrial biogas is very low. In 2013, there were about 124,000 ktoe of landfill biogas, 29,800 ktoe of sewage sludge biogas and 102,000 ktoe of biogas produced in decentralised agricultural plants, municipal solid waste methanisation plants and centralised co-digestion plants. The used biogas technologies are anaerobic digestion in closed tanks, biogas purification and dehumidification.

In Spain, biomethane has not been developed yet.

Biogas and biomethane supporting schemes

In the **electricity sector**, no direct support scheme for biogas is in place. The price regulation system for renewable energy sources, including biogas, was suspended through Royal Decree-law 1/2012. Under the price regulation system, biogas plant operators could choose between a feed-in tariff and a bonus, which was paid on top of the electricity price achieved in the wholesale market. The bonus for biogas plants (14 €ct kW/h) was not enough to guarantee profits and only about 30 plants were constructed under this scheme. Royal Decree-law 9/2013 replaced the former retribution system (feed-in tariff or bonus) by a new system which consists of two payments: 1) Return of the investment (not real but determined by the Government) plus 7.35% profit to be recovered in 25 years; 2) Compensation of the OPEX (not real but determined by the Government) which has zero impact on profits. This new retribution system affects the 30 plants which were already under the former retribution system. Since 2012, no direct support scheme for new biogas projects is in place.

In the **heat sector**, no support schemes for biogas are in place in Spain.

In the **transport sector**, biogas/biomethane is supported under the biofuel quota. The biofuel quota is the support mechanism for the use of biofuels and other renewable fuels like biogas/biomethane in transport means. Wholesale and retail operators of fuels, as well as consumers of fuels not supplied by wholesale or retail operators, are obliged to sell/consume a minimal quota of biofuels. Each obligated subject will have to present a number of certificates to the National Energy Commission (CNE) to prove compliance. In case of non-compliance with the goals, a penalty fee applies. In case of over-compliance, the amounts collected from the penalty fees are redistributed by the CNE proportionally to the subjects that sold/consumed biofuels exceeding their quota obligation. Order ITC/2877/2008 sets a value of € 763 per certificate. Each certificate indicates that the obligated party has sold or consumed 1 toe of biofuels in one year. Addressees must deliver to the CNE a yearly amount of certificates that allow meeting, from 2013 onwards, 4.1% minimal amount of sold or consumed biofuels.

Finally, biogas production is indirectly supported through the Climate Projects programme. The programme provides basically a compensation for the avoided emissions of CO_2-equivalent, which is received among others by biogas facilities for a period of 4 years. It is a supplement to the income of the installation, though it is not enough to justify an investment.

Key drivers for biogas and biomethane developments

In Spain, a potential driver for biogas and biomethane for the next future is the extensive gas network with the possibility for connecting plants. Such option was even suggested by Fenosa, the largest natural gas company in Spain, as of 2016. In the heating sector, it could be possible to develop biogas/biomethane through large plants due to largely uncovered demand, but currently with the suspension of the support schemes under Royal Decree 413/2014 and Order IET 1045/2014, it is difficult to invest in biogas/biomethane.

Spain is a country with large potential for the production of biogas/biomethane, as it has an intensive agriculture activity. Many regions in Spain (especially Catalunya, Aragon, Castilla y Leon, Andalucia and Murcia) are large producers of pork and beef and have an uncovered demand in the heating sector. The deployment of biogas/biomethane in these regions represents a good opportunity to increase the thermal energy supply.

Key barriers to biogas & biomethane growth

Lack of a framework in the electricity sector. RD 413/2014 and MO IET 1045/2014 eliminated the concept of "special regime", used before for the electricity production from renewable energy sources, cogeneration and residual wastes with retroactive effects already from 2013. The reason is that due to the widespread penetration of renewable energy it is no longer meaningful to have a specific regulation for RES. Therefore, in the adopted system, renewable plants are considered exactly the same as the rest of the technologies present in the market. As a result, banks are reluctant to new investments and revise their refinancing options (sometimes with no other option than repossess or sell the installation at a loss). It is, thus, currently extreme difficult to invest in biogas in Spain, as there is a lack of confidence in the government's agreements and of finance available to invest in new projects.

Restriction of priority access and dispatch in the electricity sector. The 2014 Electricity Law, approved in June 2014, introduced an "equality of economic conditions in the market" principle, which restricts the priority access and dispatch for renewable electricity. The principle means that such priority would be granted only in times that biogas producers would offer their electricity in the market at lower or equal prices as conventional players. It breaches the RED (2009/28/EC), which stipulates priority access and dispatch for renewable electricity independently of the price offered in the wholesale power market or the degree of dispatchability of certain power sources.

Lack of production based support instruments. The lack of implementation of production based support instruments for biogas installations in the heating sector mainly affects the operational level. The consequence is that no new biogas plants in the heat sector exists.

Insufficient targets for biofuels in the transport sector. The main barrier for the development of biofuels is the low level of the national targets. The Spanish Government approved in February 2013 a severe reduction in the biofuels consumption mandates from the year 2013 onwards. Biofuels mandate has been reduced from 6.5% to 4.1%, whereas biodiesel and bioethanol targets have been reduced to 4.1% (from 7%) and 3.9% (from 4,1%), respectively.

Key policy amendments planned

The Spanish National Renewable Energy Action Plan 2011-2020 envisages that the installed capacity of biogas should reach 220 MW in 2015 and 400 MW by 2020. However, as of 2015, the capacity for biogas represented only 20 MW.

No information on new planned policies, amendments or regulations to support biogas investments exists. There are only some R&D projects related to biogas that have been announced. In the last call of the LIFE programme, the European Commission has approved 28 projects for Spain. From these projects, five are related to biogas and one to the production of synthetic gas from wastes of the cork industry.

Appendix A.27 Sweden

Current production and consumption of biogas and biomethane

In 2014, about 277 biogas facilities were installed in Sweden that produced biogas of altogether 1,783 GwH. The greatest share of biogas was produced in facilities that used sewage sludge and co-digestion plants. Most of the produced biogas (57%) was upgraded and used as automotive fuel. Only 24% were used for production of heat and even only 3% for the production of electricity.

Biogas and biomethane supporting schemes

In contrary to most European biogas markets one of the most important support schemes is a tax regulation mechanism: The Energy tax legislation provides the framework for energy and CO_2 taxes as well as reductions for biofuels. Biogas currently receives 100 percent reduction of both energy and CO_2 tax, while tax reduction for biogas for transportation is conditioned with fulfilment of sustainability criteria. Also, there are specific support schemes for the production of biogas, including from manure, in the form of investment support within the various state programs.

In the **electricity sector**, the most important support scheme is a quota system (Electricity Certificate System) that awards the producers of electricity from renewable energy sources such as biogas with green certificates. The power producers receive one certificate for each megawatt hour of renewable electricity produced in the plant, over a maximum 15 years. These certificates can be purchased by electricity suppliers and certain power consumers which are legally obliged to annually acquire such certificates in due proportion to their electricity sales and their consumption by a set date. The electricity end-users pay for the development of renewable electricity production because the cost of the electricity certificates is included in the electricity bill. Since 1st January 2012, Sweden and Norway have a common electricity certificate market.

Key drivers for biogas and biomethane developments

A major driver for the development of biogas and biomethane in Sweden are the national performance targets. The Swedish government has set the goal of no net GHG emissions by 2050. Furthermore, there is a strategic vision of a fossil free vehicle fleet by 2030. Another important driver is the ambitious goals by the industry. The Swedish gas industry's visions are the achievement of 100% biomethane in the vehicle gas by 2030 as well as 100% biomethane in the gas grid by 2050.

In concrete terms, the key driver for further development is the above described tax exemption for energy and CO_2 tax.

Key barriers to biogas & biomethane growth

The main barrier is the **discussion with the EU on the state aid procedure** regarding the tax exemption for energy and CO_2 tax. It makes it hard for Sweden to keep using the tax exemption for biogas as motor fuel as the major support scheme for the development of biogas. The ongoing discussion has put a wet blanket on the market today, due to the insecurity what will happen after 2020.

The **ILUC regulations** limit the production of biogas and biomethane from food-based crops, even if these crops are produced in a sustainable way without having an ILUC effect. From the perspective of the Swedish biogas sector, at the moment there is a trend in the EU that electricity will cover all the transport sector which results in a scepticism regarding biofuels.

Several years ago, Sweden has already reached their 2020 transport goal of a 10% share of renewable fuels in the transport sector. Currently, a real driver for the development of biogas for transport purposes is missing, as there is **no EU transport goal for renewable energy after 2020**.

Key policy amendments planned

In December 2015, a draft for the national biogas strategy was published including a list of measures and instruments aiming at an increased use of biogas in Sweden. The following policy instruments are proposed and some of them already under investigation:

- maintain the tax exemption for biogas even after 2020;
- introduce a nationally applicable definition of "environmental truck" to support "heavy good vehicles";
- introduce a subsidy for gas-powered busses;
- introduce a bonus-malus system for light vehicles, including a bonus given to owners of vehicles with lower carbon dioxide emissions and an additional fee (malus) for owners of vehicles with higher carbon dioxide emissions;
- continue (but reduce) the benefits for company cars.

Appendix A.28 United Kingdom

Current production and consumption of biogas and biomethane

The United Kingdom is one of the front runners in the EU when it comes to biogas and biomethane production. After more than ten years of steady development the sector saw its biggest growth in 2014 (102 new plants commissioned). As of December 2015, the number of operational plants reached 424. Of these, 378 were electricity/CHP plants, 6 - heat-only plants and 40 - biomethane plants. Further 442 plants are currently in planning: 419 electricity/CHP plants with a potential installed capacity of 424 MWe and 23 biomethane plants with a potential installed biomethane capacity, m³/hr (some may not go ahead). In 2015, operational plants produced 7.4 TWh of energy: less than 0.1 TWh for heat-only and transport, 1.5 TWh injection into the gas grid and 5.9 TWh electricity and heat generation (2.2 TWhe electricity; 3.7 TWth cogenerated heat).

In the United Kingdom, biomethane is mainly used for the injection into the gas grid. However, to some small extent it is also used directly in transport.

Biogas and biomethane supporting schemes

In the **electricity sector**, biogas is mainly supported through a Feed-in Tariff scheme and the quota system called ‘Renewables Obligation’ (RO). The Feed-in Tariff scheme applicable in Great Britain, supports small-scale biogas producers up to 5 MW. Biogas plants between 50 kW and 5 MW located in Great Britain can choose between the Feed-in Tariff and RO schemes. All new installations applying for feed-in tariff on or after 15 January 2016 are subject to a new system of caps. Deployment caps, expressed in terms of aggregate total installed capacity of MW, are set on a quarterly basis. For AD max. deployment cap amounts to 5.0 MW per quarter until April 2019.

Under the RO scheme, which is the main scheme for power plants > 5 MW, suppliers of electricity are obliged to prove (by presenting certificates) that a certain percentage of electricity supplied to final consumers within the United Kingdom was generated from RES. On 31 March 2017 the RO scheme will close to all new capacities.

Since 2014, the Contracts for Difference (CfD) scheme are in place in Great Britain (to be introduced in Northern Ireland this year). It is based on a difference between the market price and an agreed “strike price”. CfD supports landfill gas, sewage gas, AD, gas formed by gasification or pyrolysis of biomass or waste. A plant operator willing to secure a contract has to take part in an allocation round. From April 2017 (when RO schemes closes), the CfD will be the only support scheme for RES projects over 5MW.

Finally, biogas producers in GB are exempt from the energy tax called Carbon Price Floor, which is levied on fossil fuels.

In the **heat sector**, biogas combustion and biomethane injection into the grid is supported under the Non-Domestic Renewable Heat Incentive (RHI) providing a fixed tariff per kWth produced. The payment is provided to industry, businesses and public sector organisations. This scheme is available in England, Scotland and Wales. The Northern Ireland RHI was closed to new applicants in March 2016.

In the **transport sector**, biomethane is supported under the quota system called Renewable Transport Fuel Obligation (RTFO). Fuel suppliers are obliged to satisfy a specified quota of biofuels in the total supplied fuel. One certificate may be claimed for every litre of supplied sustainable renewable fuel. For biogas, 1.9 certificates/kg of supplied biomethane may be claimed and 1.75 certificates/kg of supplied biobutane or biopropane (or a combination of both). The number of certificates doubles if the feedstock used is classed as a waste or residue.

Last but not least, biogas and biomethane production is indirectly supported through the Landfill Tax, which is charged by weight and has to be paid on top of normal landfill fees.

Key drivers for biogas and biomethane developments

In the United Kingdom, slow growth of biogas industry started in the 2000s. This was due to the introduction of the RO scheme in 2002. An even greater driver for both biogas and biomethane production was the launch of Feed-in Tariff (2010) and RHI (2011). Launch of these incentives resulted in the biggest growth of the sector in 2014. This was the first year when biomethane-to-grid plants were constructed and commissioned in such significant numbers. In addition, beneficial for biomethane was the growing confidence in the technology and the resolution of some regulatory issues, e.g. increasing max. permitted levels of oxygen in biomethane for injection from 0.2% to 1% or agreement of an ownership model, where biomethane producer funds, owns and operates the Grid Entry Unit.

Key barriers to biogas & biomethane growth

Lack of the right and stable framework. The support schemes are permanently reviewed and revised. With regards to the Feed-in Tariff scheme, recent cuts in feed-in tariffs resulted in reduced attractiveness of the scheme. RO will close to new capacities from April 2017. It will be replaced by the CfD scheme. However, the 2nd CfD allocation round scheduled for 2015 was postponed and as of June 2016 a new date is yet to be set. Hence, there are uncertainties resulting from changing policies and uncertainties regarding available budget beyond 2020, which remain a big concern to the industry.

Availability of feedstock, especially food waste. Due to a lack of a mandatory food collection in place – notably in England – availability of food waste is limited in the United Kingdom. In addition, there are no incentives to use manure or slurries for biogas production, no penalties for leaving manure and slurries unused or polluter pays principle in this context. Manures and slurries are largely under-utilised by the AD sector, mainly due to the low biogas yields of these wastes, which makes them uneconomical to use as a stand-alone feedstock. As a result, manures and slurries are typically used in relatively small volumes supplemented with high gas-yielding crops.

Sustainability criteria was incorporated into the RHI and the RO, and is likely to be included in FIT too. This might to some extent discourage the use of crops in AD. On the other hand, it is likely that the vast majority of crop material would meet those criteria, if reasonable steps are taken to source supply chain data and ensure that sustainable cultivation practices are undertaken. However, industry is concerned about Government proposals to limit gas yield from energy crops to 50% (50% non-crop materials).

Fall in wholesale prices of energy (gas and electricity) negatively affects deployment of biogas and biomethane.

Key policy amendments planned

In May 2016, the Department of Energy & Climate Change (DECC) launched a public consultation on the review of support for AD and micro-CHPs under the Feed-in tariff scheme. Government proposals include: continued reductions of feed-in tariffs (eliminating the tariff for AD plants above 500kW) and introducing a default degression mechanism for AD, meaning that the tariff rates fall automatically every quarter (also called pre-planned degression). Contingent degressions of 10% are to continue to operate, if a quarterly cap is reached.

An assessment of RHI tariffs against expenditure will determine whether tariffs will continue to degress in July and October 2016. Tariffs for biomethane under the RHI were reduced dramatically last year. There are ongoing discussions in government regarding whether to reset tariffs at a higher level from January 2017 next year in order to make biomethane projects financially viable again.

Finally, the consultation on legislative amendments to the RTFO shall be launched in 2016. The scheme needs to be reviewed because of the EU agreement on ILUC. The UK Government will not opt for options to meet the EU requirements by shifting from crop-based biofuels towards renewable fuel from waste.

Appendix B Assumptions and references biogas model

In this Appendix additional information on the CE Biogas model is provided. We give an overview of the technologies in the model and the assumptions and settings for the scenario calculations.

The gas quality specifications of biogas and biomethane is not uniquely defined. In this report we used the following definitions when we refer to biogas, cleaned landfill gas and biomethane:

- biomethane: upgraded biogas to natural H-gas quality with a methane content of 97.6vol% and a Wobbe Index of 50.5;
- biogas: biogas with a methane content of 60vol%;
- landfill gas (cleaned): biogas from landfills with a methane content of 56vol% (ECN, 2011).

Appendix B.1 Technologies

The following table gives an overview of the technologies used in the model for the scenario calculations in this report. Details on the parameters used in the calculations can be found in the references.

In general, for discounting capital costs a depreciation period of 16 years is assumed, with in most cases an annual capital charge of 6.2%. For determining the costs of electricity consumption we used the electricity and natural gas price of the second half of 2014 from EUROSTAT (EUROSTAT, 2015). Because these commodity prices are hard to forecast, we assume the value of 2014 is applicable in all years. Taxes and levies are not taken into account. No data is available for digestate prices per member state and are thus not taken into account

In the case of land fill gas, the investments and costs for cleaning are taken into account, not for recovering landfill gas from landfills. This is mainly because the necessary information about costs and landfills in the EU are not available. Furthermore it can be questioned if these costs should be accounted to the biogas or seen as an emission reduction measure.

Table 4 Technologies used in the CE Biogas model for the scenario calculations in this report

Category	Technology	Description	Reference
Digestion	Non-specific digester	Installation for organic waste digestion. Parameters from reference. Capacity: 950 Nm^3 raw gas/h	(ECN & DNV GL, 2015)
	Co-digester	Installation for manure digestion. Parameters from reference. Capacity: 505 Nm^3 raw gas/h	(ECN & DNV GL, 2015)
	Mono-digester	Installation for manure digestion (>95% manure). Parameters from reference. Capacity: 20.5 Nm^3 raw	(ECN & DNV GL, 2015)

Category	Technology	Description	Reference
		gas/h	
	Sewage sludge digester	Installation for sewage sludge digestion (based on parameters of co-digester) with thermal pressure hydrolysis. Parameters from references. Capacity: 340 Nm^3 raw gas/h	(ECN & DNV GL, 2015) (ECN & DNV GL, 2014) (DHV/STOWA, 2011)
	Landfill gas cleaning	Installation for cleaning landfill gas to biogas with a methane content of 56vol%. Parameters from reference. Capacity: 150 Nm^3 raw gas/h	(ECN, 2011)
Upgrading	Water scrubber	Installation for upgrading biogas with a given methane content to natural gas quality. Capacity equals the capacity of the digester.	(CE Delft, 2010)
Transport fuels	CNG	Compression and storage of biomethane to CNG	(CE Delft, 2010)
	LNG	Liquefaction plant of biomethane to bio-LNG; assumed 5% O&M costs	(SGC, 2013)
Utilisation	CHP (biogas)	Installation for cogeneration of electricity and heat from raw biogas. Parameters from reference. Capacity: 1.1 MWe	(ECN & DNV GL, 2015)
	CHP (cleaned landfill gas)	Installation for cogeneration of electricity and heat from cleaned landfill gas. Parameters from reference. Capacity: 0.3 MWe	(ECN, 2011)

In the case of cogeneration (CHP), it is assumed that 25% of the net heat produced can be put on the market, the other 75% of the nett heat is lost (the heat consumed in the process is already extracted from the gross heat production). The heat is sold at the price of producing the same amount of heat with a natural gas boiler. The heat which is sold on the market is accounted as a revenue to the costs of producing electricity. The nett costs of the whole chain – digestion and the generation of electricity by cogeneration – is used to calculate the production costs of electricity. Because the generated heat can be used in digestion, there is no need self-consumption of biogas for heating the digester, as a consequence the gross biogas production can be used for cogeneration. GHG emission reductions are fully accounted to the replaced electricity in the member states electricity mix.

In calculating the GHG emission we used the following emission factors:

Table 5 GHG emission factors per feedstock or fuel

Feedstock or fuel	Emission factor	Reference
Liquid pig manure	-75.5 $gCO_{2\text{-}eq}/MJ_{biogas}$ (excl. upgrading) -71.0 $gCO_{2\text{-}eq}/MJ_{biogas}$ (incl. upgrading) Covering the process emissions up to (and including) upgrading. Other process emissions consists of emissions due to electricity consumption, methane slip or avoided natural gas consumption. The quoted emission factors are for wet manure, but we assumed that these apply to all manure types.	Calculated from (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014)
Liquid cattle manure		
Solid manure		
Maize	31.9 $gCO_{2\text{-}eq}/MJ_{biogas}$ (excl. upgrading) 36.3 $gCO_{2\text{-}eq}/MJ_{biogas}$ (incl. upgrading) Covering the process emissions up to (and including) upgrading. Other process emissions consists of emissions due to electricity consumption, methane slip or avoided natural gas consumption.	Calculated from (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014)
Agricultural residue streams	no GHG emissions assigned to feedstock, process emissions consists of emissions due to electricity consumption, methane slip or avoided natural gas consumption.	
Organic waste		
Sludge (sewage)		
Landfill gas	All methane recovered and converted to biogas is accounted as emission reduction using a GWP of 25 $gCO_{2\text{-}eq}/gCH_4$. Process emissions consists of emissions due to electricity consumption, methane slip or avoided natural gas consumption.	
Diesel	95.10 $gCO_{2\text{-}eq}/MJ$	(Council of the European Union, 2015)
Natural gas (H-gas)	49.36 $gCO_{2\text{-}eq}/MJ$	Calculation
Heat (from natural gas in boiler)	50.81 $gCO_{2\text{-}eq}/MJ_{heat}$	calculation
Electricity	Variable per member state and year	(EU PRIMES, 2016)

Appendix B.2 Important assumptions regarding feedstock deployment

In the model we assume a linear interpolation of the feedstock deployment based on the 2014 value and the 2030 potential, using the 'Reference 2030' potential of Chapter 5 for 'growth' and the 'Accelerated deployment 2030' potential for 'accelerated' growth. We assumed in the calculations that the utilization of the 2014 biogas potential will be the same in future years. This is based on the presumption that specific investments for CHP's or upgraders have been done in the past and will be used in the future for the same applications.

The amount of energy crops is virtually unlimited; its utilization is determined by policy. In the model calculations we have assumed that energy maize is only used in co-digestion with manure in a mass ratio of at least 80% manure and 20% energy maize. The potential amount of energy crops is for every year at least equal to the 2014 amount or is increased with an amount determined by the manure/energy maize mass ratio and the amount of manure in co-digestion. This ratio applied on the mass of manure feedstocks used for co-digestion to determine the mass of energy crops for co-digestion. The share of energy crops per manure type in 2014 is assumed to be 50% liquid pig manure and 50% liquid cattle manure;

Feedstock deployment per technology is assumed to be the following for all scenario years, see Table 6.

Table 6 Feedstock deployment percentages per digestion/conversion technology

Digester type	Non-specific digestion	Co-digestion	Mono-digestion	Sewage sludge digestion	Landfill gas cleaning
Liquid pig manure		80%	20%		
Liquid cattle manure		80%	20%		
Solid manure			100%		
Energy maize		100%			
Agricultural residue streams	100%				
Organic waste	100%				
Sludge (sewage)				100%	
Landfill gas					95%

Mono-digestion is a technology in development, therefore liquid manure is assumed to be mainly digested in co-digesters along with energy maize. For 2014 we assumed that energy maize is equally mixed with liquid pig manure and liquid cattle manure. After 2014 the amount of energy crops and liquid manure is determined by the manure-maize ratio. Solid manure is not digested in 2014, but we assume that it will be digested in the future by state-of-the-art digesters, i.e. mono-digesters. We assumed that 95% of the landfill gas potential is to be cleaned to biogas, because it is difficult to recover all the methane emission from landfills economically.

The feedstock costs are assumed to be constant over the whole time window 2014-2030. The same holds for gas and electricity prices.

Appendix B.3 New capacity

An increasing feedstock availability will result in a need for new capacity for the production of biogas, leading to new investments. Investments are done without foresight but in hindsight per two years period, i.e. every new feedstock amount of the past two years results in new investments at exactly the capacity necessary. This might not reflect the investment decision of a rational investor. Between periods the production and variable costs can be reduced due to a decreasing feedstock potential, but investments done in the past, and the accompanying O&M cost, cannot be reduced since investments are depreciated over 16 years.

Because the model considers only new capacities, the total production in a certain year must include the production of the previous years. The same holds for related parameters as GHG emissions. Since the production costs of 2014 are not know, only the production costs of the new investments (2015-2030) are taken into account. Production costs are calculated without taxes and levies.