Overview of production routes and end-uses of renewable gases and existing policy frameworks in the Target European countries (Czech Republic, Estonia, Greece, Latvia, Poland, Spain and a Danube Region of Backa and Banat).

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Summary of the GreenMeUp project

GreenMeUp – Green Biomethane Market Uptake is a Horizon Europe project that aims at providing a basis for policy-makers and stakeholders to develop more informed renewable energy policies and country-tailored market uptake measures, in order to improve and complement existing biomethane policy in Europe.

The core activity of GreenMeUp is to reduce the gap between countries with higher rates of biomethane production and countries with lower development rates, by analyzing and comparing their framework conditions and market dynamics and promote enabling policies and measures at country level. The project aims at providing societal acceptance of the biomethane value chain through science-based evidence and tools.

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Executive Summary

Countries across the EU are facing their own challenges but also opportunities in biomethane production and further deployment, like differences in biomass types (wastes, residues or energy crops) and processes, gas distribution and connection to the grid, end uses (electricity, heat, transport), policy targets and applied frameworks and financial mechanisms. These differences lead to country-specific state-of-the-art for biogas and biomethane production and equally country-specific needs for policy and market uptake measures.

The aim of this Deliverable is to present the status of the biomethane market in each country and identify, list, and quantify all existing production and use routes for biomethane, as well as the existing supporting policies.

In terms of production routes, special focus is set on the used feedstock types and the assessment of the available biomass that is not yet exploited in each country. Trends in feedstock usage for the 2030 and beyond are also discussed. In addition, the current end-uses of biomethane are investigated and discussed and a split is made between usage for power generation, heating & cooling, industry, and transport. The specific focus for each partner reflecting the geographic specificities of the involved target countries is thus reported.

Policies and market dynamics which are successful in achieving biomethane production and use are investigated. The different policy frameworks are reported and discussed for each target country.

A distinction between direct and indirect support mechanisms from the production and the demand side is made, following the methodology used in Deliverable 1.1 'Overview of production routes and end-uses of renewable gases and existing policy frameworks in advanced European and Mission Innovation countries'. Several sources have been used in each target country, such as indicatively the recently submitted National Energy and Climate Plans, the financed policy measures by the Operational Programs within the framework of the CAP at EU level and other scientific papers and technical reports.

Following the above, the deliverable is structured along 7 Chapters, each for each country involved.

The recent review concluded that:

- Biomethane market

Among the Target countries, Czech Republic and Estonia are leading the way. In Czech Republic 8 plants are in operation by the beginning of 2024, producing 12 GWh, having a capacity of 372 m^3/h of biomethane. Apart from the biomethane plants, another 603 biogas plants are in operation showing the huge biomethane potential of the country. In Estonia on the contrary to all countries, only 17 biogas plants are operating, however the 7 of which are producing biomethane, and another one is currently under a start-up process. Moreover, in Estonia 28 CNG filling stations, 2 LNG filling stations and 5 grid injection points on distribution network grids are built facilitating thus the use of biomethane in the transport sector mainly.

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Spain follows with 5 biomethane plants producing 250 GWh, and Latvia with one operational plant. Finally, Greece, Poland and Hungary, Romania and Serbia, parts of which form the Danube Region of Backat and Benet have not yet established biomethane plants.

- Production routes and end uses

Production routes mainly refer to agricultural resources (manure and agricultural residues), with municipal wastes holding a lower share. Biomethane plants in all countries are mostly agricultural ones and prospects show that this trend will continue until 2030 and beyond. Estimations of biomass potentials have been performed which showed high availabilities of biomass feedstock in all countries, able to support a considerable growth of the biomethane market in their territories.

All target countries have in place gas infrastructure and storage, a natural gas infrastructure for transport and gas quality regulations; all being important prerequisites for biomethane deployment and growth.

In most of the target countries the main existing of foreseen use is in transportation and to a lesser content for power and heat.

- Regulatory framework and supportive policies

When analysing the main drivers for biogas and biomethane developments across the countries, the existence, stability and reliability of targeted policy and financial support is considered as the number one enabler, regardless of whether they already have a mature biogas/biomethane market in place or not. Dedicated national targets are also identified as an important driver for the sector, as is the year-round availability of suitable feedstocks

The policy and regulatory framework is still limited in all countries, consisting mainly of the National Energy and Climate Plans (NESPs) and adjustments of the REPowerEU.

Production-side direct investment supports are in place in Czech Republic for biomethane plant construction and upgrade as well as indirect investment supports as green bonuses for biomethane production. Demand-side support mainly refers to green electricity purchase and recognition of Guaranties of Origin (GOs). In Estonia the government has been subsidizing biomethane production, biogas plant construction, filling station construction and public transport transition to compressed gas. Estonia has a robust biomethane roadmap with identified strategies and has set mixing obligations to fuel companies which has created a demanding market for GOs.

Spain has launched an aid plan to finance biogas plants, and a regulatory framework enabling injection into the gas grid has been developed. In Poland, financial support is given from various structural funds and EU programs for all renewable energy projects (in that biogas and biomethane), whereas demand-side financial support are set for consumers of CNG/biomethane, LNG, H2 used as transport fuel, as well as regulations enabling injection and trade.

In Latvia, Greece and the Danube Region countries (Hungary, Romania and Serbia) the regulatory framework and supportive policies are still under development. In Greece the new legislation framework for biomethane is under consultation and expected to be in place by the second trimester of 2024. It is anticipated that a number of investments will be soon after initiated.

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Chapter 1: Introduction

Biomethane production volumes are rapidly growing and a record number of biomethane plants us currently under operation. At the end of 2023 a total of 1,322 biomethane plants are operating across Europe[1]. The sector produces now 37 TWh or 3.5 bcm of biomethane. The flatting growth in biogas developments that is recently noticed a shift from biogas to biomethane production is already evidenced. According to data from the European Biogas Association (EBA 2023), 2022 was the most successful year in terms of the biomethane market and the operation of new biomethane production plants in the last decade Figure 1-1.

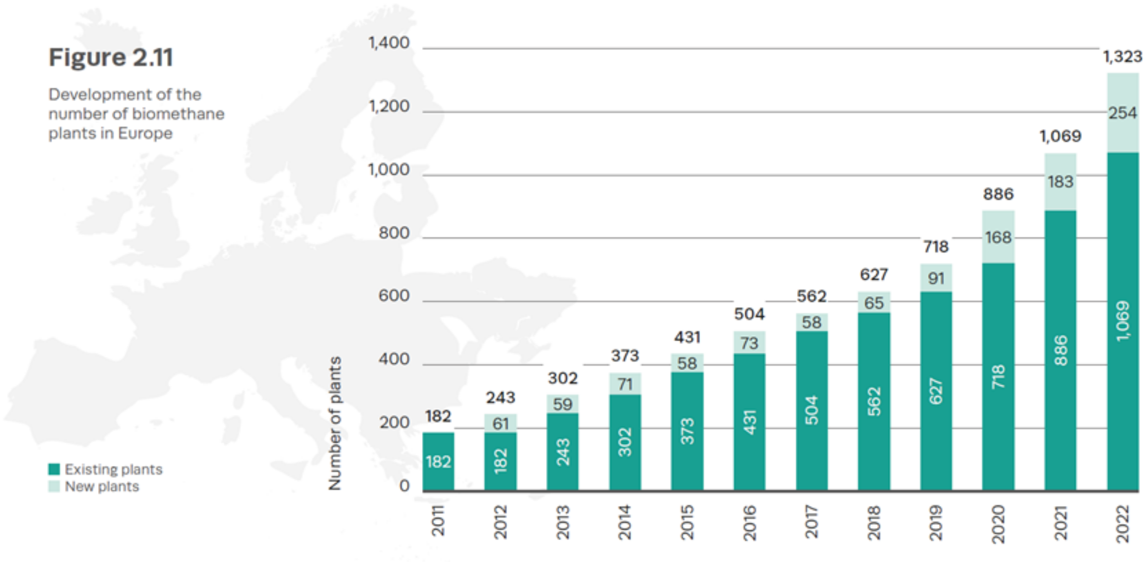

Figure 1-1. Development of the number of biomethane plants in Europe (Source: EBA Statistical Report 2023).

Feedstock used for biomethane production is progressively shifting from dedicated energy crops (energy maize) trend towards agricultural residues, manure and plant residues and -to a lesser extend- sewage sludge and organic municipal solid waste. Monocrops (maize mostly in Germany) are gradually withdrawn from 2017 onwards.

In 2023, waste and residue feedstocks were used in almost 65% of EU biomethane plants compared to 40% in 2012 (Figure 1-2). Biomethane either compressed (bio-CNG) or liquefied (bio-LNG) is able to displace both compressed natural gas (CNG) and liquefied natural gas (LNG).

Countries across the EU are facing their own challenges but also opportunities in biomethane production and further deployment, like differences in biomass types (wastes, residues or energy crops) and processes, gas distribution and connection to the grid, end uses (electricity, heat, transport), policy targets and applied frameworks and financial mechanisms. These differences lead to country-specific state-of-the-art for biogas and biomethane production and equally country-specific needs for policy and market uptake measures.

[1] EBA Statistical Report 2023

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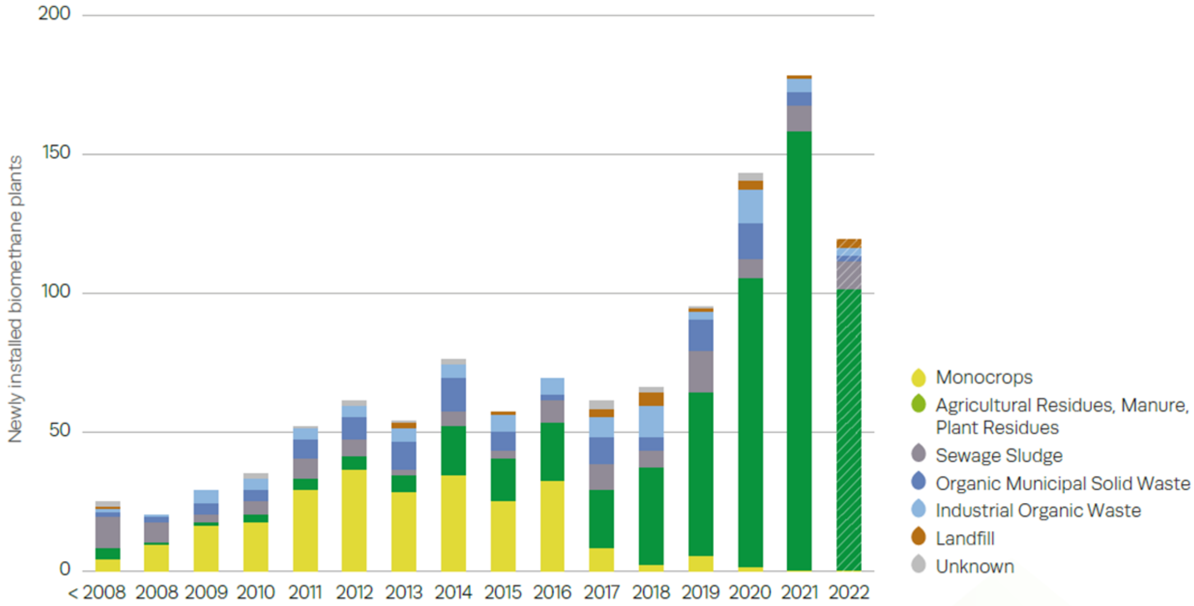

Figure 1-2. Total number of newly installed biomethane plants in Europe each year, 2008-2022, overall and per feedstock type (Source: EBA Statistical Report 2022)

Nowadays, almost all EU Member States (MS) have in place gas infrastructure and storage, a natural gas infrastructure for transport and gas quality regulations; all being important prerequisites for biomethane deployment and growth. Nevertheless, there are only a limited number of MS where biogas upgrading into biomethane and injection into the grid is supported[2]. When analysing the main drivers for biogas developments across the EU, the existence, stability and reliability of targeted policy and financial support is considered as the number one enabler in all countries, regardless of whether they already have a mature biogas market in place or not. Dedicated national targets are also identified as an important driver for the sector, as is the year-round availability of suitable feedstocks.

In **GreenMeUp** **Germany and Italy represent the ‘Advanced countries’** that will be actively involved in the policy dialogues, internal co-creation activities like PESTEL workshops, Hub meetings, B2B meetings or policy events to steer exchange of good practices and help strengthening the bioCH4 market in the target countries. The **Target Countries** to benefit from the **GreenMeUp** results are located in South and Eastern Europe and are Czech Republic, Estonia, Greece, Latvia, Poland, Spain, and the Danube Region of Backa and Banat that encompasses Serbia, Romania, and Hungary (Figure 1-3).

For each Target country an overview of the status of the biomethane market, production routes and end-uses of renewable gases as well as existing policy frameworks is developed and presented in this Deliverable.

[2] EBA Statistical Report 2023

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Figure 1-3. Total number of biomethane plants in 2022 in Europe. Advanced countries are marked in blue and target countries of GreeenMeUp project in green (Source: EBA Statistical Report 2022, modified

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Chapter 2: Czech Republic

2.1 The biomethane market

The development of renewable gasses depends on several factors. A key issue will be the existence of a certain level of public support. Some existing biogas plants (from which biomethane can be produced) could be shut down by 2030. This is due to the end of the original operating support (aimed at CHP) after 20 years of operation. Therefore, setting up financial and institutional support for the development of renewable gas production will be crucial. This includes, among other things, the transformation of existing biogas plants to biomethane production as well as new biomethane plants including their connection to the gas grid. In addition to biogas and biomethane plants, there are hydrogen production technologies as well as technologies for the production of bioLPG. Although these technologies are now well known, but the operation of these plants is currently unprofitable. Especially due to high investment and operating costs.

The Czech Republic has a huge biomethane potential. There are currently 603 biogas plants in operation. Of these, 417 are agricultural biogas plants, 95 sewage-based plants, 66 plants using landfill gas, 17 plants using industrial waste and 8 plants using municipal solid waste. In 2022, 7.948 GWh of biogas was produced in this sector, from which electricity and heat were dominantly generated. In the same year, 12 GWh of biomethane was also produced using a capacity of 372 m^3/h. As regards biomethane plants, 8 plants are in operation by the beginning of 2024. Specifically, these are biomethane stations in Jarošovice, WWTP Prague, Mladá Boleslav, Herálec, Havlíčkův Brod, Litomyšl, Rapotín and Horní Suchá. Biogas plants account for approximately 1.5% of the current approximately 15% share of the total final energy consumption from RES. Biogas plants overwhelmingly produce heat and electricity as part of combined heat and power production. The following chart (Figure 2-1, Figure 2-2) shows the expected transformation of existing biogas plants to biomethane and the addition of new biogas plants.

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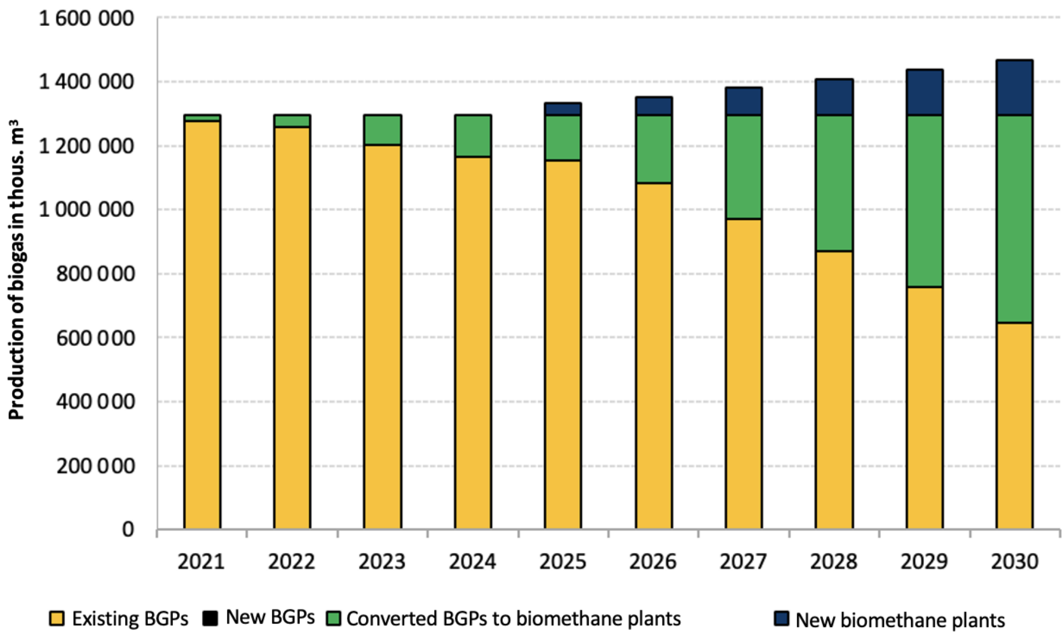

Figure 2-1 : Expected biogas production by existing, converted and new plants [1]

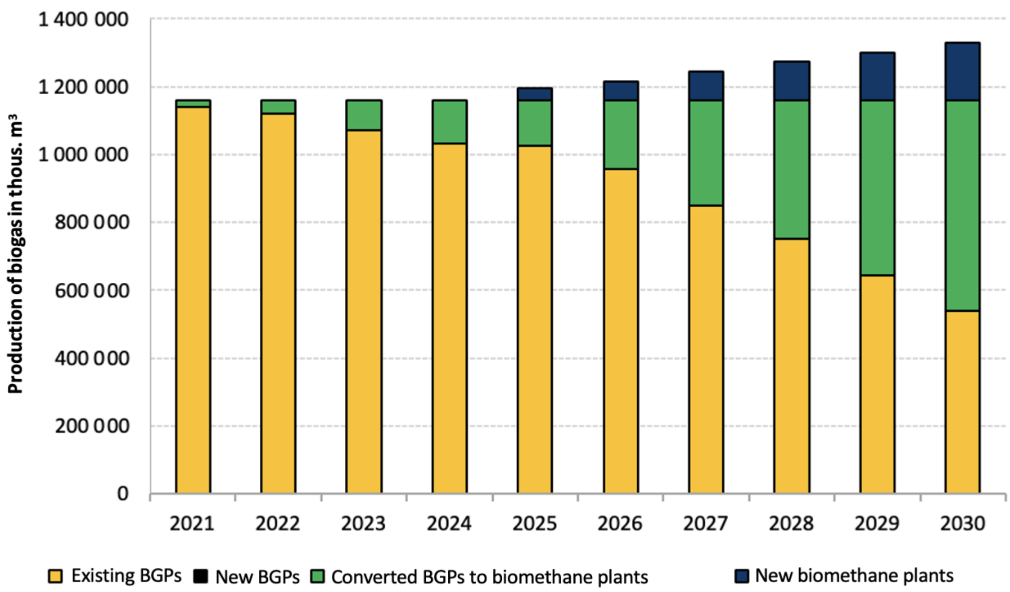

Figure 2-2: Expected biogas production (agricultural biogas plants) [1]

Figure 1-3 shows the expected distribution of biomethane by feedstock. The existing gas grid is assumed to be used to transport the biomethane to the point of consumption, taking into account the distance of the existing biogas plants from the gas grid so that they can be realistically connected. The Czech Republic would like to report on the allocation of the full volume of 'advanced' biomethane to the transport sector and will seek to find an acceptable reporting mechanism for this purpose. For "other" biomethane from agricultural raw materials, its consumption is expected to be mainly in the heating and cooling sector or in industry and households.

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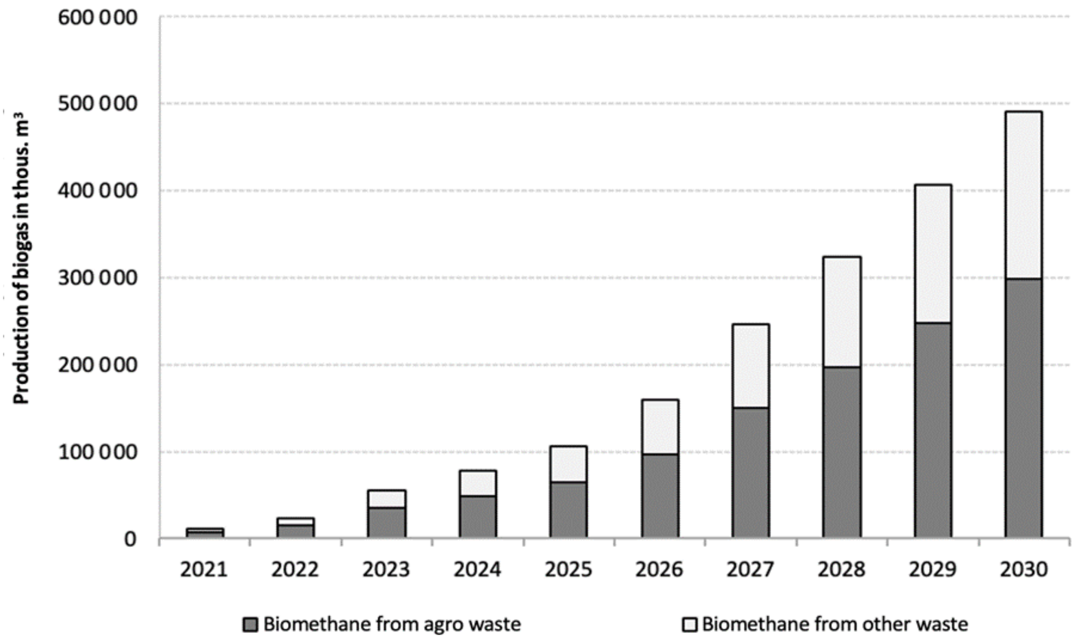

Figure 2-3: Distribution of biomethane stations by feedstock [1]

Table 2-1 shows the expected final consumption of biogas by sector. It is assumed that only "advanced" biomethane from waste feedstock will be consumed in the transport sector (the table shows consumption without multipliers).

Table 2-1. Estimated biogas consumption in different sectors in TJ [1]

Final biogas consumption	**2016**	**2020**	**2025**	**2030**
Electro energy	9 320.5	9 469.5	8 970.0	**5 683**
Transport	0	0	1 416.1	**6 554**
Heating and cooling	7 489	7 595	8 926.5	**13 582.8**
Total	**16 809.5**	**17 06.5**	**19 312.6**	**25 819.8**

In this respect, it is assumed that all advanced feedstock biomethane injected into the gas grid will be consumed within the transport sector (respecting the mass balance approach), while other biomethane injected into the gas grid will be consumed in the same proportion to natural gas consumption.

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2.1 Production routes

Most of the biogas plants in the Czech Republic were built between 2008-2012, when the operating subsidy for the electricity produced was allocated for a period of 20 years. This subsidy also included a requirement that at least 50% of the input substrates would originate from energy crops. This requirement was removed later, but the projects were designed to use a high proportion of maize silage, so even if farmers can choose their own inputs as needed regardless of the subsidy, they need to take into account how their equipment was dimensioned.

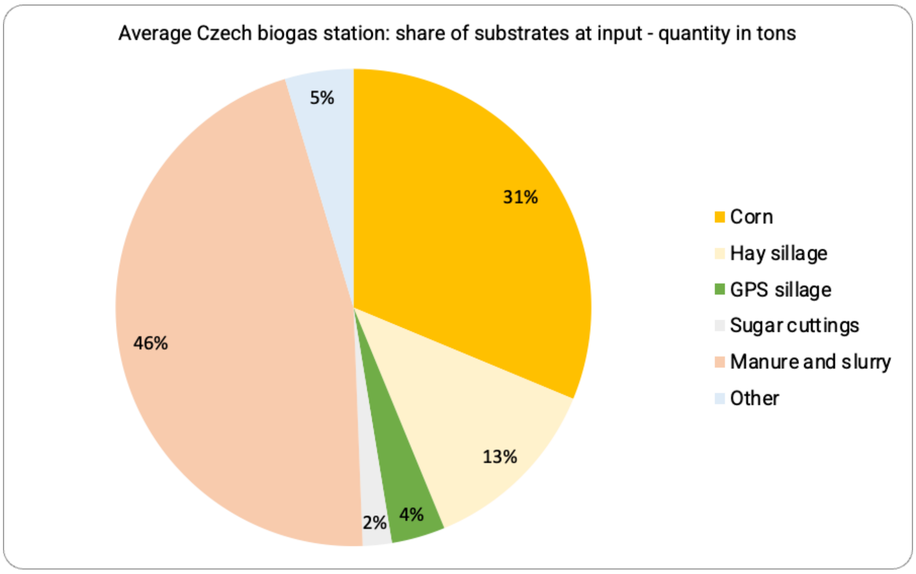

*Figure 2-4. S*hare of input substrates of average biogas plants [20]

In terms of the weight of input substrates (not the proportion of biogas produced), animal waste accounts for the largest proportion of the average biogas plant (slurry cattle with 20% and pig slurry with 16%). Of the energy crops, maize accounts for the largest proportion (31%) and a significant proportion (13% in total) is represented by haylage from permanent grassland. GPS (Ganz Pflanzen Schrott) or green harvested plant biomass is represented by 4% and sugar production waste by 2%. The average proportion and distribution of input substrates is the result of a survey of a representative sample of biogas plants (BGP) made up of more than 80 BGPs. The representative sample was determined by sorting all BGPs into statistical classes and selecting the number of respondents according to the weight of each class.

Agricultural and environmental policy is trying to move away from energy crops and replace them with waste in particular. However, in terms of the operation of biogas plants, this policy is problematic. Energy crops have the highest conversion factor of all feedstocks (they produce the most biogas per unit weight). Firstly, there is not enough waste to run all of approx. 400 agricultural biogas plants and secondly, there is the problem of low biogas production from waste. If biogas/biomethane production is to be maintained, many times more bio-waste will need to be processed to replace energy crops.

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Table 2-2. Consumption of input materials (tons) and its share (%) in biogas plant stations input substrates in the Czech Republic (installed electrical power of 332 MWel) [20]

Substrate	Input [tons]	Share [%]
Maize	2 852 607	31%
Haylage	1 142 449	13%
GPS	332 717	4%
Beet pulp	180 386	2%
Manure	895 673	10%
Slurry (cattle)	1 850 204	20%
Slurry (pig)	1 449 829	16%
Other (biowaste, agri residues etc.)	424 569	5%
Total	**9 128 433**	**100%**

A transformation of the current supply chain will be necessary to meet the biomethane targets. Feedstock potential for biomethane production is as follows: 47% sustainable agricultural waste and residues, 40% sequence crops, 13% sewage sludges, biodegradable and gastro waste.

2.2 Supportive policies

2.2.1 Vision and targets [1, 2]

EU strategy

In cooperation with the EU Member States, the transnational strategy document Repower EU was presented. It also includes an action plan for the Czech Republic, where the planned production by 2030 is 1.2 billion m3 of biomethane. This amount would make a significant contribution to energy independence from fossil fuels, especially natural gas from the Russian Federation, given the current consumption of natural gas. The total natural gas consumption in the Czech Republic in 2021 was 9 434 million m3, which corresponds to 100 737 GWh. However, the consumption in 2022 will be significantly lower (about 20%). At the same time, the Czech Biomass Association (CZ Biom) is trying to maximize the development of biomethane and according to our estimates, it is possible to realistically approach 2 billion m3 of biomethane. In a very optimistic scenario, there is also a forecast of 2.5 billion m3 per year.

National strategy and national plan

The current national strategy is determined by the National Energy and Climate Plan of the Czech Republic. This plan was prepared by the Ministry of Industry and Trade based on the requirements of Regulation (EU) 2018/1999 of the European Parliament and of the Council on the governance of the Energy Union and climate action. The obligation to prepare the National Energy and Climate Plan stems from Article 3 of the EU Regulation on Energy Governance and Climate Action, which entered into force on 24 December 2018. The document was prepared in close cooperation with other

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ministries and other relevant bodies. On 13 January 2020, the Government of the Czech Republic approved the document and entrusted the Ministry of Industry and Trade with the official transmission of the document to the representatives of the European Commission. The document was forwarded to the European Commission immediately after this decision.

Unfortunately, the document was already outdated by the time it was finalized, as it reflected the political situation in the Czech Republic rejecting the dynamic development of RES. The document implies, among other things, that the development of biogas or biomethane should not lead to an increase in the intensity of farming on agricultural land and the cultivation of energy crops, but rather to their more efficient management. The strategy of the Ministry of Agriculture of the Czech Republic with a view to 2030 allows for an increase in the energy use of agricultural biomass by up to 20% by 2030, but only on condition that the strategic level of agricultural production for food use is maintained. Currently, 350-400 thousand ha of agricultural land is used for the energy sector in the Czech Republic (13,5 %). At the same time, emphasis is placed on maximizing the use of bio-waste, including biodegradable municipal waste.

In the gas sector, one of the main points of the strategic plan is to support financially and institutionally both the transformation of existing biogas plants for biomethane production and new biomethane plants, synthetic gas plants and hydrogen production plants, including their connection to the gas grid.

2.2.2 Direct investment and production support [3, 4, 5]

(This can also include the best practices for permitting process)

Investment support

Currently, the government allows 2 direct investment supports for biomethane, one currently in use and the other still in progress. The Operational Programme for the Environment under Call 14 - Waste sorting and re-sorting includes Measure 1.5.9, which is related to the construction and modernization of waste-to-energy facilities.

The call is a round-robin (competitive) call with a one-round application evaluation model. The allocation (maximum total EU support) for approved projects is announced at EUR 500 million. The maximum amount of funds available for funding is CZK 50 million. Of this amount, the allocation for projects of measure 1.5.9 is 160 million CZK. The maximum funding rate is 85% of the total eligible expenditure.

Measure 1.5.9 specifically includes:

Construction and modernization of waste biogas plants. The condition is that the plant must annually process at least 5 % of waste catalog number 20 01 08, according to the Waste Catalog (gastro-waste), of the total capacity of the plant. In addition to this mandatory 5 % of the above listed waste types, other biodegradable waste not mentioned in the call may enter the biogas plant. Production of fuels from waste of catalog number 20 01 25.

Another option for investment subsidies is OPTAK (from "Operační Program Technologie a Aplikace pro Konkurenceschopnost" which means Operational Programme Technology and Applications for

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Competitiveness), which is currently not yet published. It will cover both the construction of biomethane stations and upgrading to biomethane, including investment support for the construction of a production pipeline.

Operating support for biomethane [19]

Operating support is enshrined in Act No 165/2012 Coll. on Supported Energy Sources. Currently, the amended Act is in force as of 1 January 2022, where operational support for biomethane is defined. On 31 October 2023, the European Commission approved a EUR 2.4 billion Czech programme to support the production of sustainable biomethane. Under this programme, biomethane will either 1) be injected into the gas grid or 2) delivered to a filling station or dispenser for use in a range of applications from transport to heating. This programme will run until December 31, 2025.

Under the programme, support will take the form of a green bonus for biomethane producers for each MWh of biomethane produced for a period of 20 years. The amount of the bonus is set annually by the Energy Regulatory Authority and will be limited only to the funding gap.

Indirect investment and production support [6, 7]

Currently, there are not many opportunities for indirect support in the biogas/biomethane sector. One option is OPTAK, which includes an investment subsidy for upstream pipelines that can be drawn on separately. However, at the moment, as mentioned above, the parameters of this subsidy are not known.

Another upcoming subsidy is the "Brown Savings", which would cover subsidies for agricultural machinery. A condition should be the incorporation of organic fertilizers into the soil, such as composts and digestate. The subsidy is currently being redesigned to correctly meet the conditions.

In the framework of the CEEAG (Climate, Energy and Environmental Aid Guidelines), the Ministry of Transport is discussing support for the purchase of public transport fleets using CNG/LNG with a mandatory share of bio-based fuel.

2.2.3 Demand-side incentives [8, 9]

Consumer interest is a very effective and important tool also in the Czech Republic. Currently, many large companies are addressing their carbon footprint with responsible carbon management. For example, most companies are buying 'green electricity', which comes from renewable sources rather than fossil fuels. And in the same way, companies can purchase "green gas," which is a simple solution to buying biomethane through the natural gas grid using guarantees of origin.

This green gas is most often purchased through a PPA (Power Purchase Agreement). PPAs are not very popular in Central and Eastern Europe. Poland was a pioneer, where the first PPA was signed in August 2018 by Mercedes-Benz and VSB's 45 MWp wind farm, which has been operating since 2013.

Legally, there is nothing to prevent PPAs in the Czech Republic, but there are also no specifically favorable conditions for them. The contract is governed by the terms of the Energy Act, as both the consumer and the producer are participants in the electricity market, whether they enter into a local

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or virtual PPA. In the case of concluding a PPA for a period longer than 10 years, attention must also be paid to Article 2000 of the Civil Code, which provides for the right of the contracting party to seek cancellation of the obligation after 10 years. However, a legal person may waive this right in advance.

In the Czech Republic, Ambient Energy (supplier-broker) and ŠKO-ENERGO (customer) are among the pioneers in concluding PPAs, for example, having concluded them for a period of 20 years. The electricity will be supplied by a wind park to be built in the Opava region by Micronix Group. The annual production is estimated at 26.3 GWh. For investors in the Czech Republic, however, RES PPAs are not yet a very attractive activity. Although there is nothing legally preventing their conclusion, the lack of financial support makes the investment riskier with a longer payback period. The current situation on the energy market and the directive price capping do not favour PPA contracts either.

Another way to motivate consumers is to introduce sustainability through ESG (Environmental Social Governance). Currently, more than 90 Czech companies with a total turnover of more than CZK 1.4 trillion, which represents about 22% of the Czech GDP, are registered in the programme. The distribution of participating companies is roughly 52% large companies and 48% small and medium-sized companies.

CZ Biom creates initiative and pressure on the state administration to create demand directly from the state. One possibility is, for example, the direct purchase of biomethane to cover the consumption of state facilities. This would create a large market demand for biomethane, create market stability and enable more progressive development of biomethane in the country.

2.2.4 Regulation enabling injection and trade [10, 11, 12, 13, 14, 15, 16, 17, 18]

Decree No. 488/2021 Coll. on conditions of connection to the gas supply system.

The subject of the regulation is the determination of the conditions of connection of gas production plants, distribution systems, gas storage facilities and customer consumption points to the gas system, the method of determining the share of costs associated with connection and with ensuring the required capacity, technical requirements for the construction of the production pipeline purchased by the distribution system operator, rules for assessing simultaneous connection requirements and the conditions for the installation of equipment in biomethane production plants.

The technical requirement for the construction of the production pipeline connecting the biomethane production plant to the distribution system purchased by the distribution system operator is the construction of the related technological facilities, which are:

a) a biomethane deodorization plant to ensure an adequate level of deodorisation of the biomethane produced,
b) equipment for compression and reflow of biomethane in the distribution system from a pressure level below 4 bar to a pressure level above 4 bar, unless the biomethane produced can be used at a pressure level below 4 bar and this is more economically efficient than connecting the biomethane production plant directly to a pressure level above 4 bar,
c) a cathodic protection station to ensure sufficient protection potential of the production pipeline, if this protection potential cannot be ensured from the existing cathodic protection

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stations of the distribution system operator to which the biomethane plant will be connected, based on an assessment by that operator,

d) the necessary associated facilities with the facilities referred to in points (a) to (c), including facilities for remote data transmission for the distribution system operator,
e) a shut-off valve at the beginning of the production pipeline to enable it to be decommissioned and a shut-off valve at the point of connection to the existing distribution system.

Decree No 166/2022 Coll. on the reporting of energy from supported sources.

This decree is quite extensive and sets out in detail how a biomethane producer should report the biomethane produced. This reporting is done through the so-called Operator of the Market (OTE), where the production and supply data is reported every calendar month through the OTE system. The data submitted also includes evidence that the sustainability criteria and greenhouse gas savings of the biomass used have been met. Furthermore, the Decree contains details on the requirements for the quality of biomethane, the odorisation of biomethane or the pressure of the biomethane produced.

Decree No. 516/2020 Coll. on fuel requirements and implementation of certain other provisions of the Fuel Act.

The Decree regulates the quality and use of biomethane when using this type of fuel in transport as a fuel, both CNG and LNG.

The specific parameters are specified in standard CSN 65 6514 (Motor fuels - Biogas for petrol engines - Technical requirements and test methods). TPG 902 02 Quality and testing of gaseous fuels with high methane content. The above decrees, CSNs and TPGs do not fully correspond with the newly issued CSN EN 16723-part 1, BM to grid (valid from 6/2017) and CSN EN 16723-part 2.

Guarantees of origin

The market operator (OTE) issues so-called guarantees of origin on the basis of the statement. Pursuant to §44 and §45 of Act No. 165/2012 Coll. (on supported energy sources), the market operator issues guarantee of origin for electricity from renewable sources and from high-efficiency combined heat and power production, based on a request from the producer of such electricity. Decree No. 403/2015 Coll. of the Ministry of Industry and Trade (on guarantees of origin of electricity) sets out the conditions for issuing and recognising guarantees of origin.

In view of the above legislative documents, the market operator has prepared the Guarantee of Origin Register (EOR). It is an information system that is fully integrated in the CS OTE portal. The guarantee of origin is registered in the EAA system in the accounts of its holder throughout its life cycle (i.e. from its issue to its exercise).

Guarantees of Origin are issued:

- For the quantity of biomethane injected into the natural gas network of at least 1 MWh for a production period of one full calendar month or calendar year;
- Valid for 1 year from the end date of the biomethane production for which it is issued. Upon expiry of this period, it shall be automatically canceled in the EAA system.

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- Guarantees of origin can be transferred between accounts within the Czech Republic or within the AIB member states. The account holder of the account to which the guarantee of origin is to be transferred must approve the incoming transaction within 30 calendar days. If the incoming transaction is not confirmed by the account holder, the transaction will not proceed and the guarantees of origin will remain in the source account.

The prices charged by the market operator related to the EAA are set by the Energy Regulatory Authority's Price Decision No 5/2021 of 29 September 2021.In order to clearly demonstrate the supply of electricity produced from renewable energy sources and/or CHP, guarantees of origin must be invoked against the end consumer or group of consumers.

2.2.5 **Sources**

[1] https://www.mpo.cz/cz/energetika/strategicke-a-koncepcni-dokumenty/vnitrostatni-plan-ceske-republiky-v-oblasti-energetiky-a-klimatu--252016/
[2]https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_cs
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[19] https://ec.europa.eu/commission/presscorner/detail/cs/ip_23_3383
[20] CZ Biom estimation (www.czbiom.cz, www.biom.cz)

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Chapter 3: Estonia

3.1 The biomethane market

3.1.1 Introduction

First biogas plants in Estonia were built in 1987 on agricultural feedstock and they were in operation until 1995. After 10 year hiatus new projects started with wastewater plant construction in Tallinn in 2005 and agricultural plant construction in Saaremaa in 2006. First use for biomethane was heat and power production which then was subsidized. Since then number of biogas plants have started growing. In 2022 there was 17 biogas plants in Estonia, out of which 7 are producing biomethane. First biomethane plants in Estonia were opened in 2018 and after with increasing demand, most of the older plants, which were generating heat and power, also upgraded to biomethane production in the following years. In year 2022 new biomethane plant was opened near Tallinn, and it is the first one producing fuel for public transport out of municipal waste. At the moment there is one new biomethane plant going through the start-up procedure and several projects under evaluation.

Most of Estonian biogas potential lies in agricultural feedstocks. According to a 2014 Estonian biomethane resource study carried out by the Development Fund, it is estimated that Estonia has the resources to produce up to 4.7 TWh (=483 mln Nm3) of biomethane a year, the raw materials for which would mainly be biomass from grasslands (83%), waste from agricultural production (9.8%) and the rest is coming from municipal waste and landfill gas. Production target by year 2030 is to produce at least 1TWh of biomethane, but in year 2022 it was 170GWh. According to those numbers, Estonia would still have room for another 30-40 biogas plants, each producing around 3-4 million Nm3 of biomethane per year. (1)

In order to achieve larger production and usage of renewable gas there are still several obstacles to overcome. It will require great communication and co-operation between potential producers, market and government officials.

3.1.2 Current status of biomethane in the national context

Market development has taken a big leap in the past years. There has been built 28 CNG filling stations, 2 LNG filling stations and 5 grid injection points on distribution network grids. Government has been subsidizing biomethane production, biogas plant construction, filling station construction and public transport transition to compressed gas. Estonia has set mixing obligations to fuel companies which has created a demanding market for GOs.

However there have been first alarming marks, that biomethane market will not be infinite. Despite high demand for gas in public transport, heavy haulage companies for example have not adapted gaseous fuels as well, due to diesel fuel still being the most efficient transport fuel to this day. Compressed biomethane is not giving transport vehicles enough range, but liquefied biomethane or LNG does not yet have availability large enough to make truck companies make the investment. For that reason latest developments in gas market have been looking forward to create international market for both gas and GOs.

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Until now, most of Estonian biomethane plants are producing CBM, which is then taken to filling stations or to grid injection point. But new technologies and demand for LBM have raised interest in new projects to start producing liquefied biomethane, which has 6 times higher density and would make biomethane export into a profitable option. LBM production will also create more LBM/LNG filling stations which could also uptake biomethane usage in both regional and international heavy transport.

According to Estonian transmission system operator (TSO) AS Elering, they are working towards common regulations in Baltic and Finnish gas grid, which will make it possible to start injecting biomethane into the main grid and to trade it on a wider market

According to Estonia's 2030 national energy and climate plan following the EU 2018/2001/EL renewable energy directive, Estonia has an aim to increase the share of renewable fuels consumed in the transport sector to 14% by 2030. In excess of 9.1 TWh of transport fuels are consumed in Estonia, almost two thirds of which is diesel and the remainder petrol **(1)** . LPG and biofuel consumption in the transport sector has so far been marginal but has shown increase in demand and usage over the path of last 5 years. In order to increase biofuel consumption in Estonia, the state plans to develop biomethane production from local raw materials and to start using biomethane more widely in the transport sector. By the end of 2022 there was 5295 passenger cars and 1344 buses and trucks in Estonia that were using gas as fuel. Build up for larger market of biomethane has so far been subsidizing both fuel companies to build new filling stations and public transport companies to purchase gas-powered buses. Estonian committee of European Union affairs announced that Estonia will continue supporting gas-powered transport even after 2030 and new mechanisms for up-taking renewable gas usage when purchasing public services (garbage trucks, road construction etc.) are in works.

By information provided on guarantees of origin system manager Elering homepage, production of biomethane has grown over 4 times since 2018 and predictably will reach 200GWh by the end of year 2023.

Estonian Biogas Association has put together Biogas & biomethane roadmap 2030 **(2),** during Regatrace project in 2022 which consisted following suggestions:

1. To set a target for the production of biomethane of 100 million Nm3 (1 TWh) per year in 2030;
2. To set the target for 2030 for cars using methane is 15,000 and for heavy goods vehicles (buses and lorries) is 1,500 and the number of methane filling stations is 50;
3. To support the use of biogas in pilot projects for the use of solid oxide fuel cells (SOFCs), in particular for small-scale installations at source. The heat and electricity generated in the SOFC can be used on site, including in autonomous areas without mains electricity, not to mention district heating;
4. As a measure to implement the EU Green Deal, to extend the eligibility period for support for biomethane producers by extending the eligibility period for support for support for the development of the biomethane market until 2030 or adopt a new similar regulation;
5. To exempt and differentiate 40% -80% of heavy goods vehicles consuming methane fuel from road tolls in Estonia on the basis of EURO classes;

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6. To introduce purchase aid for the use of local gas vehicles in Estonia (renewal of the local truck fleet from EUROIII to EUROVI on the example of Germany;
7. To exempt of heavy goods vehicle tax for gas vehicles and differentiation on the basis of EURO classes;
8. To implement the business tax rebate for biomethane consumption (Swedish example);
9. To use of more environmentally friendly biomethane-based transport when purchasing public services (setting an example in the implementation of the Clean Vehicles Directive) - so-called green procurements in road construction, State Real Estate (AS Riigi Kinnisvara) constructions, where the consumption of methane fuel provides additional points in the evaluation of tenders.
10. To continue to give preference to methane-powered buses in public transport procurement and to build methane filling stations in areas where this is not available for public transport today.
11. To participate actively in the development of an international quality standard for biomethane that takes into account the specificities of biomethane production. Also create preconditions for cross-border trade in biomethane, including certificates of origin;
12. To create opportunities for the partial replacement of natural gas with biomethane, synthesis gas or hydrogen in the production of heat
13. To establish a functioning incentive scheme for the sorting of municipal and agricultural waste in all municipalities in order to divert all bio-waste to biomethane plants; and composting and fertilizer production.
14. To allow the use of vehicles of higher weight and length in Estonian road transport (in order to remain competitive with neighbouring countries, at least up to 25,25 m, but consider allowing, for example, trains up to 34,50 m with a maximum weight of 76 tonnes).
15. To promote digestate based biofertilizer certification, to support digestate based biofertilizer export.
16. To support power-to-gas technological innovations to double biomethane production (up to 2 TWh/a) in 2050
17. To use green CO2 from biomethane upgrading units mixed with green hydrogen (wind, PV, hydro based).
18. To promote liquefied biomethane production (Bio-LNG) with objective substitute LNG by 2050 100%.
19. To promote green hydrogen production from biomethane or via mixing green hydrogen with green biomethane to increase heating value of biomethane not increasing volume and pressure, especially when using natural gas network for gas distribution.
20. To build state-owned 2-4 biomethane injection points to natural gas transmission network, which is precondition for biomethane export.
21. To use LNG tanker for storage of the liquefied biomethane, to establish state-owned 1 central biomethane liquefication unit, which increases the independence from natural gas market price fluctuations.

Most of those bulletpoints are under discussion or even in implementation and government is co-operating with institutions such as Estonian Biogas Association, Estonian Gas Association and work group of “Rohetiiger” (Green Tiger) so at the moment market uptake is looking progressive.

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3.1.3 Public acceptance

Public acceptance towards biomethane has progressed positively. Due to geopolitical conditions and will to transform energy onto renewable sources people have adapted biomethane production rather well. Interest towards locally made green vehicle fuel and gaining independence from Russian gas has clearly given biogas production good look.

Digestate has gained interest amongst agricultural businesses, as it is valuable organic fertilizer and could possibly be a substitute to large amount of fossil fertilizer.

There have not been any protests against biogas plants in Estonia, but yet it is better to build those facilities further away from population. Biogas plant is solving countryside manure problem as digestate does not smell as much as raw manure, but if the plant is built too close to homes, it might cause negative impact.

3.1 Production routes

3.1.1 Feedstock potential assessment

Majority of Estonian biogas plants are using agricultural residues as feedstock. Newly opened Maardu plant is using purely biological waste and Estonian Cell operated biogas plant in Kunda is using wastewater from cellulose processing. Unlike many biogas plants in central and southern Europe, Estonian biogas plant do not use big amounts of maize silage, but in the future grass silage will become more common substrate. According to **(3)** Analysis of the biomethane resources deployment of Estonia , 80% of biogas potential is coming from grass silage collected from unused land such as old peat fields, recultivated land on oil shale quarrys and other low fertility agricultural land that has no use for cereal farming, but will be potent enough for energy crops. Haylage is also used as a soil protector and many cereal farms, who have obligation to use grass in their cropping sequence. If it will be approved as II generation biofuel, haylage from cereal cropping land will make notable contribution to feedstock potential. In 2022 new law about sorting and separating bio-degradable waste was taken in action. Goal of this law would be to use as much biological waste in energy production and to avoid it in the landfills.

Most of additional capacity will be gained from agriculture. Around 50% of manure is already treated into biomethane, bit there is still large amunt of grassland that is waiting to be brought into use. Sequential cropping as a new source of biomass will possibly gain larger proportion within the next decade.

Many companies in Estonia, who are treating sewage and waste water, already produce biogas and have biogas plants as part of their treatment unit. But since population in Estonia is relatively low and the amount of biogas those plants produce is not enough for upgrading into biomethane, biogas is mainly used for heat or co-generation purposes.

Biodegradable waste is already collected separately in Estonia and most of it will be treated into biomethane in near future. Due to low population density in Estonia, most of the waste will be transported to suitable biomethane plant over a long distance (Figure 3-1).

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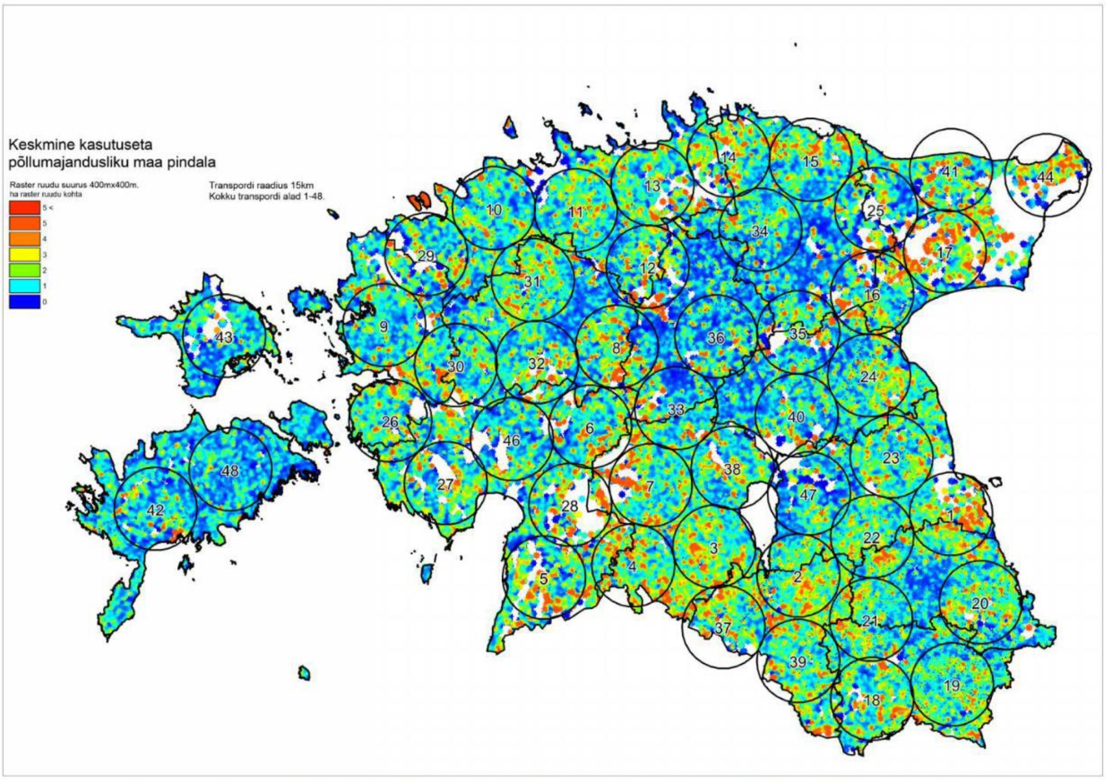

Source: Vohu, V. 2014. **KASUTUSEST VÄLJAS OLEVA PÕLLUMAJANDUSMAA RESSURSS, STRUKTUUR JA PAIKNEMINE** , Estonian Development Fund, Tallinn. [The resource, strucutre and location of unmanaged agricultural land in Estonia by 2012 data]

Figure 3-1. Transportation distances to biomethane plants, red colored areas indicate uncultivated agricultural lands, blue colored areas are in active agricultural use, circles indicate the potential number and locations of biogas plants.

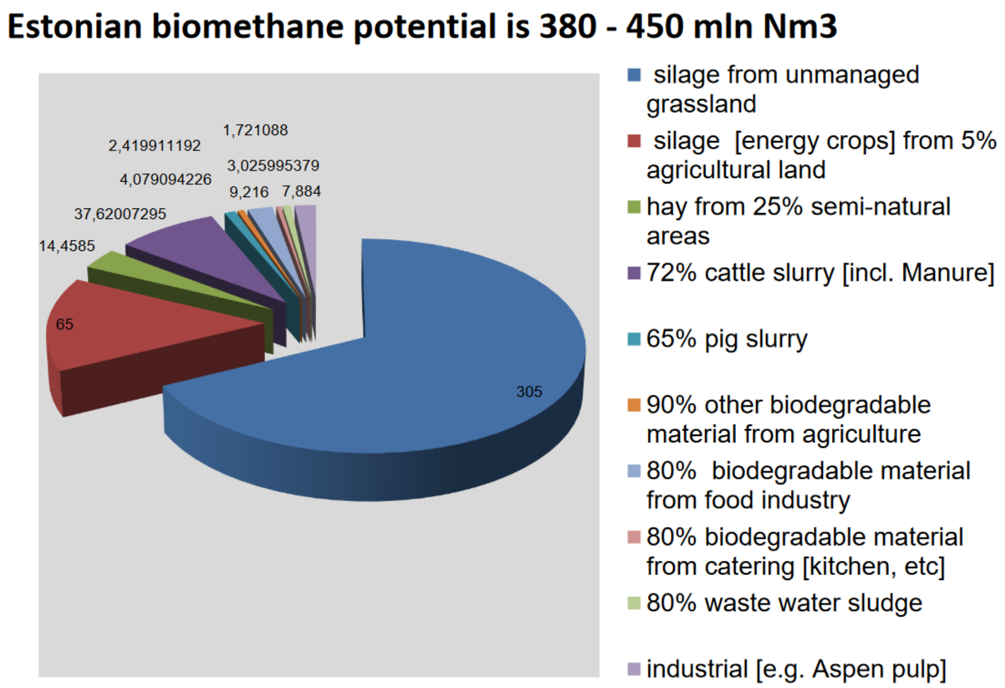

Figure 3-2. Biomethane potential in Estonia

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At the moment agricultural biogas plants are mostly built near to farms that are able to provide all the needed substrate, but to achieve 1TWh goal by year 2030 it will mean many farms to start co-operating with each other. In Estonia currently there is lack of incentives for farmers to utilise manure, silage and fodder residues in the production of biomethane. Dimensioning biogas plant needs guaranteed amount of substrates and letter of intents to be signed with feedstock providers before the investment is made, but current situation is creating too big risk so many biogas plants are operating with lower volumes than it would be possible. Therefore, one of the ways feedstocks availabilities could be improved is through synchronised agricultural and energy policy measures.

Since amount of bio-degradable waste is also rather low in Estonia, it will not be feasible for most of the communities to invest into biogas plant and it will require designing biogas plants that will be able to also treat municipal waste, without contaminating digestate with hazardous particles.

3.1.2 Natural gas grid infrastructure and future prospect

Estonian gas grid has a lot of potential, yet at the moment only 7% of households had a contract with a gas retailer in 2021 (Figure 3-3). Currently it is possible to install injection point to the transmission or distribution system, but the grid connection's investment and operational costs can create a barrier for producers. Due to most of the gas is used for heating purposes another problem is gas consumption which can differ 2-10 times in summer compared to winter. So far there are no storage solutions available or under development so the most possible way for grid transmission uptake would be to create possibility for international market.

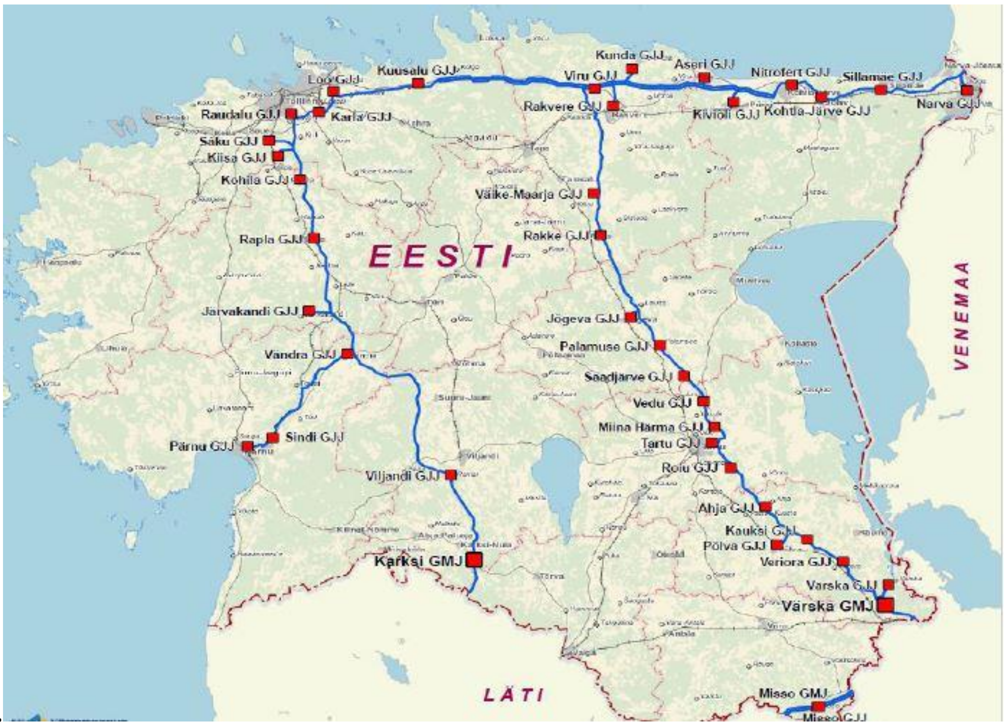

Figure 3-3. Natural gas grid infrastructure in Estonia

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Biomethane injection into Estonian gas grid is targeted to grow within next few years. Gas grid operator TSO Elering has filed an application for raising permitted O2 level from 0.02mol% to 0,5% in the transmission and distribution grid to be suitable for handling larger amount of biomethane. Another two major milestones will be common agreement with Latvia and Finland to trade with biomethane molecule over the grid. Yet obstacle to overcome will be from Latvian side Incukalns underground gas storages sensitivity to O2 level. Trading issues with Central Europe can be bothered by possible Gazprom interruption about gas grid regulations, because of grid interacts with Russian pipeline in Lithuania.

Additional ongoing grid development study is injecting hydrogen into national gas grid. Possible scenarios evaluated are 2% 5% 10% and 20% of hydrogen injection possibilities and how much upgrading will it require for the grid. Participants of the study are Estonia, Latvia, Lithuania and Finland, conclusion if it will be feasible enough for proceeding to stage II will be announced in July 2023.

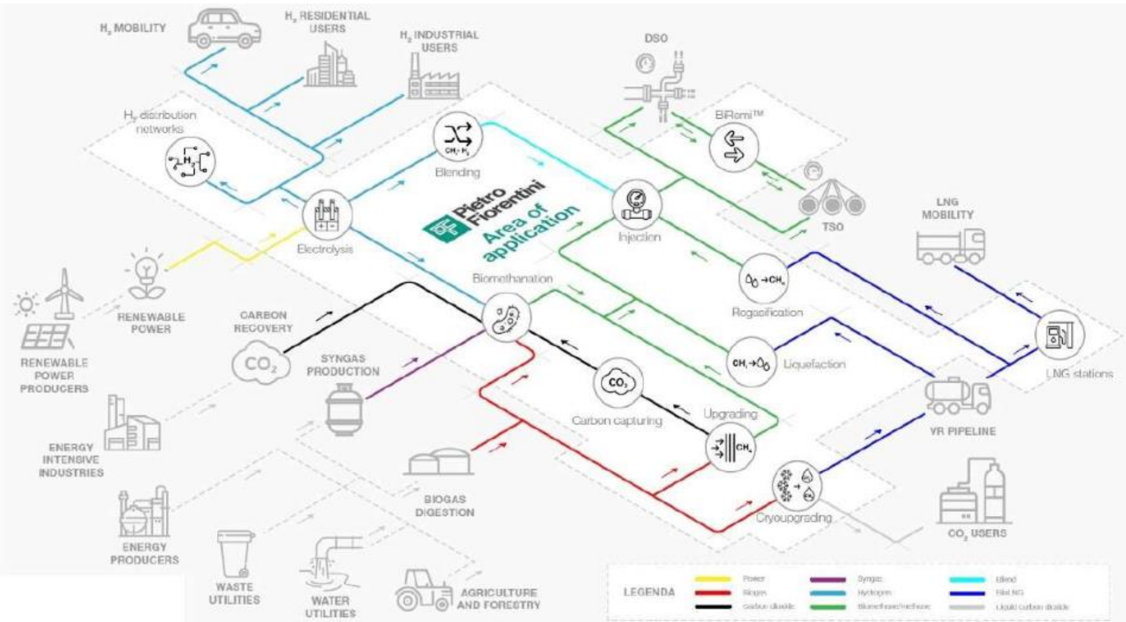

Figure 3-4: Piotro Florentinis view of future gas grid in Estonia

3.2 Regulatory framework and supportive policies

This chapter will give an overview about current incentives and support mechanisms for biomethane production from producer, consumer and retailer side. Framework for biomethane production supports almost all parts of value chain, but main measure for up-taking the usage of green gas is focusing on transport. Firstly, before there was any biomethane production, preliminary framework started up-taking the market by supporting both natural gas filling station construction and public transport switch onto using CNG. Since first users of the market were brought in development continued with construction subsidy for biomethane plants and price premium for produced gas, which made biomethane production desirable for agricultural companies and waste treatment plants as a way to create additional revenue for their business. At the moment biomethane production has

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grown exponentially and framework for support mechanisms is under constant development. Discussion for market uptake has united several ministries, energy-, recycling- and farming companies and initiated co-operation to fill in the gaps and to make the market even more vital.

3.2.1 Vision and targets

Estimation of biogas and biomethane development

The development of biomethane production depends on several factors. A key issue will be the existence of a certain level of public support. Price fluctuation and some negative exampes from the past are making the investment decision hard for new potential producers and financiers. There is now information yet what sort of subsidy or grant will be provided after current model ends in July 2024. New financial subsidy for construction and/or production will be crucial and also cooperative biomethane production/ waste treatment will need support to kick-off.

For wider market integration there will have to be uptake in gas-grid injection and possibility to trade with biomethane on international market through gas grid.

One crucial way of treating biomethane will be liquefaction, which already has a wide market, but the production remains low due to high operational and investment costs.

Currently all biogas plants that are big enough to upgrade biogas into biomethane are already producing biomethane. Smaller plants will most probably continue creating heat and power and will not start biomethane production. However there is almost 10 biogas plants in development that are looking into producing biomethane for grid injection, LBM and CBM production.

In early 2023 Lithuanian organic food producer Auga Group announced first miniseries of biomethane powered hybrid tractor production. First batch will commence field tests in summer 2023 and after that company is willing to start production for also other farmers over Europe. This invention will most probably uptake biomethane usage around the farms producing it.

National strategy and national plan

National Energy and Climate Plan is provided for by Article 3 (1) of Regulation (EU) 2018/1999 on the management on the Governance of the Energy Union and Climate Action and is submitted in the course of every 10 years **(4).** Updated versions or justifications for not requiring an update must be submitted by 30 June 2023 and 2024. In Estonia main targets for NECP 2030 are developed by Ministry of Economy and Communications, Ministry of the Climate, and Ministry of Regional and Rural Affairs and based on following documents:

- Fundamentals of Estonian Climate Policy until 2050 (FECP 2050)
- Estonia's Energy Sector Development Plan until 2030
- Climate Change Adaptation Development Plan until 2030
- Transport Development Plan for 2014–2020
- Forestry Development Plan for 2011–2020
- National Waste Management Plan for 2014–2020
- Estonian Rural Development Plan for 2014–2020.

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Main targets for NECP 2030 are

1) **Reduction of Estonian greenhouse gas emissions by 80% by 2050 (including 70% by 2030)**: greenhouse gas (GHG) emissions in 1990 were 40.4 million tCO2eq (excluding the Land Use, Land Use Change and Forestry i.e. from now on LULUCF), in 2017 Estonian GHG emissions were 20.9 million tCO2eq (including 14.7 million tCO2eq from the energy industry sector), as a result of the measures, GHG emissions are forecast to be 10.7–12.5 million tCO2eq in 2030 (excluding LULUCF).
2) **In the sectors covered by the Effort Sharing Regulation** (road transport, small industry, agriculture, waste, forestry and industry) **to reduce greenhouse gas emissions by 13% by 2030 compared to 2005**: In 2005, GHG emissions in the sectors of the Effort Sharing Regulation were a total of 6.3 million tCO2eq, i.e. in 2030, the sector's emissions may be 5.5 million tCO2eq (the exact 2030 target is revealed in 2020, when the annual national emission levels for the sectors covered by the Effort Sharing Regulation for the period 2021–2030 are established).
3) **The share of renewable energy in the total final energy consumption must be at least 42% in 2030**: in 2030, renewable energy shall make up 16 TWh, i.e. **50% of the final energy consumption**, including renewable electricity 4.3 TWh (2018 = 1.8 TWh), renewable heat 11 TWh (2018 = 9.5 TWh), transport 0.7 TWh (2018 = 0.3 TWh).
4) The final consumption of energy must remain at the level of 32–33 TWh/a until 2030: Estonia's economy is growing, and therefore keeping consumption at the same level requires significant measures. Cumulative energy savings of 14.7 TWh in the period 2020–2030 would make it possible to keep the final energy consumption at the same level. Reducing energy consumption can be done by making primary energy consumption more efficient.
5) Reduction of primary energy consumption by up to 14% (compared to the peak of recent years): in the period 2020–2030, Estonia shall have the ability to reduce primary energy consumption, including with innovations in the oil shale industry.
6) Ensuring energy security by keeping the degree of dependence on imported energy as low as possible: the use of local fuels shall be kept as high as possible (including increasing the use of fuel-free energy sources), the potential of biomethane production and use shall be used.
7) Meeting the minimum criteria for the interconnection of electrical grids between countries: Increasing the capacity towards Latvia and synchronising the electrical grid with the Central European frequency band in 2025.

Using research and development and innovation in measures to maintain the competitiveness of the economy: the implementation of the energy sector research and development programme allows measures to be implemented using research and innovation achievements.

Targets for biomethane production and consumption

According to agreement between EU Member States, the transnational strategy document Repower EU was presented. Action plan for the Estonia includes raising the planned production by 2030 to 100 million Nm^3 of biomethane. This amount would cover 25% of Estonian natural gas consumption in 2021 which was approximately 400 million Nm3. Consumption after high natural gas price significantly dropped, but since the market has stabilized it is again starting to show growth. As Estonia is working towards larger usage of biomethane in transport sector the consumption will most likely grow even more in next decades and it will keep creating room for more green gas on the market. Estonian maximal biomethane potential has been rated to be about 380- 450 million Nm3 per year.

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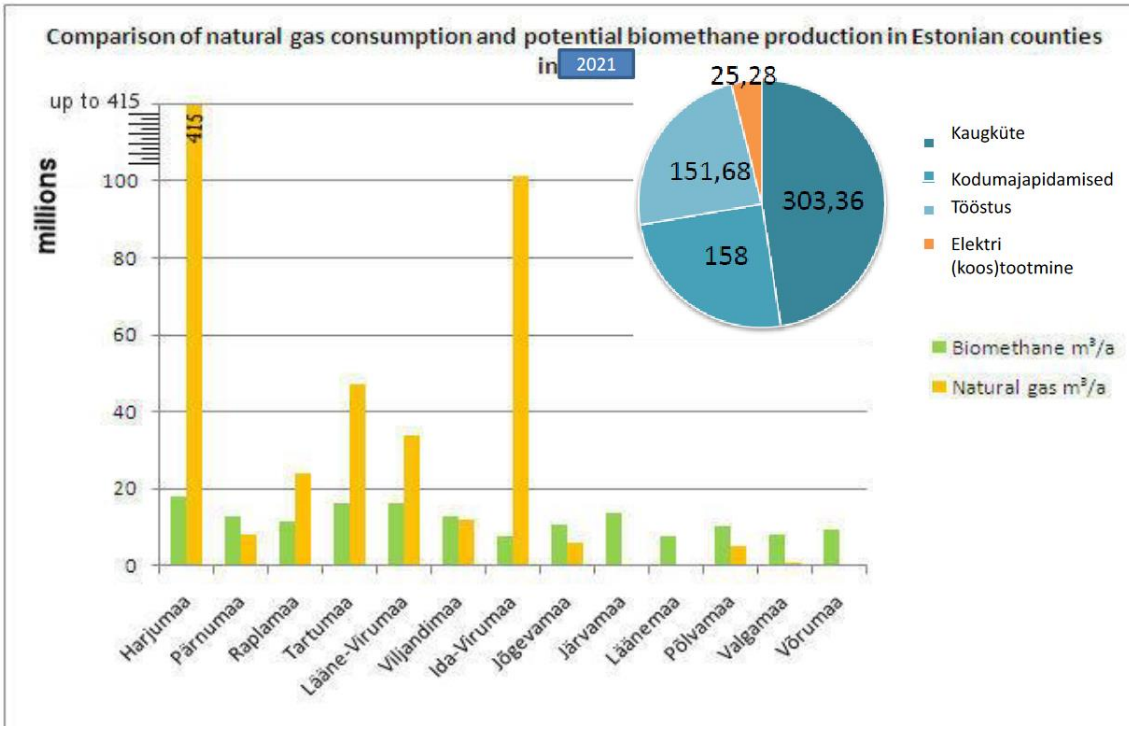

Figure 3-5. Comparison of natural gas consumption and potential biomethane production in 15 counties of Estonia.

3.2.1 Direct investment and production support

On 15 December 2022 the Government of Estonia announced financing proposals to be included in the Recovery Plan to the extent of the amount of REPowerEU and to start negotiations with the European Commission as follows: renewable energy acceleration reform 31.8 million euros; increasing biogas production and deployment 20.2 million euros; additional funding for energy efficiency of small residential buildings 20 million euros; additional funding for the capacity to integrate renewable energy production into the grid 18 million euros. That fund was open for applications until the end of year 2022 and so far there has not been announced another subsidy that would be directly applicable for plant construction.

Production support from year 2018 has been 100EUR/ MWh minus natural gas price in transport sector and it was supposed to continue until end of 2024 according to current decision. Subsidy for non- transport use is currently 93EUR/ MWh and was also supposed to continue until end of 2024. As the number of biomethane producers increased during last years and the amount of the support fund was fixed, the biomethane support finished in January 2024.

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3.2.1 Indirect investment and production support

Environmental Investment Centre of Estonia has put up fund to support the introduction to innovative technologies. Focus of the Innovation Fund will be

- Production and use of renewable energy
- The capturing, storage and disposal of carbon
- Energy-intensive industry, including replacement of carbon-intensive products
- Energy storage, including energy storage solutions for industry

Fund will not cover construction costs of biogas plants because biogas production is not considered as an innovative technology anymore, but applicable will be many technologies which are directly tied to biogas and biomethane production such as liquefaction unit, CO2 upgrading and liquefaction unit, power-to-gas solutions and so on.

There is support mechanism under development to subsidise building 3-4 grid injection points on transmissioon grid and open subsidy for constructing filling stations in rural areas.

Support to CNG stations that sell biomethane require that CNG filling should be fast filling station and opened to the public access. Subsidy is covering 35% support to CAPEX, maximum 350,000 euro per project

3.2.2 Demand-side incentives

Support for public transportation companies to promote the use of renewable energy was adopted 24.11.2015 and has since then brought over 500 CNG buses onto Estonian roads. Subsidy regulation “Condition for supporting the consumption of biomethane in the transport sector” has been introduced by government for supporting consumption and delivery of biomethane and for creating larger demand. As an addition to buses, support measure will also include investments for other public service transportation such as fire trucks, garbage trucks and machinery used in roadworks. This support is covering 30% of total investment cost and can be no less than 400 000EUR and no more than 4 000 000 EUR. Outcome so far has been positive and it has brought uptake in gas-powered vehicle usage also in private companies providing regional transportation service in 6 cities and counties in Estonia.

3.2.1 Regulation enabling injection and trade

Regulatory framework enabling biomethane market access has developed over the course of past five years and is supporting or has supported almost every part of value chain. Certification of biomethane is set in place well by AS Elering, national gas and electric transmission grid operator (TSO), and is under constant development. AS Elering has set in place registry of guarantees of origins and all biomethane produced and consumed is going through this registry, giving a good overview about current situation of market at any given time. Due to blending obligation in transport sector for petrol

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and diesel, market of GO's is granting price premium for biomethane producers and covering up the price gap between fossil fuels. Molecule and certificate can be sold separately so if biomethane producer has their own filling station for biomethane, certificate for covering energy need with renewable gas can be erased from registry by other fuel company, who has bought it to fill its blending obligation. At the moment all the biomethane produced is used in Estonia and there is no import or export, but according to AS Elering, cross border exchange of gas guarantees of origin will be possible following the renewable energy directive 2018/2001/EU provided when the solutions to meet the requirements are in place.

At the moment biogas and biomethane are exempt from excise duty giving it another advantage for becoming profitable.

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3.2.2 Regulatory and barriers assessment

In the past years we could say that despite the common barriers, biomethane production is developing progressively and there is high interest towards up-taking the market from governmental, producer and off-taker side. But since biogas production is in the field of environmental, agricultural and energy department there still are obstacles to overcome and proper communication to build.

1) At the moment there is no regulations that would obligate biowaste or agricultural residues treatment into biogas, therefore potential substrate providers are not overly motivated to co-operate with existing biogas plants and to participate in planned ones. According to department of economy, government is preparing support that would at least transportation of substrates to biogas plants, but so far there have been no public announcements to prove that.
2) Uncertainty about biomethane production subsidy has always been putting construction of new plants under a hold position. Until February 2024 the biomethane producers were granted 100EUR/ MWh price, which meant that if natural gas price was 53 EUR/ MWh, government paid the lacking 47 EUR/MWh, so the plant was feasible and financing institutions were willing to give out loan for construction. But this support scheme is ended in January 2024 and there has not been announced next steps.
3) Procedures for environmental assessment, building permit, certification of digestate and spatial plan for urban areas are taking too long and hinder sectorial development.
4) Amount of CNG filling stations is coming to the reasonable level (27), but most of them are in or around big cities and rural areas are still lacking of CNG/CBM filling options. LNG/LBM does not have enough stations yet (only 2 are in operation), which is the reason not many international haulage companies are not upgrading their fleet to LNG/LBM trucks.
5) Gas grid is dramatically underdeveloped with only 7% of households having a contract with gas retailer. Also not yet is there enough development plans and framework for up-taking the options of biomethane grid injection. Transfer costs for grid usage are not supported for biomethane producers and total investment and operational costs have been stated to be too high.
6) Digestate, which could be treated into valuable fertilizer does not have enough market opportunities and is mostly given back to substrate suppliers for free. Certification for

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digestate takes up to 12 months and is often too complicated so producers are not considering it to be additional revenue stream.

7) Long-term profitability is still under a big question mark. Many potential financiers and producers still find it too risky to make investment for biogas plant and even some banks have declined financing applications refer to business models with negative outcome from the past.

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Chapter 4: Greece

4.1 The biomethane market

4.1.1 Introduction

Following the Russian invasion of Ukraine, the European Commission published the REPowerEU plan to reduce the European Union's (EU) dependence on Russian energy imports. The REPowerEU plan sets the ambition to replace 35 billion cubic meters (bcm) equivalent to 350 TWh, of the 155 bcm of European natural gas (NG) currently imported from Russia, with domestic biomethane production in the EU-27 by 2030. This is equivalent to.0 around ten times the current annual EU biomethane production.

Today biomethane production grew to 44 TWh or 4.2 bcm in 2022, with an installed capacity of 4.5 bcm. In the EU combined biogas and biomethane production in 2022 amounted to 223 TWh or 21 bcm. The estimated investment needs to achieve the goal (350 TWh) amount to €83 billion.

The corresponding target of replacing Russian gas imports with biomethane in Greece, according to the New ESEK, is 2.1 TWh for 2030. According to data from December 2023, in Greece today 78 biogas units are in operation, with a power of 118 MW, electricity production of 584.1 GWh, and fuel energy approximately amounting to 1.8 TWh. By upgrading only the existing biogas plants to biomethane plants, therefore, the 2030 target is achieved

In today's conditions and given the strong political will from the EU for the use of green gaseous fuels from biomass (biogas/biomethane) in the energy sector, the production and use of biomethane offers significant opportunities that can boost entrepreneurship and contribute to the recovery of the economy. Responding to the challenge is possible but requires an integrated plan, coordination and systematic monitoring of the implementation of the necessary actions. Proponents further point to the benefits of energy sufficiency from diversification of fuel supply sources, sustainable waste-to-energy management and environmental protection

Biomethane is a renewable green gas, produced from biomass, offers a comprehensive solution, and is able to contribute to the goals of the country's energy policy as follows:

1. In environmental protection by reducing greenhouse gases by 2030 and achieving net zero emissions by 2050
2. In the security of energy supply: with the diversification of existing sources of energy production and a legislative framework governing the use of biomethane in the distribution network of the FA as a necessary condition
3. In sustainability: with the energy utilization of biomass mainly organic waste and ligno-cellulosic raw materials for biomethane production. Biomethane can effectively contribute to reducing the effects of climate change. Its production is also a key part of an integrated plan for the management and treatment of organic waste aimed at the production of energy and motor fuel in transport, while effectively contributing to the achievement of circular economy goals in conjunction with energy production.

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4. In competitiveness: by promoting local endogenous renewable energy sources, mainly biomass, supporting the country's primary sector, high local added value and technological innovations that promise innovative solutions, the development of a competitive market and the increase of specialized jobs at all stages of the biomethane supply chain will be achieved.

Therefore, a national green gas strategy should be considered as a key element for the development of the biomethane market. The strategy should include ambitious goals that act as lighthouses for the development of the industry. These goals are necessary to be integrated into the New ESEK so as to ensure that biomethane will be included in the energy planning of the country.

4.1.2 Current status of biomethane in the national context

Until June 04, 2010, when Law 3851/2010 was published in the government gazette, the installed capacity of biomass/biogas units in Greece was 42.4 MW with minimal applications for the granting of a license to produce electricity to RAE at that time for settlement.

Biogas plants in Greece

S/N	ENERGY TYPE	FUEL-TYPE	Location	Thermal Capacity (MW_{th})	Electrical Capacity (MW_e)	Annual Biogas Production (m3/yr)
1	ELE	SWL	Thessaloniki		5.04	22,000,000
2	CHP	MWTP	Larisa	1.83	0.60	897,120
3	CHP	MWTP	Patra	0.70	0.02	577,012
4	HEAT	MWTP	Chalkida	2.21		240,000
5	HEAT	MWTP	Alex/poli	0.33		328,000
6	HEAT	MWTP	Rodos	0.58		90,000
7	CHP	MWTP	Hraklio	0.53	0.19	672,000
8	CHP	MWTP	Chania	0.29	0.16	200,000
9	CHP	MWTP	Athens	17.20	11.4	25,774,000
10	CHP	SWL	Athens	4.00	23.4	107,000,000
11	CHP	MWTP	Volos	1.11	0.33	0
12	ELE	SWL	Volos	0.00	1.25	3,783,632
			TOTAL	28.77	42.401	161,561,764

Figure 4-1: Biogas plants in Greece

In Greece, the total number of biogas plants has risen from 12 in 2010 (Figure 4-1) to 28 in 2015, 37 in 2017 and 44 in 2018 and finally to 78 in 2023 (Table 4-1). These 78 stations are interconnected in the power grid under the jurisdiction of Renewable Energy Sources Operator and Guarantees of Origin (DAPEEP S.A), according to Law 4152/2013

The 78 biogas interconnected stations have 118 MWe installed electricity capacity (IEC) and use mostly agricultural residues, municipal wastes from landfills (SWL) and to lesser extent sewage from wastewater treatment plants (MWTP). The most important are the following:

- A co-generation plant of 24.5 MWe capacity in the SWL of Ano Liossia

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- A co-generation plant of 11.4 MWe capacity in MWTP of Psyttalia
- Two co-generation plants of 5 MWe capacity and 3.5MW in SWL in Central Macedonia.
- 64 small agricultural plants with a total capacity of 63.50 MW.
- 1 agricultural plants with total capacity of 5.2MW
- 1 organic municipal solid waste plant of 1.56MW
- 3 organic municipal solid waste plant of 3.3MW

The municipal wastes from seven (7) landfills, the installed electricity capacity of which is estimated at 36,35MW are presented in the table below. Likewise, the 64 agricultural plants of 63.50 MW, the 4 sewage plants of 14.85MW, and the organic municipal solid waste plant of 3.3MW are presented.

In 2022 the IEC was dominated by landfill-based stations (32.5%), sewage plants (13.1%), agriculture plants (53%) and organic municipal solid waste plant (1.4%). In 2023 there were 7 landfill-based producing 196.8 GWh and 4 sewage-based stations, of which only one (1) Psyttalia is generating electricity. Psytallia however works as auto-producer and uses the produced 29.36 GWh as a whole to cover own needs to dry the sludge, selling thus 0.1 GWh to the grid. 64 biogas stations are agricultural plants producing 374.3 GWh using several feedstocks (manure, corn silage and agricultural residues). The rest 3 organic municipal solid waste plants producing 12.9 GWh (Table 4-1).

Table 4-1. Feedstock for biogas production in Greece

Feedstock types	**Biogas plants**	**Total installed electric capacity**	**Electricity production**
	Number	kW	GWh
LANDIFILL	7	36,35	196.8
BIO-MUNICIPAL WASTE	3	3,3	12.9
SEWAGE SLUDGE	4	14,85	0.1
AGRICULTURAL	64	63,50	374.3
TOTAL	78	118	584.1

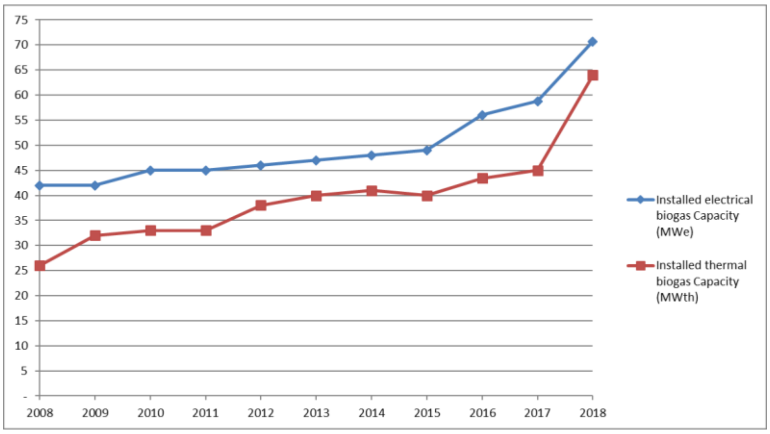

Figure 4-2: Installed electrical and thermal capacity of biogas plants in Greece

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The amount of electricity generated from agricultural plants was 374.3 GWh in 2023, representing 63.5 % of the total electricity production from biogas in the country, which amounted to 584.1 GWh.

In all biogas plants in Greece the biogas produced is not upgraded to biomethane.

4.2 Production routes

4.2.1 Feedstock potential assessment

The estimation of the biomass potential is a difficult process, due to the particularities it presents, and specifically to the difficulty of estimating and recording the elements of the raw material (quantity, availability) with precision and completeness. The present study is based on the experience gained by the Biomass Department of CRES, from 1989 until today. In addition, with flow charts, using process simulation code and numerical subroutines, it is possible to solve a mass-energy balance, resulting in the estimation of biogas production and then biomethane to be produced from the available biogas, depending on the selected biomass type.

The following are also calculated, per type of waste and animal (in relation to the category of the animal and its age): The possible production of biogas (Nm3), the methane content in the biogas (Nm3), the energy content of the biogas (MWh), the biogas power (kW), the recovered methane from the biogas (Nm3), the recovered methane losses (Nm3), the final available methane for injection (Nm3), the available biomethane for injection into the PV network (Nm3) and the energy content of biomethane available for injection (MWh).

The biomass categories examined for Greece are waste from livestock farms, cattle, pig farms, goats, sheep and poultry (manure), agricultural residues from winter cereals, durum and soft wheat, barley, oats, rye, vetch, triticale (straw), waste agro-industries (cheese) and the organic fraction of Municipal Solid Waste (MSW). The above waste will be used as raw materials for biogas/biomethane production and is in accordance with Annex XI of the amended Energy and Climate Directive (RED II).

Particularly important is the fact that for the supply or purchase of biomass, there should be fuel (biomass) contracts. Fuel contracts, in addition to legal validity and clauses on the part of the producer for his obligation to the investor regarding the delivery of a specified amount of biomass in a specific period of time, also provide the guarantee of required quality characteristics of the biomass desired by the investor of the biogas/biomethane plant. The availability of biomass production throughout the year is guaranteed by at least 30% if it is accompanied by contract farming conditions.

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Table 4-2. Theoretical biomass potential and energy content of biomethane.

Type of biomass	Biomass	Biomethane	
	Tonnes/year	m3/year	MWh/year
Livestock	23,969,935	726,846,217	7,008,106
Agricultural residue (straw)	1,002,930	242,685,210	2,339,922
Bio-industrial food waste (hey)	1,150,815	16,287,673	157,042
Bio-waste for household	2,086,089	162,237,088	1,564,258
Total	28,209,769	1,148,056,188	11,069,328

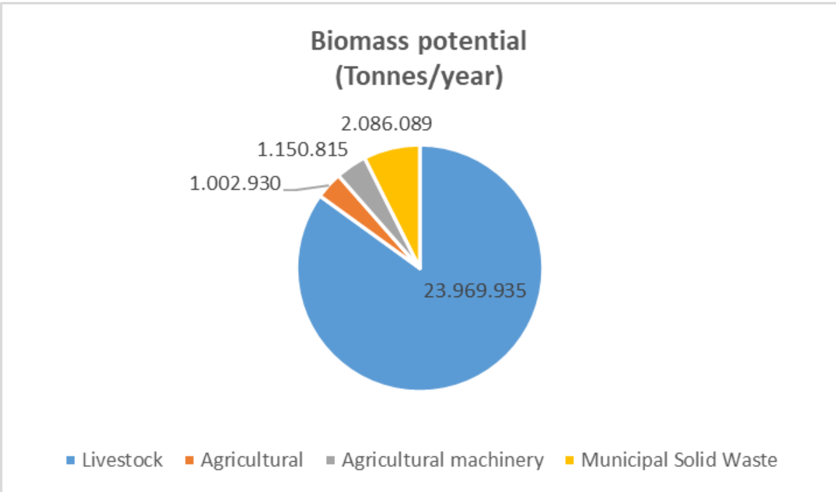

Figure 4-3: Theoretical biomass potential.

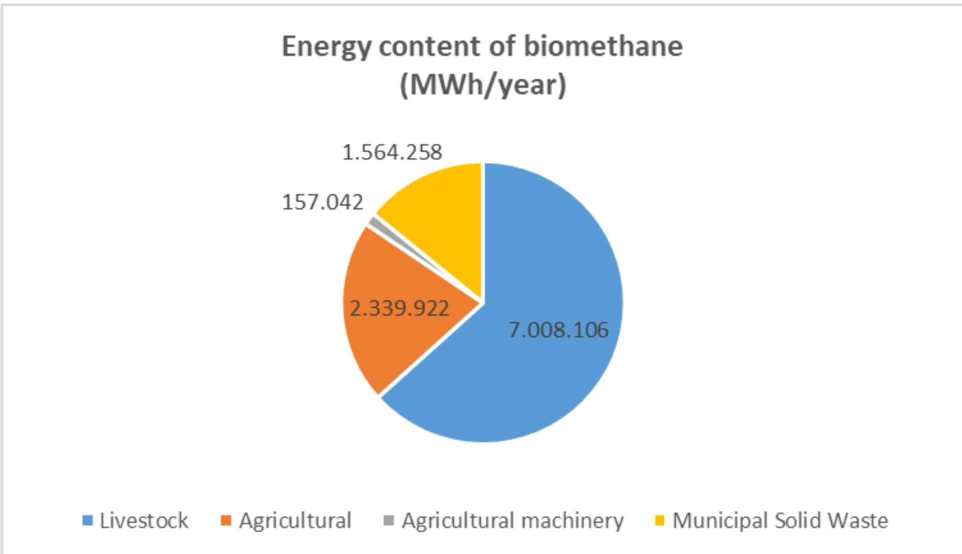

Figure 4-4: Total biomethane production.

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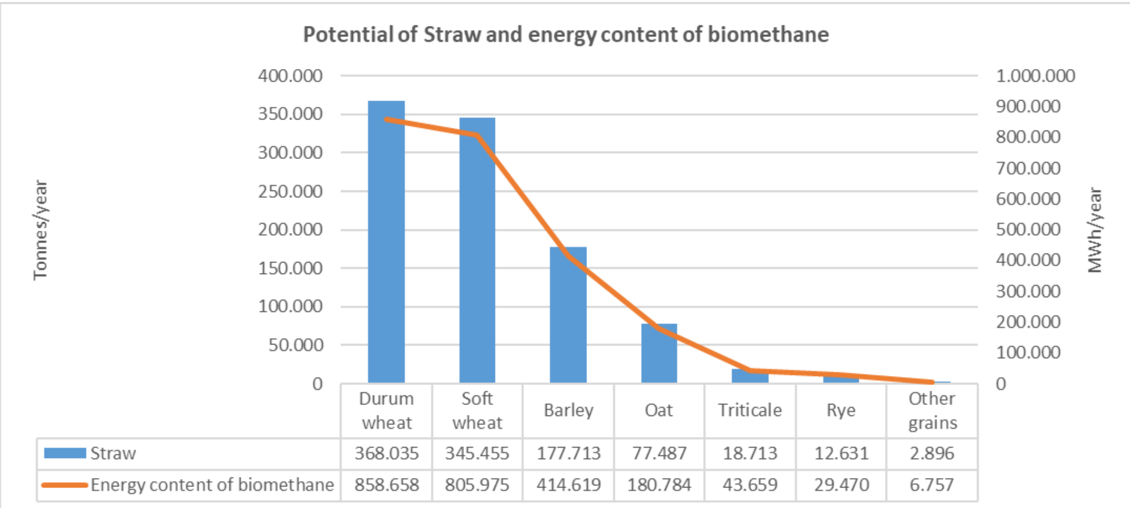
The theoretical biomass potential from livestock manure, grain straw, agro-industry waste and the organic fraction of MSW amounts to 28,209,768 tons/year, with a biomethane potential of 1.14 bcm and a biomethane energy content of 11 TWh/year (Table 4-2, Figure 4-3, Figure 4-4).

Livestock waste-manure holds the first place, with its potential amounting to 23,969,935 tons/year and biomethane's energy content of 7,008,106 MWh/year (Table 4-2, Figure 4-3, Figure 4-4). Goat manure, with 12,046,841 tons/year, holds the first place, followed by cattle manure with 10,549,544 tons/year, with biomethane's energy content of 5,136,609 MWh/year and 1,465,787 MWh/year respectively (Table 4-3).

Table 4-3. Livestock waste-manure per type of animal.

Type of biomass	Exploitation	Biomass (manure)	Biomethane injection to the grid	Energy content of biomethane
	Number	Tonnes/year	m3/year	MWh/year
Sheeps and goats	86,386	12,046,841	532,743,739	5,136,609
Cattles	15,862	10,549,544	152,024,178	1,465,787
Pigs	2,463	771,868	8,680,650	83,697
Poultry	2,613	601,682	33,397,651	322,013
Total	107,324	23,969,935	726,846,217	7,008,106

*The biomass potential from agricultural residues of winter cereals (straw) amounts to 1,002,930 tonnes/year, with biomethane's energy content of 2,339,922 MWh/year (Table 4-3, Table 4-4**Error! Reference source not found.***



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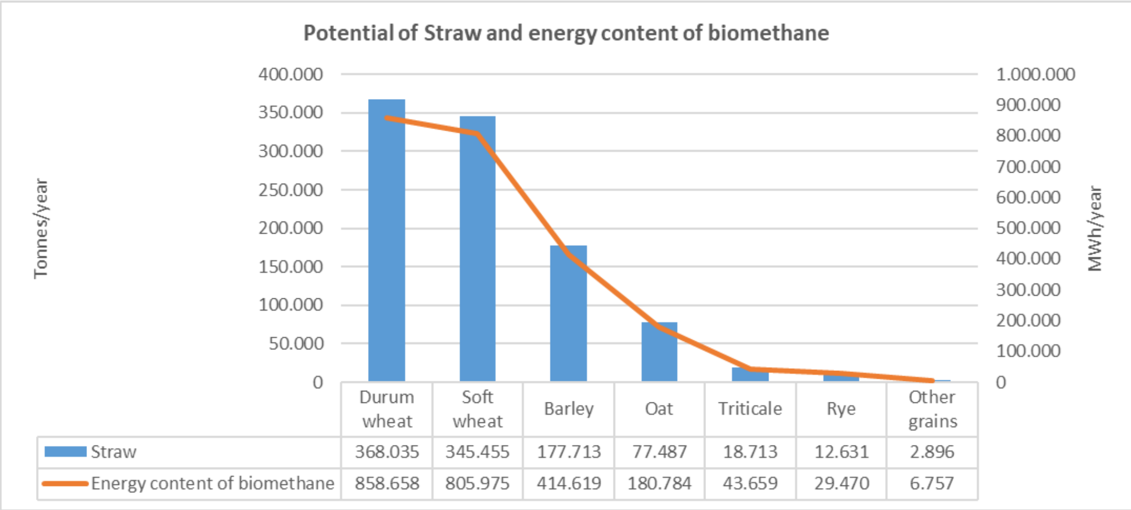

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Straw intended for animal feed has not been assessed, according to RED II requirements, but only straw not consumed by the feed market and remains in the field after the main product has been harvested. This comes mainly from the cultivation of durum and soft wheat (

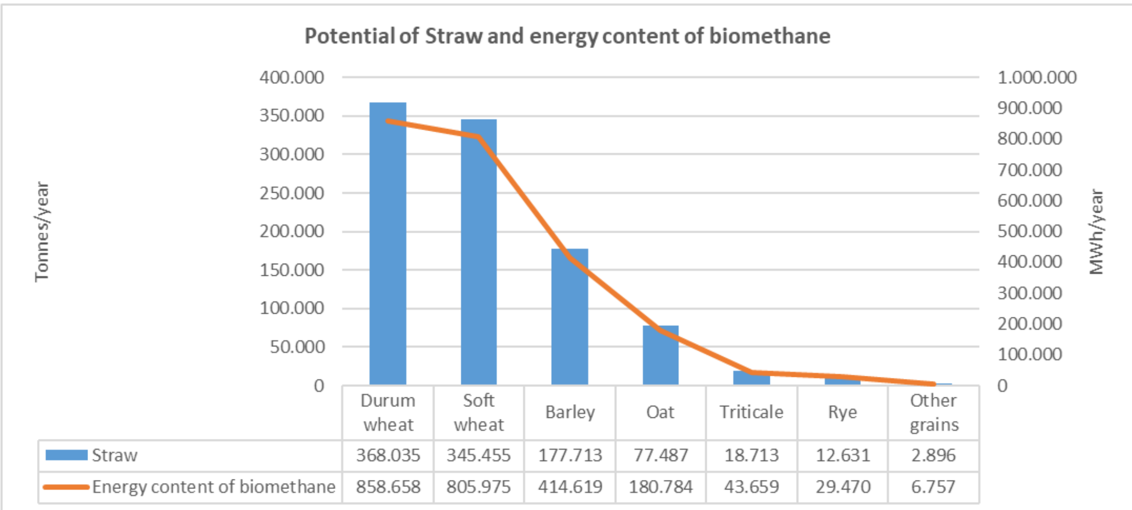

Figure 4-5).

Table 4-4. Potential of agricultural residues, straw, potential and energy content of biomethane

Type of biomass	Straw	Biomethane injection to the grid	Energy content of biomethane

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	Tonnes/year	m3/year	MWh/year
Durum wheat	368,035	89,055,788	858,658
Soft wheat	345,455	83,591,808	805,975
Barley	177,713	43,002,267	414,619
Oat	77,487	18,750,001	180,784
Triticale	18,713	4,528,054	43,659
Rye	12,631	3,056,480	29,470
Other grains	2,896	700,812	6,757
Total	1,002,930	242,685,210	2,339,922

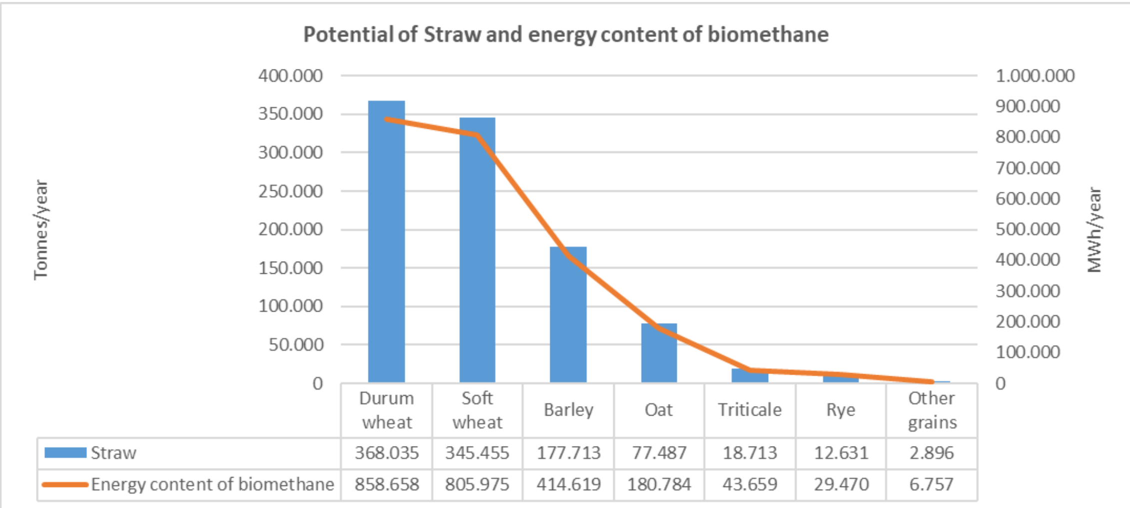

Figure 4-5. Potential and energy content of biomethane from straw.

Regarding agro-industrial waste, specifically whey, this is estimated at 1,150,810 tonnes for 2020, not including washing water (**Error! Reference source not found.**). Its energy content amounts to 157,042 MWh/year.

According to the new National Planning, the estimated amount of Municipal Solid Waste (MSW) produced in 2021 in the country is 5,628,646 tonnes, with an estimated organic fraction of kitchen waste of 2,086,089 tonnes/year (**Error! Reference source not found.**). The energy content of biomethane amounts to 1,564,258 MWh/year.

An important benefit will be the promotion and creation of innovative networks at the local level from the **development of biomass/biomethane supply chains** with the participation and representation of

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all interested parties. The development of supply chains will have as its main objective the smooth operation of the biomethane stations, while at the same time it will bring benefits to the development of the region and the securing of new jobs, thus ensuring social consent and acceptance by the local community.

A supply chain involves representatives from the primary and secondary Local Government, the local Directorates of Agricultural Economy, Directorate of Land Policy, Directorate of Environment and Spatial Planning. Also agricultural cooperatives and associations, institutes, development companies, farmers, Dimitra centers, OPEKEPE, OGA offices, SMEs of the primary sector, private investors, agronomists, transporters, traders active in the primary sector. Finally, engineers, technology service providers, contractors, specialist equipment dealers, manufacturers/machine shops, private companies, financial institutions (banks, other investors), lawyers, energy producers and PV distribution network companies participate.

The proposed biogas/biomethane supply chain in Greece is the following:

- PROCESS

RAW MATERIALS	INTERMEDIATE STAGES	BIOGAS PLANT	TECHNOLOGIES - TECHNIQUES	FINAL PRODUCT	DISTRIBUTION
• Agricultural feedstock • Agricultural residues • Sequential crops • Bio-Industrial waste (wastes from slaughterhouses, hey, katsigaros, and beverage) • Sewage sludge • Landfill waste • Bio-Municipal organic waste	• Production • Collection • Transportation • Pre-treatment • Treatment	• Feedstock analysis • Process analysis • Autonomous AD plants (German experience) • Centralized plant co-digestion (Danish experience) • Upgrading plant • Technical inspection • Operation and maintenance	• Anaerobic Digestion • Gasification • Cleaning - Hydrogen sulphite - Water - Particles - Ammonia - Halogenated hydrocarbons - Oxygen - Organic silicon compounds • Upgrading - Pressure Swing Absorption– PSA - Absorption with water - Absorption with Selexol - Absorption with chemical reaction - Membrane separation - Cryogenic process • Odorising	• Electricity • Heat • Cooling • Solid fertilizers • Liquid fertilizers • Vehicle fuels • Injection in NG – pipelines-Bio CH_4 • Bio liquid natural gas • Bio-CNG • Biogenic CO_2 • Bio-hydrogen • Fuels for fuel cell	• Biogas distribution network • Electricity distribution network • Thermal energy distribution network • Natural gas distribution network • Fertilizers promotion • Transport fuels distribution network

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- ACTORS

RAW MATERIALS	INTERMEDIATE STAGES	BIOGAS PLANT	TECHNOLOGIES - TECHNIQUES	FINAL PRODUCT	DISTRIBUTION
• Animal farms • Forest unions • Agro-industries • Local Authorities • Agricultural unions • Lawyers	• Industries users / (SMEs) • Private individuals • Dealers • Owners of transportation means (tracks, lorries, tankers) • Equipment sellers or manufacturers (i.e pumps, bankers, containers, etc)	• Technical/financial consultants\Lawyers • Technology vendors • Contractors • Equipment manufacturers (i.e pumps, bankers, agitators, containers, compressors, digesters, etc) • Financial actors (banks, investors) • Industries/end-users • Engineers • Enterprises	• Industry • Equipment suppliers • Investors • Engineers • Technical consultants • Academia	• Public Power Corporation (PPC) • DEPA Infrastructure S.A. (Natural gas Distribution Networks • Hellenic Gas Transmission System operator S.A (DESFA) • Operator of Renewable Energy Sources and Guarantees of Origin (DAPEEP S.A.) • Hellenic Electricity Distribution Network Operator S.A. (HEDNO) • Gas Supply Companies • Local authorities • Agricultural Unions • Farmers associations • Car dealers • Individuals	• DEPA Infrastructure S.A. (Natural gas Distribution Networks) • Hellenic Gas Transmission System Operator S.A. (DESFA) • Gas Distribution Companies • Gas Supply Companies • Local authorities • Contractors • Planners • Firms for piping, networks construction • Manufacturers • Civil engineers

4.2.2 Natural gas grid infrastructure and future prospect

The National Natural Gas System (NNGS) transports Natural Gas from the upstream Interconnected Natural Gas Transmission Systems of Bulgaria and Turkey, the Trans Adriatic Pipeline (TAP) and from the Liquefied Natural Gas (LNG) terminal, which is installed at Revithoussa island at Megara, to consumers connected to the NNGS in the Greek mainland (Figure 4-6).

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Figure 4-6: The natural gas grid in Greece

The Natural Gas is delivered from the Users to four (4) Entry Points to the National Natural Gas Transmission System (NNGTS) and it is off-taken by the Users via forty-four (44) Exit Points in the Greek mainland, including Reverse Flow Exit Point 'SIDIROKASTRO', through which the delivery of Natural Gas quantities to the Interconnected Natural Gas Transmission System of Bulgaria is achieved.

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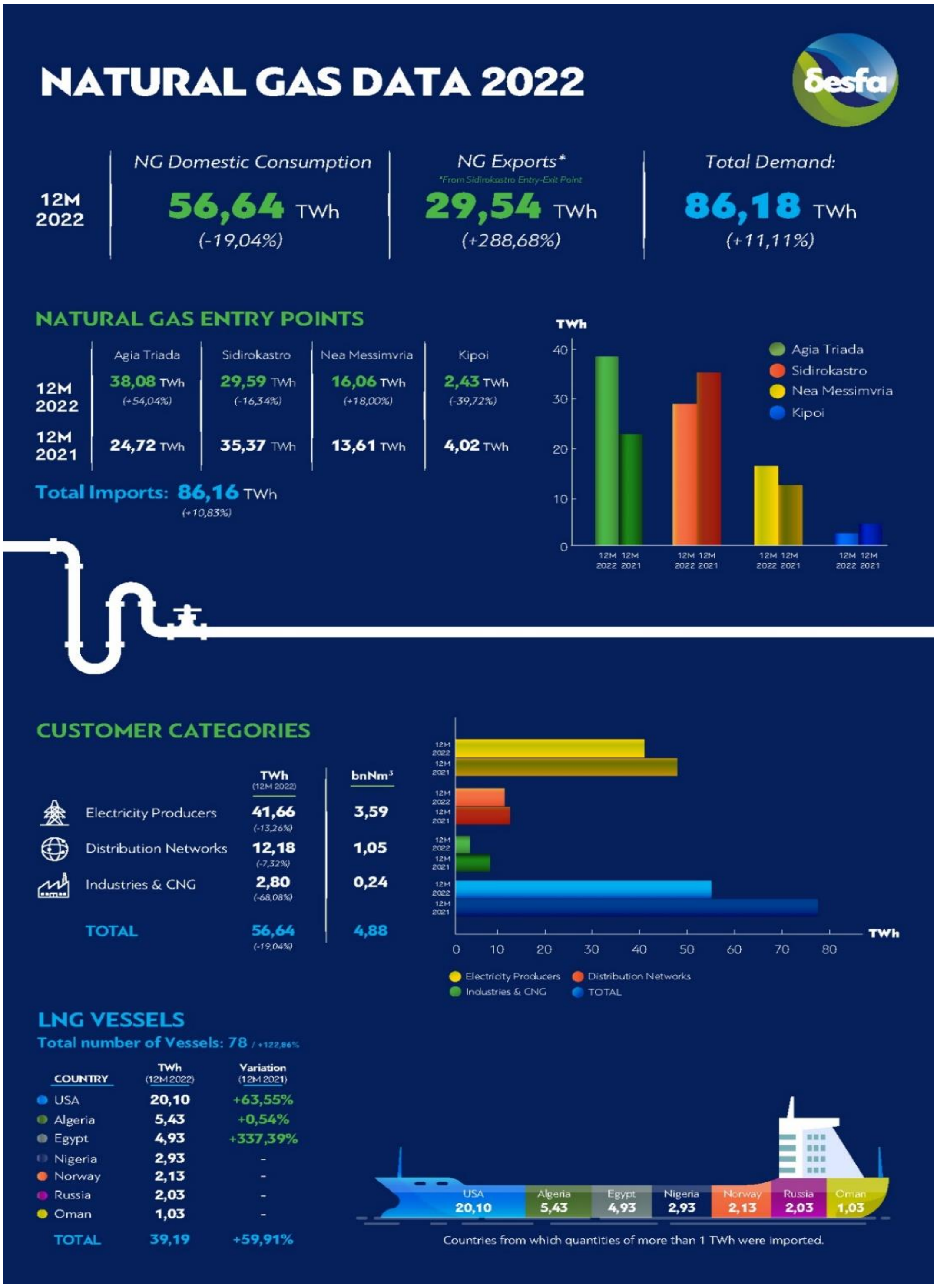

Figure 4-7: Natural gas data (Greece, 2022)

The first conversation a potential producer should have is with the distributor who owns and operates the gas network in their region.

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The distributor will provide information on all the key processes and procedures, and will have specialist employees who can act as a point of contact throughout the lifetime of the project.

The gas distributor will also be able to undertake to inform if there is available capability within the local network for the injection of biomethane.

Greece has a relatively limited gas distribution network, with only 8.3% of buildings having a natural gas connection. The distribution network primarily serves the population centers of Athens and Thessaloniki.

In 2022, four gas DSOs were operating in Greece (DEDA, EDA Attikis, EDA Thessaloniki, and HENGAS). DEDA, EDA Attikis and EDA Thessaloniki are owned by DEPA Infrastructure, which in 2022 was 100% acquired by the Italian DSO Italgas. EDA Attikis operates the distribution network in Attica. EDA Thessaloniki operates the distribution networks in Thessaloniki and Thessalia.

DEDA develops and operates distribution networks in Sterea Ellada, Central Macedonia, Eastern Macedonia, Thrace, west Macedonia, Epirus, west Greece and Corinth (Figure 4-8).

Therefore, the total number of distribution networks managed by DEDA amounts to 7, concerning 7 Regions, 45 Municipalities and 75 Municipal units, in the whole territory. The total length of the company's natural gas networks, until September2021, formed at 330.75 km of Medium Pressure and 176 km of Low Pressure for the 7its distribution networks. This picture is expected to change significantly in the coming years 5 years, through the implementation of natural gas network development works in cities for which the tender procedures for the award of works have already been completed or are expected to be completed in the near future.

DEDA in numbers:

- Seven Regions
- 2,372 km of natural gas network (until 2036)
- €450 million Investments (until 2036)
- 173,562 Number of Connections (up to 2036)

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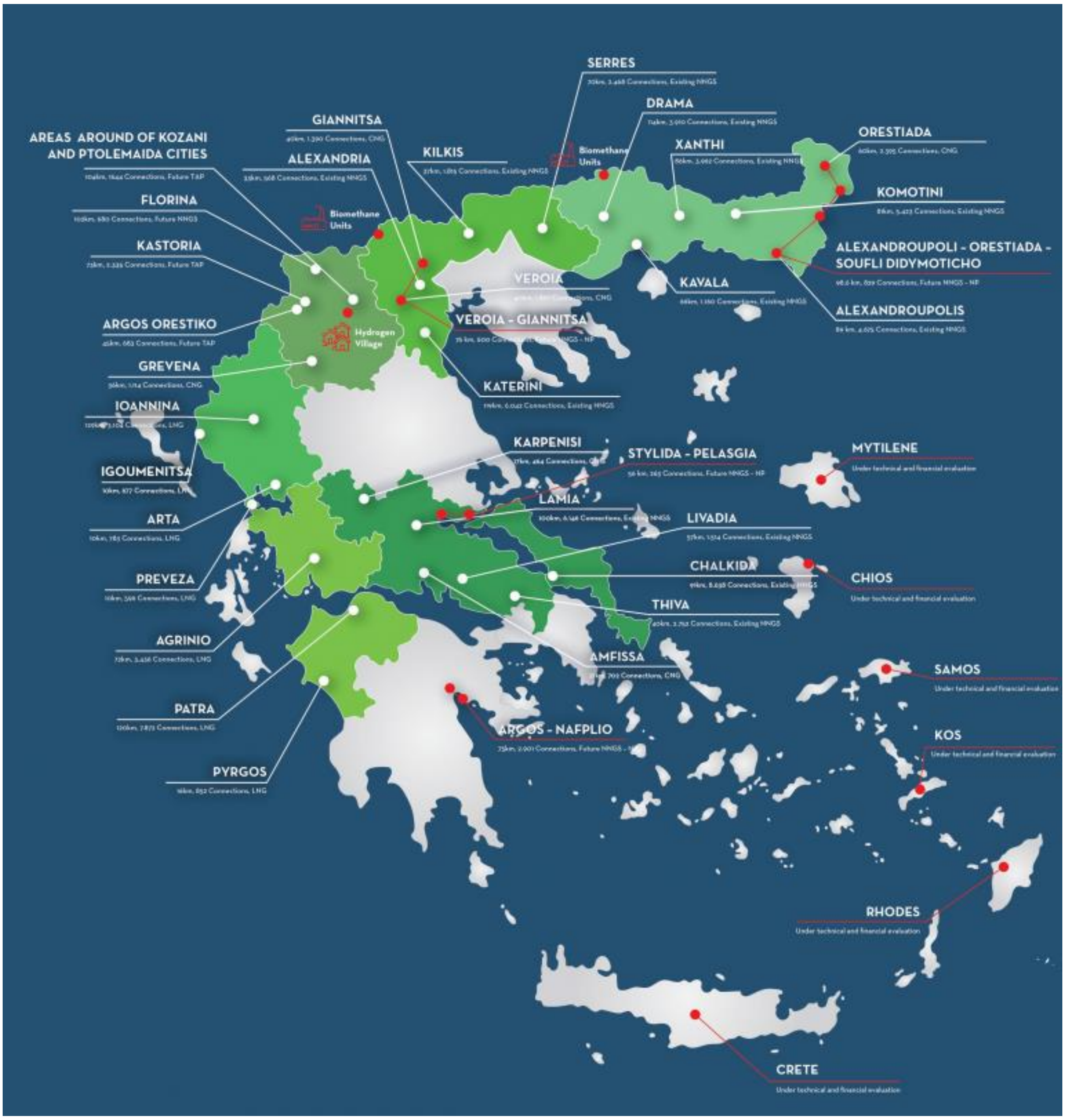

Figure 4-8: the natural gas distribution networks of DEDA

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4.3 Regulatory framework and supportive policies

4.3.1 Vision and targets

National strategy and national plan

National Energy and Climate Plan (NECP) constitutes for the Greek Government a Strategic Plan for the issues of Climate and Energy and presents in it a detailed road map for the achievement of comparable Energy and Climate Goals until the year 2030. The Ministry of Environment and Energy has completed and presented its proposal for the new National Energy and Climate Plan (NECP), which, according to the minister sets as its main goal the weaning of the country from fossil fuel imports.

The new proposed NECP, which is now open for public consultation, is structured in a way that gives surplus value to the Greek economy and domestic added value, creates new jobs while, with the transformation of the energy sector, contributes to the achievement of competitive energy prices for all consumers.

Seven interventions / technologies form the core of the new NECP of Greece:

1. Rapid growth of RES: PV and wind development (and the acceleration of offshore wind development) adding >12GW by 2030 and exploiting the country's remaining hydro potential.
2. Energy storage: The high RES penetration should be accompanied by the development of the required storage to balance and stabilize the system (batteries, pumped storage, etc.)
3. Energy efficiency: Energy upgrading of buildings (insulations, devices, heat pumps), smart energy consumption management and behavior change to reduce the required energy or the demand profile. These actions can have significant added value.
4. Electrification of light transport: Electrification of light/medium vehicles with simultaneous development of charging infrastructure and interaction with the network. A large part of the required investments will be in vehicles and their batteries. A whole battery recycling economy should be created with a possible regional role in the Balkans.
5. Creating a green hydrogen economy: Using it in transport (heavy vehicles, shipping, aviation), industry and under conditions in power generation. We already have significant mobility in the area which, combined with competitive RES, can add value to the country.
6. Development of Synthetic Green Fuels (RFNBO): With transport use (heavy vehicles, shipping, aviation) – a whole new industry that should immediately start to take shape.
7. Innovation and systemic solutions in carbon capture and storage (CCUS) for the energy transition of the country's industry (mainly cement, refining, fertilizers). A national plan and coordination will be required given the lack of scale of local companies. Similar projects are coordinated by the states in Europe and America.

Basic principles of policy design:

1. Beyond the cost of each action / technology, the economic contribution to the country (added value, trade balance, etc.) is evaluated for the optimal mix of actions. As a result, more costly but more cost-effective actions may be chosen (eg, building insulation over heat pumps).

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- The transition and required investments are an opportunity to develop relevant sectors of the economy with national champions (e.g. energy efficiency, green shipping, circular battery economy)

2. A key element of a smooth energy transition is also the security of supply / energy sufficiency of the country, especially in the transition period until 2030.

- This should also include the required backups until the transition is achieved

3. Ensuring the required infrastructure in electricity and gas networks to support development by doubling the required investments with the corresponding investment promotion plan.
4. Biomethane proposed target for 2030 estimated to 1.5 - 1.7 TWh

Targets for biomethane production and consumption

According to Biomethane production potentials in the EU the Feasibility of REPowerEU 2030 targets, production potentials in the Member States and outlook to 2050, A Gas for Climate report July 2022. Anaerobic digestion: A potential of 38 bcm is estimated for anaerobic digestion in2030 for EU-27 increasing to 91 bcm in 2050. The top 5 countries in both 2030 and 2050 consistently include France, Germany, Italy, Poland and Spain. Our country will occupy 17th place with 0.5 bcm (5.2 TWh). Of which according to the study, 0.2bcm comes from manure, 0.08 bcm from straw, 0.16bcm from crop rotation and 0.06bcm from agro-industrial waste and the organic fraction of MSW (Figure 4-9).

The overall targets of our NECP can be implemented with:

1. development of the required legislative and regulatory framework
2. development of a competitive biomass market
3. creation of biomass/biogas/biomethane supply chain
4. conversion of 45 of the 58 existing biogas plants into biomethane plants (o,5 TWh)
5. installation of 52 new biomethane stations (1 TWh)

For the economic viability, the hourly production of raw biogas for biomethane production is recommended to be between 240 Nm3- 400 Nm3.

The technical characteristics of the stations are given in the Figure 4-10 below with biomethane production and its energy content.

The biomethane producer will only be charged for the cost of the station, while the Distribution Network Operator must bear the cost of extending the PV networks to the production unit as well as the cost of the equipment for receiving and injecting the biomethane.

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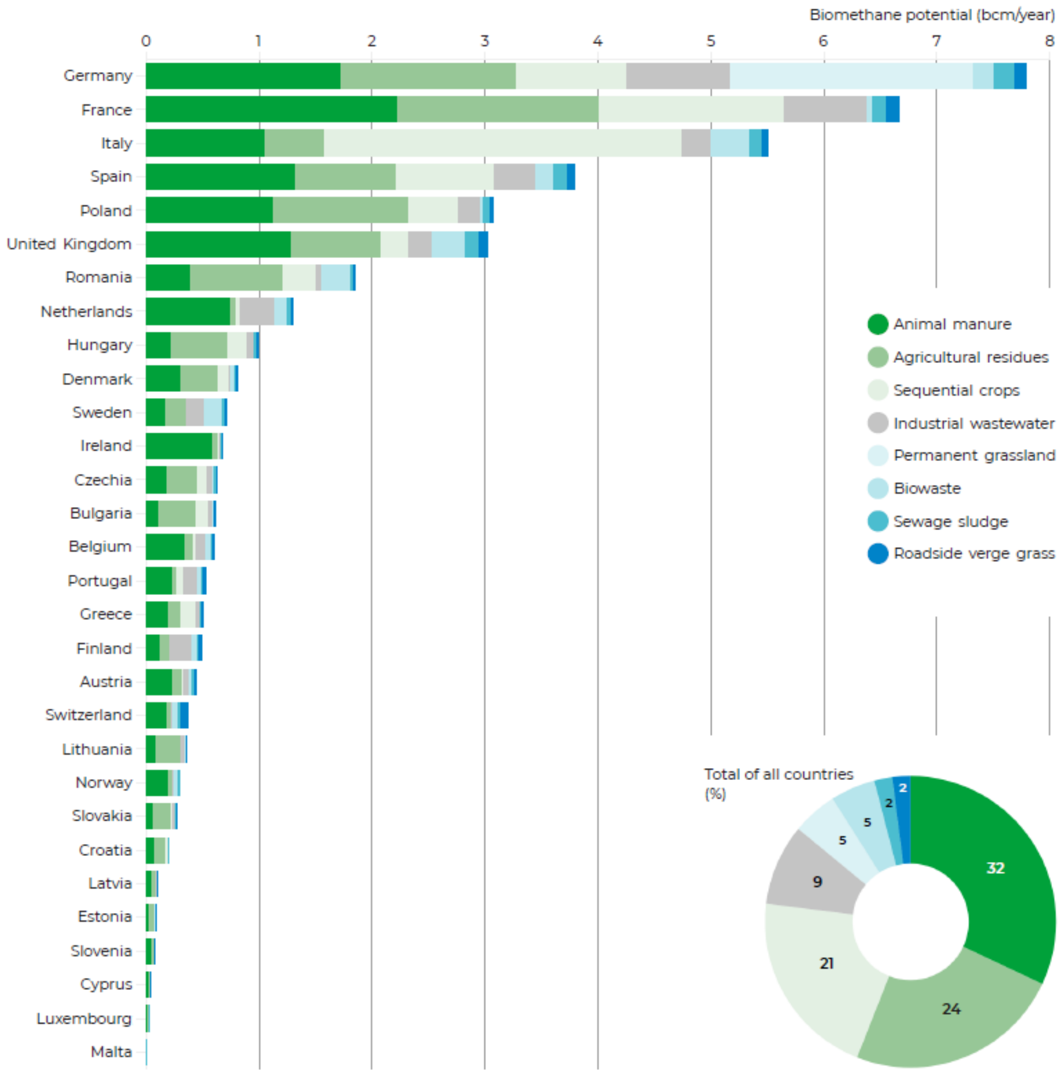

Figure 4-9: Biomethane potential in Europe (in bcm/year) for 2030 (Source: A Gas for Climate report July 2022)

Figure 4-10: Technical characteristics of the biomethane stations

Capacity of the "biogas upgrading and injection plant"	Fuel power	Biomethane injection into the NG distribution network	Energy content of biomethane
Nm^3/h	MW	Nm^3/y	MWh/y
240	1,3	1.202.247	11.592
400	2,2	2.003.745	19.320

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4.3.2 Direct/indirect investment and production support

Direct/indirect investment and production support and other demand-side investments' support is still under consideration.

4.3.3 Regulation enabling injection and trade

According to the NATIONAL RENEWABLE ENERGY ACTION PLAN IN THE SCOPE OF DIRECTIVE 2009/28/EC a report has been compiled under the supervision of the National Committee for Meeting 20-20-20 Targets and Other Requirements (20-20-20 Committee). The 20-20-20 Committee was established by decision of the Minister for Environment, Energy and Climate Change in November 2009. For the first time an official report is made by the ministry in the specific measure.

Regarding the biogas integration into the natural gas network (Article 16(7) and Article 16(9) and (10) of Directive2009/28/EC), there is no discrimination in the transmission and distribution of biogas in Greece. According to article 39 of L3428/2006 regarding the liberalization of the market of natural gas, "the use of natural gas systems according to the provisions of the Law is allowed for the distribution of biogas, a gas produced from biomass and other types of gasses, if this distribution is technically possible and the safety measures are met, taking into account the quality requirements and the chemical characteristics of these gases".

The development of the natural gas network was implemented to satisfy the expected needs of the population and the industry. A detailed map elaborated by DESFA (the Hellenic Gas Transmission System Operator S.A) showing the central pipeline, the cities connected to grids of low and medium pressure and the envisaged extensions is available at its web site. The map also includes the areas where gas production coming from RES is estimated to be sufficient to establish plants for its exploitation. From this map, it is clear that in the majority of the cases the possible integration of biogas into the natural gas grid is feasible.

In the few cases that biogas integration into the natural gas grid is not possible it is either due to difficulty in the construction of high pressure networks that would access the biogas resources or doubts about the economic viability of such a construction without any additional financial support.

It should be noted that the biogas plants currently in operation are co-generation plants and the biogas produced is used to cover their own needs in electricity and heat. As these needs may not be fully covered by the biogas produced, the biogas plants are also connected to the natural gas grid.

In the recent legislation the, there is LAW NO. 5037. March 28, 2023. No. Sheet 78. Article 105 Renewable gas access to natural gas networks and infrastructure.

Replacement of Article 92 of Law 4001/2011 (A' 179), on access of renewable gases in networks and infrastructures natural gas, is replaced as follows:

"Article 92 Renewable gas access to networks and natural gas infrastructure (par. 2 of article 20 of Directive (EU) 2018/2001)

i. The use of natural gas systems and networks distribution of natural gas is also allowed for the trans-movement of renewable gases, included of biomethane, as well as other gases, if this is

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possible, from a technical point of view, and the pre-security clearances, after taking into account the requirements quality and physicochemical characteristics of these gases.

ii. For the implementation of par. 1, its powers Waste, Energy and Water Regulatory Authority and System and Network Administrators natural gas markets also extend to renewables gases, including biomethane, as well and in other compatible gases, for their movement, with use of Natural Gas Systems and Distribution Networks of Natural Gas, as well as for operational issues of the natural gas market, including amending the relevant regulations and of context.

iii. Article 70 also applies to trafficking renewable gases, as well as other gases, through Issue A' 78/28.03.2023 GOVERNMENT GAZETTE 3923 Natural Gas Systems or Natural Gas Distribution Networks of Gas, and through infrastructures connected to them renewable gases or other gases or exclusive of Renewable Gas Systems and Networks. The decisions phases issued in accordance with article 70, they receive requirements for quality, smell and the gas pressure, as specified in the relevant provisions.

iv. The competent Natural Gas System Managers rio or Natural Gas Distribution Networks publish the connection tariffs for renewable gas injection, as well as other gases, with the relevant physical infrastructures of gas, which are based on objective, different and impartial criteria, in accordance with Article 88.

A note here that in all biogas plants in Greece the biogas produced is not upgraded to biomethane.

4.3.4 Regulatory and barriers assessment

In Greece there is lack of legislative and regulatory framework and adoption of legislation (both primary and secondary) for the seamless and efficient utilization of renewable biomethane sources, for removing potential barriers and providing appropriate financial incentives to interested investors through the established support regime. The interventions will concern:

- .Lack of balanced energy cost of biomethane and other incentives to investors.
- Lack of biomass market
- Lack of gate fee
- Lack of supply chain of biogas/biomethane
- out of the 78 biogas units operating in Greece only 38 units are in close proximity to the natural gas distribution network
- difficulties in collecting raw materials (biomass), small units, long distances
- Determination of lighthouse areas and renewable go-to areas for the installation of biomethane production stations at a short distance from the biomass production sites and biomethane injection into the PV distribution networks, in order to limit the biomass storage needs as well as the costs and losses during transport.
- Priority in the use of biomethane in the distribution networks in relation to the NG.
- Lower charge to end users in relation to the price of natural gas

4.3.5 Sources

[1] GAS FOR CLIMATE –JULY 2022

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Chapter 5: Latvia

5.1 The biomethane market

5.1.1 Introduction

Biomethane, a renewable and sustainable form of energy, holds tremendous potential in contributing to a cleaner and greener future. In recent years, the utilization of biomethane has gained considerable attention globally, offering a viable alternative to conventional fossil fuels. However, in Latvia, the development of the biomethane market remains at a nascent stage, with limited progress observed thus far.

As of 2022, Latvia boasts a total of 49 operational biogas plants, which predominantly focus on producing biogas for electricity generation and heat. While these biogas plants play a crucial role in utilizing organic waste to produce energy, only a solitary facility currently produces biomethane. This notable disparity highlights the existing gap in harnessing the full potential of biomethane as a valuable energy resource within the country.

Despite the growing recognition of biomethane's environmental benefits and its potential to reduce greenhouse gas emissions, Latvia has yet to witness significant initiatives aimed at the development and promotion of the biomethane market. The absence of specific policies, incentives, and regulatory frameworks catering to biomethane production and utilization poses a significant hurdle in realizing its true potential.

5.1.2 Current status of biomethane in the national context

The development of biomethane as a sustainable energy resource in Latvia is currently at a rudimentary stage, with only one operational biomethane plant in the country. Unlike some other countries, Latvia lacks a comprehensive Feed-in Tariff (FiT) and Guarantee of Origin (GoO) system specifically designed for biomethane production and consumption. Consequently, the existing biomethane plant primarily produces biomethane for its own use as a transport fuel, while broader incentives for biomethane remain absent within the country.

It is worth noting that between 2007 and 2012, operators involved in biogas production could apply for FiT subsidies for electricity generation from renewable energy sources (RES). However, due to the adverse economic and social effects of increased electricity costs, these subsidies are gradually being phased out, however, only one plant remains operational within the FiT system. This transition away from FiT subsidies for biogas electricity production has had implications for the biomethane sector in Latvia.

Currently, Latvia does not have a comprehensive biogas and biomethane strategy in place. To assess the potential impact of national plans on biogas and biomethane production and consumption, it is necessary to review Latvia's sustainable development strategy, nationally defined bioeconomic principles, and waste management plans. The strategies being analyzed include the National Energy and Climate Plan, the Sustainable Development Strategy of Latvia until 2030, the Latvian National

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Waste Management Plan 2021-2028, and the Guidelines for the Development of the Transport System for 2021-2027.

Latvia has set goals to increase the share of renewable energy sources (RES) in the transport sector by 7% by 2030, as outlined in its plans under the Renewable Energy Directive II (RED II). To achieve this target, Latvia aims to enhance the utilization of advanced biofuels and biogas, with biomethane expected to account for at least 3-5% of the total transport energy consumption by 2030. Additionally, the use of electricity in the transport sector will be increased.

According to RED II plans, Latvia intends to ensure that the share of advanced biofuels in the transport sector reaches a minimum of 0.2% in 2022, progressively increasing to 3.5% by 2030. The National Energy and Climate Plan (NECP) outlines a specific goal for biomethane utilization, aiming to increase its use from the current level of 0.73 PJ to 1.56 PJ by 2030. However, these estimates are indicative and can also be achieved by increasing the share of advanced biofuels. It should be noted that other options may be less cost-effective, making the promotion of biomethane utilization a financially attractive strategy.

The regulatory framework pertaining to biomethane in Latvia is currently undergoing substantial revisions. Despite the transport sector being one of the major contributors to greenhouse gas (GHG) emissions in the country, the development of the Law on Transport Energy in 2022 was still in progress.

In conclusion, the status of biomethane in Latvia presents both challenges and opportunities. While there is currently only one operational biomethane plant and no specific incentives for biomethane production and consumption, Latvia's national plans demonstrate a commitment to increasing the use of biomethane and advanced biofuels in the transport sector. By strategically promoting the use of biomethane and implementing supportive policies and regulations, Latvia can make significant progress toward a more sustainable and environmentally friendly energy landscape.

5.1.3 Public acceptance

Awareness and education campaigns should be conducted to increase public and stakeholder understanding of the benefits of biomethane and its role in achieving sustainable energy goals. This includes highlighting the environmental advantages, such as reduced greenhouse gas emissions and waste management benefits, as well as promoting the economic and social benefits associated with a thriving biomethane industry.

5.2 Production routes

5.2.1 Feedstock potential assessment

In Latvia, the predominant practice among biogas plant operators involves utilizing self-produced feedstock, consisting of crop residues and animal manure. Nonetheless, there have been plants where feedstock is sourced from neighboring farms and supplied to biogas plants through long-term contracts, employing volume-based pricing mechanisms.

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Table 5-1 presents the estimated biomethane potential calculations for dairy cow, poultry, and pig manure. The table reveals that the largest share, accounting for 61% based on Table 5-1, is attributed to the assumptive biomethane potential calculation of dairy cow manure, followed by poultry manure potential at 22%, and finally, pig manure potential. The overall potential biogas yield from poultry and pig manure ranges from 94 to 182 million m3, with a methane content of 60%. Additionally, the dairy cow manure potential is estimated to contribute to the production of approximately 113 million m3 of biogas, representing 61% of the total. The calculated biomethane potential based on these calculations falls within the range of 2.0 to 3.9 PJ.

Table 5-1: Calculation Summary of Biomethane Potential of Livestock Manure [3]

	Biogas Yield, m^3 (60% CH_4)		Biomethane Yield, m^3 (97% CH_4)		Biomethane Potential, GWh		Biomethane Potential, PJ	
	Min	Max	Min	Max	Min	Max	Min	Max
Dairy cow	56,563,353	113,126,706	34,987,641	69,975,282	337	675	1.213	2.430
Poultry	21,384,180	36,988,852	13,227,328	22,879,702	128	221	0.461	0.796
Pig	15,809,154	31,618,308	9,778,858	19,557,716	94	189	0.338	0.680
Total	93,756,687	181,733,866	57,993,827	112,412,700	559	1 084	2.012	3.902
Average	137,745,277		85,203,264		822		2.958	

To obtain a comprehensive understanding of the biomethane potential in Latvia, it is beneficial to analyze different waste groups individually. Table 5-2 presents a summary of calculations depicting the overall biomethane potential. By combining the three waste groups, it is estimated that a biomethane potential ranging from 2.21 to 4.28 PJ can be achieved if all the waste is processed into biomethane.

A significant portion of this overall potential, approximately 91%, is attributed to the processing of livestock manure. In contrast, the processing of wastewater sludge and municipal organic food waste yields a relatively lower energy output, contributing only 0.079 to 0.265 PJ and 0.113 PJ, respectively. However, it is important to note that considering the increasing costs of landfills and the imperative to control greenhouse gas emissions, the processing of these waste streams becomes not only effective but also necessary for a sustainable future.

Table 5-2: Calculation Summary for Overall Biomethane Potential

	Biogas Yield, m^3 (60% CH_4)		Biomethane Yield, m^3 (97% CH_4)		Biomethane Potential, GWh		Biomethane Potential, PJ	
	Min	Max	Min	Max	Min	Max	Min	Max
Livestock manure	93,756,687	181,733,866	57,993,827	112,412,700	559	1,084	2.013	3.902
Wastewater sludge	3,822,190	11,466,569	2,285,433	6,856,299	22.04	73.49	0.079	0.265
Municipal organic food waste	5,274,876		3,262,810		31.46		0.113	
Total	102,853,753	193,200,435	63,542,070	119,268,999	613	1.189	2.211	4.280
Average	148,027,094		91,405,535		901		3.243	

[3] Argalis, P.P.; Vegere, K. Perspective Biomethane Potential and Its Utilization in the Transport Sector in the Current Situation of Latvia. *Sustainability* **2021**, *13*, 7827. https://doi.org/10.3390/su13147827

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The emission intensity of biomethane production is primarily determined by the type of feedstock used, both during its cultivation and processing phases. Emissions occurring at various points in the value chain also contribute to emission intensity, although their impact is generally less significant compared to feedstock type.

The EU regulation identifies three main feedstock types:

1. Energy crops, represented by maize silage.
2. Agricultural waste, represented by feedlot manure.
3. Municipal organic and agro-industrial waste, represented by biowastes.

It is important to note that a higher proportion of manure as feedstock is beneficial in terms of reducing GHG intensity. The analysis aims to demonstrate that a high reliance on energy crops for biogas and biomethane production is disadvantageous in terms of GHG savings. In certain cases, this can lead to non-compliance with the targets set by the Renewable Energy Directive II (RED II). Conversely, the analysis reveals that a greater utilization of manure and waste as feedstock results in lower emission intensity.

The introduction of sustainable feedstock sourcing criteria for biofuels serves two primary purposes:

1. Avoiding GHG emissions by minimizing the risk of indirect land-use change (ILUC).
2. Protecting biodiversity by restricting the sourcing of sustainable feedstock from primary, highly biodiverse, and protected forests and grasslands.

5.2.2 Natural gas grid infrastructure and future prospect

Natural gas grid infrastructure

The distribution of the Latvian gas system primarily serves the largest cities in the country, providing approximately 45% of households with access to the central natural gas network. Among the 49 operational biogas plants in Latvia, only 10 plants have the potential for direct connection to the gas grid due to their reasonable proximity to the existing infrastructure.

Biomethane has the capability to be injected into both transmission and distribution systems. However, challenges may arise when connecting to the transmission system, particularly in meeting the requirement for an allowable oxygen volume of ≤0.02% for international pipelines. On the other hand, the limiting factor for injection into the distribution system is the consumption capacity of the existing infrastructure.

Currently, all costs associated with the connection to the gas grid are borne by the biomethane producer, as there are no specific exemptions or incentives provided for biomethane plants. The installation of connection points is impeded by the lack of a holistic approach to infrastructure development in rural areas, which can hinder the progress of biomethane integration.

To address these challenges, the Transmission System Operator (TSO) has proposed a potential solution for integrating biomethane into the gas transmission system. This solution involves the establishment of specially designed biomethane input points that can receive biomethane deliveries

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through mobile devices such as Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG) systems. However, the realization of this solution requires significant amendments to the regulatory framework governing biomethane integration in Latvia.

The limited development of grid infrastructure in rural regions of Latvia poses challenges for the integration of biomethane into the distribution gas pipeline system. The most favourable prospects for introducing biomethane lie within the domains of major cities where the natural gas distribution system is well-established. However, while the connection costs for installing injection points in larger cities may be comparatively lower, the potential hurdle arises from inadequate local gas consumption, which could deter the installation of new producer connection points. Therefore, it is imperative to conduct a thorough assessment of the average gas consumption in specific areas before proceeding with the application for new connection point installation.

The development of reverse flow systems between the Transmission System Operator (TSO) and the Distribution System Operator (DSO) holds significant importance in facilitating the efficient integration of biomethane into the gas infrastructure. These reverse flow systems enable the bi-directional flow of gas, allowing for the injection of biomethane into the distribution system and its injection into the existing transmission system network. Investment and support for virtual pipeline solutions are strongly recommended to enhance the flexibility and accessibility of biomethane transportation.

Future prospects

To ensure the optimal integration of biogas stations into the existing gas infrastructure, it is imperative to attain a minimum of 80% connectivity. This level of connectivity is crucial for maximizing the utilization and distribution of biogas resources throughout the gas network. By achieving such a high connection rate, the potential of biogas as a renewable energy source can be fully harnessed, leading to significant environmental and energy security benefits.

The connectivity of biogas stations to the gas infrastructure facilitates the injection of biogas into the grid, allowing for its seamless transmission and distribution to end-users. This interconnectedness enhances the flexibility and reliability of the gas system, enabling a more efficient and sustainable utilization of biogas resources. Furthermore, the integration of biogas stations with the existing gas infrastructure supports the decarbonization efforts by displacing fossil fuel-based natural gas and reducing greenhouse gas emissions.

To achieve the target of at least 80% connectivity, it is essential to prioritize and invest in the necessary infrastructure upgrades and expansion. This includes the installation of appropriate connection points, ensuring compatibility and compliance with technical and safety requirements. Additionally, supportive policies and incentives can play a significant role in encouraging biogas producers to connect their stations to the gas infrastructure.

5.3 Regulatory framework and supportive policies

5.3.1 Vision and targets

National strategy and national plan

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To foster the development of the biomethane market in Latvia, several strategies and measures should be implemented. First and foremost, it is crucial to establish ambitious targets for biomethane utilization in the transport and heat sectors, with a focus on replacing natural gas. Setting high targets will provide a clear direction and incentive for market growth and encourage investment in biomethane production facilities.

In order to achieve these targets, supportive policies and regulatory frameworks should be put in place. This includes developing comprehensive roadmaps that outline the planned changes in the regulatory and legislative landscape, along with short-, medium-, and long-term production targets. These roadmaps should be binding and serve as a guiding framework for the biomethane industry.

Incentives and subsidies specifically tailored to biomethane production should be introduced. Currently, Latvia primarily subsidizes electricity production from biogas, but additional support measures are needed to incentivize biomethane production. This could include financial incentives, grants, or tax breaks to attract investments and support the conversion of existing biogas facilities into biomethane production plants.

To facilitate the growth of the biomethane market, the development of an efficient and reliable supply chain is crucial. This involves improving the availability and accessibility of feedstock, particularly agricultural waste and biowaste. Encouraging collaboration and partnerships between feedstock owners, farmers, and biomethane producers can help overcome the challenges posed by feedstock fragmentation and ensure a stable and sufficient supply.

Investments should be made in the expansion and upgrade of the gas grid infrastructure, especially in rural areas, to enable the injection and distribution of biomethane. This includes developing reverse flow systems between the transmission system operator (TSO) and distribution system operator (DSO), as well as supporting the establishment of virtual pipelines to extend the reach of biomethane to areas where direct grid connections are not feasible.

Furthermore, the establishment of a robust trading system for biomethane, including certification mechanisms and a national registry, is essential. This will provide transparency, traceability, and credibility to the biomethane market, enabling cross-border trading and facilitating the recognition of biomethane as a valuable energy commodity.

By implementing these strategies and measures, Latvia can create a conducive environment for the development of its biomethane market, leading to increased production, utilization, and the eventual replacement of natural gas with a renewable and sustainable energy source.

Targets for biomethane production and consumption

Currently, Latvia does not have a comprehensive biogas and biomethane strategy in place. To assess the potential impact of national plans on biogas and biomethane production and consumption, it is necessary to review Latvia's sustainable development strategy, nationally defined bioeconomic principles, and waste management plans. The strategies being analyzed include the National Energy and Climate Plan, the Sustainable Development Strategy of Latvia until 2030, the Latvian National Waste Management Plan 2021-2028, and the Guidelines for the Development of the Transport System for 2021-2027.

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The promotion of biomethane development necessitates the establishment of production targets. In line with this objective, the Latvian Biogas Association advocates for a biomethane production capacity of 0.68 TWh by 2030. This target takes into consideration both the existing production capacity and potential future expansion.

To attain this desired capacity, the following measures need to be implemented:

1. Enhance the involvement of public procurement and local governments as catalysts in initiating the development of the biomethane market.
2. Strengthen the legal framework pertaining to nutrient recovery, encompassing responsibilities, rights, and incentives.
3. Enhance the accessibility of biogas and biomethane in the transport sector, potentially through the implementation of guarantees of origin and sustainability certificates.
4. Adjust the procurement support for heavy transport and municipal public transport vehicles, incorporating the obligation to utilize biogas during the initial years.
5. Foster an increased demand for biomethane for industrial applications.

By implementing these actions, it is anticipated that the target biomethane production capacity can be effectively pursued and realized in Latvia.

5.3.2 Regulatory and barriers assessment

The barriers affecting the biomethane market in Latvia are diverse and significant, exerting a notable influence on the sector. Key issues impeding biomethane production and consumption in the country can be categorized as follows:

National policies:

- The absence of well-defined roadmaps outlining planned regulatory and legislative changes, along with short-, medium-, and long-term biomethane production targets, creates uncertainty and risks hindering the country's ability to achieve EU targets.
- National goals regarding biogas/biomethane production lack ambition and are non-binding, which diminishes their effectiveness as incentives.
- Biomethane prioritization in the context of minimizing public resistance, particularly in sectors such as Latvian State Roads, is lacking.
- The Transport Energy law is not yet in legal force, and full transposition of RED II into national legislation is pending.

Available incentives:

- Latvia currently lacks incentives specifically supporting biomethane or biogas production, with only electricity production from biogas being subsidized (though this support measure is scheduled for phasing out by 2025). Urgent action is needed to promote the conversion of

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existing biogas facilities to biomethane, as many stations have already ceased operations, and a wave of bankruptcies looms.

- Biomethane is not adequately promoted in the transport sector, primarily due to the absence of relevant legislation.

Feedstock availability:

- Latvia's major feedstock potential, such as manure and plant residues, is closely tied to agricultural activities. However, the agricultural sector is fragmented, characterized by numerous small farms. This fragmentation poses a challenge as economically viable biomethane production often requires volumes of feedstock that single feedstock owners cannot provide. The fragmented availability of agricultural feedstock results in additional operational costs for potential producers who must collect feedstock from multiple sources (distances greater than 50 km are considered economically unviable).
- Insufficient biowaste management practices limit the utilization of available feedstock. Currently, only five out of 47 plants in Latvia produce biogas from food waste. Slow progress in establishing the necessary infrastructure for biowaste recycling, which is expected to be completed by the end of 2023, hampers the development of an effective biowaste collection system.
- There is a significant bureaucratic burden associated with using feedstock mixtures for biogas production.
- Non-fixed short-term contracts with feedstock providers are prevalent, leading to financial challenges for plants when suppliers fail to deliver substrates.

Connection to the grid and seasonality of consumption:

- Challenges related to oxygen volume limits (≤0.02% for international pipelines) may arise when connecting to the transmission system. In the distribution system, the limiting factor is consumption capacity.
- The connection process to the gas grid is costly, with no existing incentives for biomethane producers.
- Support for connection installation is lacking, and there is a dearth of regulatory frameworks for building input points.

Trading systems:

- Latvia has not yet established a certification mechanism or national registry for biogas/biomethane. As stipulated by amendments to the Energy Law in 2022, Latvian gas TSO Conexus is expected to become the issuing body and registry administrator for guarantees of origin by July 2023. Cross-border trading of guarantees of origin is crucial for the development of biomethane production in Latvia, as potential bio-premiums derived from certificate trading can ensure the economic viability of biomethane businesses. However, in some countries, proof of sustainability is sufficient.

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- Uncertainty exists regarding the accounting of injected biomethane.

5.3.3 **Sources**

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Chapter 6: Poland

6.1 The biomethane market

6.1.1 Introduction

Natural gas makes 17% of the total energy supply of Poland, out of which 84% (16.9 bcm) is imported. Poland has ability to replace about 20% of current natural gas imports with biomethane which would be beneficial for both energy security and GHG emission reduction from energy sector. Industry estimates Poland's sustainable biomethane potential as 3.3 bcm (3.1 bcm from AD and 0.2 from gasification) by 2030. Considering the potential, Poland could be among the top 5 biomethane markets the EU27 with strong impact on the national market.

6.1.2 Current status of biomethane in the national context

Presently, **there is no biomethane production** in Poland. There are over a dozen projects ready for implementation (at least 3 in final stage), but investors are waiting for the legislation and the support system. PSG (Polish OSD) has received more than 100 applications for biogas connection to its distribution network. ORLEN Group is planning to produce 1 billion cubic meters of biogas (the equivalent of about 0.65 bcm of biomethane) in modern biogas plants till 2030.

Three types of **biogas installations** are distinguished in Poland: agricultural biogas plants, biogas plants operating at sewage treatment plants or landfills (using sewage sludge or landfill gas for biogas production) and biogas plants producing energy from mixed substrates (in that wastes). The current installed capacity of biogas installations is ca. 300 MW (154,987 MW agricultural biogas plants on 19th December 2023[4]).

Definition of agricultural biogas is given in RES Act; an agricultural biogas producer is required to use only substrates listed in the definition of agricultural biogas. (Article 2(2) of the RES Act).

At the end of 2023, there were **383 biogas installations** in PL with installed capacity of ca. 300 MWe, of which 168 were agricultural biogas plants.

In Poland in agriculture sector mainly mesophilic fermentation is carried out (32–42 °C); only in few agricultural biogas plants biogas is obtained through thermophilic fermentation (50–57 °C).

6.1.3 Public acceptance

Lack of knowledge in the society about the importance, potential and environmental and economic impact of this type of plant is causing protests against building of biogas plants in several locations.

[4] www.kowr.gov.pl *KOWR (National Center for Agricultural Support)*

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101075676.

6.2 Production routes

6.2.1 Feedstock potential assessment

Currently, Polish agricultural biogas plants commonly use a mixture of several substrates, in a process called co-digestion. The waste material going to the biogas plant must not at any stage mix with other wastes than those resulting from the production profile.

In 2022 over **5,7 million tons** of raw materials[5] were used to produce agricultural biogas. The most important substrate was waste from distilleries (18,8 %), followed by manure & slurry (16,4 %), fruit and vegetable residues (15 %). Other substrates include e.g. sugar beet pulp and expired foods.

In Poland price of dedicated crops and changes in legislation stressing sustainability issues reduced significantly usage of purpose-grown biomass like maize.

In 2019 amendment of BIO Act (**19-07-2019)** introduced new biofuels – biomethane and biohydrogen for fulfillment of national indicative target (NIT[6]), so list of substrates from Annex 1 also refers to biomethane as transport fuel.

The use of waste imposes obligations on biogas installations under the Waste Law (Dz.U. 2021 item 779). Applying for a waste processing permit is obligatory for biogas plant. This is a decision issued by a competent public administration authority, which contains information on what waste codes the installation can process.

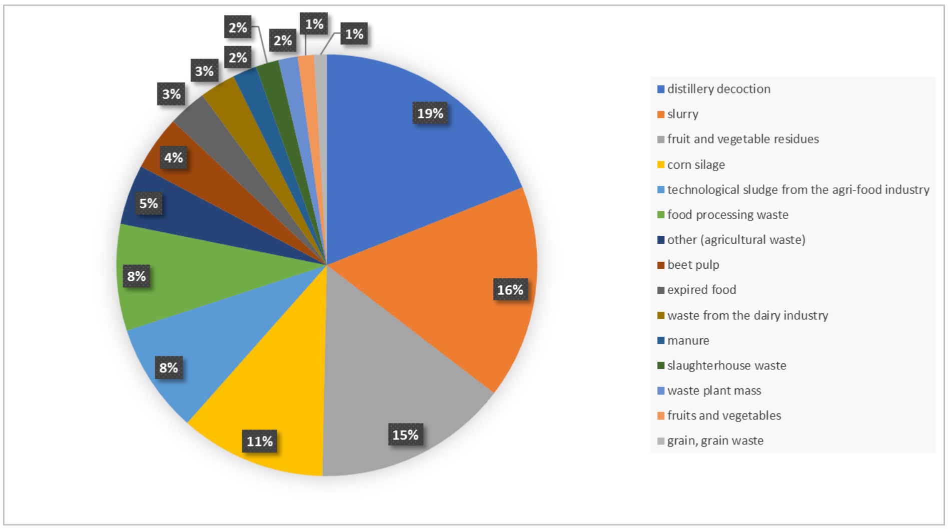

Figure 6-1. Feedstock contribution to biomethane production in Latvia

[5] www.kowr.gov.pl

[6] **National Indicative Target (NIT, in Polish NCW)** - the minimum share of other renewable fuels and biocomponents contained in fuels used in all types of transport in the total amount of liquid fuels and liquid biofuels used during the calendar year in road and rail transport, calculated according to the calorific value.

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Poland has a large potential resulting e.g. from agri-food industry, the main supplier of the substrates for biogas plants (Figure 6-1). In addition, activating the society towards the selective collection of the biodegradable fraction of municipal waste may affect the rapid and intensive development of the market.

According to Gas for Climate[7] report "Biomethane production potentials in the EU" **Poland with estimated potential over 3 bcm/year is the 5th biomethane production potential in Europe in 2030** (Figure 6-2).

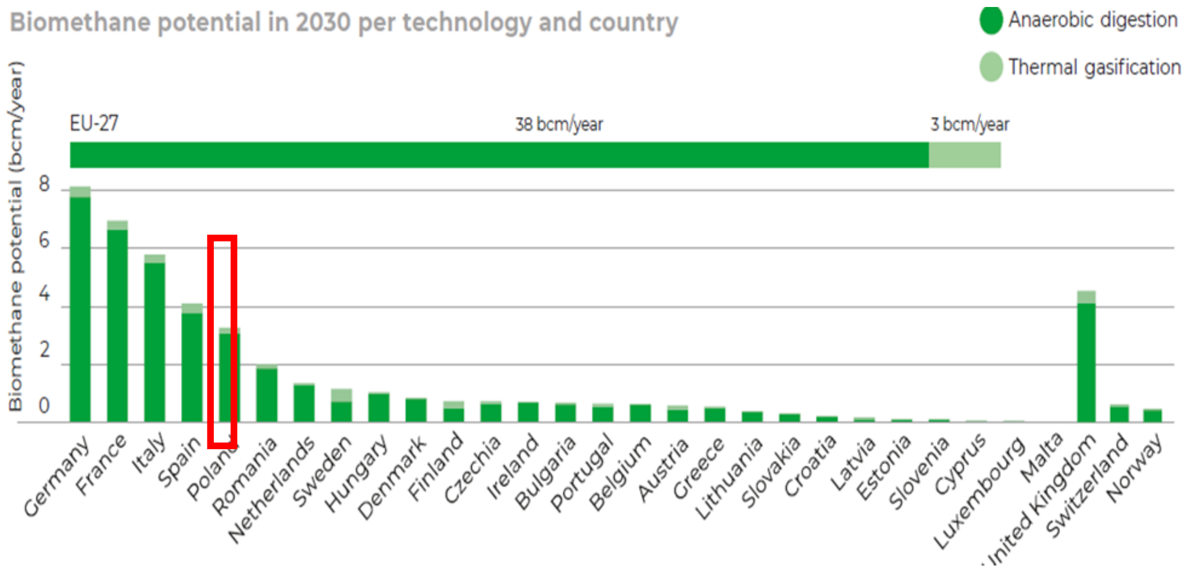

Figure 6-2. Biomethane potential in 2030 in Poland (Gas for Climate report 2022)

6.2.2 Natural gas grid infrastructure and future prospect

At the end of 2021, the gas network in Poland reached a length of about 165.7 thousand kilometers, while the number of connections to buildings was about 3,285 thousand units. Compared to the previous year, the length of the gas network increased by about 3.6 thousand kilometers (2.2%), while the number of connections to buildings increased by about 126 thousand units. (4,0%)[8].

[7] www.gasforclimate2050.eu Gas for Climate report July 2022
[8] www.stat.gov.pl Gospodarka energetyczna i gazownictwo w 2021 r.

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101075676.

6.3 Regulatory framework and supportive policies

6.3.1 Vision and targets

National strategy and national plan

In Poland one of the most important strategic document setting the policy framework is the Energy Policy of Poland until 2040 (PEP2040)[9], adopted by the Council of Ministers in February 2021. According to PEP2040, the share of renewable energy sources in the gross final energy consumption in 2030 is expected to reach at least 23%, whereas GHG emissions are to be reduced by ca. 30% (compared to 1990). The biogas sector will be playing an important part in increasing the flexibility of the new system as a means of gas storage, thereby increasing Poland's energy security. According to the this document 10% of gaseous fuels transported via gas grids should be renewable and low-emission ones in 2030. Actually amendment of PEP 2040 is under preparation. According to an update to Poland's Energy Policy, in 2040, about 73 percent of electricity will come from renewable sources and nuclear power.[10] Regarding biogas and biomass, the head of the Ministry of Climate and Environment communicated that a capacity of 2.5 GW is expected in 2030, and in 2040 - 3.4 GW.

Targets for biomethane production and consumption

VISION[11]

- In **2030**, **0.7** to **1 billion m3** of biomethane (as an advanced fuel produced from the raw materials listed in Appendix 1 to the Act on bio-components and liquid biofuels) in transport could be produced, as part of the implementation of RED II targets applicable as bioCNG, bioLNG and component for bio-hydrogen production.

- More specifically:

  2030 targets:

  - **10%** biomethane share in the gaseous fuels market, with a **100** biomethane installations.

  2050 targets:

  - **30%** share of biomethane in the gaseous fuels market, with **300** biomethane installations.

To achieve goals defined in the vision, cooperation among all market participants is needed, i.e., the regulator, ministries, politicians, state-owned companies, system operators, energy companies, local governments, and consumers, as well as entities interested in the production of biomethane.

[9] https://www.gov.pl/web/klimat/polityka-energetyczna-polski
[10] https://www.money.pl/gospodarka/polityka-energetyczna-polski-73-proc-energii-elektrycznej-bedzie-pochodzic-z-oze-i-atomu-6883382351494048a.html

[11] Based on REGATRACE D6.2 www.regatrace.eu

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101075676.

„**Agreement on cooperation for the development of the biogas and biomethane sector**" was signed in November 2021. Now in Poland there are 8 working groups formed by Ministry of Climate within this Sector Deal; national group of biomethane stakeholders in Poland increased significantly cooperation by discussing on vision and roadmap of biomethane sector development[12].

6.3.2 Financial support

Financial support for renewable energy projects (in that biogas and biomethane) is possible under various structural funds and EU programs such as:

I. European Funds "Infrastructure, Climate and Environment" (FENIKS)

- National level focus

- Budget: €25 billion, of which the Energy and Environment priority is €8.8 billion

- Support for renewable energy production:

- Installations for the production of electricity and/or heat (e.g., photovoltaic with a capacity of more than 2 MW, **biogas plant with a capacity of more than 1 MW**)

- Installations for the production of alternative fuels from renewable sources

- Electricity grids enabling connection of RES installations

- Support for energy infrastructure and smart solutions, among others:

- **Energy and gas storage**

II. Regional Operational Programs (ROPs)

Only some provinces (from 16) have planned explicitly to support **biomethane development**:

- **European Funds for Kujawy and Pomerania for 2021-2027**

"support for the construction/rebuilding of installations for the production of biomethane (...)"

- **European Funds for Lubelskie 2021-2027**

"project type - construction of installations for the production of bio-liquids and biomethane, biofuels of the second and third generation."

- **European Funds for Lodz 2021-2027**

"Support for infrastructure for the generation of electricity and heat, cooling, biomethane and 2nd and 3rd generation biofuels from renewable sources (...)"

- **European Funds for Swietokrzyskie 2021-2027**

"construction or expansion of installations for the production of electricity from RES, together with connections for the generation of energy from: (...) biogas (renewable hydrogen, biomethane)"

- **European Funds for Pomerania 2021-2027**

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[12] www.gov.pl/web/klimat

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"installations for the purification of biomethane and its injection into the gas grid, as well as projects using biogas (biomethane) to meet energy needs."

- **European Funds for Wielkopolska 2021-2027**

"infrastructure for the generation of electricity and heat, cooling, biomethane (...)"

6.3.3 Direct investment and production support

In Poland main regulation concerning renewable energy sources and agricultural biogas production is Renewable Energy Act **RES Act**[13]. In 2015, Poland's green certificate scheme was introduced by the RES Act. The Act introduced an auction scheme for newly build renewable energy projects from 2016. The Act sets out 5 technology groups (baskets). The third one was dedicated to agricultural biogas while the other biogas categories compete with thermal waste treatment installations and multi-fuel combustion plants in the first basket. The first auctions took place at the end of 2018 and end of 2019.

Auctions for agricultural biogas plants are conducted in a separate pool, in two parallel groups. The first group includes installations up to 1 MW, while the second group includes entities with a capacity above 1 MW.

Biogas plants built or commissioned after 2016 can use: (a) an auction system or (b) the feed-in tariff (FIT) or the feed-in premium (FIP) systems. The most popular solution is currently (b): the feed-in tariff (for small and micro facilities) and the feed-in premium systems, where green energy is sold under contracts with an obligated recipient, which could be a prosumer, an energy cooperative, or an obligated operator. FIP instrument applies to renewable energy sources delivering no less than 500 kWe and no more than 1 MWe. The fixed price (pursuant to Article 70e paragraph 1 of the RES Act):

- in the FIT system is equivalent to 95% of the reference price set for a given calendar year
- in the FIP system is equivalent to 90% of the reference price set for a given calendar year.

The entitlement to have the negative balance covered arises as of the first day on which the produced energy has been fed into the grid and remains valid for 15 years or until 31 December 2035.

Since the size of biogas plants operating under the FiT and FiP systems has been limited in terms of capacity, participation in the auctions is particularly recommended for units with an installed capacity of 2.5 MW or more.

6.3.4 Demand-side incentives

Financial support available for biomethane consumers

- ❑ Act on Excise Duty – zero excise duty for CNG/biomethane, LNG, H2 used as transport fuel

[13] RES Act (Dz.U. 2023 item 1762)

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6.3.5 Regulation enabling injection and trade

1) National Framework for Alternative Fuel Infrastructure Development Policy (*2017)*

- ✓ Definition of alternative fuels including natural gas CNG (biomethane), LNG, LPG, hydrogen etc.
- ✓ Requirements concerning location of alternative fuels infrastructure

2) The Act on electromobility and alternative fuels (*Dz. U. 2020 item 908, 1086*)

The amendment to the Act on Electromobility and Alternative Fuels (introduced on December 2021) mentions that local municipalities, excluding municipalities and counties with a population of less than 50,000, as of December 24, 2021, are required to ensure that the share of zero-emission buses or buses powered by biomethane in the vehicle fleet in use is 5% (in the period from January 1, 2021 to December 31, 2022), 10% (in the period from January 1, 2023 to December 31, 2024) and finally 20% (in the period from January 1, 2025).

Change of definitions in Polish law positive for biomethane:

Alternative fuels : which are substitutes for fuels derived from crude oil or obtained from its processing, in particular hydrogen, liquid biofuels, synthetic and paraffinic fuels, compressed natural gas (CNG), including that from biomethane, liquefied natural gas (LNG), including that from biomethane, or liquefied petroleum gas (LPG).

NGV - a motor vehicle within the meaning of Art. 2 Item 33 of the Act of 20 June 1997- Law on Road Traffic, using compressed natural gas (CNG) or liquefied natural gas (LNG) for propulsion, including those derived from biomethane.

Moreover according to this Act gas system operators are required to provide CNG / LNG refueling points in agglomerations and along the TEN-T (Trans-European Transport Network) corridor. The national framework assumes the operation of subsequent stations: by the end of 2025: - 14 LNG stations and 32 publicly available CNG refueling points along the TEN-T network.

3) Technical and regulatory conditions for access into gas grid:

Parameters of biomethane injected into the gas grid

In 2019 the Gas Chamber's (IGG) published technical guidelines **WT-IGG-3501:2019** "Quality and Technical Requirements for Biomethane Injected into the Distribution Network," which is recommended for use by all companies affiliated with the IGG - currently 1527 entities.

The most important parameters for biomethane are a hydrogen sulfide content of less than 7.0 mg/m3 and a combustion heat of at least 34.0 MJ/m3 (as for E5 natural gas). In practice, the Distribution Grid Operator (OSD) establishes the parameters on the basis of the instruction for operation and exploitation of the distribution network (IRiESD) and submits them to the biogas producer within gas grid connection conditions.

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In July 2022 was published **The ordinance of the Minister of Climate and Environment on the detailed conditions for the operation of the gas system**[14] **.** The document indicates the quality parameters of **gaseous fuels** transmitted through the gas transmission and distribution networks.

The main parameters that are difficult to be fulfilled by biogas plants are:

max. oxygen content - 0.5% [mol/mol], except for gaseous fuels fed into the network;

max. hydrogen content - 0.0% [mol /mol];

max. ammonia content - 2.0 mg/m3.

6.3.6 Regulatory and barriers assessment

AD constrains

- An investment in biogas/biomethane installation is a quite complex process, from the technical, logistic, economic and legal point of view. Depending on the type of biogas as well as the region of location of the future investment, administrative and legal procedures may differ significantly. Each investment requires several permits, decisions and agreements with competent administrative authorities.
- At the beginning of investment process the most important are following formal and legal procedures: 1) land acquisition – decision about location; 2) decision on environmental conditions of approval of a project and 3) building permits. It is followed by obtaining a concession from URE (installations producing other types of biogas than agriculture biogas) or a registration in KOWR (installations producing agriculture biogas) for carrying out a business activity - the generation of energy from renewable sources.
- For the realization of a biomethane project, it is necessary to obtain an environmental decision for an installation with an electrical capacity greater than 500 kW or producing more than 2 million Nm3 of biogas (In accordance with § 3 section 1 item 47 of the Ordinance of the Council of Ministers of September 10, 2019 on projects that may significantly affect the environment (Dz.U. 2019, item 1839).

Legislation concerning biomethane

- **The Act on biocomponents and liquid biofuels** – *amendment* ***19-07-2019*** *introduced new biofuels – biomethane and biohydrogen for fulfillment of national indicative target (NIT)*

2022 - The draft "revision the Act on biocomponents and liquid biofuels and certain other acts" date on ***11.02.2022****:*

[14] Dz.U. 8-09-2022 item1899 https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20220001899

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- addressing the target of 14.8% renewable energy in transport in 2030 by NCW - 10% from biofuels and 4.8% from electricity,
- 3.5% share of advanced biocomponents , including biomethane for transport,
- including the restriction for food and feed raw materials share up to the maximum level of 5.5%,
- adding new energy carriers in NIT: recycled carbon fuels and gaseous biofuels,
- minimum share of biomethane in the NIT realization: 1.75% (for refineries). It is a new obligation to have a specified % of biohydrogen in the total amount of hydrocarbon energy carriers processed imposed on refinery processing entities, with the obligation arising only in 2025 and increasing gradually until 2030.

- **The amendment of the RES Act (2023)** – *introduced changes*

The amendment to the applicable legal acts, i.e. *the Act of February 20, 2015 on renewable energy sources and other acts, i.e. the Act of April 10, 1997 - Energy Law and the Act of August 25, 2006 on biocomponents and liquid biofuels* is the solution and the intervention tool to identified problems with biomethane sector development.

The detailed scope of changes included in **the draft RES Act** stimulating the development of the biomethane sector includes a package of regulations eliminating the barriers, including:

- introduction of a definition of biomethane, and excluding the concept of agricultural biogas from the definition of biogas; in connection with the introduction of the concept of biomethane - changes were also introduced in the Act of April 10, 1997 - Energy Law in the scope of the concept - gas fuel;
- defining the principles of running a business in the field of biogas or biomethane production from biogas - by creating a "register of biogas producers" kept by the President of the Energy Regulatory Office;
- extending the scope of Chapter 3 of the RES Act (rules and conditions for conducting activities in the field of generating electricity from agricultural biogas or bioliquids and producing agricultural biogas or bioliquids) by the principles and conditions of economic activity in the field of producing biomethane from agricultural biogas - Art. 24 of the RES Acts and subsequent ones, in particular the extension of the scope of the subjective register of agricultural biogas producers by biomethane producers from agricultural biogas;
- extending the area of activity of energy cooperatives with the possibility of producing biomethane;
- repealing the provisions on the application for an official confirmation of the incentive effect (Article 47a of the RES Act) and the provisions on the agricultural biogas certificate of origin (Article 48 of the RES Act and subsequent);
- **introducing a support system adapted to the specificity of this technology, technical and economic conditions - feed-in premium (FIP) system for biomethane installations up to 1**

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MW; introduced reference prices for biomethane - PLN 538 per 1 MWh for biomethane from biogas and PLN 545 per 1 MWh for biomethane from agricultural biogas[15]

- **introducing a guarantee of origin for biomethane and extending the scope of the subject register of guarantees of origin to include data on guarantees of origin for biomethane;**
- change of the definition of gaseous fuels in the Energy Law.

Drivers for biomethane use on national market in Poland

- **Actual geopolitical situation (war in Ukraine, gas and energy prices).**
- EU and national climate and energy policy.
- Positive impact on the environment - fitting into a circular economy
- Problem with decarbonisation of transport : difficulties with fulfilment of EU requirements concerning share of RES in transport in RED (10% in 2020) and RED II (advanced biofuels)
- Uncertain support system for "green energy" - the use of biomethane in transport or injection to grid may be an interesting alternative for biogas plants
- Agrofood sector, especially poultry industry (lot of difficult but promising substrates) are interested in use of green gas (both from grid and direct in transport) - reduction of GHG emissions from their production (e.g. green labels)

Barriers:

- Significant delays in the introduction of regulations; lack of support system for larger biomethane installations (> 1 MW)/ Problems with obtaining administrative permissions
- Problems with obtaining conditions for connection to the electricity and gas grids
- Technical problems with the new technology, which has not been serviced in Poland so far
- Termination of acceptance of biomethane into the gas grid in case of minimal quality deviations - disruption of supplies to customers.
- Lack of knowledge in the society about the importance, potential and environmental and economic impact of this type of plant

6.3.7 Sources

www.kowr.gov.pl KOWR (National Center for Agricultural Support) Reports
www.isap.sejm.gov.pl Amendment of RES Act (Dz.U. 2023 item 1762): the amendment to the applicable legal acts, i.e. the Act of February 20, 2015 on renewable energy sources and other acts, i.e. the Act of April 10, 1997 - Energy Law and the Act of August 25, 2006 on biocomponents and liquid biofuels
www.gasforclimate2050.eu Gas for Climate report July 2022

[15] Dz.U. 2023 poz. 2477 https://isap.sejm.gov.pl/ isap.nsf/download.xsp/WDU20230002477/O/D20232477.pdf

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101075676.

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https://energy.ec.europa.eu/system/files/2023-09/Biomethane_fiche_PL_web.pdf
www.gov.pl/web/klimat
https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20220001899 The ordinance of the Minister of Climate and Environment on the detailed conditions for the operation of the gas system

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101075676.

Chapter 7: Spain

7.1 The biomethane market

7.1.1 Current status of biomethane in the national context

In 2022, there were around 250 active biogas plants in Spain. Spain's total biogas production in 2019 roughly amounted to 8,000 GWh (Figure 7-1).

In 2022, there were 5 active biomethane plants in Spain injecting into the gas grid. Spain's total biomethane production in 2022 amounted to 250 GWh. The coming years will be important for the development of the Spanish biomethane sector, all the sector is asking to the Spanish government for approving support mechanisms for renewable gas and its injection into the gas grid. Permitting processes are another bottle neck

Biogas plants in Spain (electricity generation): 250

- Agricultural and livestock waste: 50
- WWTP waste: 80
- Municipal waste: 50
- Other: 70

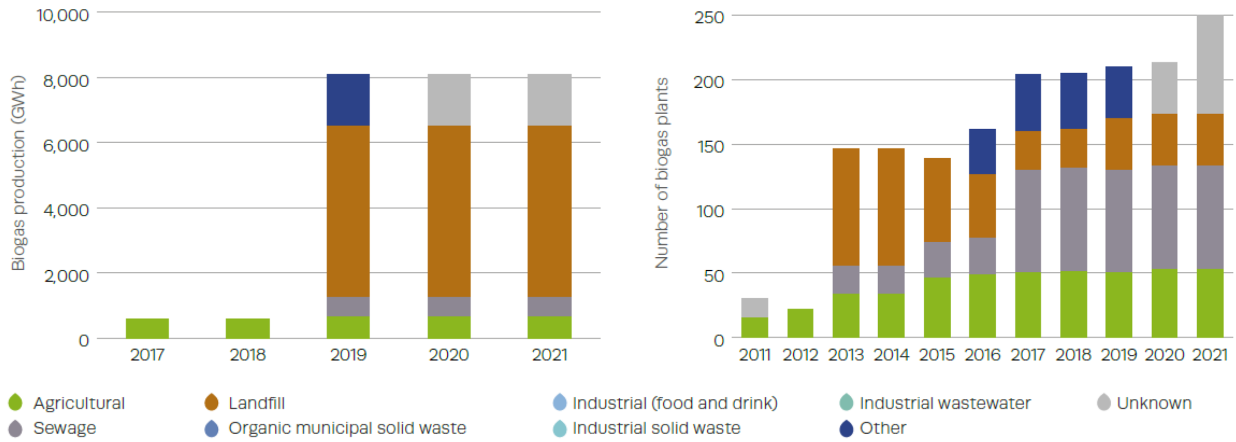

Figure 7-1. Biogas production in Spain

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Biomethane production is depicted in Figure 7-2.

Biomethane plants in Spain (injection into the gas grid): 5

- Valdemingómez (Madrid) – organic municipal solid waste
- Elena (Barcelona) - municipal waste
- Unue (Burgos) - industrial waste
- Torre Santamaría (Lleida) - agro-livestock waste
- Bens (A Coruña) – water waste

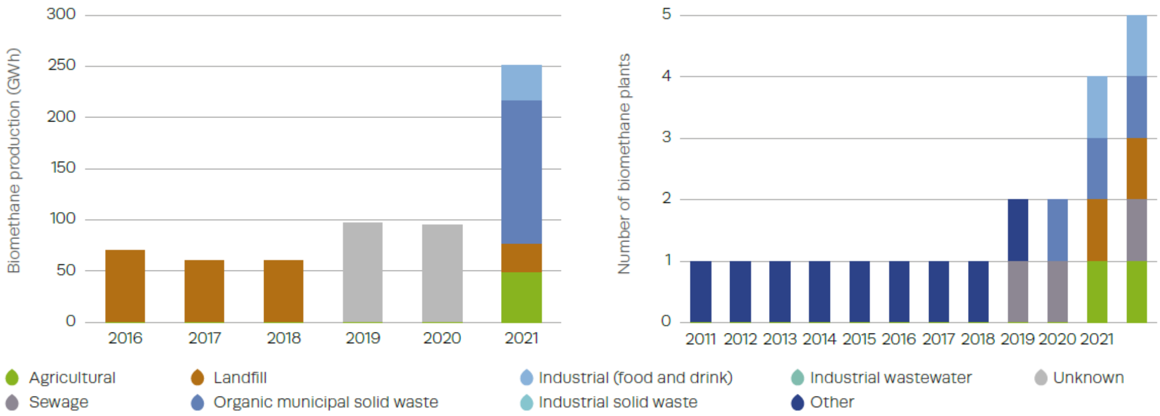

Figure 7-2. Biomethane production in Spain

Market in Spain: Private investments in biomethane production plants with focus in the EU market

7.1.2 **Public acceptance**

Growing social rejection, headed by ecological organizations, mainly against large biomethane projects. First because they are part of intensive livestock, and second for the fact that they will collect "garbage" from surrounding villages to be treated in an specific one.

7.2 Production routes

7.2.1 **Feedstock potential assessment**

According to the EUROPEAN COMMISSION – "STAFF WORKING DOCUMENT: 2023 Country Report – Spain", Spain has high additional potential capacity to produce biomethane by 2030 (approx. 4.1 bcm/year). This would allow Spain to replace approximately 13% of its current natural gas consumption with biomethane. Spain will need to increase its renewable energy target in the updated National Energy and Climate Plan to reflect the more ambitious EU climate and energy targets in the Fit for 55 Package and in the REPowerEU Plan."

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Spain is the 4th biomethane production potential in Europe: 44 TWh (4.1 bcm)

Feedstock	%
• agricultural residues	24%
• sewage sludge	6%
• biological residues	27%
• livestock residues	42%

According to Gas for Climate report "Biomethane production potentials in the EU":

Spain is the 4th biomethane production potential in Europe in 2030: estimated potential over 4 bcm/year

Per technology and country:

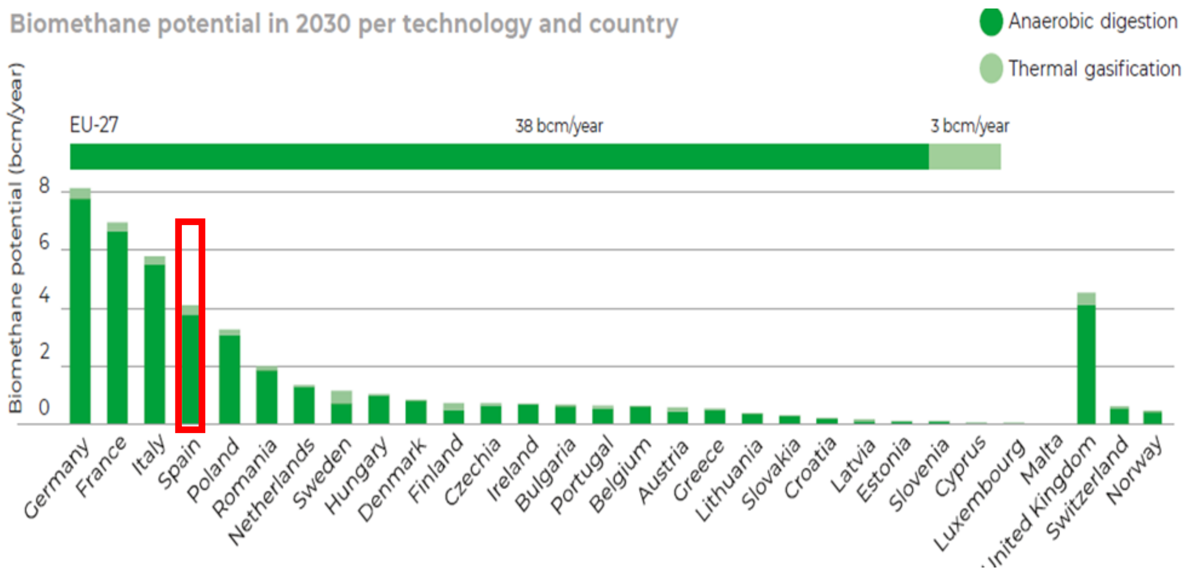

Figure 7-3. Biomethane potential in 2030 in Spain (Gas for Climate report 2022)

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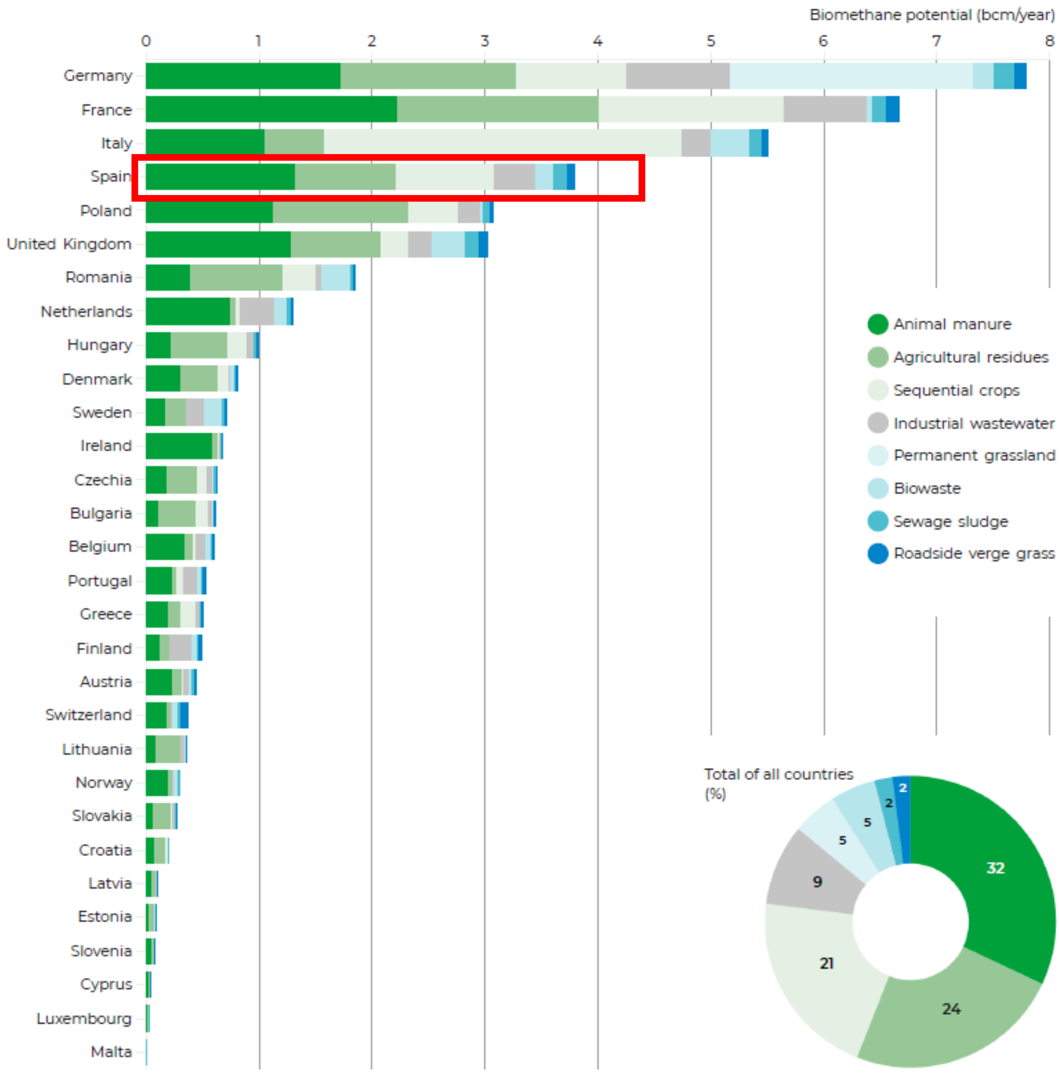

Figure 7-4. Biomethane potential in 2030 in Poland, in terms of feedstock (Gas for Climate report 2022)

7.2.2 Natural gas grid infrastructure and future prospect

Spanish gas grid has a lot of potential, involving more than 100.000 km of gas networks, transmission and distribution grids.

Currently, the manager of a biomethane plant (producer) can request the installation and operation of an injection point in the transmission or distribution system. Based on this request, the network owner carries out a technical-economic study to determine the available injection capacity and the economic valuation of the connection infrastructure (injection unit, connection branch, reverse-flow, etc.). This amount will depend on the flow of biomethane to be injected and the proximity/remoteness of the available network. These costs can represent a barrier for producers.

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The injection of biomethane into Spain's gas network is expected to increase in the coming years (Figure 7-5).

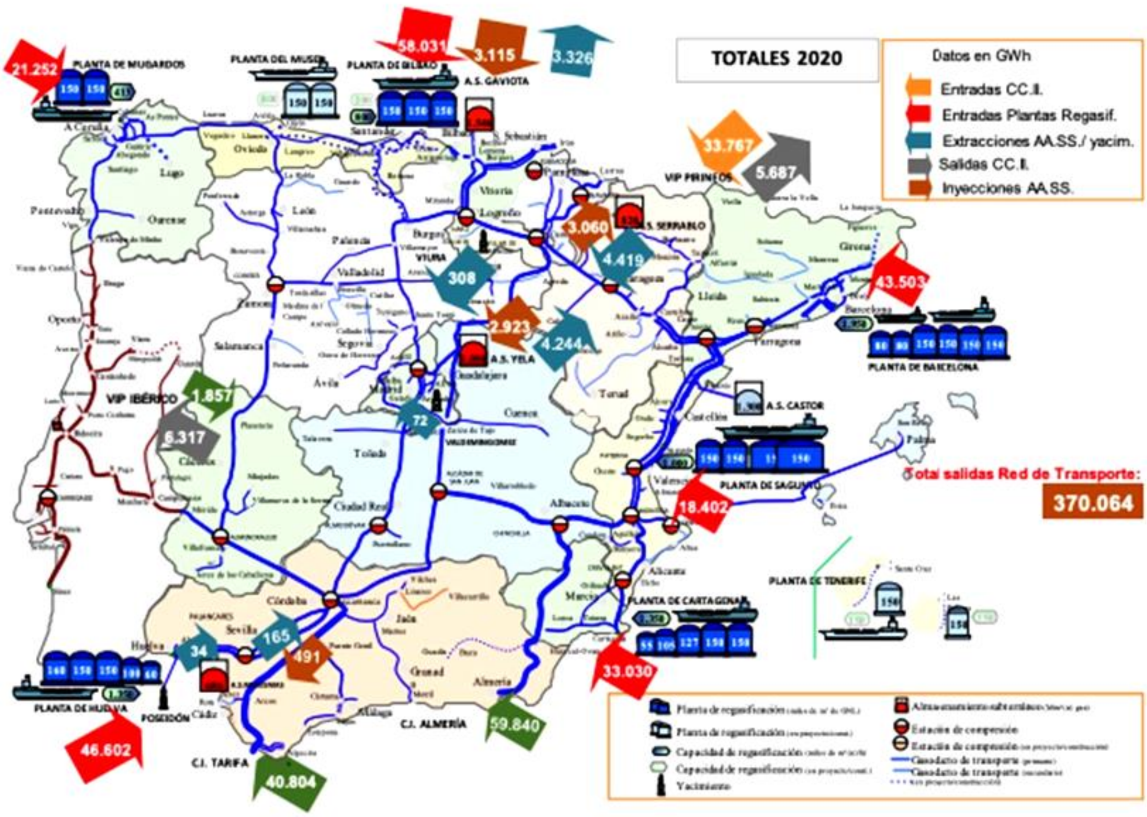

Figure 7-5. Natural gas grid in Spain

7.3 Regulatory framework and supportive policies

7.3.1 Vision and targets

National strategy and national plan

The development of the biogas/biomethane sector has taken place through a combination of basic levers for the development of the biogas/biomethane sector: Circular Economy, Renewable Energy, environmental improvement, waste valorization, demographic challenge, etc.
And additionally, with a corresponding holistic approach within the framework of the European Green Deal.
It is necessary to set biomethane production/consumption targets at national level: binding political decisions.

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The Spanish Ministry biomethane target is established as "minimum" 1% biomethane over gas consumption by 2030. Nevertheless, the sector is waiting for an update of the NECP Spanish plan and consequently a new Biogas Road Map, hoping to have a much more ambitious target, in line with REPowerEU Plan and other European countries.

The Spanish biogas/biomethane sector target, is to reach the following annual biomethane productions/consumptions:

- By 2030: 10% biomethane over gas consumption by 2030

Targets for biomethane production and consumption

The Spanish Ministry biomethane target is established as "minimum" 1% biomethane over gas consumption by 2030.

The Spanish biogas/biomethane sector target, is to reach the following annual biomethane productions/consumptions:

- By 2030: 10% biomethane over gas consumption by 2030
- with a progressive annual compliance: starting targets for 2023 and publishing targets every 2 years with annual detail
- a minimum penalty fee of €100/MWh for non-compliance with the target, updated every 2 years with annual detail
- The Spanish Ministry biomethane target is established as "minimum" 1% biomethane over gas consumption by 2030, which must be increased in the updated NECP (JUL-2023)

7.3.2 Direct investment and production support

The Government of Spain launched an aid plan to finance biogas plants. The call provided for the distribution of 73 million euros.

The incentive program for unique biogas installation projects included in component 7 of the Recovery, Transformation and Resilience Plan (PRTR) has been published by the Institute for Energy Diversification and Saving (IDAE), dependent on the Ministry for Ecological Transition and the Demographic Challenge.

According to the information published on the IDAE website, the selected proposals include biogas production actions through anaerobic digestion, heat production, generation of electrical energy, cogeneration or biomethane production, and treatment of the digestate for agricultural use.

75 Spanish projects that will receive public aid: 28 projects are located in Catalonia, 8 projects in Aragon and 7 projects in Andalusia. Castilla-La Mancha, Castilla y León and Murcia have obtained 5 projects each. Basque Country, Valencian Community and Canary Islands three, Navarra 2, while Asturias, Cantabria, La Rioja, Extremadura, Balearic Islands and the Community of Madrid will only have one subsidized project (Figure 7-6).

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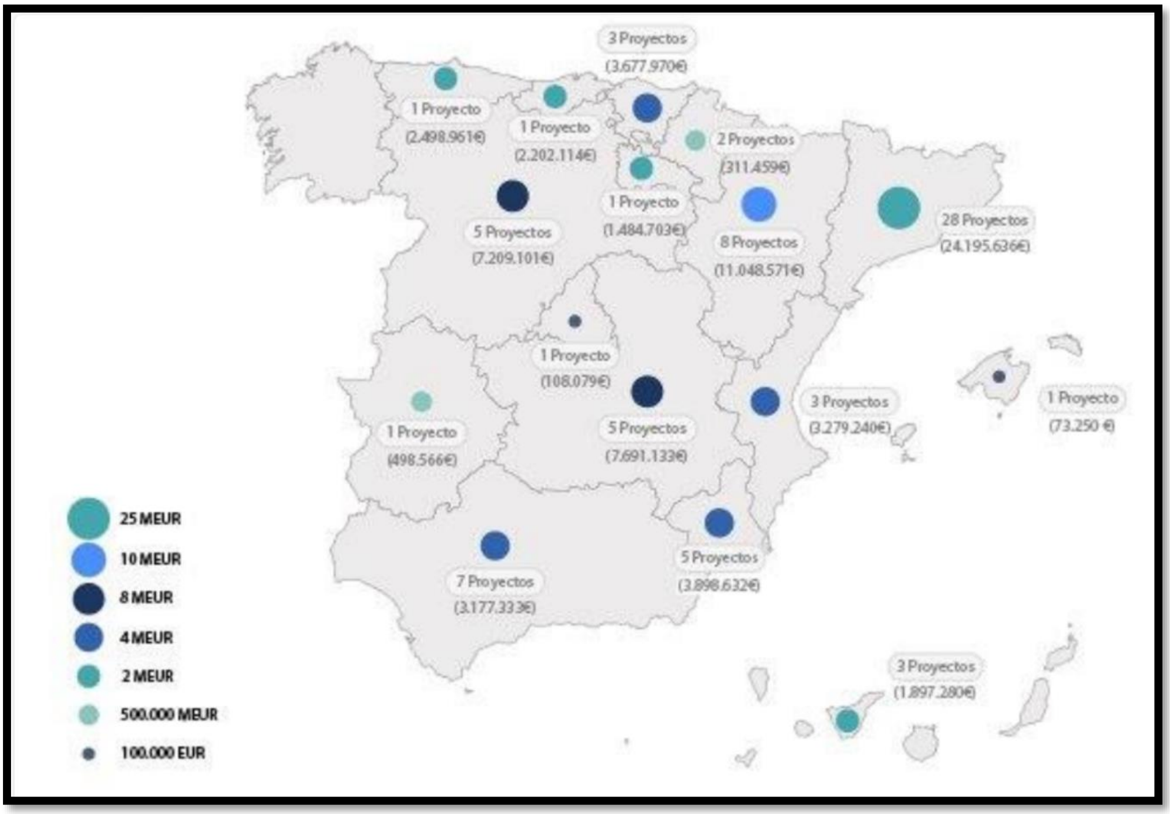

Figure 7-6. Spanish projects receiving public aid

7.3.3 **Indirect investment and production support**

There is currently no plan regarding indirect investment and production support.

Initiatives are being analyzed:

- CO_2: capture, storage and elimination.
- Digestate: normalization of use as fertilizer
- CNG/LNG refueling stations that sell biomethane bioCNG/bioLNG with quick service and open to public access.

7.3.4 **Demand-side incentives**

There is currently no plan regarding demand side incentives.

Initiatives are being analyzed:

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- public transportation companies to promote the use of renewable energy bioCNG/bioLNG: buses, garbage-trucks, freight transport trucks,…
- industries

7.3.5 Regulation enabling injection and trade

Regulatory framework enabling injection into the gas grid has been developed: the State Gazette includes the ENAGAS GTS - Technical Operator of the System norms

Norms of the Technical Operator of the System:

- Quality specifications for gas and permitted quality values (Table 7-1):

Table 7-1. Quality specifications for gas and permitted quality values

Propiedad (*)	Unidad	Mínimo	Máximo
Índice de Wobbe	kWh/m^3	13,403	16,058
PCS	kWh/m^3	10,26	13,26
Densidad relativa		0,555	0,700
S Total	mg/m^3	–	50
H_2S + COS (como S)	mg/m^3	–	15
RSH (como S)	mg/m^3	–	17
O_2	mol %	–	0,01
CO_2	mol %	–	2,5
H_2O (Punto de rocío)	ºC a 70 bar (a)	–	+ 2
HC (Punto de rocío)	ºC a 1-70 bar (a)	–	+ 5

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- Quality specifications for gas from non-conventional sources (biomethane) introduced into the Gas System.

Table 7-2. Quality specifications for gas from non-conventional sources (biomethane) introduced into the Gas System.

Propiedad (*)	Unidad	Mínimo	Máximo
Metano (CH_4)	mol %	~~95~~ 90	–
CO	mol %	–	2
H_2	mol %	–	5
Compuestos Halogenados: - Flúor/Cloro	mg/m³	–	10/1
Amoníaco	mg/m³	–	3
Mercurio	µg/m³	–	1
Siloxanos	mg/m³	–	10
Benceno, Tolueno, Xileno (BTX)	mg/m³	–	500
Microorganismos	–	Técnicamente puro	
Polvo/Partículas	–	Técnicamente puro	

(*) Tabla expresada en las siguientes condiciones de referencia: [0ºC, V(0ºC, 1,01325 bar)]

Certification of biomethane is set in place well by ENAGAS GTS - Technical Operator of the System, just under development.

7.3.6 Regulatory and barriers assessment

Policies based on an outdated **National Energy And Climate Plan**: legal uncertainty for the development of projects:

- unambitious targets
- minor developments
- financial support not aligned with EC
- GoO systems still to be implemented
- Too complex and slow permitting processes, due to high atomization of delegation of competences and lack of skills of civil servants in charge of.

Main barriers for the development of the biogas/biomethane market in Spain

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- Lack of:
  - stable regulatory framework
  - incentives for biogas upgrading infrastructures and biomethane injection infrastructures
  - waste management policies
  - guarantee of origin system (GoOs). Just on going MAR-2023.
  - REALISTIC Roadmap
  - Clear, replicable, homogeneous, permitting processes
- Need for greater coordination to biogas/biomethane integrated solutions to joint problems (environmental + agricultural + livestock + demographics + energy + climate change)
- Shortage of electrical biogas plants which could be converted to biomethane plants. And lack of incentives to do it

7.3.7 Sources

Recovery, Transformation and Resilience Plan (PRTR) published by the Institute for Energy Diversification and Saving (IDAE), dependent on the Ministry for Ecological Transition and the Demographic Challenge

https://sede.idae.gob.es/lang/modulo/?refbol=tramites-servicios&refsec=biogas-incentivos-i

National Climate and Energy Plan published by the Ministry for Ecological Transition and the Demographic Challenge

https://www.lamoncloa.gob.es/serviciosdeprensa/notasprensa/transicion-ecologica/Paginas/2023/280623-gobierno-consulta-publica-plan-energia.aspx

ENAGAS GTS - Technical Operator of the System: Norms of the Technical Operator of the System

https://www.enagas.es/es/gestion-tecnica-sistema/informacion-general/normativa-procedimientos/

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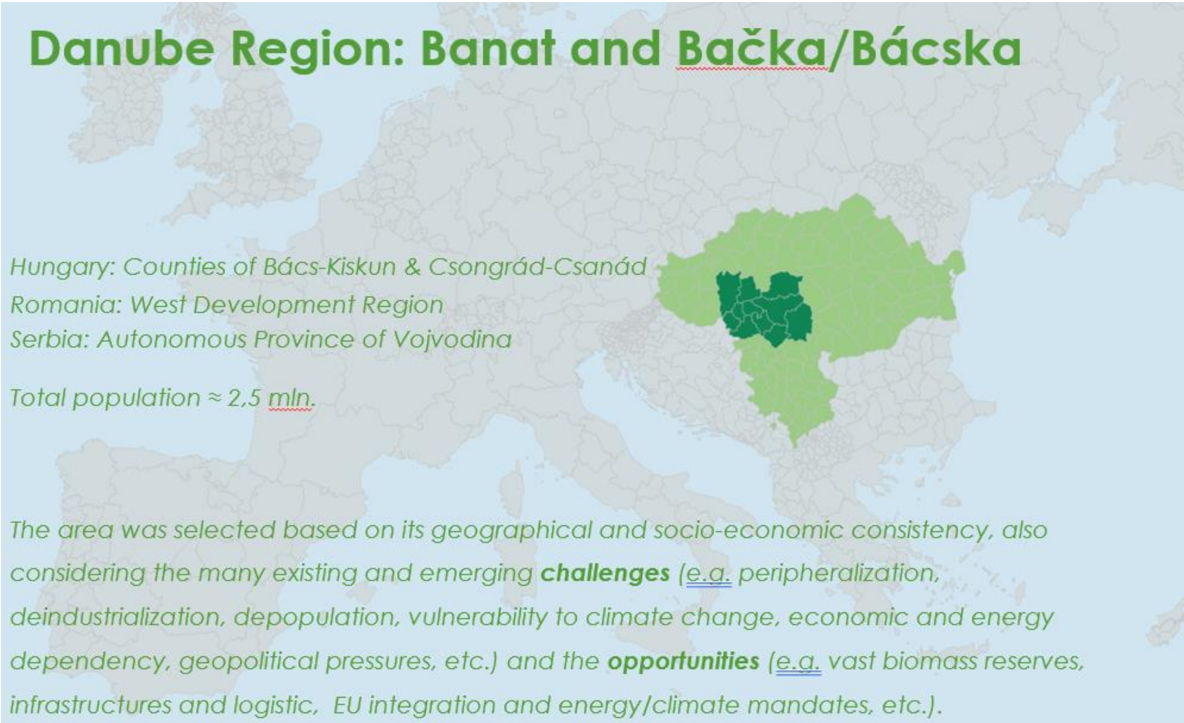
Chapter 8: Region of Backa and Banat

The peculiar geographical scope of the Danube Region case study, in comparison with the other assessments performed in the framework of the Green Me Up project, requires that this report is structured as a comprehensive text made of a synthetic overview and country sections, each of them providing detailed insight into national and sub-national characteristics of the biogas/biomethane sector and relevant value chains, including the regulatory frameworks and visions.



The geographical region encompassing Serbia, Romania, and Hungary presents a promising landscape for the development and growth of the biogas sector. Each country within this region possesses unique characteristics and resources that contribute to the potential of biogas as a renewable energy solution. A cross-border development of biogas/biomethane value, yet entailing additional complexities, chains would be practicable and potentially attractive regarding synergies and market uptake expansion.

The level of penetration in the three countries and the relevant sub-national entities encompassed in the study, while being generally low if compared to other EU countries, differ significantly as a result of past policies and support measures (incentives), overall financial capacity, the degree of prioritisation of decarbonisation and rural development in national agendas, as well as the precedence given to other RES over biogas production. In addition, the differences in the degree of capillarity of the natural gas distribution network may as well be accounted for a certain degree of coldness, particularly when addressing biomethane production.

Even though the biogas sector in three countries has been growing steadily over the past two decades, reaching a total of 150 plants currently in operation, the current conjuncture (phasing out from subsidies; increased interest for biobased materials over energy carriers; geopolitical pressures and

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financial uncertainties) could jeopardise further expansion of the sector, if not appropriately supported and encompassed in the broader circular bioeconomy discourse.

For instance, Hungary's biogas sector has grown steadily in recent years. The country has favourable conditions for biogas production due to its significant agricultural industry and large amounts of organic waste from livestock farming, food processing, and municipal sources. In previous years, the government has implemented various support schemes and incentive programs to promote biogas investments and production. These initiatives include feed-in tariffs, grants, and tax benefits. Hungary currently has 78 operating biogas plants that generate electricity and heat by anaerobic digestion of organic waste and biomass, with an output in 2020 of around 85 million m3 in biogas. The current production fulfils the unambitious targets of the National Strategy for Energy, which therefore fails to stimulate further growth, neglecting the approx. 1 bln. m3/y potential.

Romania has also witnessed the development of the biogas sector in recent years. The country has abundant agricultural resources and a significant livestock sector, providing much organic waste suitable for biogas production. The national agricultural potential is exceptionally high due to the approximately 15 million hectares of agricultural land, of which 64% is arable land; this indicator is even higher in the West Region, where agricultural land represents 65-80% of the territory. Romania has implemented support mechanisms such as green certificates and feed-in tariffs to encourage investments in biogas projects. Currently, no biomethane plants are operating or under construction in Romania. At the same time, there are 16 biogas plants in operation - considering only large-scale operations, without counting anaerobic treatment technologies applied in wastewater treatment plants, mini-biogas plants, or experimental anaerobic digestion installations. Biogas plants are located in 14 of the total 41 counties of Romania and scattered in all eight regions. Two plants are operational in the West Region: the biogas plant in Gătaia, Timiș county and the biogas plant in Arad. Both operations use as feedstock mixtures of energy crops (primarily corn, sorghum or triticale silage) and organic residues from animal farms and organics from the food industry. The lack of economic attractiveness of renewable energy, in general, and particularly biogas-biomethane, determined the decline in investments after 2016.

The biogas sector in Serbia is still emerging. Still, it has shown considerable potential owing to the significant role and volumes of the agricultural sector, which could generate substantial amounts of organic waste suitable for biogas production. Serbia started promoting biogas projects in 2010 and implemented support mechanisms to incentivise investments: since then, 35 biogas plants have been built in Serbia (two facilities already stopped working). The total installed capacity of operating agricultural biogas plants is approximately 33 MW. Practically, Serbia fulfilled the goal of 30 MW by 2020, defined by the National renewable energy action plan; however, it accounts only for biogas from manure while neglecting the potential of agricultural residues and other waste streams. The limited extension of the natural gas grid in the country might represent a severe limitation for further development of biomethane value. At the same time, there could be relevant advantages to using liquified gas in the transport sector.

Overall, Hungary, Romania, and Serbia – and consequently the area encompassed by the case study – in the recent past recognised the potential of biogas as a renewable energy source and have taken steps to promote its development by taking advantage of the favourable pre-conditions (strong primary sector, relevant R&D and industrial capacities), even though – as testified by the timid

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ambitions of the appropriate national (renewable) energy strategies – with lesser prominence if compared to other European countries that are currently leading on the biogas scene. Governments in these countries have implemented various support mechanisms in the past, including feed-in tariffs, grants, and tax benefits, which – however – are progressively phasing out and shall be substituted by auctions, premiums and other mechanisms. A side effect of such a transition, which has beneficial effects in terms of normalisation and mainstreaming of the renewable energy sector, is a remarkable degree of uncertainty that puts current operations in a "guarded" mode while new investments lag.

This said, the sector is supported by sufficient regulatory frameworks and available financial sources yet needs appropriate policy-industry-society coordination and prioritisation of market integration for biogas production.

On the other hand, the countries have favourable conditions, such as abundant agricultural resources and organic waste streams, to support the expansion of biogas/biomethane production. By leveraging their agricultural resources and addressing the challenges faced by the biogas sector, Serbia, Romania, and Hungary can unlock the potential of biogas as a sustainable and rapidly deployable renewable energy solution, also in the perspective of reduced energy dependency.

With supportive policies, infrastructure development, and investment in research and development, these countries can further drive the growth of their biogas industries, contributing to their respective energy transitions and the overall sustainability of their economies. This, indeed, would require a coordinated effort (also at transnational and cross-border levels) of both policy and industry, including the primary sector, to capitalise on feedstock potentials and the existing network of infrastructures, as well as to trigger and sustain market uptake options for biogas and biomethane.

In a context where regulatory frameworks are – more or less – in place and sufficiently robust notwithstanding the uncertainties deriving from the multiple and perduring international crises and evolving EU priorities, the key to strengthening the biogas/biomethane sector in the Danube region is in addressing non-technical barriers, mainly those that hinder the market expansion of biogas and biomethane. Another critical aspect is developing appropriate knowledge and tools to empower biomass producers and facilitate the creation of robust and secure feedstock utilisation and commercialisation patterns. Moreover, the establishment of dedicated interdisciplinary and interdepartmental working groups (eventually, following the multi-actor approach) with the explicit task of streamlining decision-making concerning biogas/biomethane value chains.

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A. Bacs-Kiskun and Csongrad-Csanad counties, Hungary

8.1 A. The biomethane market

8.1.1 A. Current status of biomethane in the national context

Hungary's biogas sector has grown steadily in recent years. The country has favourable conditions for biogas production due to its significant agricultural industry and large amounts of organic waste from livestock farming, food processing, and municipal sources. In previous years, the government has implemented various support schemes and incentive programs to promote biogas investments and production. These initiatives include feed-in tariffs, grants, and tax benefits.

Hungary currently has 78 operating biogas plants that generate electricity and heat by anaerobic digestion of organic waste and biomass, with an output in 2020 of around 85 million m3 in biogas (Table 8-1). The current production fulfils the unambitious targets of the National Strategy for Energy, which therefore fails to stimulate further growth, neglecting the approx. 1 bln. m3/y potential. There are only 2 biogas upgrading facilities; the first, a small unit, is put out of operation, and the other one exports the total production to Western Europe.

Table 8-1. Biogas and biomethane plants in Hungary

Number of biogas plants	78
Number of biomethane plants	2
Biogas production in GWh 2021	930
Biogas production per capita in MWh/inhabitant	0,1
Landfill gas	13,70%
Sewage gas	31,00%
Agriculture and others	55,20%

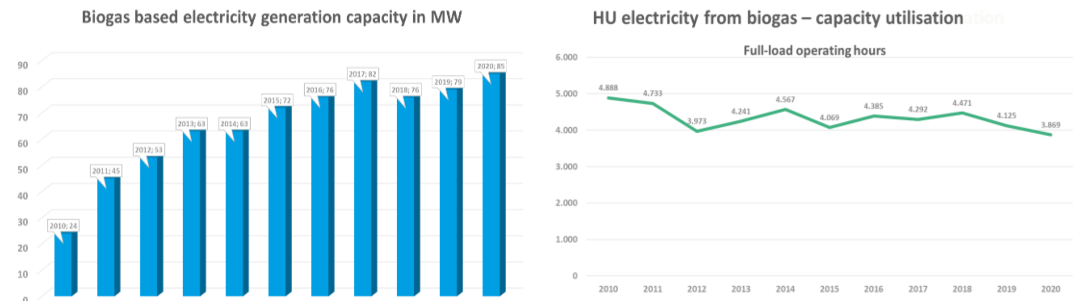

Figure 8-1. Biogas production in Hungary

8.1.2 A. Public acceptance

To mitigate NIMBY attitude, local communities should be involved at an early stage in the development of biogas and biomethane projects and informed about the potential benefits of such projects and the disadvantages and ways of avoiding/managing the technical risks. Introducing energy

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communities may significantly strengthen the acceptance of the anaerobic digestion technology while integrating biogas/biomethane production can compensate for the fluctuations in wind/solar energy generation and thus enables energy self-supply.

8.2 A. Production routes

8.2.1 A. Feedstock potential assessment

Animal manure

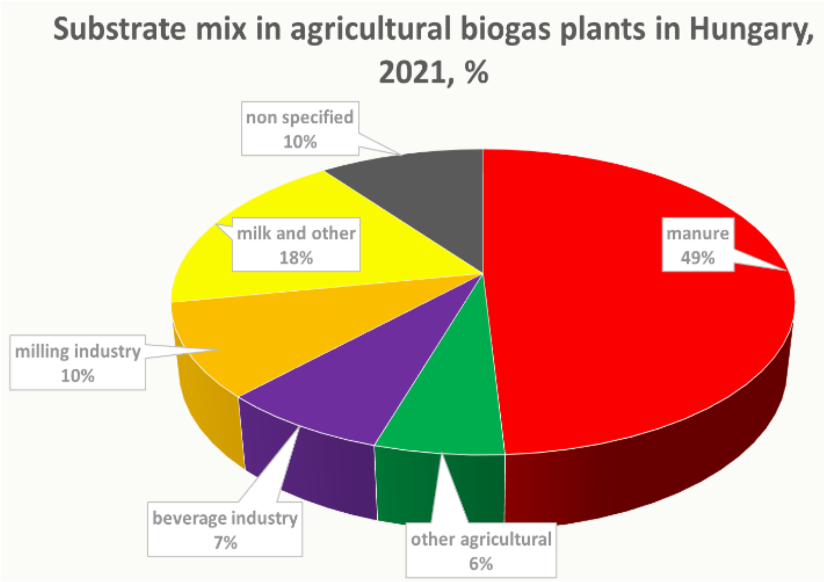

Figure 8-2. Substrate mix in agricultural biogas plants in Hungary (2022)

Animal manure is the most important biogas feedstocks currently available, both from a quantitative and climate protection point of view, potentially fulfilling up to approx. 60% of needs by 2030 if dual use of manure is promoted (energy + use of stabilized fermentation residues for fertilization instead of manure, which use was revamped by increased costs of industrial fertilizers). By developing and introducing a certification scheme, the national biomethane strategy should provide the framework for the broadest possible use of fermentation residues as biofertilisers, thus also contributing to curtailing emissions.

Bio-waste

Converting OFMSW into biogas is a consolidated and efficient approach that should be further promoted. Currently, this is mainly an environmental goal (eg. it is included in the National Waste Management Plan), while it is not encompassed by energy policies (eg. the draft National Biomethane Strategy). This owes to limited projected outputs also determined by the trends to minimize waste streams (eg. dairy industry, where the organic matter content of effluents and wastes is decreasing yearly). Therefore, the future volume of biogas/biomethane production from industrial (mainly food industry) by-products will be determined primarily by economic rather than technical considerations, the question being whether biogas/biomethane production can pay a higher price for these materials

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than alternative users. The by-products that can be processed as biogas feedstock are most often used as animal feed (feed component) or soil improvement material. This means that biogas plants can only access these materials if they pay a higher price than those available from alternative uses. From the estimated data, the 1.70 TWh of methane calculated as biogas/biomethane potential is merely the technical potential, but only the economic potential, which considers market conditions for the by-products, is of practical relevance.

Sewage sludge

Biogas plants are already in operation in most of the domestic wastewater treatment plants. Positive examples (South Pest, Miskolc, Szeged) show that integrating organic waste from external sources can make wastewater plants self-sufficient in energy. This suggests that the potential for self-supply of energy and the decades of knowledge and experience accumulated in the industry are sufficient to exploit the biogas production potential and that no specific government action in this area is needed within the national biomethane strategy.

Maintenance of green areas

Biomass from the maintenance of green areas is classified partially as waste and partly as a by-product. Mow cuttings from green areas in residential areas are classic green waste, while grass and hay harvested from nature reserves, dams, roadsides, cemeteries, sports fields, and similar areas are considered by-products on the grounds that they can be used for animal feed. However, the political opposition to cultivating energy crops on arable land instead of food and feed does not relate to maintaining green areas. This source of biomass is currently available, but its exploitation requires, first and foremost, a political/economic environment that encourages biogas/biomethane production and consumption in general and the economic feasibility of individual projects.

8.2.2 A. Natural gas grid infrastructure and future prospect

The distribution of natural gas and biogas/biomethane of natural gas quality and its injection into the natural gas system is governed by Act XL of 2008 on the natural gas supply. According to § 26, biogas/biomethane is considered suitable for sale to the consumer if it meets the technical requirements of the natural gas standard, whether or not mixed with natural gas.

In accordance with § 33, the economic entity producing biogas/biomethane has the same rights as an undertaking carrying out natural gas mining activities. Consequently, the biogas producer may sell the biogas it produces to traders or directly to consumers without a commercial licence and may reserve capacity on the public pipeline network for transit and distribution. According to the provisions of the Gas Act (§ 70), biogas/biomethane producers shall be given priority access for connection. Government Decree 19/2009 (30 I) confirms that the rules applicable to natural gas producers apply mutatis mutandis to biogas/biomethane.

Under the current rules, all the costs (investment and operating) of connection to the network must be borne by the biogas/biomethane producer. At the point of delivery or transfer to the distribution system, the producer must operate instruments for measuring the quantity, volume, pressure, temperature, composition and calorific value of the biogas/biomethane.

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In recognition of the macroeconomic benefits of biogas/biomethane for the national economy, it would be appropriate for the government, in cooperation with transmission and distribution system operators and the regulator, to set clear and transparent cost-sharing conditions for grid connection between biomethane project developers and natural gas grid operators. The most effective support would be if the network operator covered grid connection and feed-in costs, releasing biogas/biomethane producers from this burden. A possible solution for the regulator is to recognise these additional costs in the regulated asset base of gas network operators. This would allow these costs to be directly reflected in end-user tariffs and spread across the whole customer base. In addition, for the sake of transparency, the cost allocation process and the criteria to be met for connection and injection should be published on the websites of TSOs, DSOs and the regulator.

8.3 A. Regulatory framework and supportive policies

8.3.1 A. Vision and targets

Estimation of biogas and biomethane development

Considering the possibilities for biomethane production from selected feedstocks, the following potential can be summarised for Hungary in million m^3 (Table 8-2).

Table 8-2. Biomass potential in Hungary

Feedstock/Year	**2030**		**2040**	
Agri residues	362	64%	637	42%
Sequential crops	11	2%	130	9%
Sewage sludge	54	10%	64	4%
Landfill gas	36	6%	24	2%
Industrial residues	63	11%	63	4%
Municipal waste	15	3%	25	2%
Other	22	4%	572	38%
Total	**563**	100%	**1.515**	100%

According to this assessment, 5-6 TWh/year of biogas/biomethane production from currently available feedstock streams is technically feasible by 2030, provided that the national biomethane strategy formulated and followed by the government creates the right socio-economic environment.

The estimated biogas/biomethane production potential of 13-17 TWh/year by 2040 can be considered more as theoretical potential, as new biomass sources must (and can) be secured for the part above 5-6 TWh/y. In quantitative terms, the most important options are: a) substantial expansion of secondary crop production; b) dual-purpose cultivation (e.g. maize stover); c) energy crops grown on marginal land areas; d) biomethanisation (methane synthesis using the carbon dioxide content of biogas).

<u>National strategy and national plan</u>

The relevant national regulatory framework include: a) Electrical Energy Law XXIX/2011 providing the framework for subsidizing renewable electricity production, including from biogas; b) Gas Law XI/2008 introducing the possibility for grid injection of upgraded biogas and equalizes the legal status of biomethane produces with that of natural gas producers; c) Government Decree 19/2009 specifying

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the legal and technical requirements for biomethane production and injection; d) 3/2009 OM regulation sets security and protection requirements for liquid biofuels and biogas installations; e) Renewable Energy Law CXVII. 2010 corresponding to Directive 2009/28/EU with regards to renewable transport fuels; f) Government Decree 167/2011 regulating sustainability certification for biofuels, incl. upgraded biogas; g) Ministry of Rural Development Regulation 42/2010 setting rules for land use in accordance with 2009/28/EU; h) Government Decree 821/2021 transposing Directive 2018/2001/EU. Energy market developments in 2022 justify revising the biogas part of the National Energy Strategy (2020). The NES currently includes the following: *"Biogas production, purification and feed into the gas grid is seen as a high potential option with medium support needs that can contribute to meeting the targets for increasing renewable energy use and decarbonisation... domestic biogas potential has the realistic potential to replace 1% of our natural gas consumption by 2030, or 85 million m^3/y. By 2040, we expect further growth, bringing the domestic biogas potential to 100 mio m^3."*

<u>Targets for biomethane production and consumption</u>

In the case of Hungary, biomethane production and consumption targets are essentially the same, as this renewable, environmentally friendly energy carrier should be produced domestically, from domestic sources, with domestic inputs, for domestic consumption. However, the regulatory environment and the registration system must be designed to enable operators to enter the EU market as suppliers or buyers. The following target numbers seem to be achievable in Hungarian biogas/biomethane production: a) 500-600 million m^3 methane in 2030; b) 1.500-1.600 million m^3 methane in 2040; c) 2.200-2.500 million m^3 methane in 2050. The use of biomethane as a transport fuel should be mentioned explicitly among the long-term objectives. By 2030, the total amount of CNG and LNG in Hungary could be covered by biomethane.

8.3.2 A. Direct investment and production support

Contracts for difference (CFD) could be a solution for direct price support for biomethane grid injection from the production and demand sides, CFDs would promote biogas production and market sustainability through price guarantees handled by a government-authorized body to protect private companies from a sudden drop in gas market prices. Tenders for the award of CFD contracts would ensure that biomethane production takes place on the most economically advantageous terms.

8.3.3 A. Indirect investment and production support

There is a need for government regulation on GHG emission savings from biogas/biomethane at the national level, which would contribute significantly to achieving the objectives of scaling up biogas/biomethane production at the domestic level. The Government regulation could take two forms: (a) on the one hand, it would provide an easy bridge between ETS quota holders and biomethane producers; on the other hand, (b) the creation of a domestic GHG emissions savings market and certification scheme (a kind of HU ETS) could be considered, which would involve a broader range of economic actors than the EU ETS.

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8.3.4 A. Demand-side incentives

A mandatory renewable gas blending quota obligation on gas distributors would result in biomethane (and hydrogen) production if the obligated parties are subject to an appropriate penalty for non-compliance. Setting the required quota, which will increase year on year, should be based on a complex technical-economic analysis and should not impose unreasonably high requirements on the gas industry. The obligation can be fulfilled through physical renewable gas production or purchase and through acquiring domestic certificates of origin. The latter would give a function and meaning to the system of certificates of origin, the market value of which would be directly determined by the amount of the non-compliance penalty.

8.3.5 A. Regulation enabling injection and trade

According to the EU Renewable Energy Directive (RED II), the only function of the guarantees of origin is to inform the consumer about the renewable origin. A proof of origin with such a limited purpose would not represent the actual environmental benefits of biomethane and therefore could not foster the deployment. On the other hand, broader guarantees of origin could be used for meeting domestic blending quotas (or even EU ETS). In both cases, it would be necessary for the guarantee of origin to be marketable and its monetary value to be forecast over the payback period. The biomethane registry system should also be able to promote the use of biomethane for transport fuel that meets sustainability requirements throughout the country, in line with the EU RED. It would be appropriate to integrate the verification of GHG savings into a comprehensive biomethane registry. To monitor the achievement of the targets set, it is necessary to have a system for registering biogas and biomethane production in Hungary. It is also a reliable tool for monitoring the injection of biomethane into the network and its use after it is removed from the gas network. The biomethane registry, facilitated by a transparent system of guarantees of origin and in line with the European Commission's forthcoming EU database on renewable liquid and gaseous fuels, will ensure that the targets can be reliably accounted for and that all biomethane injected into the grid can be accounted for only once, regardless of the end-use sector in which it is used. This will also provide end-users with certainty that they are buying biomethane that has been produced (even if the amount taken off the grid is not physically biomethane) and allow the market to develop mechanisms to ensure that biomethane use and associated greenhouse gas emission savings are accounted for and monetised. The registry should be based on a reporting obligation for biogas/biomethane production installation operators to report their production and sales volumes. The data collected includes production and sales volumes, volumes fed into the grid, self-consumption volumes, and supporting documents on the sustainability and GHG emissions of the biogas/biomethane produced.

B. West Region, Romania

8.4 B. The biomethane market

The Romanian agricultural potential is exceptionally high due to the approximately 15 million hectares of agricultural land. The analysis of Romania's agricultural surface according to the land use reveals a significant share of 64% of arable land, followed by the meadow category (pastures and meadows),

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other less represented agricultural categories, vineyards and orchards. This percentage structure effectively translates into 14,630 thousand hectares of agricultural use land, of which 9,395 thousand hectares is arable land, and meadows are distributed on 4,828 thousand hectares.

8.4.1 B. Current status of biomethane in the national context

Currently, no biomethane plants are operating or under construction in Romania. At the same time, there are sixteen operating biogas plants - considering large-scale operations, without counting anaerobic treatment technologies applied in wastewater treatment plants, mini-biogas plants, or experimental anaerobic digestion installations. Biogas plants are located in 14 of the total 41 counties of Romania and scattered in all eight regions. The highest density of biogas plants are in the North-West region, where four biogas plants are operating in counties: Bihor (Săcueni), Satu-Mare (the only county in Romania with two biogas plants in Ardud and Carei) and Maramureș (Seini). All sixteen biogas plants were constructed and started operation between 2011 and 2017. In this period, the legal frame was generally attractive for renewable energy businesses (especially the law 220 / 2008). The first biogas was put into function in 2013: "Genesys Biotech" in Filipeştii de Pădure, Prahova county, with a CHP unit of 2 MWe installed capacity. The last biogas plant started the energy action in January 2017 – located in Gătaia, Timiș county, operated by Maxagro and with a CHP unit of 1 MWe installed capacity. All biogas plants that started energy production before December 31st 2016, receive one, two or three green certificates per each megawatt-hour delivered to the electricity greed. Regarding the biogas plant in Gătaia, Timiș county, because the operation started after Law 220/2008, the law ceased to be put into practice, and the only income received from selling electricity on the Romanian energy market.

Figure 8-3. Biogas plants in Romania (gr 1Figure 4.1. Biogas plants in Romania (green dots). Regions are marked with numbers: 1-North East; 2-South East; 3-South; 4-South West; 5-West; 6-North West; 7-Center and 8-București

As displayed on the map (Figure 8-3), two biogas plants are operating in West Region: the biogas plant in Gătaia, Timiș County and the biogas plant in Arad. Both processes use as feedstock mixtures of energy crops (mainly corn, sorghum or triticale silage) and organic residues from animal farms (cattle manure, pigs slurry, chicken wastes etc.) and organics from the food industry. The lack of attractiveness of the economic situation in renewable energy in general and the biogas-biomethane sector in particular determined the need for more investments after 2016 in these sectors. This situation is determined mainly by the legal frame driving these sectors, which will be explained in the following section.

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8.5 B. Production routes

8.5.1 B. Feedstock potential assessment

In this section, residues, by-products or wastes generated in the Romanian bioeconomy have been assessed according to data available in relevant publications. The publications issued by the national statistical institute (INS Romania) have been used to quantify the number of animals, crop yields, or data from the food processing sector. Residues-to-products ratios, quantities of wastes produced by animals, have been considered those reported by other authors and studies (*Scarlat et al., 2019; Martinov M. et al., 2020; Antonopoulou G. et al., 2010; Engie 2021*). Biochemical methane potentials (BMP) have been reported in several publications and obtained by the author in laboratory tests using the AMPTSII system. Feedstock potential presented represents the one relevant only for future biomethane plants. Since there is a small number of biogas plants for electricity generation in Romania and no biomethane plant, the feedstock is in large proportion available for biomethane production. However, to be instead considered a conservative or pessimistic study than a study embracing the optimistic scenario, the theoretical potential is not highlighted here. Instead, two levels of potentials are presented for the considered feedstock: a) technical potentials comprise the complete or existing amount of feedstock generated in large industrial operations, available to be collected and transported; b) sustainable potentials considering environmental criteria and competitive uses of the organic materials in other applications or economy sectors.

Table 8-3. Biomass technical and sustainable potential in Romania

Specification (1000 $m^3 CH_4$/year)	ROMANIA		WEST REGION	
	Technical potential	Sustainable potential	Technical potential	Sustainable potential
Total	3393099	1718081	311967	157613
Animal waste	137716	55086	22002	8801
Crops residues	3184778	1592389	282305	141153
MSW	26882	26882	2796	2796
SWWTP	42060	42060	4317	4317
Food processing	1663	1663	546	546

Comparing the technical potential for biomethane production in Romania of 3.39 billion m3 / year with the natural gas consumption of 11 billion m3 / year (Table 8-3), it can be estimated that by using technically available organic wastes from the Romanian bioeconomy, 1/3 of the natural gas consumption of the country can be covered by a biomethane production system based exclusively on organic wastes!

Municipal solid waste

The total amount of municipal solid waste generated in the West Region in 2021 was 569000 tons.

The total amount of MSW collected (according to *PLANUL JUDEȚEAN DE GESTIONARE A DEȘEURILOR ÎN JUDEȚUL TIMIȘ*) from the population of 705000 inhabitants from Timis county in the last three years in around 210000 tons/year. The total amount of organic fraction (OMSW) collected in 2022 in Timiș county by RETIM Ecologic Service was 35000 tons (personal communication). After the mechanical

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sorting of this fraction, the small fraction under 80 mm was 18500 tons (53% of total organics collected). This fraction is treated by biological treatments, currently in bio-containers by aerobic decomposition. This fraction was tested for methanogen potential in the Laboratory of Industrial Biotechnology and Microbiology from the University of Life Sciences from Timișoara in the AMPTSII system. The results varied depending on the sample collected by RETIM Ecologic Service from Timișoara, with methanogen potential varying between 29.4 and 79.0 m^3 CH_4/ton of OMSW, resulting in an average potential of 54.2 m^3 CH_4/ton OMSW. In conclusion, the 18500 tons of small fraction under 80 mm collected from the population of 705000 inhabitants from Timis county can deliver 1002700 m^3 CH_4/year. That is a potential of 1.4 m^3 CH_4/year/inhabitant, calculated for the actual conditions of waste collection and management in Timiș county. Extrapolating this technical potential to the population of Romania and the West Region, the following technical methane potentials can be considered:

Romania, with a population of 19,201,662 inhabitants, can treat OMSW by anaerobic digestion, delivering 26,882,327 m^3 CH_4/year. The West Region of Romania, with a population of 1,997,377 inhabitants, can treat OMSW by anaerobic digestion, delivering 2,796,328 m^3 CH_4/year

Sludge from wastewater treatment plants

The total amount of sludge from the wastewater treatment plant (SWWTP) of Timișoara is around 5200 tons D.M. /year. Samples of sludge and greases were collected from WWTP operated by Aquatim SA Timișoara. They were tested for methanogen potential in the Laboratory of Industrial Biotechnology and Microbithe ology from the University of Life Sciences from Timișoara in the AMPTSII system. The results indicated an average methanogen potential of 1,880,805 m^3 CH_4/year. That is a potential of 4 m^3 CH_4/year/inhabitant, calculated for the actual conditions of wastewater treatment applied by Aquatim. Extrapolating this theoretical potential to the population connected to wastewater treatment systems in Romania and West Region, the following methane potentials can be considered:

In Romania, 10,514,924 inhabitants are connected to wastewater treatment systems, delivering SWWTP, which can be treated by anaerobic digestion, providing 42,059,696 m^3 CH_4/year. In the West Region of Romania, 1,079,268 inhabitants are connected to wastewater treatment systems, delivering SWWTP, which can be treated by anaerobic digestion, delivering 4,317,072 m^3 CH_4 / year.

Wastes from abattoirs and meat processing

According to data obtained by testing samples collected from WWTP of an abattoir in Timișoara and tested for methanogen potential in the Laboratory of Industrial Biotechnology and Microbiology from the University of Life Sciences from Timișoara in AMPTSII system, the annual potential of organics resulted from this industrial operation can deliver 361900 m^3 CH_4 / year. Considering that over 1.3 million animals are processed yearly in the abattoir, or 155354 tons of live weight, the methanogen potential per processed animal is 0.278 m^3 CH_4 / processed animal, or 2.3 m^3 CH_4 / ton live weight processed animal.

In Romania, 723,202 tons of animals (live weight) are processed: 168,206.1 tons of cattle, 495,074.7 tons of pigs, 127,744.7 tons of sheep&goats and 662,924.8 tons of poultry. This quantity of processed

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meat generates organic wastes, which can be treated by anaerobic digestion, delivering 1,663,364.6 m^3 CH_4 / year. In the West Region of Romania, 237,274 tons of animals (live weight) are processed: 8,651.6 tons of cattle, 168,701.2 tons of pigs, 19,606.6 tons of sheep&goats and 40,314.6 tons of poultry. This quantity of meat processed generates organic wastes, which can be treated by anaerobic digestion, delivering 545,730 m^3 CH_4 / year.

8.6 B. Regulatory framework and supportive policies

8.6.1 B. Vision and targets

Renewable energy sources offer wide availability of production and use in Romania while ensuring the security of energy supply under the conditions of sustainable economic development. To achieve these, it is necessary to implement coherent policies in the field of renewable energy and the circular economy on a national level.

The biomethane sector in Romania depends on the legal framework of renewable energy, natural gas, waste management, and fertilisers.

- In 2022, Romania adopted the National Strategy for Circular Economy and national action plan (https://dezvoltaredurabila.gov.ro/strategia-nationala-privind-economia-circulara-13409762).

- Law no. 3/2001 ratifying the Kyoto Protocol regarding the UN Framework Convention on Climate Change.

-Decision no. 1535 of 18.12.2003 regarding the approval of the Strategy for capitalising on renewable energy sources

- Law no. 220 of October 27, 2008, for establishing the system to promote energy production from renewable energy sources - Republished (Synthetic form dated February 20, 2019), creates the legal framework for expanding the use of renewable energy sources.

This law defines the term biomass in Article 2, letter b) *biomass – the biodegradable fraction of products, waste and residues of biological origin from agriculture (including plant and animal substances), forestry and related industries, including fishing and aquaculture, as well as the biodegradable fraction of industrial and municipal waste, codified according to legal provisions.*

In the content of this law, in article 2, letter h), the notion of a *green certificate* is introduced - a title that certifies the production from renewable energy sources of a quantity of 1 MWh of electricity.

h) green certificate – *title certifying the production of a quantity of electricity from renewable energy sources. The certificate can be traded, separately from the amount of electricity it represents, on the organised market, in accordance with the law. The green certificate is not a financial instrument*.

The same article at letter ai) defines energy crops.

a) *energy crops – crops of agricultural or non-agricultural plants intended, in particular, for producing biofuels or producing biomass used for city and thermal energy*.

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In Article 3(1) letter e), biomass is included in the system to promote electricity from renewable energy sources for energy delivered to the electricity network and/or consumers.

Entry as a producer of electricity from renewable energy sources in the promotion system is conditional on holding the certificate of origin for biomass used as fuel or raw material, according to Article 3, points 9, 10 and 11.

- Law 139/2010 amends and completes Law no. 220/2008 for establishing the system to promote energy production from renewable energy sources.

In point 12, biomass is included in renewable energy sources – non-fossil energy sources, and in point 14, Article 3(1), the system for promoting electricity produced from renewable energy sources also applies to electricity produced from biomass.

-The memorandum of June 8, 2010, for the Approval of the final values of Romania's objectives for the Europe 2020 Strategy. This document established measures to counteract climate change, including the increase in the share of energy produced from renewable sources.

-Government Decision no. 1884 of 22 December 2005 (updated) on the use of biofuels and other renewable fuels for transport (applicable from 24 October 2010) transposes Directive 2003/30/EC for the promotion of the use of biofuels and other renewable fuels for transport.

-Order 46, of March 5, 2012, issued by the Ministry of Agriculture and Rural Development regarding the approval of the issuance of the certificate of origin for biomass from agriculture and related industries used as fuel or raw material for the production of electricity.

The annexe includes – List of energy crops intended for biomass production used for the purpose of electricity production.

- H. G. 219 / 2007 - regarding the promotion of cogeneration based on the demand for valuable thermal energy

- H. G. 1461 /2008- approval - Procedures regarding the issuance of guarantees of origin for electricity produced in high-efficiency cogeneration MO 813/ 2008

-The procedure of July 28, 2016, for issuing certificates of origin for biomass from forestry and related industries and used in producing electricity from renewable energy sources.

- Electricity and natural gas law no. 123/2012, Art. 98.: (1) This title establishes the regulatory framework for carrying out activities regarding the production, transport, distribution, supply and storage of natural gas, the methods of organisation and operation of the natural gas sector, and market access, as well as the applicable criteria and procedures for granting authorisations and/or licenses in the natural gas sector. (2) The provisions of this title apply in a non-discriminatory manner to biogas, gas obtained from biomass or other types of gas, to the extent that it is technically possible for them to be injected or transported through the transport systems/ distribution of natural gas and through upstream supply pipes and/or to be used in utility installations, in complete safety.

- The digestate has to comply with Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising

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products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003, Official Journal of the European Union, L 170, Volume 62, 25 June 2019

- On 20.07.2022, the Romanian Parliament issued Law no. 254/20.07.2022 for the amendment and completion of the Land Fund Law no. 18/1991 and other normative acts, published in the Official Gazette no. 736 of July 21, 2022. As a notable innovation, the law also introduces third-class quality land into the category of agricultural land on which renewable energy projects can be carried out, including biomass for bioenergy. In Article 92, the introductory part of paragraph (2) is amended and will have the following content: (2) By way of exception to the provisions of paragraph (1), on *agricultural lands of the III, IV and V quality classes,* having the category of arable use, pasture, vineyards and orchards, as well as those arranged with land improvement works, located in the outskirts , based on the building permit and the approval of the definitive or temporary removal from the agricultural circuit, the following investment objectives can be located: 2. In Article 92 paragraph (2), after letter i), a new letter is inserted, letter j), with the following content: j) specific to the production of electricity from renewable sources: production capacities of *solar energy, wind energy, energy from biomass, bioliquids and biogas, electricity storage units, transformation stations or other similar systems* that they can be located on the agricultural lands located outside the village, in a maximum area of 50 ha.

C. Autonomous Province of Vojvodina, Serbia

8.7 C. The biomethane market

8.7.1 C. Introduction

In Serbia, a new policy framework was adopted recently with the new Renewable energy law (MMERS, 2021) and accompanying by-laws (GRS, 2021a; 2021b; 2022a; 2022b), which define the status of the biogas and biomethane sector. Therefore, the key incentive measure facilitated through feed-in tariffs for all renewable electricity fed to the grid, including biogas, was replaced by a hybrid model. This model is based on an auction system for market premiums and feed-in tariffs for plants smaller than 500 kW. Although announced for the beginning of 2022, the auctions were not conducted until the end of the year. Plants with a capacity below 500 kW and demonstration plants can obtain feed-in tariffs. However, the administrative effort is similar to the auction system with market premiums. The difference compared with from model with a feed-in system is that there is no uniquely defined feed-in tariff. Still, the potential investor should also participate in the auction. If accepted, the offered feed-in tariff on the auction would be fixed throughout the project's lifetime, and it would not contain the variable part that depends on the electricity market price. In both cases, the new system delayed further biogas sector development. Practically, no investors are interested in new projects for multiple reasons. The COVID-19 pandemic and the war in Ukraine caused the increased feedstock purchase price and the increased CAPEX and OPEX, practically forcing investors to stop even consideration of new biogas projects. The season of 2022 was arid, and meagre yields of energy crops led to an even higher price for this type of feedstock. Additionally, auction prices would reduce the potential income

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compared with the previous incentive model. Currently, there are no biomethane plants in Serbia. Though a project is announced to produce liquified biomethane (LBM) for export, *i.e.* it is not facilitated through the national policy framework and infrastructure. The capacity of the planned project is about 630 Nm^3/h of biomethane (approx. 2.4 MWe_{eqv}). Nevertheless, the new policy framework in Serbia provided initial conditions for future biomethane uptake. The new Decree on conditions of delivery and supply of natural gas (GRS, 2022b) recognises biogas as a fuel suitable for injection in the natural gas grid. Unfortunately, the term is wrongly used and unrelated to purified biogas, *i.e.* biomethane. A significant obstacle is that no defined technical conditions exist for biomethane injection in the natural gas grid. In 2022 the price of natural gas in the EU was very high and reached approximately 340 €/MWh; this could have been a significant driver for biomethane uptake. But the price continued decreasing and, in the second quartal of 2023, dropped below 50 €/MWh (Anonymous, 2023). In Serbia, the price of natural gas for individual consumers was redefined in October 2022 at 47 €/MWh and remained stable, thus not triggering the urgent search for alternatives. The first interested investors in biomethane plants were and still partly are the biogas plant owners that are at the end of their biogas project lifetime since their privileged status to receive a feed-in tariff of 12 years is expiring in the coming years. Therefore, there is an opportunity to reconstruct the existing biogas plant into biomethane plants. Thus, they could continue their business in the renewable energy sector, and the production price of biomethane would be significantly lower compared to a greenfield than

8.8 C. Production routes

8.8.1 C. Feedstock potential assessment

Feedstock potential in this chapter represents the one relevant only for future biomethane plants. Since there is not a single biomethane plant in Serbia and considering the existing biogas plants for electricity generation, the feedstock, *i.e.,* the substrate potential for biomethane production, does not comprise already used feedstock potential in those existing biogas plants on the Serbian market. In that sense, the four levels of potentials are presented for the considered feedstocks: a) theoretical potential comprising all existing feedstocks; b) technical potential estimated on collection capacity, logistics, availability, etc.; c) sustainable potential including socio-economic or environmental criteria as well as competitive uses; d) biomethane potential determined after competitive uses for energy or other services. This is the realistic potential if appropriate decisions are made to mobilise considered feedstocks.

Manure

Around 250,000 t/a of manure, of which 33% is solid, is being used on the existing biogas plants in Serbia, mainly from farms with more than 1,000 CU (Cattle Units). The total (theoretical) potential subsumes all livestock types and all existing farm sizes (Table 8-4, Table 8-5). The technical potential is calculated for farms with more than 100 CU. The sustainable potential represents the technical potential from which is excluded manure produced at farms that could not contribute to at least 500 CU in a single municipality. Such farms exist only in Central Serbia, whereby the technical and

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sustainable potentials are equal for Vojvodina. The biomethane potential is calculated from sustainable potential by subtracting the manure from those farms with less than 500 CU and the amount of manure used on the existing biogas plants to produce electricity (but only those that will still operate in 2030). The share of 60% of the 250,000 t of the already treated manure could be used for biofuels (about 33% is solid manure), and it is in Vojvodina. The share of 80% of solid manure originates from cows and 20% from chickens, and 60% of liquid manure originates from cows and 40% from swine. The following two tables present four balanced levels of manure potentials in Serbia and Vojvodina.

Table 8-4. Manure potential in Serbia (SM: Solid manure. LM: Liquid manure)

Livestock	Theoretical		Technical		Sustainable		Biomethane	
	SM, t	LM, m3	SM, t	LM, m3	SM, t	LM, m3	SM, t	LM, m3
Cows	12.436,892	920,752	544,879	920,752	536,594	913,230	146,372	543,142
Pigs	5.168,264	7.640,218	174,175	3.187,835	171,762	3.179,229	24,221	2.626,415
Broilers	533,353	0	330,275	0	324,889	0	127,274	0
Laying hens	818,639	0	324,749	0	316,802	0	0	0
Sheeps	1.313,864	0	32,008	0	31,364	0	0	0
Goats	159,429	0	1,069	0	673	0	0	0
Total	20.430,441	8.560,970	1.407,155	4.108,587	1.382,084	4.092,459	297,868	3.169,557

Table 8-5. Manure potential in Vojvodina (SM: Solid manure. LM: Liquid manure)

Livestock	Theoretical		Technical		Sustainable		Biomethane	
	SM, t	LM, m^3	SM, t	LM, m^3	SM, t	LM, m^3	SM, t	LM, m^3
Cows	3.399,254	506,613	391,962	506,613	391,962	506,613	88,115	214,948
Pigs	1.710,598	3.971,205	109,003	2.543,334	109,003	2.543,334	14,062	2.178,099
Broilers	282,897	0	194,070	0	194,070	0	90,145	0
Laying hens	252,470	0	138,435	0	138,435	0	0	0
Sheeps	237,657	0	17,148	0	17,148	0	0	0
Goats	40,252	0	475	0	475	0	0	0
Total	5.923,128	4.477,818	851,092	3.049,947	851,092	3.049,947	192,322	2.393,047

Crop residues

Crop residues, or so-called agricultural/herbaceous biomass, or harvest residues, are the essential biomass potential in Serbia and are even more critical in Vojvodina, which is the agricultural region. The crucial aspect is that harvest residues are (valuable) by-products from agricultural production, but certainly not waste. However, using this lignocellulosic biomass in anaerobic digestion requires energy-intensive and costly pre-treatment. On the other side, the sustainable potential of wooden biomass is already used predominantly for technical use (furniture production and construction elements) and as a solid fuel for household heating and cooking. Potentials of crop residues in Serbia and Vojvodina were assessed in numerous previous studies and publications. Here are presented the two most relevant, which provide energy potentials, *i.e.* the amount that could be used for various energy generation pathways, after competitive use was considered (bedding in animal husbandry) (Table 8-6).

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Table 8-6. Crop residues potential in Serbia and Vojvodina

Crop	SERBIA				VOJVODINA			
	Sustainable potential, 1,000 t		Energy potential, 1,000 t		Sustainable potential, 1,000 t		Energy potential, 1,000 t	
	Large farms	S/M farms	Large farms	S/M farms	Large farms	S/M farms	Large farms	S/M farms
Wheat	374	1,080	355	970	264	320	250	280
Rye	2	14	2	14	1	1	1	1
Barley	80	154	80	138	52	50	48	45
Corn	s 130	s 735	s 130	s 660	s 114	s 310	s 110	s 280
	c 15	c 1,200	c 15	c 1,200	c 10	c 360	c 10	c 330
Sunflower	0	0	0	0	0	0	0	0
Soybean	105	50	105	50	150	130	150	130
Rapeseed	2	2	2	2	6	5	6	5
Total	708	3,235	689	3,034	597	ca. 1,176	ca. 575	ca. 1,071
	3,943		3,723		1,773		1,646	

The biomethane potential is determined for crop residues only from larger farms. For the region of Vojvodina and Belgrade, farms with a minimum of 5 ha were considered, and for other areas of Serbia, a minimum of 10 ha. Additionally, corn harvest residues are considered only for early hybrids (FAO groups 100-400), where only biomass with low moisture content and soil contamination is considered usable. Allocation of harvest residues for other uses was conducted as well. Harvest residues used for bedding in animal husbandry were determined based on Viskovic et al. (2022), which rate around 615,000 tons of dry mass of wheat straw annually. For heating, it is calculated that arabout00,000 tons of dry mass are used annually in Serbia, based on heating energy needs, and deducting other energy sources recorded (firewood, natural gas, district heating, etc.). Competitive biofuel production is also considered, whereby it is assumed that a large-scale lignocellulosic (LCB) bioethanol production facility which uses 200,000 t of dry straw would be built as well. For the determined potential, crop residues should be collected from between 5% and 10% of the used agricultural land in Serbia and between 6% and 11% of the utilised agricultural land in Vojvodina.

<u>Organic waste from the food industry</u>

The theoretical potential remains to be discovered since literature sources provide contradictory data on the generated amount of this type of waste. The technical potential is determined according to the collected amounts reported by SEPA (2023). The sustainable potential is determined using the coefficients for waste appropriateness and usability for anaerobic digestion, which are expert assumptions and rates between 40% and 100%. The biomethane potential is the same as the sustainable potential since it was assumed that no other disposal pathway would be implemented. Thereby, it is expected that the generated waste from one site (food industry) would not be disposed of at the biogas plant within this site, but transported to the external one, due to insufficient waste.

Despite questionable reliability of available data, organic waste from industry represents another significant source of biogas feedstock (Serbia: 77.216 t/a; Vojvodina 59.078 t/a according to SEPA, 2023). Wastes form sugar mills, starch factories and breweries are of particular interest (Table 8-7).

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Said potential is referred in terms of energy that could be generated from anaerobic digestion while a significant share is already used at the existing plants for electricity generation.

Table 8-7. Organic waste potential in Serbia

Source	MWe	GWhe/a	MNm3/a
Sugar mills	4.8	36.4	10.1
Starch factories	2.0	16.0	4.1
Breweries	3.5	28.0	7.2
Total	10.3	80.4	21.4

UCO – Used cooking oil and fats

The collected amount of UCO is relatively low in Serbia, as shown in the following table. Serbia could reach UCO collection by about 17,000-21.250 t/a; the lowest level could be around 10,000 t/a. The average in EU27 is 5.6–7.2 kg UCO per capita (Djurisic-Mladenovic *et al.*, 2018). The theoretical potential of UCO rates 21,250 t/a in Serbia, whereby the potential for Vojvodina was determined using the share of population in this province (26.18%) and rates 5,563 t annually. Figures for this and the following balances are used from Djurisic-Mladenovic *et al.* (2018). The technical potential is 10,000 t annually, representing the lowest amount that can be collected (according to literature data). For Vojvodina, the potential is 2,600 t annually. The sustainable potential for Serbia is about 5,000 t annually since a somewhat lower amount was managed to be collected in 2022. The quantity for Vojvodina is reduced compared to the number of inhabitants (1,040 t). The biomethane potential is considered 10% of sustainable, both for Serbia and Vojvodina, since it was assumed that most of this waste would be used for other biofuel production pathways, e.g., to produce 2G biodiesel.

Slaughterhouse waste

The potential determined within the study of Martinov et al. (2020) was adopted as the biomethane potential for Serbia since there is no recorded appropriate slaughterhouse waste disposal by anaerobic digestion. Nonetheless, estimations show that slaughterhouse waste utilization could generate 5.0 Mwe or 40.0GWe/a or 10.3 MNm3/a. Therefore, the complete potential could be used in the future for biomethane production on the newly commissioned biomethane plants. For Vojvodina, it was assumed that 60% of this potential.

Sewage sludge

According to Martinov et al. (2020), biogas potential for 2020 was assessed to be 6.8 MW_e (14 × MNm^3 methane or 54 GWh_e/a). The potential beyond 2020 was evaluated to be about 8.2 MW_e (17 × MNm^3 methane or 65 GWh_e/a). According to the Statistical Office of the Republic of Serbia, about 308 million m^3 (74% from households) and 72 million m^3 (75% from households) of wastewaters are discharged in public canalisation in Serbia and Vojvodina, respectively (SORS, 2023b). In Serbia, only around 19% of waste waters are treated (2% primary, 10% secondary, 7% tertiary); in Vojvodina, 25% (10% secondary, 15% tertiary). The total sludge production from the existing wastewater treatment plants is estimated at 11,000–15,000 tDM/a, according to the *Specific Plan for implementing EU Directive 91/271/EES on municipal wastewater*. Municipal utility companies mainly manage wastewater treatment plants in Serbia, which are also responsible for sludge management. The

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estimated sludge production by 2041 will reach 135,190 tDM/a (Anonymous, 2022) after fully implementing the Municipal Wastewater Treatment Directive. According to the Water management plan on the territory of the Republic of Serbia for the period 2021 to 2027 (MAFWM, 2021), in Table TX number of new plants, the range of their capacities and the population comprised are presented. The total (theoretical) potential is the total number of population equivalent (7.15 million PE), practically Serbia's total population. Analogically, the total potential for Vojvodina is estimated based on the share of people (26.18%), which gives 1.87 million PE). The technical potential is determined for those plants that cover a minimum of 10,000 PE, which for Serbia rates 5.94 million PE and for Vojvodina 1.55 million PE. The sustainable potential subsumes plants with a minimum of 50,000 PE, which for Serbia rates at 4.32 million PE and for Vojvodina 1.13 million PE. The biomethane potential was determined based on the assumption that biomethane will be produced only at the largest group of plants (4), which includes 2.74 million PE for Serbia. For Vojvodina, only the single planned plant in Novi Sad with 450,000 PE was considered (Martinov & Djatkov, 2013).

OFMSW– Organic Fraction of Municipal Solid Waste

In Serbia, there is no primary selection of waste in households. An established logistical system must exist for separate collection, logistics and waste disposal. However, based on estimations the total (theoretical) potential represents the total biodegradable waste for 2030 that rates 2.061.251 t. The technical potential is the value of the collected amount (1.208,302 t). This amount already accounted for population change, as well as the composting in households. The sustainable potential is the amount that will not be allowed to landfill in 2030 (801.263 t), which is 50% of total biodegradable waste in the reference year of 2008. The biomethane potential is assumed to be the remaining amount when 340,000 t (40% biodegradable fraction for anaerobic digestion) will be incinerated in the incineration plant in Vinča with 30 MW_e and 56.5 MW_t for district heating. Additionally, it was assumed that 50% of this remaining potential would be disposed of by composting. For Vojvodina, the assumption was based on the share of the population (26.18%).

Landfill gas

The total (theoretical) potential of landfill gas either in Serbia or Vojvodina is still being determined because there is significant uncertainty in the conditions prevailing at landfills in Serbia (depth of the landfill, the possibility of coverage to transform it into a sanitary one. This potential could not be determined using data on the population and the waste generation (with the appropriate share of the organic fraction). The data are mainly extracted from the Faculty of Technical Sciences, Department of Environmental Engineering database, collected through numerous projects and on-field measurements and expressed as potential in the capacity equivalent to installed electricity generation. Belgrade landfill located in Vinča has built a cogeneration plant for landfill gas with a capacity of 4 MW_e, wherewith this capacity could not be foreseen for biomethane. Additionally, a waste incinerator of 40 MW_e is being built, and the waste generated in the future will be partly utilised in this facility. Therefore, the balance could not include capacity from the capital of Belgrade. The technical potential of 10 MW_e for the Province of Vojvodina represents the sum of potential for the landfills. Additionally, the value is extrapolated for the missing municipalities (with a population larger than 25,000). The technical potential for Serbia 16 MW_e was determined similarly but considering the

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reduced waste collection rate in the remaining part (Central Serbia). The sustainable potential for 2030 is part of the technical, namely 50% of the (organic) waste that will be allowed to be landfilled in that year. Thus, the sustainable potential in Vojvodina is 5 MW_e, and in the whole of Serbia, 8 MW_e. The biomethane potential for 2030 comprises only the landfill gas potentially produced on the larger and sanitary landfills in Vojvodina, which make in total of 2.5 MW_e.

Total potentials

Total or overall potentials for biomethane are presented through the produced biomethane quantity in Nm^3 (normal cubic meters) or primary energy contained in the produced biomethane expressed in four different units (due to the opportunity to compare the potentials among other sources). Biomethane potentials are presented for Serbia and Vojvodina, which is the focus of this study. Additionally, the share of biomethane potentials among all considered feedstocks is provided in two additional figures for Serbia and Vojvodina. Compared with the RePowerEU target for biomethane production in 2030 of 35 bcm across the EU, the biomethane potential for Serbia and Vojvodina makes the relative share of 1.84% and 1.01%, respectively (Table 8-8).

Table 8-8. Biomethane potential for Serbia and Vojvodina

	SERBIA					VOJVODINA				
Feedstock	**Biomethane**	**Primary energy**				**Biomethane**	**Primary energy**			
	MNm^3 CH_4/a	**TJ/a**	**MNm^3 CH_4/a**	**ktoe/a**	**MWe_e qv**	**MNm^3 CH_4/a**	**TJ/a**	**GWh/a**	**ktoe/a**	**MWe_e qv**
Manure	79	2,848	791	68	34.3	59	2,103	584	50	25.3
Energy crops	259	9,289	2,580	222	111.9	153	5,509	1,530	132	66.4
Sequential crops	93	3,356	932	80	40.4	42	1,525	424	36	18.4
Crop residues	146	5,235	1,454	125	63.1	70	2,507	696	60	30.2
Organic waste (food industry)	3	96	27	2	1.2	3	96	27	2	0.9
UCO	0	9	2	0	0.1	0	2	1	0	0
Slaughterhouse	10	370	103	9	4.5	6	222	62	5	2.7
Sewage sludge	17	594	165	14	7.2	3	98	27	2	1.2
OFMSW	25	883	245	21	10.6	8	279	77	7	3.4
Landfill	7	249	69	6	3.0	6	207	58	5	2.5
Total	**639**	**22,928**	**6,369**	**548**	**276.3**	**350**	**12,547**	**3,485**	**300**	**150.9**

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8.8.2 C. Natural gas grid infrastructure and future prospect

The distribution grid in Serbia subsumes two levels of pressure (0-4 bar low pressure; 4-16 bar medium pressure). The transport grid is high-pressure (16-50 bar). The following Figure 8-4 is the natural gas grid in Serbia (dashed is the future pipeline), with the emphasized measuring-controlling station, underground reservoir, and compressor station. It is evident that Vojvodina is significantly higher covered with natural gas grid than other parts.

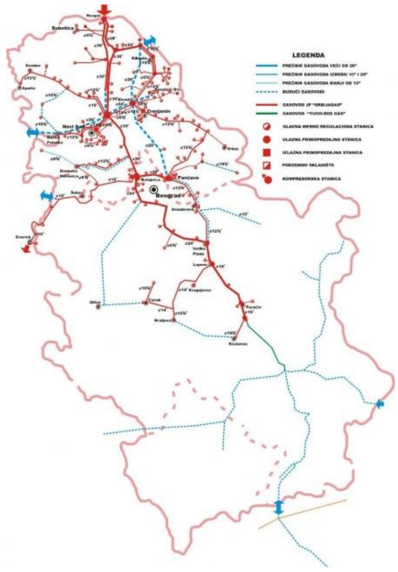

Figure 8-4. Map of the natural gas pipeline in Serbia

Vision for biomethane injection potential

It should be emphasized that there have yet to be any official strategies and plans for biomethane in Serbia. Therefore, here are listed options which stand for expert assessment based on the consultation with stakeholders in Serbia. Besides the injection of biomethane in the natural gas grid, options could be: 1) biomethane compression and injection in high presser vessels, transported to end-users; 2) biomethane filling station for public transport vehicles fleet at anaerobic digestion facility site for waste disposal. These options should be though thoroughly investigated from technical and economic aspects.

8.9 C. Regulatory framework and supportive policies

8.9.1 C. Vision and targets

There is yet to be an official strategy for biomethane in Serbia. Here presented figures in the following subchapter are an expert assessment based on the status of the biogas sector. The Biogas sector started in 2010, and since then 35 biogas plants have been built in Serbia (MMERS, 2022a), whereby only two of them are not agricultural. Unfortunately, two facilities have stopped working in the meantime) (MMERS, 2022a). The total installed capacity of operating agricultural biogas plants is approximately 33 MW. Practically, Serbia fulfilled the goal of 30 MW by 2020, defined by the NREAP (MEDEP, 2012). However, the goal was defined for capacity from manure, and the stated installed capacity is not only from manure. In that sense, either the goal is wrongly defined (should be 30 MW from agricultural feedstocks), or there is still room for further biogas sector development.

The table below gives an overview of installed capacities of biogas plants in Serbia from the official Register of privileged electricity producers, temporary privileged producers of electricity and producers from renewable energy sources of the Ministry of Mining and Energy of the Republic of Serbia (MMERS, 2023a). All the presented plants produce biogas and utilise it for electricity generation. Theoretically, the biogas plants, which will end the operation period of 12 years until 2030, within which they received a feed-in tariff for the electricity fed into the grid, could be reconstructed

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for biomethane production. This potential could be assessed as biomethane potential for 2030, which rates around 16.5 MW_e. Except for the one plant of 1,738 kW_e, which is industrial and strongly depends on the yeast production capacity and generated waste, the first several biogas plants will lose the privileged status and stop obtaining feed-in tariffs already in 2024. The remaining listed biogas plants for electricity generation will get the same status at the latest in 2034. Therefore, this potential could be assessed as biomethane potential for 2050. These potentials are additional and should complement those presented in Subchapter 2.1, comprising feedstocks that are only available and not already used for biogas production to electricity or other energy or material pathways. The relative increase in the potentials rate is about 6% for Serbia and 11% for Vojvodina.

Besides the existing plants, there are announced biogas projects that obtained temporary privileged statuses with a total capacity of 76,481 kW_e (MMERS, 2023a) (Table 8-9). These were biogas projects in the planning phase for which the intention was to obtain this temporary status before the expiration of the old Energy law (MMERS, 2014) and by-laws. Thus, they could still get feed-in tariffs and not switch to the recently announced auction system. Practically, the increased CAPEX and OPEX costs, including feedstock purchase prices, postponed or cancelled these projects. Still, this shows that there are potential investors in the biogas sector when the incentive measures are appropriate. This could also be the case with biomethane if these potential projects were coordinately renamed into biomethane projects, and a suitable incentive system would be adopted. However, my expert assessment is that not all the planned 76,481 kW_e could be reached since some projects fulfilled administrative criteria to obtain this status, but with no careful consideration of reliable and sufficient feedstock provision.

Table 8-9. Overview of installed capacities in the biogas sector in Serbia (MMERS, 2023a)

<table>
<tr><th>Installed power, kW_e</th><th>Commissioning date</th><th>Expiry date</th><th colspan="2">Power,MW_e</th></tr>
<tr><td>1,738</td><td>11.05.2011</td><td>11.05.2023</td><td rowspan="16">16.491</td><td rowspan="16">Potential for biomethane for 2030</td></tr>
<tr><td>999</td><td>12.03.2012</td><td>12.03.2024</td></tr>
<tr><td>990</td><td>02.10.2012</td><td>02.10.2024</td></tr>
<tr><td>635</td><td>05.12.2012</td><td>05.12.2024</td></tr>
<tr><td>500</td><td>16.01.2014</td><td>16.01.2026</td></tr>
<tr><td>600</td><td>12.05.2016</td><td>12.05.2028</td></tr>
<tr><td>3,570</td><td>12.09.2016</td><td>12.09.2028</td></tr>
<tr><td>650</td><td>03.11.2016</td><td>03.11.2028</td></tr>
<tr><td>650</td><td>03.11.2016</td><td>03.11.2028</td></tr>
<tr><td>2,000</td><td>14.08.2017</td><td>14.08.2029</td></tr>
<tr><td>637</td><td>26.12.2017</td><td>26.12.2029</td></tr>
<tr><td>650</td><td>02.03.2018</td><td>02.03.2030</td></tr>
<tr><td>637</td><td>29.06.2018</td><td>29.06.2030</td></tr>
<tr><td>635</td><td>27.11.2018</td><td>27.11.2030</td></tr>
<tr><td>800</td><td>11.12.2018</td><td>11.12.2030</td></tr>
<tr><td>800</td><td>11.12.2018</td><td>11.12.2030</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>999</td><td>20.02.2019</td><td>20.02.2031</td><td rowspan="7">17.795</td><td rowspan="7">Potential for biomethane for 2050</td></tr>
<tr><td>200</td><td>24.04.2019</td><td>24.04.2031</td></tr>
<tr><td>999</td><td>06.06.2019</td><td>06.06.2031</td></tr>
<tr><td>999</td><td>27.05.2019</td><td>27.05.2031</td></tr>
<tr><td>530</td><td>16.07.2019</td><td>16.07.2031</td></tr>
<tr><td>999</td><td>19.02.2020</td><td>19.02.2032</td></tr>
<tr><td>499</td><td>10.03.2020</td><td>10.03.2032</td></tr>
</table>

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999	21.05.2020	21.05.2032		
999	17.06.2020	17.06.2032		
999	23.07.2020	23.07.2032		
2,126	20.07.2020	20.07.2032		
999	05.03.2021	05.03.2033		
999	16.04.2021	16.04.2033		
1,203	06.05.2021	06.05.2033		
999	02.12.2021	02.12.2033		
999	10.02.2022	10.02.2034		
250	11.03.2022	11.03.2034		
999	30.06.2022	30.06.2034		
999	31.01.2020	31.01.2032		
		Total	**34.286**	

Estimation of biogas and biomethane development

In Serbia, there have yet to be any official targets for biomethane production and consumption. In the following table are presented with the opportunities to contribute to different sectors that consume energy and, additionally, a chance to replace national natural gas consumption. Data from the Energy Balance of the Republic of Serbia for 2022 were used (MMERS, 2023b). Focusing particularly on the transport sector, where biomethane used as a biofuel could reach 20% at the national level and 11% in Vojvodina. In Serbia, the natural gas domestic production rates are 0.285 Mtoe (357 Mm^3), and the imported is 2.227 Mtoe (2,797 Mm^3). Using the figure on the biomethane potential determined within Chapter 2, the energy share in domestic natural gas consumption could reach about 22% (potential from the entire Serbia) and about 12% (potential from the Autonomous Province of Vojvodina) (Table 8-10).

Table 8-10. Biomethane potential in energy consumption in Serbia (MMERS, 2023)

National energy consumption		Coverage from biomethane, %	
Sector	Mtoe	Serbia	Vojvodina
Industry	2.096	26.3	14.5
Transport	**2.718**	**20.3**	**11.2**
Households	3.547	15.6	8.6
Agriculture	0.169	326.7	180.1
Other	0.911	60.6	33.4
Total	9.441	5.8	3.2
Natural gas consumption		22.3	12.3

<u>National strategy and national plan</u>

The Integrated National Energy and Climate Plan of the Republic of Serbia for the period 2030, with the projections up to 2050 (MMERS, 2023c), is in the preparation phase. In the draft version, which is the subject of public discussion, the two targets are mentioned—the amount of 49 ktoe of all biofuels for transport as the obligation for biofuel blending. The amount of 87 ktoe of biomethane (hydrogen as well) is foreseen by the demonstration projects for all end-use sectors. These figures rate about 9% and 16% of the total biomethane potential of Serbia, which is significantly below the realistic potential that could be devoted to biomethane potential.

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Targets for biomethane production and consumption

The Energy law from 2014 introduced the guaranteed share of biofuels on the Serbian market (MMERS, 2014) so that energy entities that produce and trade fossil fuels are obliged to place a certain amount of biofuel on the market. The same law defines that biofuel, *i.e.* biogas/biomethane as well, should be counted twice if produced from organic waste, harvest residues and manure. Energy entities should theoretically pay penalties if they do not fulfil this obligation, making financing biofuel production more profitable. Unfortunately, the sustainability criteria are in accordance with RED I and not RED II, although the last was already effective at the time of the Energy law adoption. The Decision on determining the mandatory share of biofuels obliges to put into circulation on the market of the Republic of Serbia (GRS, 2022a) states that by the end of 2025, the energy share should be 1%. Biogas (the regulation uses the wrong term) needs to meet sustainability criteria to be considered eligible to count as a biofuel. The most crucial criterion is undoubtedly the GHG emissions saving (GRS, 2019).

Besides the current targets for the share of biofuels, the biomethane sector is a part of the Renewable energy law (MMERS, 2021). Biomethane is classified in biofuels for transport, and the term is here used appropriately. The Investment State Aid was introduced as an incentive measure intended for advanced biofuels, whereby it is not defined precisely whether biomethane produced from waste could have that status. Unfortunately, the by-laws that should assemble this area have not yet been adopted.

The Integrated National Energy and Climate Plan of the Republic of Serbia for the period 2030, with the projections up to 2050 (MMERS, 2023c), is in the preparation phase. It is expected that it will be finally adopted in autumn 2023. Biomethane is mentioned as the instrument for the sector coupling that will contribute to the maximisation of the RES in the different end-uses. One such measure is mixing biomethane (hydrogen as well) into the natural gas network. The gradual exploitation of biomethane (hydrogen as well) in the district heating networks is planned as well, but not stated the energy contribution, share, etc.; Biomethane for transport, besides green hydrogen, is foreseen through the implementation of demonstration projects. Therefore, it needs to be clarified whether demonstration projects are relevant to biomethane, which could be a misleading approach since biomethane plants are very mature technology. The amount of 49 ktoe of biofuels for transport is the level that should be achieved to fulfil the obligation for biofuel blending. The amount of 87 ktoe of biomethane (hydrogen as well) is foreseen to be financed through demonstration projects in all end-use sectors. In the part where the impact of planned measures and policies is assessed, it is stated: *Electrification of heating and transport is coupled with an increased share of RES in electricity generation. At the same time, green hydrogen will be introduced initially in demonstration projects and after 2030 in larger quantities. Biomethane is gradually introduced in thermal applications and included in blending with natural gas, together with green hydrogen, after 2030.* This isn't very clear since biomethane use in the transport sector is not assessed.

It is still being determined how the mechanism for emission trading will be implemented in the sector of biogas/biomethane in Serbia. The Law on climate change (MEP, 2021) has been adopted recently, and by-laws still need to be included. The certification bodies don't have enough experience and capacity to state how, or even at all, this trading system will be implanted in Serbia in the sector of

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biogas/biomethane. This is important since the guarantees of origin (GOO) and other types of green certificates could be an additional source of their income.

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