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BIOGAS PRODUCTION AND BIOMETHANE UPGRADING OPPORTUNITIES

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Abstract. As a member state of the European Union (EU), Latvia has undertaken to introduce measures to reduce the negative consequences of climate change, as stated in the European Green Deal climate neutrality strategy. In order to tackle the challenges identified in the European Green Deal, one must reach an equilibrium between the production and the absorption of greenhouse gases (GHG) by 2030. The EU goal is to achieve a 55% reduction in GHG emissions by 2050, as compared to 1990. It is also planned to make future human activity more climate-neutral, which means saving resources, optimising energy consumption, recycling waste into new products, using agricultural products, including food, to their full extent, without losses.

Significant changes in the key economic sectors of member states are to take place in accomplishing the EU climate neutrality goals. Recycling of waste is an integral component of circular economy. Biogas reactors make it possible to efficiently recycle biological waste, producing biogas. Biogas is a resource suitable for generating electric power and heat; while refining biogas, one can produce biomethane, to serve as an alternative to currently used types of fossil fuels.

The goal of this study is to analyse the possibility of manufacturing biomethane from organic waste, through the use of biogas plants that receive funding via the mandatory procurement system in Latvia. The study revealed that at least half of the biogas plants, if repurposed for the manufacture of biomethane, would be able to generate EUR 70.2 million in revenue within a year, assuming a biomethane price of EUR 100 per MWh^{-1}, thus fully compensating any income not received through mandatory procurement funding.

Keywords: biogas, agricultural waste, bioenergy production, biomethane.

JEL code: O13

Introduction

Production of biogas prevents methane emissions to the atmosphere and helps reduce net greenhouse gas emissions (H. Fredriksson et al., 2006). Methane (CH_4) is a much more powerful GHG gas than carbon dioxide (CO_2), and is usually emitted into the atmosphere from agricultural land development and animal enclosures not equipped with biogas fermenters. This is why collecting methane via anaerobic fermentation and using it as fuel significantly reduces net GHG emissions (Van der Meer HG et al., 2008). Biogas can be produced out of all types of organic waste, and many countries use manure from animal farming, algae, sewage water sludge, agricultural and municipal food, and hard organic waste. (A. Hilkiah et al., 2008) Biogas yield largely depends on the time spent in the biogas fermenter, and the chemical composition of the substrate (Briand X. et al., 1997). The contribution of this waste to global warming through natural decomposition resulting in these gases is well-documented, and is enormous (M. Poeschl et al., 2012). One should keep in mind that over a 20-year period, the negative effects of methane are 80 times higher than those of carbon dioxide (Y. Xiao et al., 2009). The main components of biogas are methane and carbon dioxide, but it can also contain hydrogen sulphide (H_2S), nitrogen (N_2), carbon monoxide (CO), oxygen (O_2), ammonia (NH_3), hydrogen (H_2) and water vapour (H_2O) (K. F. Chin et al., 2020). In essence, all of the well-functioning general gas separation methods work for refining biogas, even though the efficiency and output depend on the technology (W. K. E. H. Warren et al., 2012).

Biogas and the biomethane made from it play an important role in reducing GHG emissions. EU Directive 2018/2001 on the promotion of the use of energy from renewable sources took effect in Latvia on July 2021, stating that biogas/biomethane plants using manure may be employed in the manufacture of the biogas, following the standard values for the substrates used in the production of biogas, in order to

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reduce GHG emissions. These standard values specified in the directive indicate how much GHG is produced or saved through the raw material used for the production of biogas and biomethane. Biomethane is a first-generation biofuel that meets the biofuel sustainability criteria specified in Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Biomethane produced from manure generates 103 g CO_2 eq/MJ, or a 206% reduction compared to diesel fuel. A 1 MW biogas plant produces 19000 MWh or 68.4 million MJ within a year, then it generates 7045 t CO_2eq, and using its product instead of diesel fuel can save 172.6 CO_2 eq/MJ, for a total annual reduction of 11805 CO_2 eq. Replacing diesel fuel with biomethane reduces emissions by 43 to 206% (Giuntoli J., 2017). Using various processes, biogas can be used to produce various other vehicle fuels, with compressed biogas (CBG), liquefied biogas LBG, hydrogen, methanol, dimethyl ether and Fisher-Tropsch (FT) fuels being the likely options. In many places in the world, for example, in Germany, liquefied biomethane (LBG) is used in road vehicles, mixed with liquefied natural gas (LNG), as BIO-LNG fuel (Sofia Dahlgren et al., 2020). Biomethane shows even better results in comparison with diesel fuel. Lorries that use biomethane as fuel have a 76% smaller carbon footprint than diesel lorries (Ravigne E. et al., 2021).

Using biogas in making biofuel or introducing it in the natural gas system requires a number of conditions to be met, largely associated with the purification of biogas, so that it has the level of quality set in Latvian laws and regulations (Biofuel quality…, 2021). Biogas contains less energy than biomethane, which is produced by increasing the quality of biogas, making it possible to use it as biofuel. In terms of its energy characteristics, biomethane does not differ from natural gas. Different technologies exist for making biomethane out of biogas (M. Prussi et al., 2019). According to Tricase C. and co-authors (2019), animal farming largely causes indirect CO_2 emissions (because direct emissions due to breathing take up a very small proportion of net carbon emissions), coming from:

1) using fossil fuels in manufacturing and transporting feed;
2) using chemical fertilisers;
3) differences in the quantity of carbon sequestered within the ecosystem, which are caused by changes in land use (e.g. clear-cutting forests for feed and pastures).

The Communication from the Commission to the European Parliament, the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions on an EU strategy to reduce methane emissions states that the production of biogas, and potentially, biomethane is to play a key role in promoting a circular economy and reducing methane emissions (EU strategy..., 2022).

In February 2022, biomethane in Europe was 30% cheaper (EUR 54 per MWh^{-1}) than natural gas (EUR 80 per MWh^{-1}) (Europe biogas association, 2022). That same month, the price of natural gas showed a 4.4-time increase, compared to 18 EUR MWh^{-1} a year before. The EU resolution of 1 March 2022 (022/2564(RSP)) calls for a significant reduction of energy dependence, especially from the gas, oil and coal imported from Russia, by diversifying the sources of energy, which includes the expansion of terminals and delivery routes for liquefied natural gas, unbundling of gas storage, increasing energy efficiency and the speed of clean energy transition, completely abandoning the Nord Stream 2 pipeline. This is why one must positively evaluate the decision of the German government to suspend the certification of Nord Stream 2, urging the European Commission and EU member states to create a coordination mechanism and use all available gas storage facilities to ensure a continuous supply of gas to EU member states.

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Natural gas prices are expected to rise even further during the 2022/2023 heating season. National governments are trying to reduce the negative impact of the rising energy prices, and the European Biogas Association believes that the solution lies in ramping up the production of biomethane.

In January 2022, 40 biogas cogeneration plants with a total power output of 44.556 MW were eligible for government subsidies as part of mandatory procurements in Latvia. The rated power output of the biogas cogeneration plants is 0.5-2 MW, and the location of these plants correlates well with the location of major farming businesses. However, the biggest biogas plant in Latvia, with an output of 6.3 MW, is in a landfill (State Construction…, 2022). The electric power generated from biogas is procured, following the regulations in effect in Latvia by AS 'Energijas publiskais tirgotajs' ('public trader'), which then resells it at the hourly prices set at the Nord Pool power exchange for the Latvia trading region. More than EUR 40 million was paid as mandatory procurement compensations in the biogas sector in 2019, which were partially covered by the government, and partially, by electric power consumers that paid the electric power mandatory procurement component (MPC) fee. Given the negative social and economic effect of the rising cost of electric power, such compensation must be gradually phased out. Mandatory procurements are limited in time, meaning that their negative effects will subside gradually even if no additional measures are taken. Without subsidies, the manufacture of biogas and its use for generating electric power is not economically feasible (Budzianowski, W. et al., 2015). This is why there is a risk of biogas plants shutting down once the electric power mandatory procurement period ends, leading to an increase in GHG emissions and problems associated with the requirements set by the EU in the field of waste management. In waste management, biogas production could be subsidised differently, whereby the producer of the waste could pay the additional costs, subsidising the production of biogas via income from waste. There could be a faster transition to the manufacture of biomethane, even before the period for receiving MPC runs out, meaning a reduction in MPC fees for the consumers of electric power in Latvia (Deutche Gesellshaft fur…, 2017).

For this reason, the goal of this study is to analyse the possibility of manufacturing biomethane from organic waste, through the use of the biogas plants that receive funding via the mandatory procurement system in Latvia. Two objectives were accomplished to achieve the goal of the study: (1) describe the operating indicators of the biogas plants working as part of the electric power mandatory procurement system; (2) calculate the economic benefit if at least half of the biogas plants operating as part of the mandatory procurement system transition to the production of biomethane.

Research methods. The research employed general and structural research methods. The descriptive, analysis and synthesis methods were used to formulate research results. The research made calculations using secondary data, which were available in public reports provided by public administration institutions. Information on the number of biogas plants and their distribution by origin of inputs was obtained from the Ministry of Economics of the Republic of Latvia (Ministry of Economics…, 2022), on the installed electric capacities of agricultural biogas plants – from the State Construction Control Bureau of Latvia (State Construction…, 2022). The data were used to model the transition of biogas plants from mandatory procurement to biomethane production. The data on installed electric capacity and the number of biogas plants are given for 2021 and first quarter of 2022.

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Results and Discussion

1. OPERATING INDICATORS OF THE BIOGAS PLANTS WORKING WITHIN THE MANDATORY PROCUREMENT SYSTEM

In Latvia, the construction of biogas plants at municipal waste landfills and waste water treatment facilities began in 1999, and in 2002, the generation of electric power began at the completed plants. As the government support mechanisms were put in place in 2007 and 2009, the expansion of biogas picked up speed, with plants built to process agricultural waste and biomass. However, given the need to limit the negative effect of MPC on the economy, a few restrictions were introduced. For example, the issue of new generation permits was suspended in 2012, which led to an end of the construction of new biogas plants, with the last one built in 2015 (Biomethane production…, 2022). Since 2015, there have only been expansions of existing plants in Latvia, intended to reach the maximum capacity specified in the permits already issued.

As 2021, 47 biogas plants operated as part of the mandatory procurement system in Latvia. Table 1 shows the 2021 operating indicators for these plants. These data are publicly available on the website of the State Construction Control Bureau - the institution that supervises the operation of biogas cogeneration plants in Latvia. In 2021, most of the plants in Latvia, 23 or 48.9%, had a capacity of more than 0.5-1.0 MW, 11 or 23.5%, had a capacity of more than 1.5-2.0 MW, and there were 6 small plants with a capacity of up to 0.5 MW. Thus, medium 0.5-1 MW biogas plants were the most common in Latvia in 2021. One biogas plant was classified as a micro plant because its output was 0.16 MW.

Table 1

Latvian biogas plant operating indicators broken down by their current capacity, as of 2021

Installed capacity, MW	**Biogas plants**		**Amount of MP purchased, GWh***			**Amount purchased, without VAT, millions of EUR**			**Average price, EUR kWh^{-1}***	**Subsidy in addition to market price, millions of EUR**		
	Quantity	% of the total	Total	% of the total	1 plant average	Total	% of the total	1 plant average		Total	% of the total	1 plant average
<0.5	6	12.7	7.02	3.3	1.17	1.09	3.14	0.18	0.18	0.611	3.58	0.10
0.5–1.0	23	48.9	95.27	44.7	4.14	16.13	46.48	0.70	0.17	8.27	48.5	0.36
1.0–1.5	5	10.6	27.36	12.82	5.47	4.72	13.6	0.94	0.16	2.31	13.6	0.46
1.5–2.0	11	23.5	70.49	33.1	6.40	11.25	32.41	1.02	0.16	5.40	31.7	0.49
2.0–6.5	2	4.3	12.96	6.08	6.48	1.52	4.37	0.76	0.12	0.44	2.62	0.22
Total	**47**	**100.0**	**213.1**	**100.0**	**4.73**	**34.71**	**100.0**	**0.72**	**0.16**	**17.03**	**100.0**	**0.32**

1 GWh = 1000 kilowatt-hours kWh

Source: author's calculations, using data from the Ministry of Economics…, 2022

16 biogas plants in Latvia have a capacity of 1 to 2 MW, of which most use raw materials of agricultural origin. Only one plant has a capacity of 6.5 MW, and it is located in a landfill. There are also a few businesses in Latvia that are not classified as biogas plants, but generate biogas and use it for their own needs, e.g. Ltd. 'Cesu alus' (Cesu beer…, 2022).

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The total amount of electric power sold by biogas plants as part of MP in 2021 was 213.1 GWh, of which 44.7% was by plants with a capacity of 0.5-1.0 MW, 33.1% by 1.5–2.0 MW plants, and 6% by 2.0-6.5 MW plants. The average amount of electric power sold by a single plant fluctuated between 1.17 GWh in the smaller ones, and 12.88 GWh in the larger plants, with an average of 4.73 GWh.

In 2020 and 2021, several plants withdrew from the mandatory procurement of the electric power system at their own initiative, and stopped their operation. Another plant shut down due to a difficult financial and legal situation. As of 1 January 2022, only 40 biogas plants, with a total power capacity of 44.556 MW, actually operated as part of the mandatory procurement system. Nevertheless, there are a total of 56 biogas plants with a total power capacity of 62.113 MW that still generate electricity.

2. POTENTIAL TRANSITION OF BIOGAS PLANTS TO THE PRODUCTION OF BIOMETHANE

The authors assume that in each of the plant size groups, at least half of biogas plants will choose to switch their business from the cogeneration of electric power to biomethane production within the coming two years. In Latvia, current biogas power plants transitioning to making biomethane could be an important process for those biogas plants whose mandatory procurement period has run out, as well as all of the other biogas plants, in view of the expected rise in energy prices.

The Latvian State Construction Control Bureau supervises the biogas cogeneration plants operating as part of the mandatory procurement system, and the requirements set for their operation specified in applicable law are becoming increasingly difficult to meet by these businesses, because of a significant administrative overhead created for the biogas plants. In 2021, a number of biogas plants in Latvia decided to end their participation in the mandatory procurement system, but did not shut down, continuing to process waste and produce biogas. The first model for operating cogeneration plants is to sell electric power they generate at market prices on the exchange, without MPC. The market price changes every hour, and biogas plants must adjust the output of their cogeneration facilities to match the fluctuations of the market price of power if they are to gain maximum financial benefit from it. The second model for operating cogeneration plants is to sell electric power at an average daily market price, resulting in uniform operation of the cogeneration facilities throughout the entire day, with the price paid being the average 24-hour price at the exchange. The authors reviewed the daily prices at the Nord Pool exchange over a period of 6 months. A trend of slightly lower prices during night hours (00:00-07:00) was observed; however, overall, there were no correlations noted that would make it possible to predict the prices of future periods. Various factors affect the market prices at the exchange, such as the current season, weather, international politics, changes in consumer behaviour etc. Selling electric power at market price on the exchange is an alternative to the mandatory procurement system; however, in order for the producer of biogas to generate maximum profits, it must monitor price forecasts and adjust the output of its cogeneration facilities as often as every hour. The third operating model for cogeneration plants is to sell electric power to another business that needs electric power generated from renewables. In this case, the cogeneration plant has a contract with the buyer of its electric power, setting the conditions for the plant's operation. There is an electric power price option that the consumer is charged that does not contain the transmission fees and the mandatory procurement component, if the electric power supply systems of the consumer and the producer are connected without JSC 'Sadales tikls' (which manages the supply of electricity in Latvia) acting as an intermediary. The fourth model of the operation of biogas cogeneration plants is to manufacture electric power and heating for internal consumption. This model is preferred by those biogas plants that engage in other activities that consume power.

If a biogas cogeneration plant withdraws from the mandatory procurement system, this will result in less administrative overhead for its operator; however, choosing the option of selling electric power at market prices means the need to constantly monitor the output of the plant, which can be seen as an impediment in operation. Meanwhile, if after withdrawing from the mandatory procurement system, the biogas plant operator decides to continue operating as a producer of biomethane, the nature of the plant's cogeneration activities could change. A reduction in operating costs is expected for the biogas plants that transition from selling cogenerated electric power and heat to producing biomethane and selling it, but this requires an initial investment in biomethane purification facilities. As part of manufacturing biomethane, one can add a CO_2 collection system to the biomethane purification facility, thus making it possible to efficiently use CO_2 for another purpose before it is returned to nature. Selling the CO_2 could be a source of additional income for biogas plants.

In the Year 2022, the 40 biogas cogeneration plants that operate as part of the mandatory procurement system (their number has fallen by 7 since 2021) have a total power capacity of 44.556 MW, and theoretically are allowed to generate this quantity of electric power. This yields 1069.344 MWh in 24 hours. Generating 1 MW of electric power takes approximately 450 m^3 of biogas with a methane content of 52.5%.

The price of biomethane can be 30% lower than the price of natural gas in February 2022. Biomethane can be produced at a price as low as EUR 55 MWh^{-1}, whereas natural gas cost EUR 80 MWh^{-1} in February 2022, without taking the CO_2 prices into account. The authors believe that biomethane is likely to remain cheaper than natural gas in the short and the long run. Even though other renewable gases, such as green hydrogen, need time for their production capacities to increase, they are still 2-4 times more expensive than biomethane. The price of green hydrogen in Q1 2022 was EUR 180 MW^{-1}. The authors predict that if one is to take into account the expected reduction in the supply of gas from Russia in 2022, the price of biomethane will be at least EUR 140 MW^{-1} in Q3 2022. This will be associated with the generally rising prices of energy resources, as well as the goals of the European Green Deal. At this biomethane price level (140 EUR MW^{-1}), at least half of the biogas cogeneration plants operating within the mandatory procurement system will consider switching their activities to the production of biomethane. Table 2 shows the results of calculations for the possible operation of the biogas plants working within the mandatory procurement system if they switch to the production of biomethane.

Making 1 MWh of biomethane takes 94.88 Nm^3 of biomethane. Between 1 January and 30 April 2022, the price of biogas in Latvia was EUR 104.58 per MWh, including the government subsidy to hold back the increase in energy prices (Actual gas tariffs, 2022).

Table 2 shows that the 21 biogas plants selected could manufacture 80 MWh worth of biomethane an hour (using the quantity of the biogas used for the generation of electric power to calculate the biomethane output). This is as high as 1922 MWh every 24 hours, and 701,597 MWh a year. In total, these biogas plants could generate EUR 70.2 million in revenue, assuming a biomethane price of EUR 100 per MWh^{-1}. This amount is more than what the 47 biogas plants generated in 2021 (EUR 34.71 million) and the total MPC subsidy (EUR 17.03 million) put together, as shown in Table 1.

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Table 2

Latvian biogas plants broken down by installed capacity and biomethane potential, as of January 2022

Installed capacity, MW	Number of biogas plants in January 2022	At least half of the plants in every group	Average capacity of the plants, MW x number of plants	Biogas quantity for generating 1 MW of electricity, m^3 **	Biogas quantity, Nm^3h^{-1}	Theoretical biomethane quantity, Nm^3h^{-1}***	Theoretical biomethane energy value, MWh^{-1} ****
<0.5	6	3	0.864	450	388.8	205.14	2.162
0.5–1.0	19	10	7.84	450	3528.0	1861.5	19.62
1.0–1.5	5	3	3.91	450	1759.5	928.4	9.785
1.5–2.0	8	4	12.89	450	5800.5	3060.6	32.258
2.0–6.5	2	1	6.5*	450	2925.0	1543.3	16.266
Total	**40**	**21**	**32.01**	**-**	**14401.8**	**7598.94**	**80.091**

(Normal cubic metre (Nm^3) is a quantity of natural gas or biogas that is consumed and registered by meters, and it is recalculated for certain base gas parameters (temperature 20 °C, pressure 1.01325 x 10^5 Pa).)

**** There are only 2 plants in the 2.0–6.5 MW range, and average capacity cannot be assumed, if only 1 plant decides to switch to the production of biomethane;***

***** Amount of biogas necessary to generate 1 MW of electric power, Nm^3, assuming a methane content of 52.5%;***

****** Biomethane with a methane content of 99.5%, Nm^3h^{-1};***

******* The value of biomethane is expressed in MWh, and its price, in EUR MWh^{-1};1 Nm^3 100% methane contains 10.54 kWh.***

In order to convert an existing biogas cogeneration plant, one needs to invest in biomethane purification equipment. The cost of this equipment is a result of various factors, such as the type of technology, manufacturer, capacity, delivery deadlines etc. Additional investments will be necessary for the method of transporting the biomethane from storage to the place of its consumption, meaning that producing biomethane will take significant investments. This is why every biogas plant should assess the risks and the possible returns. For this reason, in the opinion of the author, there is a need for mechanisms to support those plants that are beginning the production of biomethane, making it possible to find better-priced alternatives with the reduction in the quantity of natural gas imported from Russia.

Depending on the amount of investment subsidies available, and the sale price of biomethane in the future, the production of biomethane could be theoretically possible at plants with a power capacity of at least 0.5 MW, even though larger biogas plants would possibly be more stable in their profitability.

Conclusions

1) The manufacture of biogas and biomethane is desirable from the viewpoint of reducing climate change, and should be supported. The CH_4, NH_4 and CO_2 greenhouse gases produced as a result of decomposition of organic compounds will end up in the atmosphere in any case, and with the use of biogas fermenters, this process is controlled, at least preventing CH_4 emissions as a first step.
2) If half of the biogas plants in Latvia operating within the mandatory procurement system as of January 2022 decide to fully transition from generating electricity to producing biomethane, they would be able to produce 701,597 MWh of biomethane a year. In total, these biogas plants could generate EUR 70.2 million in revenue, assuming a biomethane price of EUR 100 MWh^{-1}.
3) Biomethane sees increasing use as a biofuel for road vehicles, replacing CNG and LNG, used as Bio-LNG or CBG, provided that biomethane is manufactured in sufficient quantities, and there are fuel

stations for it. Compared to fossil fuels, biomethane has a lower CO_2 impact, as no new CO_2 is emitted into the atmosphere with the combustion of biomethane, as that CO_2 is returned into natural circulation absorbed by plants.

4) As part of manufacturing biomethane, one can add a CO_2 collection system to the biomethane purification facility, thus making it possible to efficiently use CO_2 for another purpose before it is returned to nature. Selling the CO_2 could be a source of additional income for biogas plants.

5) One should assess how independent biogas plants could be in selling biomethane on a free market in the context of rising energy prices in the EU, because this will also increase the cost of buying and operating the production equipment.

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