Biomethane production in Serbia – GAP analysis of policies, potentials, supply, infrastructure and market trends

– Consultants' report –

Authors:
Djordje Djatkov, Miodrag Viskovic, Dejan Ubavin
Faculty of Technical Sciences Novi Sad (FTS)
Department of Environmental Engineering & Occupational Safety & Health

Novi Sad, November 2024

This report was prepared with the financial support of the Government of Switzerland within the project "EU for Green Agenda in Serbia". This project, with the technical and financial support of the European Union and in partnership with the Ministry of Environmental Protection, is implemented by UNDP in cooperation with Sweden and the European Investment Bank (EIB), with additional funding provided by the governments of Sweden, Switzerland and Serbia. The content of this publication, as well as the results presented within it, are the sole responsibility of the author and do not necessarily reflect the views of the EU, the Government of Switzerland, or UNDP.

TABLE OF CONTENTS

A B B R E V I A T I O N S

1G and 2G	Non–advanced and advanced generation biofuels
AD	Anaerobic Digestion
APV	Autonomous Province of Vojvodina
ABS	Accreditation Body of Serbia
AU	Animal Units
bio-CNG	Compressed biomethane
bio-LNG	Liquefied biomethane
BM	Biomethane
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCU	Carbon Capture and Utilization
CNG	Compressed Natural Gas
DSO	Distribution System Operator
EBA	European Biogas Association
EE	Energetska efikasnost
EGD	European Green Deal
EP	Equivalent Population
EU	European Union
EU-ETS	EU Emissions Trading System
FAO	Food and Agriculture Organization
FiP	Feed-in premium, market premium
FiT	Feed-in tariff
GEF	Global Environmental Facility
GHG	Greenhouse Gases
GoO	Guarantee of Origin
HHV	Higher Heating Value
HORECA	Hotels, Restaurants, Caffes
INECP	Integrated National Energy and Climate Plan
ISCC	International Sustainability and Carbon Certification
JRC	Joint Research Center
ktoe	kilo tons of oil equivalent
LCOE	Levelized Cost of Energy
LHV	Lower Heating Value
LULUCF	Land Use, Land Use Change, Forestry
MBW	Municipal Biodegradable Waste
MEP	Ministry of Environmental Protection
MME	Ministry of Mining and Energy
NABISY	Nachhaltige Biomasse System

NBO	Non Biological Origin
NG	Natural Gas
NIMBY	Not In My Back Yard
OPEX	Operating Expense
PBP	Payback Period
PM	Policy Measure
PoS	Proof of Sustainability
PPEE	Privileged producer of electricity from renewable energy sources
PPPEE	Temporary status of privileged producer of electricity from renewable energy sources
PSA	Pressure Swing Adsorption
RED	Renewable Energy Directive
RES	Renewable energy sources
RBP	Reconstructed biogas plants to biomethane
RS	Republic of Serbia
TSO	Transport System Operator
TRL	Technology Readiness Level
UNDP	United Nations Development Programe
VAT	Value Added Tax
WWTP	Wastewater treatment plants

Executive summary

The goal of the project, as outlined in this report, is to analyze the following in Serbia: 1) the strategic and legal framework relevant to biomethane; 2) the status of the biogas and biomethane sector; 3) the biogas and biometan value chain with current and potential participants; 4) the potential for biomethane production; 5) the national target for biomethane production and its effects; 6) the infrastructure for integrating biomethane; 7) the possibility of integrating innovative technologies; 8) the barriers to biomethane integration into the market; 9) the applicability of incentive schemes that will initiate and sustain the biomethane sector. Achieving these objectives is intended to lay the foundations for development and long-term define the direction for the successful development of the biometan sector in Serbia.

The European Union is clearly committed to the European Green Deal and its goals, which also impact the biogas and biometan sectors (EU strategy for reducing methane emissions, REPowerEU, Integrated National Energy and Climate Plans, Circular Economy Action Plan). REPowerEU, an ambitious addition to the REDIII directive, establishes a target of 35 billion cubic meters of biometan by 2030 (3.5 billion cubic meters were achieved in 2021). The goal is to replace natural gas with biomethane, particularly in the transport and energy sectors. In Serbia, through the Law on the Use of Renewable Energy Sources and numerous other regulations in force, solid foundations have been laid for integrating biometan into the market. The Integrated National Energy and Climate Plan (INECP) initially defines goals for biometan production in Serbia.

The legal and sub-legal documents in Serbia need to be supplemented with national goals for biogas production that can be realistically and sustainably achieved based on available feedstocks. It is necessary to define incentive schemes that will create an adequate environment for investments and the achievement of national biogas production goals, including long-term goals for 2050. Existing regulations should continue to be harmonized with each other, and a verification system should be established. Only after fulfilling these prerequisites can the construction of the first biogas plants in Serbia be expected.

The production cost of biogas at potentially reconstructed existing biogas plants in Serbia would amount to up to 90 €/MWh, and the required income to ensure profitable operation with a return should be increased by at least 15%. For newly constructed biogas plants in Serbia, the corresponding income is over 115 €/MWh, which would enable the investment payback time to be under 10 years. Although, aside from potential investors, there are clear direct and indirect benefits of biogas production for local communities and society as a whole, it is necessary to continue raising awareness and including all potential stakeholders. It is only through this approach that the biogas sector can fully realize its potential in areas such as energy, environmental protection, transport, and waste management.

The minimum dry matter content of manure in the total dry mass of all raw materials used for biogas production should be: 10% when used in transport; 30% for electricity generation; and 50% for heating/cooling. Additionally, it is necessary to burn waste gas and cover the fermentation residue tanks. This ensures the fulfillment of greenhouse gas emission savings criteria, which depend on the sector in which biogas is used. For example, the savings criterion for transport is 65%, while for heating/cooling and electricity generation, it is 70% or 80%.

For the integration of biogas into the natural gas sector and existing infrastructure in Serbia, there is a solid foundation, with the sector and infrastructure still developing. Existing regulations defining the quality of natural gas provide a basis for defining and harmonizing the requirements for the quality and composition of biogas. A technical barrier

for injecting biogas into the natural gas grid is the required oxygen content, which can be overcome in cooperation with gas network operators. Economic barriers include the high price of biogas compared to natural gas, as well as high investment costs for connecting to the natural gas grid, which require incentives.

For the short-term period (2027), it is recommended to apply only commercially mature and proven technologies for biomethane production. For the medium term (2030), it is only recommended to adopt innovative technologies for the pretreatment of crop residues as feedstock for biomethane production. While this approach requires additional investment, it can significantly reduce operational costs associated with raw material procurement, which represents the largest expense. Post-2030, demonstration projects could be considered to promote innovative technologies and ensure their timely integration. Cryogenic technology has the potential to support the production of liquefied biomethane (bio-LNG) for transport while also generating 100% pure bio-CO_2. Methanation technology could foster the development of Carbon Capture and Utilization (CCU) systems, effectively contributing to decarbonization and the production of e-fuels. In the long term, gasification technology combined with methanation could enable large-scale biomethane production in Serbia, though it would require the mobilization of significant amounts of raw materials.

Short-term (2027) biomethane production potential is largely reliant on agricultural feedstocks (manure, energy crops, secondary crops, and crop residues). Enhancing the use of waste for biomethane production requires an intersectoral strategy and collaboration between the energy and environmental sectors. In the short term, biomethane has the potential to replace 40–90% of final consumption, 16–35% of imports, and 13–30% of Serbia's total domestic natural gas consumption. Long-term potential (2050) could be maximized by utilizing waste, contributing about half of the feedstock. At this stage, biomethane could replace 50–200% of final consumption, 24–48% of imports, and 23–88% of total domestic natural gas consumption. These potentials form the basis for setting national targets, considering technical, technological, and economic criteria, as well as the feasibility of raw material mobilization over time.

Proposed biomethane production targets for Serbia are as follows: short-term 32 ktoe; medium-term 186 ktoe; long-term 365 ktoe. The short-term target could be fully utilized in the transport sector, supplying about 90% of the energy anticipated for liquid biofuels and natural gas under the INECP. Thus, biomethane could become the primary tool for achieving decarbonization targets in the transport sector. For the medium and long term, it is proposed that the targets be used in transport to the extent necessary to fully meet the energy share projected under INECP for liquid biofuels and natural gas, with the remaining volume applied in other sectors of final consumption, replacing 16–29% of natural gas. This approach leverages the lower production costs and greater greenhouse gas savings potential of advanced biomethane compared to advanced liquid biofuels, which are mandatory in the transport sector. Consequently, it ensures better outcomes at lower costs.

1 The context of the importance of biomethane in Europe and Serbia

Europe

An overview of the most important information about the market is presented in the following text, as well as the role and importance of biomethane plants in Europe. In 2022, 1,323 biomethane plants were installed in 24 European countries, of which 75% inject biomethane into the natural gas (NG) network. Most are connected to the NG distribution network (58%), and only about one-fifth to the transport network (17%). Bio-CNG (compressed biomethane) and bio-LNG (liquefied biomethane) are produced at around 10% of existing plants. Bio-LNG is currently produced in 10 countries, and by 2025, 109 new bio-LNG plants are expected[1].

In Europe, 29% of biomethane is used in the transport sector, 28% in households, 26% in industry, and about 17% in the service sector and other sectors [1]. In countries like Italy, Finland, Estonia, it is exclusively used in traffic, and in Belgium for industry. All sectors are represented in Germany. In the surrounding area, the number of biomethane plants is minimal, only two in Hungary, while the implementation of new plants is announced or under construction in Croatia and Slovenia.

The form of biomethane in the Scandinavian and Baltic states is mainly bio-CNG, while in the rest of Europe, injection into the NG network is more dominant. Italy stands out for its high proportion of bio-LNG plants. The map of biomethane plants classified by form can be found at the link: Map. There is a codependence on the form of biomethane produced, the sector in which it is used and the availability of the NG network. In countries where bio-CNG plants are dominant, it is mostly used in traffic, and where there is an available NG network, the possibility of connection and appropriate consumption, injection is practiced.

The choice of the form of biomethane on the market also depends on strategic decisions for incentives. Stimulating the production of biomethane in European countries is an important factor that initiated the development and is still carried out on a large scale. Formed incentive incentive schemes differ by country, but cross-sectoral coordination (energy, agriculture, waste, decarbonization, finance) is key. The essence is to create an environment in which the investor has low investment risks, while achieving the desired social goal.

Incentive measures are defined in the form of **support for production** (direct stimulation of biomethane producers, which ensures market availability) or **support for use** (subjects are obliged to use biomethane, which ensures market demand), and a combination of these two approaches is also used[2]. **Production support** is achieved through mechanisms such as Feed-in Tariffs (FiT), market premiums, contracts for difference and direct support for capital investment costs (CAPEX). **Support for use** is achieved through sectoral goals - mandates, for example for biofuel system obligees (traders and importers of fossil fuels) in the form of a share of energy from biomass fuel, obligations to reduce greenhouse gas emissions - GHG (EU-ETS or obligations for fuel producers), tax credits, and there are also examples of FiT for electricity from biomethane.

At the EU level, there is a clear commitment to the European Green Deal (EGD) and its goals. In particular, the EGD is supported by documents that directly affect the field of

---

[1] *European Biogas Association (EBA). 2024. EBA Statistical Report – Tracking biogas and biomethane deployment across Europe. https://www.europeanbiogas.eu/eba-statistical-report-2023/*

[2] *Biomethane Industrial Partnership (BIP). 2024. Biomethane incentives and their effectiveness. Prepared by Task Force 1. https://bip-europe.eu/downloads/?filter%5B%5D=12 (pristupljeno maja 2024. yearine)*

biogas and biomethane: the EU strategy for reducing methane emissions[1], REPowerEU[2], integrated national energy and climate plans, but also indirectly through documents such as the Action Plan for the Circular Economy[3].

In 2021, biomethane production in the EU was 3.5[4] billion m^3. REPowerEU[2], a more ambitious addition to REDIII[5] directive, establishes a goal of 35 billion m^3 of biomethane by 2030. Each of the EU27 members, in accordance with their own potential, should contribute to the fulfillment of the goal. **Table 1** provides an overview of the biogas and biomethane sector in the EU. The availability of raw materials, the development of agriculture, as well as the presence of other forms of renewable energy sources (RES) play a significant role in defining the potential of biomethane. There is certainly a clear tendency to replace NG with biomethane, primarily in the transport and energy sectors.

Table 1: Biogas production capacities and biomethane potential in the EU [3]

Country	**Biogas production, 10^9 Nm^3/year**	**Share of biogas in NG consumption, %**	**Biomethane potential, 10^9 m^3/year**	**Estimated replacement of imported NG, %**
Denmark	0.7	32.4	0.8	100
Austria	0.2	2.1	0.7	13-16
Bulgaria	0.1	2.1	0.7	25
Croatia	0.1	4.1	0.3	5
Belgium	0.3	1.6	0.6	3.5
Czech Republic	0.7	7.8	0.7	9
Germany	8.4	9.6	8.1	-
Hungary	0.1	0.9	1.0	15
Italy	2.3	3.3	5.8	9

NG: Natural Gas.

Serbia

The existence of an appropriate legal framework will be extremely important for the implementation of biomethane production facilities in Serbia. The existence of the biogas sector since 2012 can serve as a good example. The development of the biogas sector was made possible by: a clearly defined national goal; incentive measures (with a clear incentive mechanism); guides for the realization of investments for biogas projects; the effort of the biogas sector through the Association of Biogas Serbia to coordinate incentive measures in accordance with market trends.

The national goal for biogas production was defined by the National Action Plan for the use of renewable energy sources of the RS, which amounted to 30 MW of installed electrical power and was to be realized by 2020. This clearly defined the role of the biogas plant as a renewable source of electricity. However, the document defines that the goal

---

[1] *EC. 2020. Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions on an EU strategy to reduce methane emissions. https://energy.ec.europa.eu/system/files/2020-10/eu_methane_strategy_0.pdf*

[2] *EC. 2022. REPowerEU: Joint European action for more affordable, secure and sustainable energy. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483*

[3] *EC. 2020. Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions. A new Circular Economy Action Plan. For a cleaner and more competitive Europe. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A98%3AFIN*

[4] *EC. 2023. General Publications: 2023 biomethane country fiches. Directorate-General for Energy. https://energy.ec.europa.eu/publications/2023-biomethane-country-fiches_en*

[5] *European Commission (EC). 2023. Directive (EU) 2023/2413 on the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. Official Journal of the European Union, 32023L2413. http://data.europa.eu/eli/dir/2023/2413/oj*

refers to the production of biogas from "manure", which is not practical or techno-economically feasible, because agricultural plants use a mixture of raw materials (most often manure and energy plants, with the addition of organic waste).

The construction of biogas plants was further initiated in 2010 with the entry into force of the first *Regulation on incentive measures for the production of electricity using renewable energy sources and the combined production of electricity and heat*, which resulted in the commissioning of the first biogas plants in 2012. Then the financial incentive measure - FiT - was defined. The FiT value has been redefined several times, and the most favorable one was introduced in 2015, which clearly resulted in increased construction of new biogas plants (Figure 1). As an additional incentive, the relevant ministry, in cooperation with the Global Environmental Facility (GEF) and the United Nations Development Program (UNDP), awarded grants for 4 biogas plants.

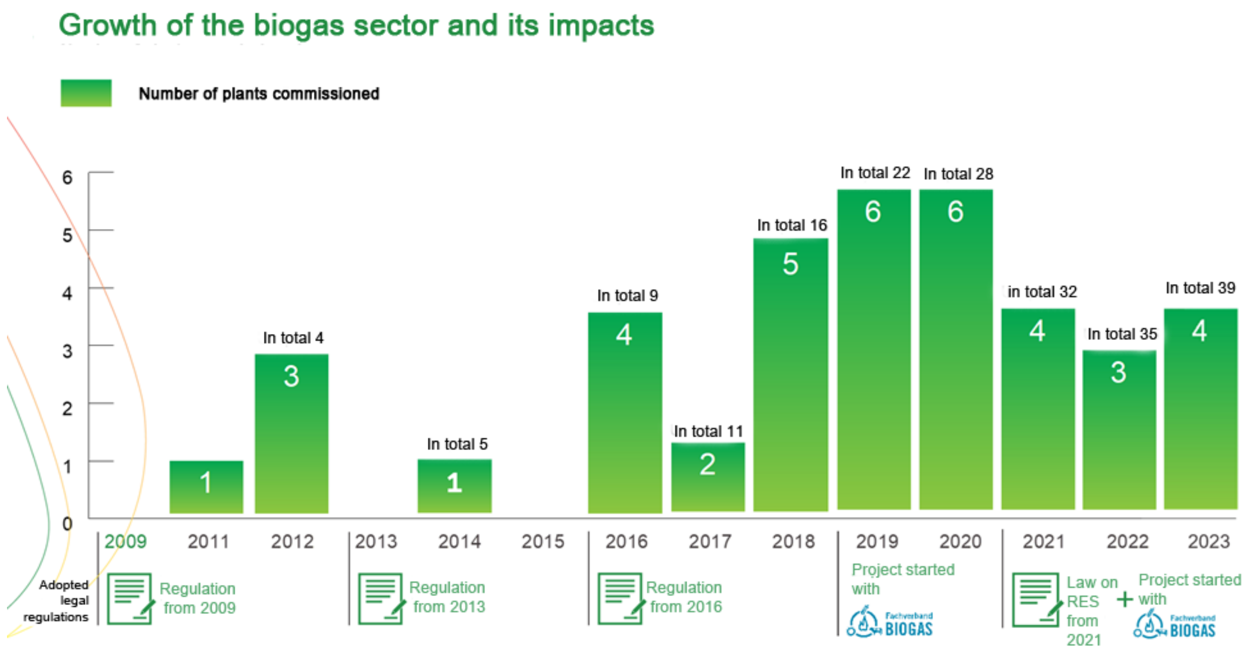


Figure 1. Development of the biogas sector in RS

Specialized guides for investors also made a significant contribution[1,2], as well as public presentations organized by the Council for Biomass and the Provincial Secretariat for Energy and Mineral Resources APV. There were also administrative incentive measures (e.g. exemption from customs duties and taxes for importing equipment from the EU, exemption from balance responsibility), but it is not known to what extent they influenced the development of the sector.

Due to the increase in investment and operating costs during and after COVID-19, due to the energy crisis, geopolitical instability, climate disasters, and low prices of fossil fuels in Serbia, further development of the sector has slowed down. The biggest impact was a significant increase in the price of raw materials (for example, 60 €/t for corn silage in 2022, compared to 35 €/t in 2012). Potential investors recognized this, and did not carry

[1] *Lepotić Kovačević B, Stojiljković D, Lazarević B. 2010. Izgradnja postrojenja i proizvodnja električne/toplotne energije iz biomase u Republici Srbiji - Vodič za investitore. Ministarstvo rudarstva i energetike Republike Srbije, Beograd.*

[2] *Martinov M, Djatkov Dj. (eds). 2012. Biogas postrojenje – uputstvo za izradu prethodnih studija opravdanosti sa primerom za jedno biogas postrojenje. Pokrajinski sekretarijat za energetiku, AP Vojvodina. Fakultet tehničkih nauka Novi Sad.*

out further activities, even though *the Law on Energy* and accompanying regulations were valid until the end of 2020, which enabled obtaining FiT for delivered electricity.

Through the Integrated National Energy and Climate Plan [1] (*INECP*), initial steps were taken towards defining goals for biomethane production in the RS. Through the regulations in force in the RS, the Law on the Use of RES [2] and numerous other documents laid good foundations for the integration of biomethane on the RS market.

The existence of an appropriate legal framework for biomethane will be crucial for the development of this sector in the RS. In contrast to the biogas sector, the importance of biomethane is its possible role as a gaseous fuel for the decarbonization of the transport sector, and also as an energy source for the heating/cooling sector and industry. Accordingly, it is necessary to consider the sustainability of production (also defined by European directives), primarily in terms of saving GHG emissions, sustainability criteria and contribution to achieving goals for reducing GHG emissions at the national level. This makes the development and harmonization of the legal framework more complex compared to the beginning of the biogas sector. Also, it is necessary for the biomethane sector to contribute significantly to the circular economy, environmental protection and sustainable sectors, primarily traffic in the RS. For that, it is necessary to harmonize complex regulations in several sectors (energy, transport, waste, agriculture, finance, environment). This would enable the use of various by-products or waste of organic origin in the value chain of biomethane production.

The legal framework for biomethane in the RS should include short-term, medium-term and long-term goals that can be realistically and sustainably achieved, taking into account the available potential of raw materials. Also, it is necessary to define incentive schemes that will provide an adequate environment for investments for many years, including direct incentives for delivered biomethane, direct incentives for investments and innovative projects, procurement of equipment, indirect incentive measures (exemption of customs duties and taxes), state aid, but also market mechanisms through guarantees of origin and emissions trading, which is a clear trend in EU countries.

[1] *Vlada Republike Srbije. 2024. Integrisani nacionalni energetski i klimatski plan Republike Srbije za period do 2030. yearine sa vizijom do 2050. yearine.* www.mre.gov.rs/extfile/sr/1138/INEKP_pre%C4%8Di%C5%A1%C4%87en_tekst_1.8.24.pdf

[2] *Zakon o korišćenju obnovljivih izvora energije. Sl. glasnik RS", br. 40/2021 i 35/2023*

2 The status of the biogas and biomethane sector in RS

Biogas

The total number of biogas production plants that were in operation in the RS at the beginning of 2024 is 35, with a total power of 34.8 MW_e (range 250-3,570 kW_e, average 996 kW_e). This refers to plants that have the status of a privileged producer of electricity (PPEE) and deliver electricity to the public electricity network at a subsidized price, i.e. feed-in tariffs (FiT). In addition, 3 biogas plants with a total capacity of 3,428 kW_e have terminated their PPEE contracts and ceased operation, and 7 outside the PPEE status produce biogas and use it as an energy source for wastewater treatment plants (WWTP).

The total amount of biogas is 107.3+3.7 MNm^3/year (in the PPEE status and outside the PPEE status), and the methane contained in the biogas is 55.8+2.3 MNm^3/year (in the PPEE status and outside the PPEE status).

In 2023, biogas plants in PPEE status delivered 227,671 MWh of electricity to the public electricity grid. The average utilization of the total capacity is low and amounted to 71%, which is a consequence of work stoppages or insufficient amount of raw materials. The amount of electricity for the operation of these plants was 6.4% of the delivered amount, while the criterion for the maximum value of an individual plant is 10%. Apart from covering the needs for heating the fermenter, the generated thermal energy is not used in the existing biogas plants (the exception is Global Seed LLC, which uses a low share for heating water for feeding animals on the farm). Natural gas, as a supplementary fuel, contributed about 1.3% to the total amount of electricity obtained, while the permitted value for an individual plant is 10%.

Of the raw materials used, animal manure dominates by mass share with 56% (**Table 2**), and **Figure 2** shows the representation of different types of manure. Then follow energy plants including second harvest and organic waste with about 20% each, while harvest residues are 3%. The energy share is the highest from energy crops including second harvest with 35%, organic waste 34% and manure 24%, while the remaining 7% are harvest residues (cereal straw and maize). Therefore, the mentioned biogas plants are almost exclusively agricultural, where various types of by-products and waste of organic origin are disposed of: sugar, oil and starch industry, dairy industry, silage, potato processing, alcohol industry, confectionery industry. The exception is the plant in the Apatin Brewery with an installed electrical power of 250 kW_e, which is the only industrial biogas plant that serves to dispose of sludge from wastewater treatment after the production process. The stated amount of energy plants is produced on a maximum of 5,000 ha (0.15%) of agricultural land in Serbia, which is a low percentage, but a favorable way to market agricultural products and generate income. Slaughterhouse waste is used as a raw material in only one plant in the amount of about 3,000 t/year (6.5% of the mass input at the given plant).

Table 2: Overview of raw materials used in biogas plants in PPEE status

Raw material	Mass, kt	Mass fraction, %	Share of dry matter, %	Biogas, MNm^3/year	Methane from biogas, MNm^3/year
Energy herbs	174	21	30	34.8	18.1
Manure	472	56	41	23.6	12.9
Harvest residues	28	3	12	6.9	3.5
Organic waste	168	20	17	33.6	18.5
In total	842	100	100	98.9	53.0

PPEE: privileged producer of electricity.

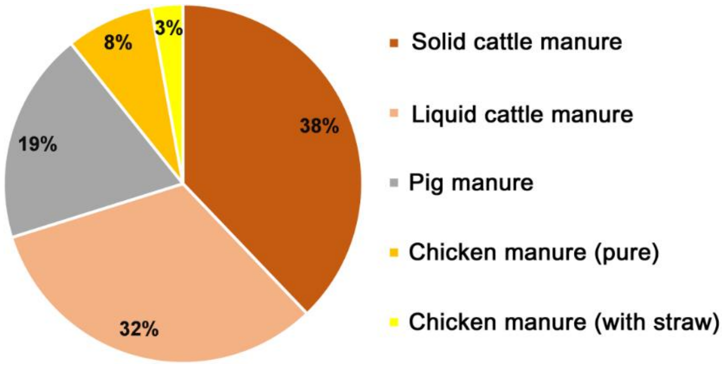


Figure 2: Mass share of individual types of animal manure used in biogas plants in 2023

The represented technology of all the mentioned biogas plants is based on wet fermentation (the content of dry matter in the fermenter mass in anaerobic fermenters is below 12%), in a (semi) continuous regime of adding raw materials, with a mesophilic temperature regime (38-42 °C). The absence of technology based on dry fermentation with a batch (discontinuous) mode of adding raw materials, which is typical for the disposal of municipal biodegradable waste, but also of organic waste from the food industry or food waste (expired), confirms the fact that the listed facilities are of an agricultural type.

Of the 7 biogas plants outside the PPEE status,1 serves for stabilization of organic matter sludge from wastewater treatment from the food industry (*Carlsberg Srbija LLC*, Čelarevo) and 6 from sewage treatment (Subotica, Vrbas, Sombor, Kruševac, Vranje, Leskovac). The produced biogas is used in cogeneration to obtain electricity and thermal energy to drive machines and devices at the wastewater treatment plant (water line) and stabilization of organic matter (sludge line), as an energy source for obtaining thermal energy and partial replacement of natural gas, or possibly flaring to burn the methane and convert it into carbon dioxide for a lower impact on climate change.

Number of biogas plants under planning and construction in temporary status privileged producer of electricity (PPPEE) is 66 and the total planned power is 66,260 kW_e. In most cases, PPPEE status was obtained based on the initiative of potential investors to take advantage of the opportunity until the end of 2021 as the term of validity of the *Law on Energy*, by which it was possible to earn FiT. However, a large proportion of these projects does not have a secured raw material base for the planned capacity and/or do not have the appropriate infrastructure. Therefore, not all potential projects are expected to be built.

Biomethane

There is currently no biomethane production plant in Serbia that is in operation. The company WABIO Technologie GmbH is currently the only company implementing the construction of a plant in Srpska Crnja, the completion of which is planned for 2026. The planned capacity of the plant is 625 Nm^3CH_4/h (the energy equivalent is the electric power of the biogas plant of 2.5 MW_e). The facility is intended for the production of liquefied biomethane (bio-LNG), along with the production of liquefied carbon dioxide. WABIO supplies technology, invests and, in partnership with a company from Germany, plans to use the produced amount of liquefied biomethane for export to the German market at an attractive price of €360/MWh_{HHV}. According to the statement of the owner of the Netherland company, REGAZZ, the initial activities for the development of two more projects for the construction of a biomethane production plant in Serbia have been initiated.

Table 3: Overview of the biogas sector in RS

Number of biogas plants						
Total number in operation					Plants	42
Number in PPEE status					Plants	35
Number out of PPEE status					Plants	7
Total number in planning and construction					Plants	68
Number in PPPEE status					Plants	66
Number out of PPPEE status					Plants	2
Number of biomethane plants						
Total number in operation					Plants	0
Total number in planning and construction					Plants	3
Indicators of the biogas sector in the PPEE status						
Total installed capacity in PPEE status					kW_e	38,281
Installed PPEE capacity in operation					kW_e	34,853
Installed capacity of non-operational PPEE					kW_e	3,428
Amount of biogas produced					MNm^3/year	107.3
The amount of methane produced					MNm^3/year	55.8
Amount of primary energy in methane (HHV)					GWh_p/year	617.1
The amount of electricity delivered to the network					GWh_e/year	227.7
Amount of heat energy used except for drive					GWh_e/year	~0.0
The amount of electricity taken from the grid for operation					GWh_e/year	14.6
Amount of natural gas as supplementary fuel from the network					MNm^3/year	0.782
Share of natural gas as supplementary fuel from the network					%	1.3
Energy herbs	Mass, kt/year	172	Mass fraction, %	21	Energy share, %	35
Manure		467		56		24
Harvest residues		26		3		7
Organic waste		163		20		34
Indicators of the biogas sector outside the PPEE status						
Amount of biogas produced					MNm^3/year	3.7
The amount of methane produced					MNm^3/year	2.3
Amount of primary energy in methane (HHV)					GWh_p/year	25.1
Share of primary energy – cogeneration for own needs WWTP					%	51.8
The share of primary energy – thermal energy for the WWTP's own needs					%	48.2
Share of primary energy – disposal by flaring					%	0.0

PPEE: privileged electricity producer; PPPEE: temporary privileged electricity producer; HHV: Higher Heating Value; WWTP: wastewater treatment plant.

3 Overview and conclusions of the GAP analysis

Below is a tabular overview of the most important aspects and conclusions of the conducted GAP analysis, in relation to the defined goal of the analysis, which is to establish the sector of production and use of biomethane on the RS market. The legal regulations and supporting documents that should regulate the field of biomethane in the RS were analyzed and compared with the corresponding ones from the EU.

Table 4: GAP analysis

Definition of biomethane
The Law on the Use of RES defines **biomethane as a gaseous fuel used in traffic**, obtained by processing or purifying biogas. In the Law on Energy, the term - **gaseous fuel for transport from biomass** is used within the term biofuel In the Regulation on sustainability criteria for biofuels, bioliquids and fuels from biomass, the term **biogas used in traffic** is constantly used. In Annex 2 of the Regulation on sustainability criteria for biofuels, bioliquids and fuels from biomass however, the term **biomethane** is correctly used. In the Regulation on the share of biofuels on the market and Regulations on conditions of delivery and supply of natural gas the term **biogas** is used, although it is clear that it refers to biomethane. The law on pipeline transport of gaseous and liquid hydrocarbons and distribution of gaseous hydrocarbons uses the term **biogas**. The Law on Excise Taxes is recognized as an act that is harmonized with the Law on Energy, so biomethane is interpreted as a gaseous biofuel. REDII mentions (gaseous) biomass fuel, but the annexes use the term biomethane. In INECP, **the use of biomethane in the heating and cooling sector** is considered, and defining it exclusively as a fuel for traffic is a limitation. It is proposed to harmonize all regulations with the definition from the Law on the Use of RES, with possibly an additional definition in which sector it is used exactly.
Proposal for amendments to the Law on Energy and by-laws
Apart from the definition of biomethane in the Law on Energy, it is necessary to harmonize the definition of A) Energy activities; B) Energy permits; and C) Licenses for biomethane production. **Energy activity** It should include the case where a biomethane plant can supply fuel to another entity that also performs energy-related activities. This particularly applies to cases where the produced biomethane is sold to a trader of liquefied and/or compressed natural gas (CNG), who would need to have their energy activity expanded to include compressed and/or liquefied biomethane. Additionally, it should cover the case where a biomethane plant also produces compressed and/or liquefied biomethane.. **Energy permit** It should also include facilities for the production of fuel from biomass, in addition to biofuel production facilities, and the Rulebook on Energy Permits needs to be harmonized with these aspects. In general, it is necessary to allow for the possibility of other gaseous fuels that are not biomethane. **License** A license is required for a biomethane production plant, potentially for multiple energy activities. Errors in interpreting biomethane production as biofuel need to be corrected. The term 'biogas' should be replaced with 'biomethane,' with options to consider compressed and/or liquefied biomethane. In addition to biofuels, it is necessary to include fuels from biomass. In general, it is necessary to allow for the possibility of other gaseous fuels that are not biomethane. Additionally, the proposal is to align the title of the Regulation on the share of biofuels in the market with the REDII and REDIII directives, which include a subtitle covering biogas used in transport. This would also enable the possibility of double-counting the energy contribution of biomethane in transport.
Basis for encouraging biomethane projects
INECP and the Low-Carbon Development Strategy represent the foundations for promoting projects involving biomethane plants, as they address goals that involve the application of the anaerobic fermentation process (the process of biogas/biomethane production). Specifically, the achievement of the following INECP goals is enabled through the realization of biomethane projects: decarbonization, energy security and internal energy market, research, and development. In the Low-Carbon Development Strategy, the implementation of anaerobic fermentation projects is identified as necessary in the agriculture sector for certain scenarios (M3 and M4), aiming to reduce methane (CH_4) and nitrous oxide (N_2O) emissions from manure management, in order to achieve the overall GHG emissions reduction targets.
National goals for biomethane production
In the Republic of Serbia, there are no defined binding national goals for biomethane production, based on established potentials for biomethane production with determined effects. Currently, INECP includes a quantified goal defined by a policy measure (MP_D38), which amounts to 87 ktoe. However, this policy measure pertains to demonstration projects for promoting biomethane (and hydrogen), which could serve

as a foundation for the long-term development of the biomethane sector. The overall goal for RES in transport by 2030 is 3.2% without and 7% with multipliers, of which biofuels account for 2.1% (49 ktoe), but this does not apply to biomethane.

The interpretation of the Law on the Use of RES qualifies biomethane as a gaseous fuel that can contribute to achieving the share of RES in the transport sector. The Regulation on the Share of Biofuels in the Market and the accompanying Decision had a target for 2024 of 1% energy from biofuels in total energy in transport, but this was withdrawn. The REDII Directive breaks down the RES targets for transport, introducing a limit for non-advanced biofuels (7%). A limit is also proposed for raw materials from List B of Annex IX (1.7%), and a minimum required share is introduced for raw materials from List A (3.5%). Therefore, a complex pathway is being established to reach the main EU target of a minimum of 14% energy content from RES by 2030. The RED III Directive introduces more stringent goals, which, in addition to the energy share, are also linked to greenhouse gas (GHG) emissions savings in the transport sector.

Incentives for biomethane

Incentives for biomethane are not directly defined in the legal regulations of the Republic of Serbia, although there is a foundation in accordance with the state aid mechanism. Obtaining investment and operational state aid is defined by the Law on State Aid Control, along with the accompanying regulations. Encouraging biomethane projects can be facilitated by forming investment or operational state aid with limitations and rules in accordance with the Regulation on the Conditions and Criteria for Compliance with State Aid for Environmental Protection and in the Energy Sector.

Use of innovative technologies and new renewable energy sources

Innovative technologies that can be considered for biomethane production include those that would enable the pretreatment of raw materials that have not been successfully or extensively used in the anaerobic fermentation process, as well as technologies for the production of raw biogas or biomass conversion, and innovative technologies for further conversion or for purifying raw biogas into biomethane. When selecting any of the aforementioned types of innovative technologies, potential risks for successful market integration must be considered. An example of technologies in early development is those for the production of non-biological fuels or hydrogen.

Guarantees of origin (GoO)

The definition of Guarantees of Origin (GoO) in the Law on the Use of Renewable Energy Sources cannot be fully applied to biomethane, but only to electricity. The Regulation on Guarantees of Origin clearly defines the guidelines for the use of GoO, but again, only for electricity. The GoO system should be expanded to renewable gases (specifically biomethane), in accordance with REDII. INECP envisions the expansion of GoO for RES.

Sustainability criteria, GHG savings, and verification

The Law on the Use of Renewable Energy Sources introduces sustainability criteria and GHG savings that must be met for biomethane considered for RES goals. The Regulation on Sustainability Criteria for Biofuels, Bioliquids, and Biomass Fuels outlines four sustainability criteria for agricultural biomass and two for forest biomass. An example of GHG savings is when biomethane is used in transport and the savings must exceed a limit of 65%, compared to fossil fuel counterparts. According to RED III, there are no new developments regarding sustainability criteria or GHG savings limits. The only novelty is that facilities producing gaseous fuels from biomass with a flow rate greater than 200 m^3 of methane equivalents per hour must meet both aspects if the gas is injected into the grid. The Regulation on Sustainability Criteria for Biofuels, Bioliquids, and Biomass Fuels sets a clear verification system for biofuels and biomethane in transport (for both electricity and heat energy), introducing terms such as Verification Scheme, Scheme Holder, and Verifier. Verification schemes applicable in Serbia need to establish a verifier registry.

Carbon pricing

The foundation for joining the European carbon pricing system is provided by the Law on Climate Change, which is actively being worked on, with a working group established and the public informed about the CBAM (*Carbon Border Adjustment Mechanism*). However, an operational system for monitoring, reporting, and verifying GHG emissions has not yet been identified. At the EU level, an advanced carbon pricing system is being implemented, which will also include emissions from transport (implementation begins in 2027, with preparations starting in 2025), considered a great opportunity for the biomethane sector's development. In Serbia, it is advisable to begin activities to secure timely benefits for the biomethane sector.

Fermentation residue (Digestate)
The Law on Plant Nutrition and Soil Conditioners and the Regulation on the Conditions for Classification and Determining the Quality of Plant Nutrition Products do not recognize fermentation residue as an organic fertilizer or soil conditioner. Harmonizing these regulations with Regulation 2019/1009, which regulates fertilizing products (EU Fertilising Products) in the EU for improving soil quality, is desirable. Regulation 2019/1009 confirms all the rules of Regulation 1069/2009 concerning the treatment of animal by-products.
By-products of animal origin
The Law on Veterinary Medicine and the Regulation on the Classification and Handling of By-products of Animal Origin establish rules for the use of these by-products in accordance with Regulation 1069/2009. This primarily applies to slaughterhouse waste and kitchen waste, and the presence of pathogens is controlled by the Veterinary Inspection, Veterinary Directorate. Laboratory analyses for controlling the use of these specific raw materials should be conducted within existing accredited laboratories. Regulation 2019/1009 introduced amendments regarding additional conditions and methods for the treatment of fermentation residue derived from substrates covered by Regulation 1069/2009. Further harmonization is required to enable the use (market placement) of fermentation residue.
Excise taxes
The Law on Excise Taxes defines excise duties for biofuels, which are specified in the Energy Law. Excise duties are not applicable to biomethane when sold as compressed biomethane. However, an excise tax is applied to the consumption of natural gas for motor fuel purposes, so if compressed biomethane becomes available, it is likely that excise duties will also be introduced for this form. This requires harmonizing the Excise Law with the definition in the Law on the Use of RES. In other sectors, the excise tax on natural gas applies. Exemption from excise duties is theoretically possible under Article 19 with corrections to the definition, but only if the transaction is based on an international agreement that provides for an excise exemption.
Activity codes
The Law on Classification of Activities and the Regulation on Classification of Activities define activity codes. A proposal for activity codes for a potential biomethane production facility is based on possible cases: 1) the facility produces biomethane and supplies it to the network operator; 2) the facility compresses/liquefies biomethane and sells it to fuel suppliers; 3) the facility compresses/liquefies biomethane and sells it to consumers; 4) a fuel supplier purchases biomethane from the production facility and sells it. Branch 35.2 – Production of gas and distribution of gaseous fuels via gas pipelines (applicable) Branch 46.7 – Other specialized wholesale trade (include biomethane) Branch 47.3 – Retail trade of motor fuels in specialized stores (including biomethane) Branch 38.2 – Waste treatment and disposal (applicable)

For biomethane as the final product, there are basic legal regulations, but further harmonization is required, both inter-nationally and with EU regulations (guaranties of origin, carbon pricing, fermentation residue). It is necessary to establish a verification system in accordance with European standards. National targets for biomethane production are completely absent. However, INECP has defined policy measures that can stimulate the implementation of biomethane projects.

No specific, comprehensive incentive mechanism applicable to biomethane production has been identified. There is a lack of harmonized aspects related to energy activities, energy permits, and licenses applicable to biomethane facilities.

For raw materials such as slaughterhouse waste and kitchen waste, systems for application and control need to be established. For fermentation residue, there are no appropriate legal provisions, and they should be aligned with the latest EU regulations.

4 Prerequisites for the integration of biomethane into the market of RS

4.1 Socio-economic aspects

Economic parameters and investment feasibility

The presented results are based on data from: 1) Foreign technology suppliers related to the biogas and biomethane market; 2) Literature relevant to the real biomethane sector in European countries (not theoretical calculations); 3) Existing biogas plants in Serbia regarding all actual production costs of raw biogas and biomethane-ready production (currently in the status of "Qualified Producer of Electricity from Renewable Energy Sources" - PPEE). The presented data refers to biomethane (BM) injected into the natural gas grid or liquefied biomethane (bio-LNG). In the first case, there is more experiential data and a greater number of existing plants in other European countries, making it expected that this type of plant will be the first to be implemented in Serbia. In the case of bio-LNG, even though the first biomethane plant being built in Serbia is of this type, it is not expected to be the dominant type for the initial series of constructed plants.

Table 5: Overview of economic parameters for biomethane production

Br.	Description	Type	Production cost	Note / Other parameters
1	Experience of the Technology Supplier	BM	80-120 €/MWh$_{HHV}$	–
	Project in development in RS	bio-LNG	–	CAPEX 18.5 M€ for 625 Nm^{3}CH$_4$/h ~ 2.5 MW$_e$, Income 360 €/MWh (including L-CO$_2$), PBP 3 yr
2	Experience of the Technology Supplier	BM	82 €/MWh$_{HHV}$	PBP 6-8 yr
3	Real data from biomethane industry	BM	84 €/MWh$_{HHV}$ (0.91 €/Nm^3) 91 €/MWh$_{HHV}$ (0.98 €/Nm^3) 54 €/MWh$_{HHV}$ (0.58 €/Nm^3)	300-780 Nm^{3}CH$_4$/h ~ 1.2-3.1 MW$_e$ (all raw materials) 300-780 Nm^{3}CH$_4$/h ~ 1.2-3.1 MW$_e$ (without MBW) > 1200 Nm^{3}CH$_4$/h ~ > 4.8 MW$_e$ (all raw materials)
4	Forecast LCOE for year 2050 (CAPEX+OPEX without raw materials)	BM	66(30+36) €/MWh$_{HHV}$ (0.71 €/Nm^3) 51(23+28) €/MWh$_{HHV}$ (0.55 €/Nm^3) 40(18+22) €/MWh$_{HHV}$ (0.43 €/Nm^3) 33(15+18) €/MWh$_{HHV}$ (0.36 €/Nm^3) 55(28+27) €/MWh$_{HHV}$ (0.59 €/Nm^3)	100 Nm^{3}CH$_4$/h ~ 400 kW$_e$ (1G) 250 Nm^{3}CH$_4$/h ~ 1 MW$_e$ (1G) 500 Nm^{3}CH$_4$/h ~ 2 MW$_e$ (1G) 750 Nm^{3}CH$_4$/h ~ 3 MW$_e$ (1G) 1100 Nm^{3}CH$_4$/h ~ 4.5 MW$_e$ (2G)
5	CAPEX+OPEX reconstruction to biomethane	BM	–	1.78 M€+250 k€/year (140 Nm^{3}CH$_4$/h ~ 635 kW$_e$) 2.21 M€+337 k€/year (235 Nm^{3}CH$_4$/h ~ 1 MW$_e$) 2.59 M€+358 k€/year (470 Nm^{3}CH$_4$/h ~ 2 MW$_e$)
6	PPEE Year 12	BM	A: 0.79 €/Nm^3 (74.1 €/MWh$_{HHV}$) B: 0.68 €/Nm^3 (63.6 €/MWh$_{HHV}$)	A: CAPEX 1.8 M€ for reconstruction 635 kW$_e$ to biomethane B: CAPEX 2.6 M€ for reconstruction and extension to 2X635 kW$_e$ to biomethane ~ 2 eq-MW$_e$
7	PPEE Year 4	BM	0.73 €/Nm^3 (67.4 €/MWh$_{HHV}$)	CAPEX 2.2 M€ for reconstruction 999 kW$_e$ to biomethane
8	PPEE Year 3	BM	0.96 €/Nm^3 (89.3 €/MWh$_{HHV}$)	CAPEX 2.2 M€ for reconstruction 999 kW$_e$ to biomethane

BM: Biomethane injected into the NG grid; bio-LNG: Liquefied Natural Gas (Liquefied biomethane); CAPEX: Capital Expenditures (Investment costs); OPEX: Operating Expenses (Operational costs); PBP: Payback Period (Time for investment return); MBW: Municipal Biodegradable Waste; LCOE: Levelized Cost of Energy (discounted production cost, excluding raw material costs); PPEE: Qualified Electricity Producer (existing biogas plant for electricity, which can be reconstructed for biomethane production); HHV: Higher Heating Value of biomethane.

The production cost of biomethane is specified by the amount of energy based on its Higher Heating Value (HHV) in €/MWh$_{HHV}$. For comparison purposes, it is also converted to a normalized volume of biomethane (€/Nm^3). This parameter is the most readily available in literature and other sources, and it is presented here as a basis for comparison, as it can directly indicate the necessary revenue to ensure economic viability.

Additionally, values for capital expenditures (CAPEX) and operational expenses (OPEX) are presented. The payback period (PBP) also provides a clear indication of the economic impacts of biomethane projects. The complexity of the technology depends on the type of raw material used, which directly affects CAPEX/OPEX. Therefore, both first-generation (1G) and second-generation (2G) biomethane are considered separately, with the contribution of advanced biomethane potentially counted double in the transport sector. The recommendation is to consider additional investment support specifically for advanced biomethane produced from waste.

In the following table, the effects of the achieved revenue from the sale of biomethane on the payback period (PBP) for the construction of a new biomethane production plant (greenfield investment) are presented. A revenue range of 100–120 €/MWhGCV is analyzed over a 15-year project duration, where the upper limit corresponds to the highest feed-in tariff (FiT) in European countries, if applicable. This data can certainly be used to compare the total revenue that a biomethane producer needs to achieve, regardless of the source (FiT, Feed-in Premium (FiP), market price of natural gas (PG), or Guarantees of Origin (GoO)). The analysis was conducted for two plants with different capacities, where the first corresponds to a biogas plant with an installed capacity for methane production of 1 MW_e (CAPEX = 5.8 M€; OPEX = 1.4 M€/year), and second biogas plant with an analogue of 2 MW_e (CAPEX = 9.1 M€; OPEX = 2.8 M€/year). Although a plant with a larger capacity is recommended because it can achieve more favorable economic results, the challenge lies in securing a sufficient amount of raw materials (predominantly manure) to ensure the required level of greenhouse gas (GHG) emissions savings. Most of the existing biogas plants in Serbia have a capacity similar to the first example, so the analysis of prerequisites should be more focused on this case. If the discounted payback period is considered, which takes into account the time value of money over the project's lifespan, it is advisable for biomethane producers to achieve a revenue of around 120 €/MWh_{HHV}.

Table 6: Effects of revenue on the profitability of biomethane production

Capacity ~ 250 Nm^3CH_4/h		
Revenue, €/MWh_{HHV}	**PBP (simple), yr**	**PBP (discounted), yr**
120	6	8
115	8	9
110	9	11
100	10	12
Capacity ~ 500 Nm^3CH_4/h		
Revenue, €/MWh_{HHV}	**PBP (simple), yr**	**PBP (discounted), yr**
120	4	4
100	7	8

PBP: Payback Period; HHV: biomethane Higher Heating Value.

Economic benefits for the local community and industry

The economic benefits for local communities and industries primarily stem from the utilization of fermentation residues (digestate) and, potentially, the use of heat energy generated. This has been a common experience in agricultural biogas and biomethane plants in other countries. However, in Serbia, these two aspects have not yet reached a satisfactory level.

In rural areas where agricultural production is prevalent, digestate is used as an organic fertilizer, serving as a replacement for mineral fertilizers, while also offering additional benefits beyond its N/P/K content. Often, local livestock farmers provide manure to biogas or biomethane plant owners without charge, in exchange for receiving an equivalent amount of digestate to be distributed across their fields. This arrangement benefits farmers by providing a sustainable solution for manure disposal, which otherwise requires resources they often lack, such as proper storage facilities, labor, and machinery. In the future, if manure management regulations are enforced, this model could become more sustainable. For the plant owners, the motivation is to collect additional manure and have access to nearby agricultural land for digestate distribution. Alternatively, farmers could sell their manure to generate extra income but would then forgo receiving the digestate.

For biomethane plants, the opportunity to sell heat energy is only viable if it is generated continuously by an additional cogeneration facility (engine with generator), as heating the fermenters is not required. External users of this heat energy could include: 1) Residential and public buildings (e.g., schools, hospitals) for heating and/or hot water supply; 2) Agricultural production and processing facilities (e.g., greenhouses, drying plants); 3) Industrial facilities that use hot water or steam. The cost of heat energy for these users would be lower compared to traditional sources (solid fuel, natural gas). For biogas or biomethane plant owners, selling all available heat energy can provide additional income. In other countries, bonuses are offered if heat energy is utilized. Local municipalities often finance the construction of micro district heating networks.

Biomethane production also brings indirect benefits to society and industry, such as reducing emissions in agriculture through improved manure management, enhancing energy security via decentralized supply, and improving soil fertility and health. Even in countries with more advanced biogas and biomethane sectors, these aspects are often overlooked in climate or energy policies, despite their tangible benefits.

Value chain factors, obstacles, and proposals for overcoming them

Table 7: Value chain factors for biogas/biomethane

Municipal biodegradable waste
The waste generators include households, the commercial sector, and to some extent, the industrial sector. Waste operators are primarily public utility companies managing waste, but also companies responsible for maintaining green spaces.
Landfills for municipal waste
Municipal waste generators encompass the population, the commercial sector, and partially the industrial sector. The majority of municipal waste, including biodegradable waste, ends up in landfills without any prior treatment. Landfill management is predominantly controlled by public companies, though the involvement of the private sector is gradually increasing. The regionalization of waste management systems is leading to larger landfills, meaning fewer locations with larger waste volumes, which in turn increases landfill gas production. Initial activities in collecting, treating, and utilizing landfill gas have been observed among private operators. Consumers of electricity and/or heat generated from landfill gas include the public and industry.
Biogas plants as part of WWTP
The main wastewater generators are the population, along with industries that are obliged to partially treat their own wastewater. Wastewater management systems are primarily run by public companies. In many towns, even in larger cities, no proper treatment or purification exists, except for primitive mechanical separation of large particles (paper, etc.). Untreated wastewater is mostly discharged into rivers. Projects to develop wastewater treatment plants (WWTP) with anaerobic stabilization units (sludge treatment) have been initiated in a few cities. A few towns have already constructed wastewater treatment plants and sludge treatment lines. The biogas produced in these plants is used for covering the energy needs (both electricity and heat) of the wastewater plants themselves. In some cases, biogas is flared, but efforts are being made to transition to energy utilization.
Agricultural biogas plants
Farmers are the producers of biomass from crop production (energy crops, biomass from secondary harvest) and generators of byproducts from agriculture and livestock (crop residues, manure). Larger agricultural enterprises generally own biogas plants and supply them with raw materials from their own production, occasionally purchasing additional quantities from smaller farms. Owners of biogas plants seldom buy the majority of their raw materials externally. Since agricultural biogas plants also handle

organic waste from the food industry, the generators, operators, and transporters of this waste are important value chain actors. Slaughterhouse waste is used in minimal quantities. Although crop residues present the largest potential for biogas and biomethane production, they are not widely utilized due to technical and technological limitations. The electricity generated from biogas is consumed by the population and industry, while heat is used in negligible amounts for on-farm needs. The users of the fermentation residue (digestate) are biogas plant owners for their own fields, as well as for other farmers' fields in the vicinity of the plant.

Table 8: Obstacles in collaboration and proposals for overcoming them

Municipal biodegradable waste
Legally binding reduction of biodegradable waste landfilling and diversion to other processing technologies, including anaerobic digestion (AD), is hardly being implemented at all. From a technical standpoint, there is no separate waste collection nor capacity for processing biodegradable waste. Initial activities for processing include composting green waste, while treatments that result in energy recovery do not exist. The problem is the low level of public awareness regarding the importance of waste segregation at the source. The investment in technology for anaerobic treatment of this type of waste is high. The possibilities for disposal of the residual fermentation product on agricultural land are limited due to the presence of impurities and the need for additional treatment (technical composting, sieving). The proposal is to intensify activities and gradually introduce separate collection of biodegradable waste, accompanied by secured processing capacity. Considering the specifics of generators and the time required to increase treatment capacity, priority should be given to increasing the collection rate of biodegradable waste from the commercial and industrial sectors, and only then from households.
Municipal waste landfills
Landfill gas is sporadically collected at landfills in Serbia and, in extremely rare cases, used for energy purposes, even though there is an obligation to collect, process, and utilize it for energy production. If it cannot be used for energy, it should be burned at the landfill. Most landfills fall into the category of unsanitary – dumpsites (lacking operational permits). Poor management and long periods of operation have led to a significant loss of the potential for generating and utilizing methane. There is generally no infrastructure for collecting, processing, and utilizing landfill gas. The level of landfill gas production and quality in the upcoming period is uncertain, as it is unknown when or if the reduction of biodegradable waste disposal will begin. It is not clear when the obligation to collect, process, and utilize landfill gas will be implemented at old unsanitary or sanitary landfills. The proposal is to install landfill gas collection and utilization systems as soon as possible at existing unsanitary landfills (in larger cities) as well as at constructed sanitary ones, then intensify activities for the construction of regional sanitary landfills, and after that, proceed with closing and remediation of unsanitary landfills.
Biogas plants as part of WWTP
The high competitiveness of the current usage model (covering only part of its own energy needs and reducing operational costs) leaves little room for other energy uses, such as electricity/heat or biomethane, which could be used by the population and industry. Stabilized sludge is currently disposed of in landfills (owned). Other disposal methods are not possible because the quality does not meet the standards for distribution on agricultural land, mainly due to the higher content of heavy metals, which are prohibited from entering the food chain. The proposal is to define and apply methods for using this type of sludge, such as for covering landfills and similar uses.
Agricultural biogas plants
Smaller livestock farms face challenges in managing manure, which requires significant logistical effort (storage space, manpower, and machinery for timely distribution). They lack enough raw material for their own biogas plants and do not have sufficient financial resources, even to contribute to a loan. The proposal is to encourage (and even subsidize) such farms to deliver manure to biogas/biomethane plants, with an appropriate agreement to accept the residual fermentation product (in the same quantity as the manure delivered). To use crop residues as raw material for biogas or biomethane, proper pre-treatment is required. Suitable pre-treatment technologies for crop residues (lignocellulosic biomass) have been developed but are not yet sufficiently mature for the market (with only a few examples in practice). The investment is high, and operational conditions are unreliable, although the operational cost of the raw material is lower in these cases. The proposal is to thoroughly analyze pre-treatment technologies in direct contact with the companies offering them and to support their implementation through investment aid. Generators are required by law to dispose of organic waste in an appropriate manner (e.g., anaerobic stabilization) and strive to place it on the market for biogas production. Companies with permits for waste collection take or purchase organic waste (depending on the competitive use and value) and deliver it for free or sell it to biogas plants. If the raw material can be used for other purposes, the plants pay a price that is not attractive enough to replace energy crops. The proposal is to advise biogas plants to obtain

their own permit for waste collection (and transport), alongside the permit for treatment they already hold, as well as to enhance the control over how generators dispose of organic waste.
Although it has been proven that the residual fermentation product has improved characteristics compared to untreated manure, some farmers, due to distrust, are reluctant to accept its distribution on their land. This holds true even though the general situation in agriculture is that there is less manure due to the reduction of livestock farming, and there is a trend of soil degradation and loss of fertility.
The proposal is to work under the relevant ministry, through agricultural advisory services and organizations/associations, to promote and organize the use of the residual fermentation product, in accordance with EU quality standards. The proposal is to encourage the efficient use of remaining thermal energy for entities that can prove they have secured market outlets, through direct investment support that would allow potential users to connect to the micro grid to the plant.

Recommendations for improving the participatory process and raising public awareness

Key recommendations for improving the participatory process have been formed based on identified gaps in the value chains and legal regulations, as well as enhancing communication between key stakeholders for the realization of biomethane projects in the territory of Serbia:

- Improving communication between the MME and Serbian Biogas Association, due to direct contact with entities involved in the realization of biomethane projects in the short term, exchanging key information that can contribute to achieving biomethane goals;
- Considering the specifics of MBW and slaughterhouse waste as raw materials, direct communication needs to be established between MME and around ten potential project developers for biomethane or suppliers of these specific raw materials;
- Forming a register of farms (100-500 cattle units (CU), and over 500 CU), based on the agricultural census conducted in 2023, as these are significant entities for mobilizing and utilizing manure;
- Establishing contact between MME and companies for the implementation of verification schemes in the EU, as well as launching at least one scheme in Serbia to prepare potential operators for the entire process of sustainability verification and certification issuance;
- Recognizing the residual fermentation product as a soil conditioner and improving farmers' awareness of the possibility of using this nutrient, which should be supported by the relevant ministry and implemented by agricultural advisory service.

Raising public awareness about the potential and acceptance of biogas as a renewable fuel for various purposes needs to be directed in two main directions. The first is targeting decision-makers in relevant companies, and the second involves campaigns aimed at the general population:

- Informing the responsible individuals in utility companies about the possibilities of using bio-CNG-powered vehicles (buses, waste trucks, delivery vehicles), which would lead to an increase in the fleet of vehicles that can use either virtual or physical biogas;
- Informing fuel suppliers (there are 57) about what biogas is and its role in fulfilling obligations for renewable energy share in transport;
- Raising awareness among the general population, especially for the formation of a primary waste separation system for MBW, with the relevant ministry supporting public information campaigns along with pilot and demonstration projects;

- Timely raising awareness within local communities to avoid potential resistance due to inadequate information about the construction of facilities – the NIMBY (Not In My Back Yard) effect.

The production cost of biogas, from potentially reconstructed biogas plants to biomethane in Serbia, is up to approximately 0.95 €/Nm^3 (90 €/MWh_{HHV}). It should be noted that these production prices for biomethane (without profit for the investor, i.e., without a profit margin) do not include the investment for the pipeline from the plant location to the injection point, nor the required infrastructure at the connection site. The necessary revenue height that would ensure profitable operation needs to be at least 15% higher than the production cost. The appropriate revenue level for newly built biomethane plants in Serbia is over 115 €/MWh_{HHV}, which would allow for an investment payback period of less than 10 years, assuming the project lifespan is 15 years.

Although there are clear benefits for the local community and society as a whole, it is necessary to work on raising awareness and involving all potential actors in the biomethane sector, which relies on multiple sectors (energy, environment, agriculture, etc.).

4.2 Technical Aspects

Integration potential BM into the NG sector and existing infrastructure

The total NG consumption in RS during 2022 amounted to 28.2 TWh[1]. The gas sector includes: 1 NG Producer (NIS a.d.); 3 transport systems operator – TSO (*Transportgas Srbija d.o.o.*, *Yugorosgaz-Transport d.o.o.*, *Gastrans d.o.o.*); 31 distribution system operators – DSO; 63 energy supply entities; 30 public supply energy entities; 7 licenced wholesale supply energy entities. There is one natural gas storage facility (*PSG Banatski dvor d.o.o.*). As of 2022, over 320,000 end-users (accounting for 18% of total NG consumption) were under regulated supply (households and small customers consuming less than 100,000 m^3/a) and over 1,300 customers on the free market accounted for 82% of NG consumption. Up to 10% of NG consumption is in the form of CNG, which defines the potential for utilizing biomethane produced in Serbia.

The transport network operates at pressures above 16 bar, with a total length of approximately 2,600 km in 2022. Additional 400 km of transport pipelines serve a transit function, connecting the Bulgarian and Hungarian borders. The companies *Transportgas Srbija* i *Yugorosgaz-transport* are potential candidates for connecting biomethane facilities to the transport network. The distribution network operates at pressures below 16 bar and spannes over 22,000 km in 2022.

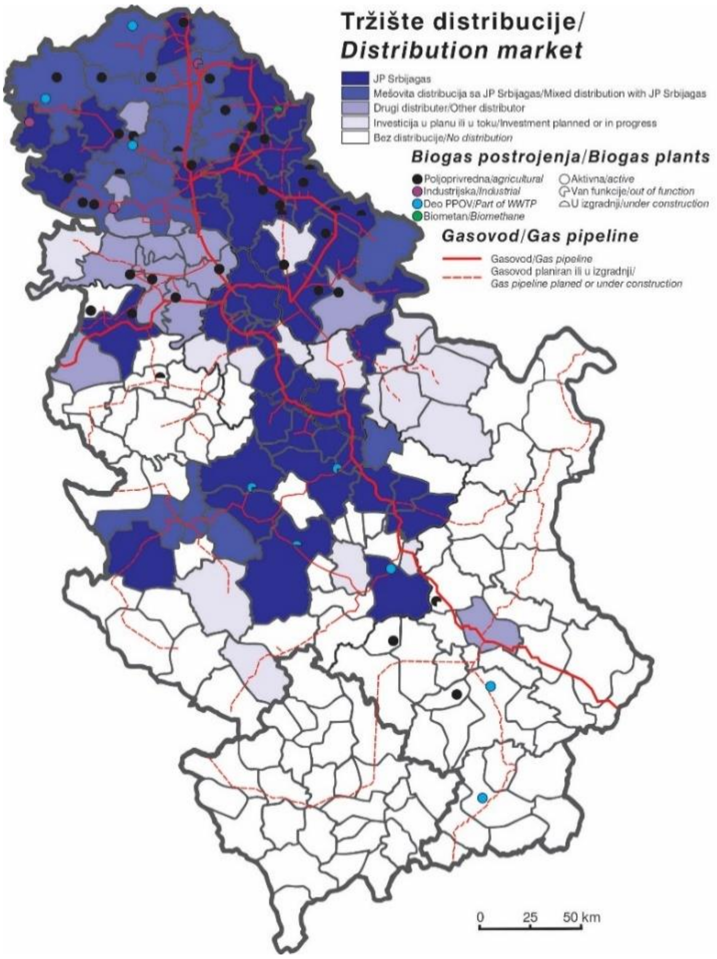


Figure 3: Distribution market NG, gas network and biogas plants[2,1]

---

[1] *Ministarstvo energetike i rudarstva RS (MRE). Energetski bilans Republike Srbije za 2023. yearinu.* *www.mre.gov.rs/extfile/sector/sr/734/ENERGETSKI%20BILANS%20ZA%202023.pdf*

[2] *AERS. 2022. Izveštaj o radu agencije za energetiku za 2022. yearinu. Agencija za energetiku RS, Beograd.*

Figure 3 provides an overview of the distribution market across municipalities in RS. The dominant supplier (and network operator) is JP Srbijagas, which in some municipalities shares supply rights with local providers, while in a few, only local suppliers are present. The NG infrastructure remains incomplete, leaving parts of Serbia without access to the distribution network. Although the construction of gas pipelines is ongoing, not all projects are expected to be fully realized in the near future.

The production of CNG requires access to the NG network. Through a metering and regulating station (MRS), natural gas is transported to purification equipment (to remove moisture and impurities) and then to a compressor station for pressure boosting up to 250 bar maximum, with simultaneous cooling and oil removal. Subsequently, it is stored on-site and either directly supplied to consumers or loaded into mobile systems (trucks equipped with steel cylinders) for transport to end-users. A very similar production process applies to bio-CNG, with the key difference being the need to remove a higher volume of impurities before entering the process.

There were 48 production sites of CNG in 2023, with equal amounts of NG sourced from both transport and distribution pipelines. Around 30 facilities are producing CNG, and 3 of them make up around 80% of RS market. According to the Energy Balance of Serbia, the plan for 2024 indicates that 15-20% of the total consumption of CNG is in the transport sector. The increasing trend in the number of registered vehicles will enhance the potential for utilizing bio-CNG in transport.

Composition and quality of biomethane

There are numerous quality requirements for injecting biomethane into the natural gas grid and for producing bio-CNG. A regulation on the conditions for the delivery and supply of NG[2] has been adopted, specifying the quality and chemical composition standards for biomethane that is received or delivered. Additionally, a Rulebook on the quality and chemical composition of NG has been enacted.[3].

Table 9: Comparative overview of biomethane quality requirements

Regulation on conditions of delivery and supply of NG		**Rulebook on the quality and chemical composition of NG that is taken over and delivered from part of the transport system**	
Chemical composition	**mol %**	**Chemical composition**	**mol %**
Methane (C_1)	min. 92	Methane (C_1)	min. 85
Ethane (C_2)	max. 4		
Propane (C_3)	max. 2		
Butane (C_4)	max. 1.5		
Pentane and heavier (C_{5+})	max. 0.5		
Hexane	max. 0.2		
Nitrogen (N_2)	max. 2	Nitrogen (N_2)	max. 6
Carbon Dioxide (CO_2)	max. 1	Carbon Dioxide (CO_2)	max. 2.5
Oxygen (O_2)	max. 0.02	Oxygen (O_2)	max. 0.02
Sulfur content (mg/m³)			
Hydrogen sulfide (H_2S)	max. 2	-	max. 5
Mercaptan sulfur (C_2H_5SH)*	max. 5.6	Mercaptan sulfur (C_2H_5SH)*	max. 6
Total sulfur	max. 20	Total sulfur	max. 21
Higher Heating Value HHV 25 / 0 °C (kWh/m³)	10.38 – 12.20	Higher Heating Value HHV 25 / 0 °C (kWh/m³)	10.23 – 13.26
Wobbe upper (25/0) kWh/m³	13.22 – 15.37	Wobbe upper (25/0) kWh/m³	13.85 – 15.32
Water dew point*			

[1] *Bajatović D. 2021. Modeli tranzicije i predviđanja sistema snabdevanja prirodnim gasom. Doktorska disertacija, Fakultet tehničkih nauka, Novi Sad.*

[2] *Uredba o uslovima isporuke i snabdevanja prirodnim gasom. "Sl. glasnik RS", br. 49/2022, 32/2023 i 97/2023. https://www.paragraf.rs/propisi/uredba-o-uslovima-isporuke-i-snabdevanja-prirodnim-gasom.html*

[3] Pravilnik o kvalitetu i hemijskom sastavu prirodnog gasa koji se preuzima i isporučuje sa dela transportnog sistema. "Sl. glasnik RS", br. 107/2023. http://demo.paragraf.rs/demo/combined/Old/t/t2023_12/SG_107_2023_010.htm

There is no water condensation at minus 8 degrees centigrade (-8°C) and absolute pressure of 3.92 MPa.	
Hydrocarbon dew point* There is no hydrocarbon condensation at 0 degrees centigrade (0°C) and at distribution pressure.	
* Odorant ethyl mercaptan can be used as an odorizing agent until December 31 of 2022.	
It must not contain solid impurities, resin or substances that produce it and liquids (hydrocarbons, condensates, glycols, water, etc.).	

Standards governing this field include: SRPS EN 16723-1:2017[1]; SRPS EN 16723-2:2017[2]; SRPS CEN/TR 1723:2018[3]; SRPS EN 16726:2023[4]. Requirements for oxygen and carbon dioxide levels in these standards are more lenient. There are no specific requirements for hydrocarbon content; instead, the methane number is monitored, and for the expected composition of biomethane, there is no risk of failing to meet this criterion. Regarding hydrogen sulfide, the relaxation of conditions is already present in parts of Serbia's natural gas transport system, which is even aligned with gas standards.

Not all existing biogas upgrading technologies are capable of meeting the required quality and composition criteria for biomethane. Variations in feedstock composition result in differences in the quality of produced biomethane, which in turn affects purification needs. At the European level, there is a lack of consistency in gas network requirements for biomethane quality, though efforts toward harmonization are underway. The expert community within the EU is analyzing the introduction of a unified standard for biomethane quality and composition, expected by 2025. This initiative aims to facilitate the unimpeded cross-border flow of biomethane. EU member states exhibit either low or high tolerance for oxygen content, while under Serbia's Regulation on the Conditions for the Delivery and Supply of Natural Gas, a low tolerance is maintained.

Potential example of biomethane consumer for non-energy purposes is A.D. Metanolsko-sirćetni kompleks (MSK) Kikinda, with natural gas consumption up to 30.000 Nm^3/h to produce methanol. Based on initial information, the integration is possible in the production process to produce green methanol. This plant could consume biomethane from 120 average facilities in Serbia (250 Nm^3/h, i.e. equivalent of 1 MW_e).

It is proposed that the Regulation on the Conditions for the Delivery and Supply of Natural Gas (Article 55, Paragraph 4) serves as the foundation for defining quality and composition requirements for biomethane. These requirements should be specifically applicable to biomethane plants that inject biomethane into the NG network or produce bio-CNG.
The recommendation is that, for injection into the network, the conditions for quality and composition should be fully aligned with Standard[1] while also meeting the Wobbe index and calorific value requirements specified in the Regulation. Operators of both the transport and distribution gas networks should be involved in drafting the new regulation.
For bio-CNG production, the requirements should be fully harmonized with Standard[2] for use in transport. The option for virtual bio-CNG production—where biomethane is injected near production sites and extracted from the NG network at a different location for CNG production—should not be subject to these requirements.

---

[1] *SRPS EN 16723-1:2017. Prirodni gas i biometan za korišćenje u transportu i biometan za injektovanje u gasovod prirodnog gasa – Deo 1: Specifikacije za biometan za injektovanje u gasovod prirodnog gasa.*

[2] *SRPS EN 16723-2:2017. Prirodni gas i biometan za korišćenje u transportu i biometan za injektovanje u gasovod prirodnog gasa – Deo 2: Specifikacije za goriva za motorna vozila.*

[3] *SRPS CEN/TR 1723:2018. Predložene granične vrednosti nečistoća u biometanu na osnovu kriterijuma za ocenjivanje ugrožavanja zdravlja.*

[4] *SRPS EN 16726:2023. Gasna infrastruktura – Kvalitet gasa – Grupa H.*

4.3 Environmental protection aspects

This chapter presents an analysis **<u>of the sustainability criteria and GHG emission savings</u>**, which are **requirements for energy from biomethane to be considered sustainable**[1]. Meeting these requirements can be established as a formal condition to receive financial incentives, allow accounting for RES in energy balances, and provide the biomethane buyer with a guarantee for biomethane on the market.

The process of formally determining the fulfillment of these conditions is called verification. Sustainability criteria (if applicable) are checked, and GHG emission savings are calculated according to the methodology from REDII. This process is carried out by an authorized verifier (listed in the Verifier Registry) according to one of the voluntary or national verification schemes (currently there are 15 voluntary schemes approved by the European Commission that can be found at Link). The verifier is "accredited" by the holder of the verification scheme, and their role is typically to conduct and oversee the verification.

Within the verification process, there is also a governmental body that potentially plays multiple roles. For example, in Germany, the Federal Agency for Agriculture and Food recognizes the accreditation of verifiers and manages the NABISY (*Nachhaltige Biomasse System*) database for controlling certificates. The biomethane production plant provides all required information to the verifier and receives a Certificate (sustainability confirmation) and an additional Proof of Sustainability (PoS – *Proof of sustainability*). The PoS contains specific data on the GHG emission savings for all sectors to which verification applies, and the validity period is one year. The governmental control body or the biomethane buyer uses this information to implement incentives or purchase the biomethane.

Sustainability criteria

There are a total of four sustainability criteria that are relevant for the production of agricultural biomass used as raw material for biomethane production. These specifically apply to the production of energy crops, second-crop plant biomass, and harvest residues. The first criterion defines that the raw material can only be collected from agricultural land if there is a Plan for monitoring and managing the impact on soil quality and carbon in the soil. It is not expected that the production of raw materials in Serbia will violate the fulfillment of this criteria, but it is necessary to establish reporting and monitoring procedures in a timely manner (form, scope and content of the submitted plan, as well as roles). The remaining three criteria are not applicable because agricultural production is not planned on land important for the preservation of biological biodiversity or with a high carbon content, as well as on peatland.

Two groups of criteria are distinguished for forest biomass. The first requires that at the level of the state and the forest area where the biomass was produced, regulations for the regulation of felling and the forest felling monitoring system are applied. The second requires the fulfillment of the LULUCF (Land Use, Land Use Change, Forestry) criteria, in relation to the fulfillment of the state's obligations to ratify documents, submit reports and pass regulations in that area, and also that it was produced in an area that provides a carbon sink. It is not expected to use forest biomass for the production of biomethane using gasification in the short or medium term. Therefore, sustainability criteria should only be considered in the long term. Part of the forest biomass potential will probably be used

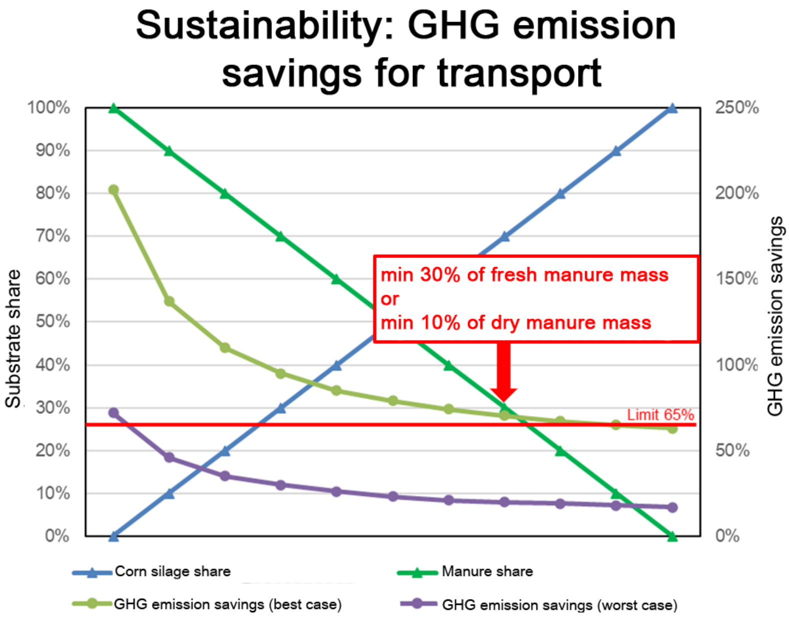
[1] *Uredba o kriterijumima održivosti za biogoriva, biotečnosti i goriva iz biomase, "Službeni glasnik RS", broj 96 od 2. novembra 2023.*

for other competitive purposes by then, so it is only in that time period that the verification system for this raw material can be expected to be in operation.

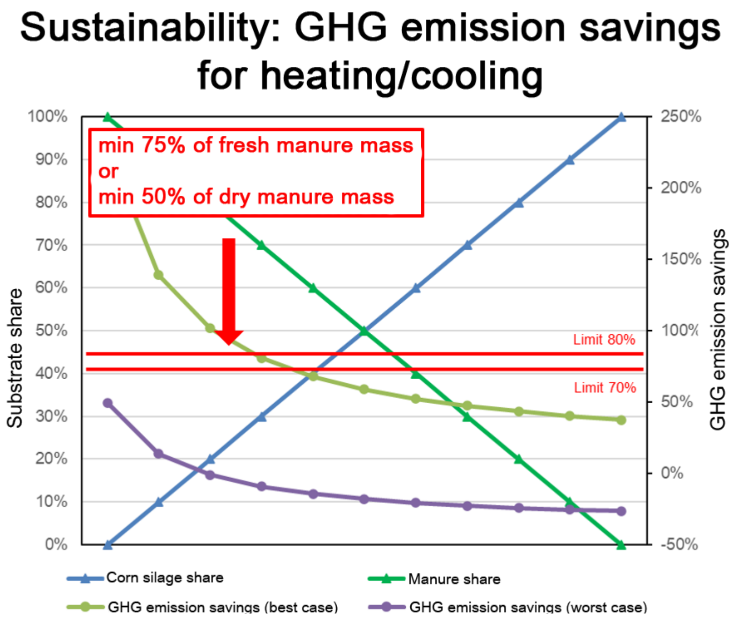
Organic waste does not have to meet the stated sustainability criteria. Therefore, GHG emissions savings, which are elaborated below, require a focus and more detailed consideration.

GHG emission savings

The most important guidelines for achieving as much savings value as possible are: maximizing the share of manure due to bonus - negative emissions, as well as encouraging technological options for burning waste gas (transformation of methane into carbon dioxide, i.e. the less methane in the waste gas, the higher the value of saving GHG emissions) and covering the fermentation residue tank (collection of residual methane emissions from the fermentation residue, preventing uncontrolled release into the atmosphere).



a) use in transport sector



b) Use in the heating and cooling sector

Figure 4: GHG emission savings for different proportions of corn silage and manure

Figure 4 shows the results of the possibility analysis of sustainable biomethane production, using data from REDII[1]. The use of liquid manure and maize silage for co-fermentation as raw materials was considered. Various mass shares of raw materials were simulated, along with boundary cases of technological options. The most favorable case involves the application of waste gas combustion and covering fermentation residue tanks, while the least favorable case assumes the absence of these measures. The minimum share of dry matter from manure required to produce sustainable biomethane is 10% when used in the transport sector and 50% when used in the heating and cooling sector. Considering both cases of use, if the least favorable technological options are applied, it would theoretically only be possible to achieve minimum savings when applied in transport and using 100% manure, which is not a common practice. The use of biomethane for electricity generation requires it to be produced from a mixture of raw materials with a minimum of 30% dry matter manure content. Compliance with sustainability criteria and GHG emission savings is generally a requirement for obtaining financial incentives when biomethane is injected into the NG grid, whereas compliance with sustainability criteria is assumed when biomethane is marketed.

The GHG emission savings criterion depends on the sector in which biomethane is used. It is easier to achieve when used in transport than as fuel for generating heat/cooling or electricity. Therefore, the minimum savings required for sustainable biomethane in the transport sector should be 65%, compared to the emissions of a fossil comparator of 94 gCO_{2ekv}/MJ. The minimum GHG emission savings for the use of biomethane for generating heating/cooling and electrical energy is 70% or 80% (depending on the commissioning date of the plant). The emission factor of the fossil comparator for heating/cooling energy is 80 gCO_{2ekv}/MJ, and for electricity generation 183 gCO_{2ekv}/MJ.

Environmental protection aspects considered for biomethane production include sustainability criteria and GHG emission savings criteria. If met, energy from biomethane is deemed sustainable, fulfilling conditions for financial incentives, inclusion in RES balances, and providing the buyer with a guarantee that they have purchased sustainable biomethane on the market.

Only one criterion related to the production of agricultural biomass is applicable in Serbia. Even in this case, timely establishment of reporting and monitoring procedures would ensure compliance. The use of forest biomass for biomethane production or similar applications is expected only in the long term, at which point sustainability criteria ensuring carbon sinks should be considered. Organic waste is exempt from meeting these sustainability criteria. Consequently, GHG emission savings require focused and detailed consideration.

The most important guidelines for ensuring biomethane sustainability include maximizing the share of manure and promoting technological options such as burning waste gases and covering fermentation residue reservoirs. The minimum dry matter content of manure should be 10% when used in transport, 50% for heating/cooling, and 30% for electricity generation. The GHG emission savings criterion depends on the sector in which biomethane is used, amounting to 65% for transport and 70% or 80% for heating/cooling and electricity.

[1] *European Commission (EC). 2018. Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources. Official Journal of the European Union, 02018L2001.* http://data.europa.eu/eli/dir/2018/2001/oj

5 Barriers to the integration of biomethane on the RS market

Following technical, administrative and economic barriers that can affect the establishment of biomethane on the market of RS are considered in relation to the past, but also the current state of the biogas sector. This allows for consideration of potential solutions that will guide successful implementation in the appropriate direction and incentives. This is achievable by understanding the position of biomethane plants in relation to other energy entities in the NG sector, the organization of the NG sector, and the choice of sectors for biomethane deployment.

5.1 Technical barriers

TB1. Required oxygen content in biomethane for injection into the NG network

The required quality of biomethane injected into the NG network prescribes a permissible oxygen content of 0.02% (Regulation and Rulebook, see Chapter 4.2). Oxygen has corrosive properties and the potential to form an explosive mixture with methane. There is a risk that the produced biomethane may not meet this quality requirement. Within the rules for the operation of the NG distribution system, DSOs have an additional specified gas composition requirement at the NG network entry point applicable in the case of connecting biomethane plants to the distribution network, which does not include an oxygen quality requirement. However, this requirement would still need to be met. DSOs can adjust the required quality for NG suppliers, which could also apply to biomethane plants if quality corrections are necessary. In European practice, oxygen content is considered strictly in cases where sensitive industrial consumers (e.g., glass factories) or gas storage facilities are located along the gas pipeline route where biomethane is injected.

TB2. Connection to the transport gas network (minimum 4,000 m³/h)

TSO specifies in the network connection algorithm that the minimum capacity for connecting biogas producers is 4,000 m³/h. This effectively excludes biomethane plants in Serbia (RS), as expected capacities are approximately 250 Nm³/h (equivalent to 1 MW_e) or around 500 Nm³/h. This would mean that the minimum required capacity for a biomethane plant would need to be up to 16 times larger. Due to challenges such as securing sufficient raw materials and managing fermentation residues, it is assessed that such plants are unlikely to be realized. Strict interpretation would prevent biomethane plants from connecting to the transport NG network (TSO jurisdiction, pressures above 16 bar). However, a connection would be permitted if biomethane quality requirements are met. Revision of this rule is recommended if an application for connection to the transport network is submitted.

TB3. Limited consumption in the NG network

The expected production capacity for biomethane in RS is up to 500 Nm^3CH_4/h, or over 4 MNm³/year of biomethane. A critical factor is consumption along the section of the network where biomethane is injected. NG consumers can be on public supply (regulated) or private supply (free market). The consumption threshold is 100,000 Sm^3/year. Public supply is available via distribution pipelines up to 6 bar and 6–16 bar, while private supply is available via distribution pipelines of 6–16 bar and the transport network. If the distribution network (up to 6 bar) primarily serves small consumers (households), there is no guarantee of consistent consumption throughout the year, with demand mainly peaking in winter. A request to the DSO would be required in each case, but a negative response (rejection) is likely. An exception would be if there are more than 50 industrial consumers on public supply, but it is assessed that such cases do not exist in RS. The same principle applies to the distribution network (6–16 bar), where consumers on public supply and those purchasing NG on the free market are served, likely ensuring sufficient consumption. A request to the DSO would be necessary.

TB4. Bio-CNG quality analysis

In Serbia, the practice in CNG production is that CNG quality is not controlled since NG is obtained from the network where quality criteria are met. The DSO uses the TSO data on NG quality. The DSO and TSO can provide NG buyers, who further compress it, with daily quantity reports as proof of gas quality, but this is not done in practice. *The draft Regulation on Technical and Other Requirements for Compressed NG* aligns entirely with the *Regulation on NG Supply and Delivery Conditions*[1], meaning it reflects the expected CNG quality based on NG from the network. In practice, problems may arise with implementing the regulation for sampling and analysis, as NG quality analysis is conducted centrally, whereas CNG quality control would require local sampling (at the production site). The draft regulation references standard SRPS EN ISO 15403-1[2], which should provide appropriate sampling methods, and alignment is needed to allow chromatographic analyses. Several institutions in Serbia have laboratory capacities to conduct accredited measurements, but preparation (at least one year in advance) for specific accredited methods should be initiated on time. The Accreditation Body of Serbia (ABS) should be included in the process for accreditation and ensuring qualified inspectors. Standard SRPS EN 16723-2:2017[3] was specifically adopted to meet market needs for bio-CNG quality. The most significant aspect introduced, compared to the draft regulation, is additional impurity control focusing on silicon compounds that can damage internal combustion engine components in vehicles. These compounds may form during the treatment of waste materials with high chemical content (e.g., cleaning agents) in WWTP sludge lines. The likelihood of constructing such biomethane plant in Serbia is low (discussed in detail in Chapter 7). If these analyses are included, establishing laboratory capacities would be even more complex. It is recommended that the final adoption of the regulation be carried out only after potential laboratories confirm their capability to meet sampling and analysis requirements.

The regulation in its proposed form (perhaps with an added note on CNG sampling methods) should only be enforced if the laboratories confirm their ability to respond to sampling/analysis demands. After establishing adequate capacities and reviewing implementation, further alignment with standard SRPS EN 16723-2:2017 should be considered in the future.

5.2 Administrative Barriers

The main barrier is the definition of biomethane (detailed in Chapter 3). Below are potential barriers for investors and institutions in cases of biomethane plant construction.

AB1. Selection of energy activity, obtaining energy permits and licenses

Biomethane production is not currently recognized as an energy activity, and it is proposed that biomethane production be introduced as such. According to the Regulation on Energy Permits, facilities with a production capacity exceeding 10 tons of biofuels per year must obtain an energy permit. Considering that a biomethane plant may inject biomethane into the NG grid or produce bio-CNG/bio-LNG, the need for permits should be clearly stated for

[1] *Uredba o uslovima isporuke i snabdevanja prirodnim gasom.* "Sl. glasnik RS", br. 49/2022, 32/2023 i 97/2023

[2] *SRPS EN ISO 15403-1[2] Prirodni gas — Prirodni gas koji se koristi kao komprimovano gorivo za vozila — Deo 1: Određivanje kvaliteta, koji verovatno treba da ukaže i na odgovarajući način uzorkovanja gasa*

[3] *SRPS EN 16723-2:2017[3] Prirodni gas i biometan za korišćenje u transportu i biometan za injektovanje u gasovod prirodnog gasa – Deo 2: Specifikacije za goriva za motorna vozila*

both cases. Given the type and capacity of potential biomethane plants, the responsibility should rest with the relevant ministry. In the case of biomethane, it is necessary to define the need for obtaining a license concerning the specified capacity (for example, for biogas plants, it is required for capacities greater than 1 MW_e).

AB2. Implementation of biomethane plants for local municipal infrastructure needs
A unique case involves a biomethane plant that processes the organic fraction of municipal waste and provides fuel for waste collection vehicle fleets or sells it at market prices to companies operating urban public transport. In such cases, direct incentives for investment costs could be provided. Such projects exist in Europe, but challenges to implementation include: the possibility of obtaining state investment aid; the absence of a legal basis for secured financing; the economic viability of the project; adequate consumption (sufficient vehicle fleet size); the application of primary separation of waste; the feasibility of secondary separation; and the use of fermentation residue from such plants. This model is applicable only to the largest urban centers in Serbia (most likely only Belgrade)

AB3. Biomethane verification
There is still no implementation of a verification system and issuance of certificates that would allow produced biomethane to be certified against sustainability criteria and GHG emission savings. This aspect is expected to be ensured by the holders of the verification scheme, potential verifiers, and the responsible ministry. Investors need clear procedures for obtaining certificates, necessary conditions, and reporting methods.

5.3 Economic barriers

EB1. NG prices
Lower procurement/market prices of NG, compared to the production costs of potential biomethane plants in Serbia, could directly affect the competitiveness of biomethane and its market placement potential. This is particularly relevant for the price of NG for public supply (around 40 €/MWh_{HHV} without VAT and margins), as well as for price of CNG (around 80 €/MWh_{HHV} without VAT, no excise duty). From the beginning of 2025, the introduction of excise duty on CNG is expected. If there is a possibility of exempting bio-CNG from excise duties, the competitiveness of biomethane would improve. Therefore, the integration of biomethane into the Serbian market is only feasible with appropriate incentives.

EB2. Financing of gas infrastructure
Connecting to the NG network, in addition to the administrative procedure, requires the construction of appropriate infrastructure and the procurement of equipment, which is significantly influenced by the micro-location of the biomethane plant. This includes the gas pipeline to the connection point, MRS, telemetry devices, gas chromatographs, etc. DSO and TSO are unwilling to bear these high costs, which must be covered by the biomethane plant investor.

A potential technical barrier is the required oxygen content limit. There is a possibility of exceeding this limit, which must be addressed with the permission of gas network operators, following trends in EU countries. Other barriers include the minimum biomethane flow rate required for injection into the transmission network and ensuring adequate consumption, both of which can be overcome in cooperation with operators. A specific technical barrier is the quality control of bio-CNG, but the Draft Rulebook on Technical and Other Requirements for Compressed Natural Gas offers a possible solution.

Administrative barriers caused by the definition of biomethane in legal regulations have led to its lack of recognition in energy activities, energy permits, and licenses. Alignment is necessary to remove obstacles to implementing investments in biomethane plants.

Among economic barriers, the low price of NG compared to biomethane is prominent, necessitating the provision of incentives. Another potential economic barrier is the high investment cost for infrastructure if biomethane plants are located far from the point of connection to the NG network.

6 Availability and integration potential of innovative technologies

This chapter provides an overview of technologies considered innovative compared to those currently used in Europe and Serbia, which could be implemented in the field of biogas and biomethane. It specifically examines technologies for feedstock pretreatment, technologies for the production of raw biogas or biomass conversion, as well as post-conversion or purification of raw biogas into biomethane.

The maturity of technologies that could be implemented in Serbia needs to be assessed. Therefore, technologies at a low level of development—either in the laboratory stage (TRL– *Technology Readiness Level*, ranging from1-4) or validated/demonstrated in a relevant environment (TRL 5-6)—are not meaningful to analyze for short-term (2027) or medium-term (2030) implementation. The latter part of this chapter also considers potential technologies still under development, which could be considered for long-term implementation (by 2050). Technologies identified as innovative and evaluated as feasible for medium- and long-term implementation in Serbia, provided that technical, technological, and economic prerequisites are met, are elaborated further. The BIP[1] report serves as a reference source.

6.1 Innovative technologies for 2030

Utilization of Harvest Residues

When harvest residues (e.g., corn stalks, wheat straw) are used as an individual substrate (in mono-fermentation) or as a dominant substrate with a smaller percentage of another substrate (in co-fermentation), pretreatment is required. The use of untreated harvest residues is not feasible with standard (conventional) biogas production technology. Such substrates (lignocellulosic biomass) can only be used in minimal quantities—several tons per day (e.g., up to 3 tons/day in existing biogas plants with a capacity of 1 MW_e). Slightly higher amounts may be utilized if basic pretreatment methods like mechanical grinding or chopping are applied. However, this remains an insignificant quantity in terms of energy contribution and cost savings compared to more expensive substrates like corn silage.

Harvest residues, being lignocellulosic and fibrous materials, decompose slowly and with difficulty in anaerobic digestion (AD). They often cause operational issues, such as sedimentation, crust formation, and clogging, which reduce the working volume of the fermenter, block gas production, and obstruct pumps and pipelines. They require longer retention times in the fermenter due to their molecular structure, which is not readily accessible to anaerobic microorganisms and enzymes (e.g., crystalline structure or limited surface area), resulting in lower biogas yields. The primary sources of methane in these residues—sugars and other small molecules—are embedded within cellulose, hemicellulose, and lignin. Lignin, being highly resistant to degradation, forms a protective layer that prevents access to cellulose and hemicellulose. Appropriate pretreatment methods can alter substrate characteristics, such as increasing the surface area available for bacterial action and breaking the protective lignin barrier. This helps address the mentioned challenges associated with harvest residues. Positive effects of pretreatment include: Reduced viscosity, lowering the energy input required for mixing; Shorter substrate retention time; Increased biogas yield; Enhanced pumpability; More intensive material exchange; More homogeneous fermenter content, among others.

[1] *Biomethane Industrial Partnership (BIP). 2023. Innovative technologies for biomethane production: Review of the current state of the art. Prepared by Task Force 5. https://bip-europe.eu/downloads/?filter%5B%5D=20)*

The following describes two technologies whose providers have stated they can process and utilize substrates for biogas/biomethane production based entirely on harvest residues. AGRES SYSTEMS GmbH offers the ECONOMIZER[1], pretreatment technology, which precedes the conventional technological units for biogas/biomethane production supplied by other technology providers. WABIO[2] offers an integrated pretreatment system as part of its proprietary anaerobic fermentation plant, which is provided as a complete technological unit. Neither of these technologies is widely used in practice.

ECONOMIZER

The ECONOMIZER is a trademarked pretreatment technology based on the principle of steam explosion. Its main advantage is the ability to liquefy fibrous substrates (harvest residues), as illustrated in **Figure 5**. The technology includes: Intermediate storage equipped with a dosing system for loose harvest residues, after which the raw material is sent to the pretreatment facility. Following pretreatment, the liquefied material is pumped into fermenters using standard biogas production technology.

Figure 5: harvest residues before (on the left) and afte pre-treatment (on the right)

The pretreatment process begins with dosing and moistening the material using recycled steam from the previous cycle (batch). During the pretreatment phase (at a temperature of 180–220°C and a pressure of 10–25 bar), organic acids from hemicellulose are separated through heating at elevated pressure. This treatment lasts about 20 minutes, after which the pressure is rapidly reduced to atmospheric levels. Due to the sudden pressure change, water instantly boils (rapid change in volume and pressure—explosion), breaking down the structure of the surrounding mass and liquefying the raw material. The mass is then cooled before being pumped into the fermenter. According to the company's website, there are currently three reference facilities (in Italy, Germany, and Ukraine), two of which are biogas production plants, and one is a biomethane production plant.

WABIO

WABIO is a company offering a specific technology that, according to the supplier's claims in the Serbian market, enables the exclusive use of harvest residues. The supplier highlights the following features of this technology: the absence of mechanical mixing in the fermenter, replaced by hydraulic processes; a hydrolysis phase conducted in separate tanks; adapted fermentation of the hydrolysate; and batch post-fermentation with filtrate recirculation for suspension preparation.

[1] https://www.agres.systems/en/

[2] https://wabio.de/

According to the company's website, there are six reference facilities (three in Germany and one each in Indonesia, China, and Serbia). In addition to the one in Serbia, built in Vrbas (a biogas plant producing electricity from sugar refinery residues), one is under construction in Srpska Crnja (a plant for bio-LNG production from manure and harvest residues), and another is in the commissioning phase in Jarak (a biogas plant producing electricity from digestate from another biogas plant combined with harvest residues).

6.2 Innovative technologies for 2050

Cryogenic Technology

Cryogenic technology can be utilized in biogas production in several variants: purification of biogas to high-purity biomethane, additional purification of biomethane to achieve high-purity biomethane, Liquefaction of high-purity biomethane to bio-LNG.

In the first variant, the process begins with the primary removal of impurities from biogas, followed by cooling to low temperatures where CO_2 freezes and is thereby separated from gaseous methane. Frozen CO_2 is then removed in liquid or gaseous form from the specific section of the plant during the subsequent (sequential) phase of the process. The product is high-purity biomethane with CO_2 concentrations ranging between 50–100 ppm. Currently, this system is suitable for small and medium capacities, with expectations for future development to accommodate larger capacities and reduced investment costs. In the second and third variants, further purification and liquefaction of high-purity biomethane to bio-LNG are achieved by additional cooling of high-purity biomethane to temperatures below -160°C. Most other biogas purification technologies cannot achieve the quality of high-purity biomethane, making cryogenic technology a viable option.

There is a limited number of suppliers and a small number of facilities equipped with cryogenic technology. Since its current implementation is feasible only for small and medium capacities, cryogenic compressors (a critical component of such plants) for these capacities are not widely available for purchase.

Figure 6: Part of the plant for biogas purification to liquefied biomethane H_2S removal and drying (on the left), cryogenic cooling for CO_2 separation (on the right)

The example of a plant for the production of liquefied biomethane near Turin, Italy (visited in March 2023 as part of the GreenMeUp project) is shown. The production capacity of the plant is 250 kgCH$_4$/h and 400 kgCO$_2$/h. The plant concept is designed to use raw materials from a farmers' cooperative, but without energy crops (instead, it uses manure, other crops, harvest residues, and organic waste). The produced liquefied biomethane is used exclusively for transport. Cryogenic trucks arrive several times a week to pick up the bio-LNG. The company that purchases the liquefied biomethane and owns the LNG infrastructure is located on the highway near Milan. This is one of 10 existing bio-LNG plants, with plans for the construction of about 20 new ones in the near future. The technology itself includes a purification unit with activated carbon for H_2S removal. Cooling to low temperatures is achieved by using ammonia as the refrigerant and Stirling engines. Then, cryogenic cooling is applied for the separation of CO_2 and NH_3, then, drying is applied to remove moisture. Additionally, PSA (Pressure Swing Adsorption) technology is used to remove residual amounts of CO_2, with the maximum allowed concentration being 50 ppm, as solid CO_2 presents a risk in infrastructure.

Biogenic CO2 as a Source for Methanation

CO_2 is a greenhouse gas and thus contributes to climate change. However, recently, it is being considered as a resource that is already widely used in industry and innovatively in energy production. Unlike fossil CO_2 obtained from the combustion of fossil fuels), biogenic CO_2 (generated from biomass energy production, circulating in the atmosphere through emission, and then used in photosynthesis for plant growth) does not contribute to the greenhouse effect and does not affect climate change. Therefore, utilizing biogenic CO_2 for any purpose is seen as necessary in the pursuit of decarbonization goals. For example, the EU forecasts demand for CO_2 to reach around 500 Mt/year by 2050 around 500 Mt/year, compared to 41 Mt/year in 2022, of which 4 Mt/year was in liquid form[1].

Biomethane production is a source of biogenic (and concentrated) CO_2. For the production of 140 Nm^3CH_4/h, a 110 Nm^3CO_2/h is also produced. The purity of biogenic CO_2, depending on the applied technology, ranges from 96% (membrane separation) to 100% (cryogenic cooling for bio-LNG production). A competitive method is to use surplus renewable electricity to capture atmospheric CO_2 which is present at a very low concentration (around 400 ppm).

Thus, an option for utilizing biogenic CO_2 obtained from biomethane production (by separating CH_4 and CO_2) is the production of additional biomethane via the methanation process (CCU– *Carbon Capture and Utilisation*). This involves using H_2 and CO_2 as feedstocks to produce CH_4 (i H_2O as a by-product). The process can be carried out in the fermenter itself (in-situ), but this technology is still not mature (TRL=3-5). A mature demonstration technology (TRL=9) uses a separate methanation plant (ex-situ) at the biomethane production site. There are technological options for both biological and catalytic methanation.

The main barrier to this technology is the cost of production and the availability of hydrogen, as the investment and operational costs for hydrogen production are high. The CAPEX for methanation equipment ranges from 20-200 €/MWh, and the operational expenditure OPEX is 13 €/MWh. If methanation is integrated into a biomethane plant, continuous operation at the designed capacity must be ensured. If hydrogen is produced from renewable sources (solar or wind), the plant will have intermittent operation, so large CO2 storage must be provided.

In biological methanation, the process is carried out with the help of microorganisms, which are characterized by low methane productivity, requiring large reactor volumes. The energy efficiency of the entire process is low, ranging from 50% to 60% (with 80%

[1] *Biomethane Industrial Partnership (BIP). 2024. Biogenic CO_2: The role of the biomethane industry in satisfying a growing demand. Prepared by Task Force 4.1.* *https://bip-europe.eu/wp-content/uploads/2024/04/TF4.1_BioCO2-from-biomethane-production_final-report.pdf*

efficiency for the reaction and 70% efficiency for the electrolyzer). Catalytic methanation, on the other hand, is done with the help of a metal catalyst at higher temperatures and pressures. The essential requirement is to remove impurities from the CO_2 that reduce the reactivity of the catalyst and interfere with the process.

Biomethane obtained through methanation is considered synthetic methane, also referred to as methane of non-biological origin (NBO). In the EU, approximately one-third of the available biogenic CO_2 is projected to be utilized for the production of synthetic fuels (e-fuels) by 2050, among other applications[1]. However, it is recommended that long-term biomethane potential evaluations for this technology should not assume the utilization of all available. Relevant studies consider all sources of "captured" CO_2. For biomethane plants, it is more logical to produce additional biomethane (or other e-fuels) on-site than to transport biogenic CO_2 to other locations for alternative uses. There are limitations, for example, in the food industry, which requires CO_2, purity levels that can only be ensured by cryogenic cooling, achieving 100% pure CH_4 and CO_2.

Biomass gasification and syngas methanation

Gasification is a process for producing gas from solid fuels, initially used to produce gaseous household fuels from coal and peat. It involves incomplete combustion (with insufficient oxygen) at high temperatures and pressures[2], resulting in a combustible gas known as "syngas." Syngas can be further utilized in combustion or for the production of other energy carriers. It comprises energy-carrying components such as CO, H_2, CH_4, along with C_2H_6 and C_3H_8, as well as impurities like condensable gases (tar and water vapor) and particulates.

The process involves drying, thermal decomposition, incomplete combustion, and gasification. In direct gasification, thermal energy from the exothermic biomass reaction is used, while in indirect gasification, an external energy source is required. A recent innovation in indirect gasification involves microwave heating, which eliminates nitrogen presence and allows for converting any type of biomass into syngas. In subsequent methanation (biological or catalytic), impurities such as CO_2 i H_2O, and other contaminants must be removed.

For biomethane production, typical capacities range from tens to hundreds of MW. The technology readiness level (TRL) is 6–8, corresponding to a demonstration stage. Further development is needed to confirm reliability for continuous and large-scale industrial production. Advantages include suitability for various fuel types, potential for high-capacity facilities, and achieving high biomass conversion efficiencies. Challenges include high production costs (exceeding 100 €/MWh), mismatched economic scales for gasification (below 50 MW) and methanation (above 50 MW), low biomass energy density (resulting in high logistics costs), and technical hurdles such as syngas purification and feeding biomass into pressurized chambers. Only a few technology suppliers are currently available.

An example of an integrated biomass gasification and methanation process is the GoBiGas (*Gothenburg Biogas Gasification*) project[3], which has made significant

---

[1] *Butnar I, Cronin J, Pye S. 2020. Review of Carbon Capture Utilisation and Carbon Capture and Storage in future EU decarbonisation scenarios. Final report prepared for The Carbon Capture and Storage Association. UCL Energy Institute. https://zeroemissionsplatform.eu/wp-content/uploads/Report-Review-of-CCU-and-CCS-in-future-EU-decarbonisation-scenarios.pdf*

[2] *European Technology and Innovation Platform Bioenergy (ETIP Bioenergy). 2020. Bioenergy Fact Sheet– Biomethane. www.etipbioenergy.eu/images/ETIP_B_Factsheet_Biomethane.pdf*

[3] *Thunman H. GoBiGas demonstration – a vital step for a large-scale transition from fossil fuels to advanced biofuels and electrofuels. Chalmers University of Technology, Gothenburg, Sweden. ISBN: 978-91-88041-15-9. https://research.chalmers.se/publication/503260/file/503260_Fulltext.pdf*

advancements. The project's key achievement is the demonstration phase, with a production capacity of 20 MW of primary energy in biomethane using forest biomass. The recommended practical capacity is around 200 MW. The required biomass input is approximately 450,000 tons of dry biomass annually. The production cost of biomethane is 60 €/MWh, with15 €/MWh attributed to raw material costs.

For the short-term period (2027), the application of innovative technologies for biomethane production is not recommended, except for those already implemented in the EU and RS, i.e., those that are market-ready and proven in operation in the biogas and biomethane sectors.

For the medium-term period (2030), the only recommended innovative technology is the pretreatment of crop residues to be used as raw material for biomethane production. The integration of technologies for the pretreatment of crop residues would allow for the use of raw materials that are cheaper compared to energy crops, manure, and organic waste. Although this requires additional investment, the operational cost for raw materials would be significantly reduced and would compensate for the initial investment. The selection of the technology provider, financing conditions, and project implementation should be carefully conducted to reduce the risk of underutilizing the designed capacity and jeopardizing the investment's profitability.

For the long-term period (2050), innovative technologies that are not recommended for the medium-term period due to technological shortcomings, high investment costs, and low technology availability can be considered. After 2030, demonstration projects could be considered to promote innovative technologies and ensure their integration. Cryogenic technology could promote the production of liquefied biomethane (bio-LNG) for transport, with the production of 100% pure bio-CO_2. Methanation technology could promote CCU (*Carbon Capture and Utilization*) technologies that effectively contribute to the decarbonization process, as well as the production of e-fuels. Gasification technology combined with methanation can, in the long term, provide large capacities for biomethane production in Serbia. However, a centralized facility with large amounts of raw materials would only be feasible by organizing new logistics chains of forest biomass and potentially crop residues.

7 Assessment of raw material potential for biomethane production

Since there are currently no biomethane production plants in Serbia, the raw material potential presented below refers to balances relevant only for future potential plants. Existing biogas plants for electricity generation have already utilized a certain amount of raw material potential, and their potential conversion to biomethane plants after the expiration of their PPEE is considered as a special type of potential.

Four levels of potential were evaluated for the considered raw materials: 1) Theoretical: this consists of the total amount of raw materials; 2) Technical: depends on the possibilities for collection, applied logistical approach, availability, etc.; 3) Sustainable: includes socio-economic and/or environmental protection criteria, which could also be used for purposes other than biomethane production; 4) For Biomethane: determined after considering competitive uses for energy or other purposes, representing the realistic potential if appropriate decisions are made for the mobilization of raw materials.

The potentials for biomethane are defined for three time periods: 2027 (short-term), 2030 (medium-term), and 2050 (long-term). For each period, three types of potential were established, applying a conservative approach, one for expected potentials, and one optimistic. The obtained results were used for the analysis of national goals.

7.1 Manure

Total production in Serbia amounts to 16.70 Mt/year of solid manure and 11.23 Mm^3/year of liquid manure (theoretical potential). The potential for biomethane is 0.29 Mt/year originating from solid and 3.17 Mm^3/year from licquid manure. These figures, as presented below, represent the state recalculated from statistical data[1] and conducted research on manure in Serbia[2].

The potential for biogas production includes manure from farms with more than 500 cattle units (CU = animals weighing 500 kg) and the amount of manure used in existing biogas plants for electricity generation until the expiration of the renewable energy status PPEE. The potential is focused on manure from cattle, pigs, and poultry (broilers), which is applicable in the anaerobic fermentation process. The figures presented so far refer to conservative potentials. Expected potentials for the short-term period imply the collection of manure from farms with 100 to 500 CU. Optimistic potentials for the short-term period assume that 50% of the manure will be collected from farms with 50 to 100 CU.

Optimistic potentials for the medium-term period assume the collection of 100% of the manure from farms with 50 to 100 CU. Conservative potentials for the long-term period suggest that 25% of the manure from farms with 20 to 50 CU will be used for biogas production, while the expected potential is 50%, and for the optimistic scenario, it is 100% of this type of manure, along with poultry manure from farms with more than 100 CU.

Manure is the most important raw material that should form the basis of the biogas sector, primarily because it ensures the sustainability of production through GHG emissions savings. A more detailed description of this aspect is provided in subsection 4.2. The current state of the livestock sector in Serbia is unfavorable, with the latest agricultural census showing a decrease in livestock numbers: cattle by 18%, pigs by 31%, and poultry by 5%. Although the decrease primarily concerns the smallest farms, which are largely not considered for this potential, it will certainly affect the future mobilization of manure.

[1] *Republički zavod za statistiku (RZS). 2021. Anketa o strukturi poljoprivrednih gazdinstava, 2018. Lična komunikacija.*

[2] *Viskovic M, Djatkov Dj, Nesterovic A, Martinov M, Cvetkovic S. 2022. Stajnjak u Srbiji – količine i emisije gasova s efektom staklene bašte. Journal of Agricultural Sciences (Belgrade) 67(1): 29-46. https://doi.org/10.2298/JAS2201029V*

7.2 Energy crops

The analysis of the potential for energy crops is based on corn silage, which has the highest energy yield per unit of agricultural land area, with a well-established production and logistical chain. The assumption for the conservative potential is that 40% of the dry matter from corn silage will be used in a mixture with manure (the restriction approach applied to existing biogas plants in Serbia). For the expected potentials, the assumption is 45% of the dry matter share, while for the optimistic potentials, it is 50%. The data analysis from the Statistical Office of Serbia[1] in the following table shows the land area data for Serbia and Vojvodina (total, agricultural land used, and unused). According to the short-term conservative goal, it would be necessary to use 0.4%-0.6% of the utilized agricultural land in Serbia, while for the long-term optimistic goal, 3.2%-4.5% of the agricultural land would be needed. These values for long-term goals would increase proportionally if the impact of climate change on the expected yield reduction in 2050 is considered.

Table 10: Land in Serbia and Vojvodina[1]

Type of land	Serbia, ha	Vojvodina, ha
Total available	5,178,692	1,983,154
Used agricultural	3,475,894	1,574,366
Unused agricultural	289,953	64,643

7.3 Other crops

The potential from other crops includes the production of triticale and rye on the same agricultural area as corn silage. Half of the area covered by corn silage would be used for growing rye, while the other half would be used for triticale. Rye and triticale have proven to be good practices for existing biogas plants in Serbia. The principle is to use the same agricultural area, achieving lower production costs, but with reduced yields of green biomass and lower biogas yields. The approach used assumes that the second crop will be grown by farmers who already produce corn silage for biogas production. Other crops, such as sorghum, were not considered because past practices at biogas plants in Serbia have shown that it causes process issues, such as the formation of crusts in fermenters, and farmers are increasingly reluctant to use this feedstock.

7.4 Harvest residues

Harvest residues (agricultural biomass) are the most important biomass potential in Serbia, particularly in Vojvodina, which is an agricultural region. However, the use of lignocellulosic biomass in the anaerobic fermentation process requires energy-intensive and costly pretreatment technology. The total potential is defined based on the yields of field crops and data from literature, allowing the calculation of residue mass based on the mass of the grain[2][3]. Technically, the amount that can be collected from the fields is considered, taking into account losses and the characteristics of the residues (moisture content, contamination)[4]. The sustainable potential is the amount that can be removed from the field without negatively affecting soil fertility. A coefficient of 40% of the theoretical potential was applied.

[1] *Republički zavod za statistiku (RZS). 2023. https://data.stat.gov.rs/Home/Result/1300020201?languageCode=sr-Latn*

[2] *Republički zavod za statistiku (RZS). 2020. Baza podataka republičkog zavoda za statistiku Republike Srbije. https://data.stat.gov.rs/Home/Result/130102?languageCode=en-US*

[3] *Scarlat N, Martinov M, Dallemand J.F. 2010. Assessment of the availability of agricultural crop residues in the European Union: potential and limitations for bioenergy use. Waste management, 30(10), 1889-1897.*

[4] *Martinov M, Djatkov Dj, Viskovic M. 2019. Potentials of crops residues – A case study for the province Vojvodina. Die Bodenkultur: Journal of Land Management, Food and Environment, 70, 181-188.*

The potential for biogas from harvest residues is for the Vojvodina and Belgrade regions from farms with a minimum of 5 hectares, while for other regions, it is for farms with a minimum of 10 hectares. For corn stalks, only early hybrids (FAO groups 100-400) were considered to ensure the collection of residues with low moisture content and minimal contamination with soil. An allocation of harvest residues for other uses in the future was also carried out, including already utilized quantities. These include bedding in livestock farming of 615,000 tons/year of dry wheat straw[1], 60,000 tons/year of dry wheat straw, and 140,000 tons/year of dry soybean straw for household heating. A competitive use is also the production of biofuels from lignocellulosic biomass, such as a bioethanol factory using 150,000 tons/year of dry wheat straw and 100,000 tons/year of dry corn stalks. The defined conservative potential for harvest residues results in an indicator that the listed quantity should be collected from around 5% to 10% of agricultural land in Serbia.

The expected potentials for the short-term period assume that no lignocellulosic bioethanol production plant will be built, so the previously mentioned quantity can be included in the annual potential. Optimistic potentials for the short-term period assume the inclusion of residues used for household heating.

The potentials for the medium-term period assume that the yield of plant species (both grain and harvest residues) will decrease by 10% due to the impact of climate disasters (drought, storms). This aspect already affects agricultural production and should definitely be considered for the future. Improvements in corn irrigation are not expected to be widespread, which could compensate for the estimated loss. Even improved collection processes cannot compensate for this loss because there is no more available biomass that can be removed from the fields due to limitations on maintaining soil fertility and preventing erosion. The potentials for the long-term period assume that the yield of plant species will decrease by 30% due to the impact of climate disasters.

7.5 Landfill gas

The analysis of the potential for biogas production from municipal waste landfills considered minimum economic and technical criteria. Landfills were evaluated based on their capacity for extracting at least 125 Nm^3CH_4/h, or 250 Nm^3/h of landfill gas, equivalent to a cogeneration plant of approximately 500 kW_e. Additionally, the requirements of the Waste Management Program[2], were incorporated, which mandates a reduction in biodegradable waste disposal at landfills (to 75% by 2028, 50% by 2032, and 65% by 2039 compared to the 2008 baseline). When implemented, this regulation will decrease methane production at landfills. Data from the National Pollutant Emissions Register, maintained by the Environmental Protection Agency, were used, detailing waste generation levels in municipalities and cities across Serbia. Waste Management Program data were also included. Calculations were conducted using the "Central-Eastern Europe GMI Landfill Gas Model", based on data from the national waste management database for municipalities and regions in Serbia. For the period up to 2027, active sanitary landfills and non-sanitary sites (e.g., Novi Sad and Niš dumpsites) were considered. Although they meet technical requirements, it is unlikely that gas collection and utilization systems will be built at these sites. By 2030, a larger number of landfills are expected to meet the minimum criteria, increasing the potential for biogas production. The analysis also

[1] *Viskovic M, Djatkov Dj, Nesterovic A, Martinov M, Cvetkovic S. 2022. Stajnjak u Srbiji – količine i emisije gasova s efektom staklene bašte. Journal of Agricultural Sciences (Belgrade) 67(1): 29-46. https://doi.org/10.2298/JAS2201029V*

[2] *Vlada Republike Srbije. 2022. Program upravljanja otpadom u Republici Srbiji za period 2022 – 2031. yearine. Službeni glasnik RS 30/18. www.srda.rs/wp-content/uploads/2022/02/Program-upravljanja-otpadom-u-Republici-Srbiji-za-period-2022-2031.-yearine.pdf*

explored options for reducing biodegradable waste disposal to meet Waste Management Program targets. By 2050, full implementation of waste reduction requirements is expected, further decreasing the number of landfills meeting the minimum economic criteria for biomethane production.

7.6 Sewage sludge

In 2020, the biogas potential from sewage sludge was estimated at 6.8 MW_e (equivalent to 14 MNm^3CH_4/year), and post-2020, this potential could increase to 8.2 MW_e (17 MNm^3CH_4/year)[1]. Approximately 308 Mm^3 of wastewater (74% from households) is discharged into Serbia's sewage system[2], but only about 19% of the wastewater is treated (2% primary, 10% secondary, 7% tertiary treatment). The total production of sludge from existing wastewater treatment plants (WWTPs) is estimated at 11,000–15,000 t_{DM}/year (dry matter), consistent with the Specific Plan for Implementing EU Directive 91/271/EEC on Urban Wastewater Treatment. WWTP in Serbia are mainly managed by public utility companies, which also handle sludge management.

Table 11: Planned new wastewater treatment plants in Serbia [3]

Capacity	**Number 2018.-2032.**	**Number 2033.-2044.**	**Population (millions EP)**
EP > 150,000	4		2.74
50,000 < EP ≤ 150,000	12		1.58
15,000 < EP ≤ 50,000	49		1.37
10,000 < EP ≤ 15,000		19	0.25
2,000 < EP ≤ 10,000		255	1.18
EP < 2,000		19	0.03
Ukupno	**65**	**293**	**7.15**

EP: Equivalent Population.

The theoretical potential relevant for the total equivalent population in Serbia (7.15 million EP = 37.0 ktoe) is based on **Table 11**. The technical potential is determined for plants covering a minimum of 10,000 EP, while the sustainable potential is for a minimum of 50,000 EP. The potential for biomethane is determined based on the assumption that biomethane would only be produced at the largest facilities, of which there are four (2.74 million EP = 14.2 ktoe). At the same time, the possibility of consolidating plants for anaerobic stabilization of sludge collected from multiple individual WWTPs is considered. Additionally, the general approach to considering biomethane production from sewage sludge assumes the established practice of using the produced biogas at such plants to meet their own energy needs, both for the "water line" (WWTP) and the "sludge line" (biogas plant).

For the short-term period, the assumption is that it is not possible to build new WWTPs where sludge could be generated and used as a raw material for biomethane production. Conservative and expected potentials assume that biogas produced at existing WWTPs is used for cogeneration to meet the energy needs of the plants themselves. For optimistic potentials, it is assumed that the existing plant in Subotica will be reoriented toward demonstration biomethane production.

---

[1] *Martinov M, Scarlat N, Djatkov Dj, Dallemand J.F, Viskovic M, Zezelj B. 2020. Assessing sustainable biogas potentials - case study for Serbia. Biomass Conversion and Biorefinery 10(2): 367-381. doi.org/10.1007/s13399-019-00495-1*

[2] *Statistical Office of the Republic of Serbia (RZS). 2023b. Baza podataka republički zavod za statistiku Republike Srbije. https://data.stat.gov.rs/Home/Result/25010306?languageCode=sr-Cyrl*

[3] *Ministarstvo poljoprivrede, šumarstva i vodoprivrede (MPŠV). 2021. Plan upravljanja vodama na teritoriji Republike Srbije za period 2021. do 2027. yearine. https://rdvode.gov.rs/doc/Predlog_Plana_upravljanja_%202021-2027-01112021.pdf*

For the medium-term period, it is assumed that WWTPs with more than 150,000 EP will be built. Optimistic potentials assume that all the largest WWTPs, with a total capacity of 2.74 kEP, will be used for biomethane production. For the long-term period, it is assumed that all planned WWTPs will be built. Optimistic potentials involve the construction of a "sludge line" at plants with over 50,000 EP, while for those over 10,000 EP, sludge would be collected centrally and treated on a "sludge line."

7.7 Slaughterhouse waste

The basis for determining potential is previous research by the authors of this study[1], adapted and recalculated for biomethane production. So far, slaughterhouse waste in Serbia has only been used at one biogas plant, in a quantity of about 3,000 t/year. Therefore, practically the entire amount of slaughterhouse waste could be used in the future at plants for biomethane production, amounting to 10.3 MNm^3/year or 8.8 ktoe. This represents a unified theoretical, technical, and sustainable potential for biomethane. All three timeframes are considered equally, assuming that the amount of slaughterhouse waste will not change over time. Conservative potentials assume that 25% of the slaughterhouse waste potential will be utilized for biomethane production, expected potentials assume 50%, and optimistic potentials assume 75%. The remaining portion of the slaughterhouse waste would be managed through alternative methods.

7.8 Kitchen waste from the commercial (HORECA) sector

To meet the requirements for reducing biodegradable waste in landfills, special attention will be directed towards reducing food waste, which dominates as a biodegradable fraction. Separate collection of food waste and its redirection to biological treatments such as AD and composting will simultaneously reduce the amount of landfill waste and the potential for methane production in landfills, while also creating opportunities for methane production through the AD process.

The total amount of food waste generated in Serbia is estimated to be about 900,000 t/year. Although comprehensive measurements to determine the share of various food waste sources have not yet been conducted, available data analysis, i.e., sectoral studies, have yielded the following information: the commercial sector accounts for 48% (432,000 t/year) of total food waste generation, of which the food industry generates 29% (261,000 t/year), the HORECA sector 12% (108,000 t/year), and retail 7% (63,000 t/year)[2][3][4]. About 170,000 t/year of food waste from the food industry is already managed based on the analysis conducted in Chapter 2 (data on the biogas sector and existing biogas plants). The main assumption for determining potentials for the three timeframes is that most of this type of organic waste will be processed through AD, i.e., in biomethane production, and that future waste generation will increase.

---

[1] *Martinov M, Scarlat N, Djatkov Dj, Dallemand J.F, Viskovic M, Zezelj B. 2020. Assessing sustainable biogas potentials - case study for Serbia. Biomass Conversion and Biorefinery 10(2): 367-381. doi.org/10.1007/s13399-019-00495-1*

[2] *Anonim. 2021. Merenje količine i morfološkog sastava otpada od hrane iz domaćinstava u Beogradu. Izdavač: Centar za unapređenje životne sredine, Beograd. ISBN 978-86-82252-00-9.*

[3] *Centar izvrsnosti za cirkularnu ekonomiju i klimatske promene. 2020. Upravljanje viškovima i otpadom od hrane. Finansirao GIZ, Novembar 2020.*

[4] *NALED. 2019. Analiza sistema upravljanja otpadom od hrane u Republici Srbiji. https://naled.rs/htdocs/Files/04672/Analiza_Otpada_od_hrane.pdf*

7.9 MBW – Municipal Biodegradable Waste

The Waste Management Program[1] mandates a gradual reduction in the landfilling of biodegradable waste and its redirection to other treatment and utilization methods to reduce GHG emissions and ensure more rational use of natural resources. Households in Serbia are the largest generators of municipal biodegradable waste, particularly in the form of bio-waste, such as food waste. It is estimated that households currently generate 468,000 tons/year of food waste. One of the main challenges in utilizing this fraction is the lack of primary waste separation in households in Serbia. Additionally, a logistical system for separate collection, transport, and disposal has not been established.

The theoretical potential is the total biodegradable waste for 2030, amounting to 2,061,251 tons. The technical value is based on the assumption that it is possible to collect 80% of bio-waste, 30% of paper and cardboard, 20% of green waste, and 30% of other biodegradable waste, totaling 1,211,908 tons. This quantity already accounts for changes in population numbers and composting a portion at the household level. The sustainable potential is the quantity that must not be landfilled in 2030, amounting to 801,263 tons, which is 50% of the total biodegradable waste in the reference year of 2008. The potential for biomethane is assumed to be the remaining quantity after utilizing 340,000 tons (40% of the biodegradable fraction predicted for anaerobic stabilization and biomethane production), which will be incinerated at the Vinča incineration plant (30 MW_e and 56.5 MW_h for district heating). An additional assumption is that a significant portion of this type of waste will already be redirected to composting.

7.10 Biomethane from reconstructed biogas plants

Existing biogas plants operating under the status PPEE represent infrastructure for the disposal of organic waste and by-products, with well-established logistical chains and good practices in technology usage. After the expiry of the PPEE period, it is assumed that most biogas plant owners would be interested in reconstructing their plants to biomethane production facilities. The realization of this would depend on various factors, such as profitability, suitability of existing capacity, conditions for connection to the natural gas network, and the marketability of biomethane with adequate financial compensation. The baseline for balancing potential is the data from Chapter 2, referring to biogas plants operating in 2023, with additional assumptions about new capacities built starting in 2024.

For the short term, biogas can be considered for plants whose PPEE status will expire by 2027, with a total installed electrical capacity of 1.6 MW_e; for the medium term, 11.2 MW_e; and for the long term, 34.8 MW_e. It is assumed that from 2024 onwards, additional capacities of up to 30 MW_e will be installed, including those built for PPEE status with FiT for electricity, under the new auction-based electricity pricing system, as well as projects granted PPEE status but not yet realized. These projects are expected to operate as biomethane production plants. By 2050, biogas plants whose PPEE status has expired will amount to 64.8 MW_e.

Conservative potentials assume 30% utilization of capacity for the medium and long term, while for the short term, it is limited to the first plant constructed in Serbia with a capacity of 635 kW_e. Expected potentials assume 50% utilization, while optimistic potentials assume 70%.

[1] *Vlada Republike Srbije. 2022. Program upravljanja otpadom u Republici Srbiji za period 2022 – 2031. yearine. Službeni glasnik RS 30/18. www.srda.rs/wp-content/uploads/2022/02/Program-upravljanja-otpadom-u-Republici-Srbiji-za-period-2022-2031.-yearine.pdf*

7.11 Biogenic CO_2 as a source for methanation

Chapter 6 outlines technologies enabling additional biomethane production from biogenic CO_2 (bioCO_2), obtained from purifying biogas by separating CO_2 i CH_4. Biomethane produced through methanation is considered synthetic methane, also referred to as e-fuel or NBO fuel. This type of fuel is expected to gain significance in the future, as demonstrated by the REDIII requirement for a minimum share of 2.6% of all types of NBO fuels in the transport sector, and RePowerEU's minimum of 5.7%. It is not expected that all bioCO_2 derived from previously mentioned raw materials will be used solely for synthetic methane production but only a portion, with the rest directed to other applications. The implementation of this technology is not anticipated in the short term in Serbia. By 2030, the possibility exists only for demonstration projects, whose contribution to overall potentials would be low or negligible, and therefore, this potential has not been included. The potential for non-biological biomethane production is considered only for the long term. Conservative potentials for 2050 assume 10% utilization of bioCO_2 from all previously mentioned sources, expected potentials assume 30%, and optimistic potentials assume 50%.

7.12 Forest biomass

According to the draft Energy Development Strategy of Serbia[1], the technical potential of wood (forest) biomass is estimated at 1,668 ktoe. Assuming that one-third remains unutilized, this amounts to approximately 556 ktoe by 2050, with the sustainable potential being the same as the technical. For biofuels, about 30% of the sustainable potential is considered, as wood biomass can also be used as solid fuel for heating and electricity generation, which are deemed competing uses.

The following results are based on the principles outlined in Chapter 6 regarding innovative technologies. Conservative potentials assume no construction of forest biomass gasification and syngas methanation plants. Expected potentials assume the construction of a plant with a capacity of 100 MW, expressed as the primary energy of biomethane, requiring about 225,000 tons of dry biomass annually (97 ktoe, assuming the lower calorific value of absolutely dry forest biomass is about 5 MWh/t). This would represent half of the recommended capacity for said technology, but it is assumed that CAPEX will decrease by 2050. Optimistic potentials assume the construction of a plant with a capacity of 200 MW, requiring 450,000 tons of dry biomass annually (193 ktoe). This is exactly the recommended capacity plant. Although the required amount of forest biomass exceeds the sustainable potential, it is assumed that additional logistical chains will be organized to collect waste forest biomass.

7.13 TOTAL POTENTIALS

The results matrix for analyzed potentials across three timeframes and using three different approaches is presented in **Table 12**. Results are shown using multiple energy units and are calculated based on HHV values. The effects of biomethane potentials on substituting natural gas (final consumption, imports, total domestic consumption) are also presented.

An example of the classification of optimistic potentials by raw materials under the REDII directive is presented in Table 13. Biomethane produced from corn silage is classified as non-advanced. In contrast, all other fractions of biomethane potentials originate from raw materials listed in Annex IX (Lists A and B) of the REDII directive.

[1] *Nacrt Strategije razvoja energetike RS za period do 2040. yearine sa projekcijama do 2050. yearine*

Biomethane from these two lists is considered advanced and can be counted twice (calculated with a multiplier) if used in the transport sector. The limitations and requirements for shares in total energy in the transport sector are: non-advanced, a maximum of 7%; advanced from List A, a minimum of 3.5%; and List B, a maximum of 1.7%.

Table 12: Biomethane potentials – overview and substitution effects of NG

Unit	Short term by 2027	Mid term by 2030	Long term by 2050
Conservative			
$MStm^3$/year	415	560	741
MNm^3/year	393	531	702
TJ_{HHV}/year	15,656	21,138	27,970
GWh_{HHV}/year	4,349	5,872	7,769
$Kten_{HHV}$/year	374	505	668
% final consumption NG*	40.6	47.9	52.4
% import NG*	15.5	18.9	24.1
% domestic consumption NG*	13.4	16.6	23.4
Expected			
Unit	Short term by 2027	Mid term by 2030	Long term by 2050
$MStm^3$/year	696	798	1,459
MNm^3/year	660	756	1,383
TJ_{HHV}/year	26,259	30,111	55,072
GWh_{HHV}/year	7,294	8,364	15,298
$Kten_{HHV}$/year	627	719	1,315
% final consumption NG*	68.2	68.2	103.2
% import NG*	26.0	26.9	47.5
% domestic consumption NG*	22.4	23.7	46.2
Optimistic			
Unit	Short term by 2027	Mid term by 2030	Long term by 2050
$MStm^3$/year	924	1,064	2,770
MNm^3/year	876	1,008	2,626
TJ_{HHV}/year	34,860	40,089	104,338
GWh_{HHV}/year	9,683	11,136	28,983
$Kten_{HHV}$/year	833	958	2,492
% final consumption NG*	90.5	104.1	195.6
% import NG*	34.5	35.8	90.1
% domestic consumption NG*	29.8	31.6	87.5

*ekv-MW_e: equivalent of biomethane production expressed in equivalent electrical power in cogenerative gas engines; MNm^3: million (10^6) normal cubic meters; $MStm^3$: million standard cubic meters; HHV: Higher heating value (calculations based on HHV of biomethane); TJ: Tera (10^{12}) joule; GWh: giga (10^9) watt hours; ktoe: kilo (10^3) ton of oil equivalent (toe = ton oil equivalent); *: energy indicators from INECP projection for scenario S.*

Table 13: Optimistic potentials - classification according to REDII (Annex A/B)

Raw material/Source	% in 2027	% in 2030	% in 2050	Type	Comment
Energy herbs	28.6	29.4	22.3	–	Non advanced for transport
RBP 1G*	0.05	0.5	1.2		
Manure	17.9	18.4	14.0	A	Advanced for transport, it counts double
Other crops	13.2	13.5	10.3		
Harvest residues	35.7	28.3	8.7		
Landfill gas	2.4	4.3	0.8		
Sewage sludge	0.04	1.5	1.2		
Forest biomass	0.0	0.0	5.6		
Kitchen waste	0.6	1.0	0.9		
MBW	0.5	1.2	1.0		
RBP 2G-A*	0.1	1.0	2.2		
RBP 2G-B*	~0	0.03	0.1	B	Advanced for transport, it counts double
Slaughterhouse waste	0.9	0.8	0.3		
Bio-CO_2	0.0	0.0	31.5	e-fuel	Advanced for transport, it counts double

*RBP: Reconstructed biogas plants to biomethane; MBW: Municipal biodegradable waste; *: obtained by recalculating the raw materials used for biogas production in existing biogas plants based on annual reports; e-fuel: sinthetic fuel (obtained from electricity, mainly for hydrogen used in methanation).*

Conservative potentials for biomethane production in the short term (by 2027) are almost entirely (95%) enabled by agricultural raw materials (manure, energy crops, secondary crops, harvest residues). Although nearly half of this potential is accounted for by harvest residues (47%), this potential should be viewed with caution due to technological limitations detailed in Chapter 7. The low share of biomethane potential from waste is due to inadequate representation of appropriate logistical chains, insufficient infrastructure, and lack of clear strategies for energy utilization. For a significant possibility of waste utilization for biomethane production, an inter-sectoral strategy and collaboration between government administrations in the energy and environmental sectors are required. Biomethane potential could replace 40–90% of final consumption, 16–35% of imports, and 13–30% of total domestic natural gas consumption in 2027, depending on the applied balancing approach.

Conservative potentials for biomethane production in the long term (by 2050) maximize the utilization of waste, which would account for 45% of the total potential, alongside agricultural raw materials at 55%. Biomethane production facilities from waste would be built at locations where waste sources are significant (larger cities), assuming that the waste will not be managed through competing processes (incineration, composting) or landfill gas utilization in cogeneration. The largest share of waste-derived biomethane would be produced using biogenic CO_2 methanation technology (details in Chapter 6). Innovative technologies such as the gasification of forest biomass and potentially harvest residues combined with methanation would also contribute, though this process has the drawback of not allowing for the return of organic nutrients from the biomass back to agricultural land. Biomethane potential could replace 50–200% of final consumption, 24–48% of imports, and 23–88% of total domestic natural gas consumption in 2050.

The defined potentials will, according to the adopted methodology from the guidebook for developing national biomethane strategies, be used to propose national targets for biomethane production. This will include consideration of the mobilization potential from specific raw materials, application of technological limitations, the share of raw materials meeting GHG emission reduction criteria, and more.

8 Proposal for national biomethane production targets

The proposal for national biomethane production targets in Serbia is elaborated for three defined timeframes: 2027 (short-term), 2030 (mid-term), and 2050 (long-term). Depending on the timeframe, potentials for biomethane production have been considered based on conservative, expected, or optimistic approaches. For closer timeframes, the focus has been on conservative potential utilization, as it is not anticipated that significant changes in the availability of certain types of raw materials will occur by 2030 or 2050. For later timeframes, the focus has shifted to utilizing potentials derived from expected and optimistic approaches, considering greater mobilization of raw materials and the application of innovative technologies.

Short-term target (2027)

This target is primarily based on the partial utilization of existing capacities for biogas production, which is currently used for electricity generation. Existing biogas plants can collectively contribute **18.6 ktoe**. The timeframe required to convert a biogas plant to a biomethane production facility is up to one and a half years, covering the entire process of gathering bids, selecting technology and contractors, and carrying out refurbishment and reconstruction. If plant owners make timely decisions and define necessary prerequisites, preparations can begin before the expiration of the PPEE status, significantly reducing lead time and enabling production capacity readiness by 2027.

For new biomethane plants utilizing available raw material potentials in the short term, and considering technological limitations for harvest residues, a total of **13.3 ktoe** can be achieved. hese plants would use raw materials such as manure, energy crops, secondary crops, harvest residues, and kitchen waste (from the HORECA sector). By 2027, no targets are set for biomethane production from slaughterhouse waste, sewage sludge, or municipal biodegradable waste. Organic waste from the food industry, which is of suitable quality and form, is already integrated into the value chain for biogas production in Serbia, and its use is planned through logistical chains for existing biogas plants being converted to biomethane production.

The shares of raw materials in **Table 14** satisfy the recommended minimum mass share of 50% dry matter from manure in the mix of all raw materials, ensuring compliance with GHG emission reduction criteria. Jedino biometan proizveden iz energetskog bilja predstavlja nenapredni biometan. Only biomethane produced from energy crops is classified as non-advanced biomethane. All other biomethane shares originate from raw materials listed in Annex IX, List A of the REDII[1] Directive, representing advanced biomethane eligible for double counting (calculation with a multiplier) when used in the transport sector.

Table 14: Proposed national biomethane target for 2027 (new plants)

Raw material	**Amount of DM, kt/year**	**Energy, ktoe**	**Energy share, %**	**Type, REDII**
Manure	29.2	6.2	46.1	A
Energy herbs	9.2	3.1	23.1	1G
Other crops	6.5	2.1	15.4	A
Harvest residues	3.4	1.0	7.7	A
Kitchen waste	3.8	1.0	7.7	A
Total	**52.1**	**13.3**	**100.0**	**–**

DM: Dry matter; REDII: Renewable Energy Directive (classification of biomethane according to the type of raw material used for production, Annex IX– lists A and B); toe: ton oil equivalent; 1G: first generation (nonadvanced biomethane).

[1] REDII: Renewable Energy Directive

Mid-term target (2030)

The mid-term target encompasses existing biogas plants that would be converted to biomethane production facilities and newly constructed biomethane production plants. The total potential is estimated at **186.5 ktoe**. The composition and share of raw materials are similar to those planned for 2027 to ensure compliance with GHG emission reduction criteria. It is estimated that manure mobilization could produce approximately 80 ktoe/year of biomethane out of the available conservative potential of 123 ktoe/year. This represents a maximized sub-target for manure, aiming to reduce overall GHG emissions in Serbia through its mobilization for biomethane production.

Table 15: Proposed national target for biomethane for 2030

Raw material	Amount DM, kt/year	Energy, ktoe	Energy share, %	Type, REDII
Manure	415	80	42.9	A
Energy herbs	207	64	34.3	1G
Other crops	102	30	16.1	A
Harvest residues	36	10	5.4	A
Kitchen waste	10	2.5	1.3	A
Total	**770**	**186.5**	**100.0**	**–**

DM: Dry matter; REDII: Renewable Energy Directive (classification of biomethane according to the type of raw material used for production, Annex IX– lists A and B); toe: ton oil equivalent; 1G: first generation or nonadvanced biomethane.

Long-Term Target (2050)

The long-term target is based on a similar approach as the mid-term target. It is estimated that sufficient manure could be mobilized to produce approximately 118 ktoe/year of biomethane out of the expected potential of 227 ktoe/year. Slaughterhouse waste and MBW are also included. The optimistic potential for biomethane production from slaughterhouse waste by 2050 is 7.3 ktoe, with a contribution of 4.1 ktoe/year to the target, as the remaining quantities will be processed through competitive methods. From municipal biodegradable waste, about 23.9 ktoe of biomethane could be produced, contributing 7.5 ktoe/year to the target. Additionally, biomethane produced from biologically sourced CO_2 (bioCO_2) is included. This CO_2 is obtained during the biogas purification process to biomethane. It is assumed that around one-quarter of the CO_2 remaining from biomethane production from all other raw materials will be utilized for additional biomethane production, while the rest will be allocated for other competitive uses.

Table 16: Proposed national target for biomethane for 2050

Raw material	Amount DM, kt/year	Energy, ktoe	Energy share, %	Type, REDII
Manure	612	118	32.3	A
Energy herbs	306	94	25.9	1G
Other crops	149	44	12.1	A
Harvest residues	52	15	4.0	A
Kitchen waste	30	8	2.2	A
MBW	43	8	2.2	A
Slaughterhouse waste	108	4	1.1	B
bioCO_2	-	73	20.0	e-fuel
Total	**1,150**	**365**	**100.0**	**–**

MBW: Municipal biodegradable waste; bioCO_2: biomethane produced from CO_2 of biological origin, obtained by purifying biogas to biomethane; DM: Dry matter; REDII: Renewable Energy Directive (classification of biomethane according to the type of raw material used for production, Annex IX– lists A and B); toe: ton oil equivalent; 1G: first generation or nonadvanced biomethane.

Effects of proposed national targets

The following table provides an overview of the energy indicators for the proposed targets, presented in alternative (energy) units to allow recalculation for other purposes. Variants for the HHV and LHV (Lower Heating Value) of biomethane are included.

Table 17: Energy indicators of the proposed national goals for biomethane in the RS

Based on the higher heating value (HHV) of biomethane						
Deadline	**ekv-kW$_e$**	**MNm^3/year**	**MStm^3/year**	**PJ$_{HHV}$/Year**	**TWh$_{HHV}$/year**	**Ktoe$_{HHV}$/year**
2027	15,560	33,555	35,397	1,336	0.371	31.91
2030	90,919	196,064	206,830	7,806	2.168	186.45
2050	177,813	383,447	404,504	15,267	4.241	364.65
Based on the lower heating value (LHV) of biomethane						
Deadline	**ekv-kW$_e$**	**MNm^3/year**	**MStm^3/year**	**PJ$_{LHV}$/Year**	**TWh$_{LHV}$/year**	**Ktoe$_{LHV}$/year**
2027	15,560	33,555	35,397	1,204	0.335	28.77
2030	90,919	196,064	206,830	7,037	1.955	168.08
2050	177,813	383,447	404,504	13,763	3.823	328.72

ekv-MWe: equivalent of biomethane production expressed in equivalent electrical power in cogenerative gas engines; MNm^3: million (10^6) normal cubic meters; MStm^3: million standard cubic meters; HHV: Higher heating value (calculations based on HHV of biomethane); LHV: lower heating value (calculation carried out on the basis of LHV of biomethane); PJ: peta (10^{15}) joule; TWh: tera (10^{12}) watt hours; ktoe: kilo (10^3) ton of oil equivalent (toe = ton oil equivalent).

The effects of the proposed national targets for biomethane production in Serbia in the following table are analyzed in relation to the energy balance projections of the Republic of Serbia as defined in the adopted version of INECP. Data for three timeframes are used for scenarios **S** and **S-N**, which include the implementation of additional measures compared to the baseline scenario (**WEM**). The goal of both scenarios is to reduce emissions by increasing RES and energy efficiency (EE). Scenario **S-N** additionally considers the introduction of nuclear power plants with a total capacity of up to 1,000 MW into the energy system of the Republic of Serbia. Furthermore, the Draft Energy Development Strategy of the Republic of Serbia was used to define the values for NG energy in the gross domestic consumption of the Republic of Serbia, as well as NG imports.

Table 18: Effects of the proposed national goals

Parameter	**Unit**	**2027**		**2030**		**2050**			
		HHV	**LHV**	**HHV**	**LHV**	**HHV**		**LHV**	
		S/S-N	**S/S-N**	**S/S-N**	**S/S-N**	**S**	**S-N**	**S**	**S-N**
Replacement of NG total	%	1.1	1.0	6.1	5.5	12.8	13.7	11.5	12.4
Replacement of NG u FC	%	3.5	3.1	17.7	15.9	28.6	28.6	25.8	25.8
Replacement of imported NG	%	1.3	1.2	7.0	6.3	13.2	14.1	11.9	12.7
Replacement of NG in transport	%	95.4	86.0	100.0	100.0	100.0	100.0	100.0	100.0
Contribution of BM in transport[1]	%	1.3	1.2	2.3	2.3	1.5	1.6	1.5	1.6
Contribution of BM in transport[2]	%	2.3	2.1	3.8	3.8	2.7	2.7	2.7	2.7
GHG savings	ktCO_{2ekv}/year	190	185	555	510	975		890	
Total GHG savings in RS	%	0.3	0.3	1.1	1.0	3.7	3.9	3.4	3.6
Needed investments[3]	M€	75-95		430-550		845-1,065			
Value of BM[4]	M€/year	45	40	260	235	510		460	

NG: natural gas; FP: final energy consumption; BM: biomethane; GHG: Green House Gases (gases that contribute to the greenhouse effect); HHV: higher heating value (calculation carried out on the basis of HHV of biomethane); LHV: lower heating value (calculation carried out on the basis of LHV of biomethane); 1&2: without and with double calculation of the amount of energy of advanced biomethane (multiplication); 3: the value of the required total investments for the construction of a plant for the production of biomethane (CAPEX); 4: necessary total revenue for producers.

The energy effects are expressed through the potential replacement of natural gas (gross domestic consumption – total; final consumption; imported quantity). Additionally, the contribution of biomethane energy in the total energy of the transport sector is highlighted. A distinction is made between the share calculated without and with double counting of advanced biomethane, provided it is produced from eligible feedstock. It is noted that scenarios S and S-N, and consequently the analyzed effects, differ only in the projections for the year 2050, and are thus specifically presented.

The short-term goal assumes that the entire quantity of biomethane predicted by this target will be used in the transport sector. In this case, under scenario S, natural gas in the transport sector would be replaced by over 95%. This quantity would cover the shares of energy for natural gas and liquid biofuels as defined in INECP. For the medium- and long-term goals, the remaining amount of biomethane is redirected for use in final consumption as a substitute for natural gas.

An additional effect in the form of potential reductions in total GHG emissions would be achieved through the reduction of methane emissions from manure, which would be adequately managed in biomethane production facilities, and by replacing NG as a fossil fuel. The range of total investments needed for the construction of biomethane production facilities is estimated regardless of the source of funding, i.e., whether the investment cost is partially borne by the investor with a bank loan or covered by a specific subsidy. The value of biomethane represents the total required revenue intended for biomethane producers from the sale of produced biomethane, encompassing production costs and profit, regardless of the funding source. It is assumed that the total revenue level is similar to that in other European countries where biomethane is present in the market and where there is a FiT for biomethane (e.g., Italy, France).

The proposed biomethane production targets for Serbia are:

- Short-term (2027): 31.9 ktoe;
- Medium-term (2030): 186.5 ktoe;
- Long-term (2050): 364.7 ktoe.

It is proposed that the medium-term target be fully utilized in the transport sector. This would provide about 90% of the energy in transport projected in INECP to come from liquid biofuels and natural gas. It is considered unlikely that Serbia will establish production capacities for liquid biofuels (e.g., biodiesel and bioethanol) by 2027, especially for advanced generations of biofuels produced from non-feed raw materials, such as by-products (e.g., straw) or waste (e.g., municipal, kitchen waste). Consequently, biomethane will be the dominant tool for decarbonizing the transport sector in the short term.

For the medium- and long-term, it is proposed that targets be utilized in transport to the extent needed to fully (100%) meet the share of energy predicted in INECP for liquid biofuels and natural gas. The remaining quantity would then be used in final consumption across relevant sectors, replacing 16–29% of natural gas.