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PROSPECTS FOR STATE SUPPORT OF THE DEVELOPMENT OF THE BIOMETHANE INDUSTRY IN UKRAINE UNTIL 2040

The paper considers the prospects for the state support for the development of biomethane industry in Ukraine from 2025 to 2040. The main financial incentives for the use of biomass-derived energy are a special tariff for heat from sources other than natural gas, and a feed-in tariff (the auction price in the future). In the EU, biomethane production is gaining ground due to available financial incentives (premiums to the cost of natural gas, and feed-in premiums). The main obstacle to the large-scale spread of biogas (and, accordingly, biomethane) is the high cost of equipment. The amounts of state support for biogas production with its purification to biomethane and supply of the latter to the gas transmission and gas distribution networks under the conditions of biomethane production in the amounts provided by the draft Roadmap for Bioenergy Development in Ukraine until 2050 were assessed. While maintaining the price of natural gas at 2021 prices (EUR 0.24/m³), the need to subsidize biomethane production from 2025 to 2040 can reach EUR 0.263-3.5 billion, on average EUR 16.5-217 million per year. Infrastructure expenditures were not taken into account in the assessment. The possibility of electricity output from biomethane was not considered, as biogas refining to the quality of biomethane requires additional funds. The statutory auction price may be sufficient only for certain types of feedstock and for large biogas plants.

The use of biomethane may be appropriate in the transport sector, as biomethane is an "advanced biofuel", and Ukraine already has a relatively extensive network of methane filling stations. Biomethane production in Ukraine will require state support, particularly in the form of direct subsidies to biomethane producers (in the form of premium to the price of natural gas), and in the form of a premium to the auction price. The use of biomethane will partially reduce dependence on imported fossil fuels, being also an important element in the

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decarbonization of sectors using natural gas, replacing up to 0.76 billion m3 of the latter in 2040, which is in line with the global leading decarbonization trends.

Keywords: *biomethane, biogas, bioenergy, Ukraine*

In Ukraine, the consumption of energy from renewable sources is gradually increasing. While the issue of power generation based on solar and wind energy is accompanied by significant media attention, the consumption of energy from biomass remains unnoticed by citizens. Nevertheless, of all renewable energy sources (RES), biomass takes the main place: according to the State Statistics Service, in 2019 the supply and consumption of wind and solar energy was 426 ktoe, and that of biomass and waste energy - 3786 ktoe [1], that is, almost nine times more. It is through the use of biomass that cities in Ukraine can consume more energy [2]. This is important because 69% of the population live in cities, while the rural population is decreasing. Despite the fact that the cost of energy production from renewable sources may remain higher than the cost of energy from fossil fuels, attention to RES is growing for environmental reasons, in particular through the significant potential to reduce greenhouse gas emissions [3].

Leading Ukrainian scientists as Yu. Matvieiev, M. Shlapak [4], H. Heletukha, P. Kucheruk [5], L. Sakun [6], H. Kaletnik [7], S. Tkachenko [8], I. Skorokhod [9], etc., pay attention to the development of biogas technologies in Ukraine. Despite the relatively slow development of the industry, there is a significant amount of unresolved problems, such as providing access to credit, the need to raise awareness of the benefits of biogas technology, improving the tools of state regulation of the biogas market and many others.

To increase the share of biomass energy in the energy balance of Ukraine, a number of financial incentives have been created, in particular, the establishment of a tariff for heat from renewable sources at the level of 90% of the tariff for heat from natural gas is envisaged. The main economic incentive for the development of electricity production from biogas is the "feed-in" tariff in the amount of 12.39 eurocents/kWh, whose coefficient will not be reduced until the end of 2029. It should be noted that some biogas facilities were commissioned even before the introduction of the "feed-in" tariff and these facilities sold electricity to the grid at the general tariff. During 2020-2021 a number of draft laws of Ukraine were developed to increase the share of energy from biomass in the energy balance, in particular, a draft law on amendments to some legislative acts of Ukraine regarding the mandatory use of liquid biofuels (biocomponents) in the transport sector; on exemption of biofuels from CO_2 emissions tax; on development of the sphere of energy plant cultivation in Ukraine; on amendments to some legislative acts of Ukraine on development of trade in solid biofuels [10]; and on amendments to some legislative acts of Ukraine on the development of production and consumption of biomethane [11].

The purpose of the article is to assess the prospects and ways of providing state support for the development of the biomethane industry in Ukraine until 2040. The draft law defines the term "biomethane" as "biogas, which by its physical and

technical characteristics complies with the regulations for natural gas for feeding into the gas transmission and distribution system". As of April 2021, there are 53 biogas plants in Ukraine with a total capacity of 103.4 MW, which operate at the "feed-in" tariff. According to the National Renewable Energy Action Plan for the period until 2020, biogas capacity should be 290 MW as of 2020. To ensure the quality of biomethane acceptable for supply to the gas transmission and distribution networks, its verification is necessary, but so far the mechanism of its procedure has not been agreed upon. Also it is necessary to provide guarantees of biomethane origin, which is expected to be achieved with the adoption of this draft law [12]. In EU countries the purification of biogas to the level of biomethane is subsidized (similar to "feed-in" premiums), because the process is costly, while in Ukraine such a subsidy is not yet provided, so for the possibility of biomethane production it is necessary to develop additional incentive tools. In addition, technologies of biogas purification to the level of biomethane are not yet presented in Ukraine [13].

Available technologies allow production of biomethane by biogas post-treatment or by gasification of solid biomass [14]. In world practice 90% of biomethane is produced by biogas post-treatment. The use of biomethane is advisable in industries where it is necessary to abandon fossil fuels, to switch to carbon-free forms of energy, where the use of technology Carbon Capture and Storage (CCS) is economically unjustified or technologically difficult, as well as in transportation. Biomethane helps avoid both CO_2 emissions from natural gas and emission of methane, which is a more dangerous greenhouse gas than CO_2 itself. Thus, biogas plant "Oril-Leader" during 2013-2019 helped avoid 500 thousand tons of CO_2 emissions, and "Ladyzhyn Biogas" after the launch of the second phase will avoid emission of 200 thousand tons of CO_2 annually [13]. Raw material for the production of biogas and biomethane can be not only cattle manure, pulp or post-alcoholic bard, but also landfill gas and sewage sludge (though, the economic feasibility of building such biogas plants can be achieved by using non-market instruments).

Ukraine has a significant potential for the production and use of biogas and biomethane due to available raw material resources, and a developed gas supply system, so there is a technical possibility of connecting biomethane producers to gas distribution networks of medium and low pressure for local supply of biomethane as a substitute for natural gas [15], since by its chemical properties biomethane is similar to the latter. At the end of 2020, a Memorandum of Understanding and Cooperation was signed between the Bioenergy Association of Ukraine and the Ukrainian GTS Operator. There is also the Project of the European Bank for Reconstruction and Development (EBRD) "Zoning of biomethane production and assessment of the possibility and conditions of connecting biomethane producers to gas transmission and distribution systems in Ukraine".

As at February 2021, the capacity of biomass energy generation plants in Ukraine was 199.5 MW [16], of which the total capacity of biogas plants is 103.4 MW. 53 biogas plants work with "feed-in" tariff, and the average capacity of one plant is 1.98 MW. For comparison, in Germany as of 2019 there were 9.5 thousand plants with a total capacity of 5228 MW, so the average capacity per plant is 0.55 MW [17].

Biomethane purification and supply of biomethane to the network is common practice [18], and the European continent is the world leader in biomethane production compared to others [14]. In order to stimulate the demand and supply of biomethane, a number of EU countries (Germany, Italy, Netherlands, UK) have introduced incentive instruments for the use of biomethane in transport.

The main investors in biogas projects in Ukraine are agricultural holdings, they implement projects with a minimum capacity of 2.5 MW [19], while the available agricultural potential allows construction of small plants. Biogas projects require higher investments than those in wind or solar energy [20].

According to the Law of Ukraine No 810-IX "On the Amendments to Certain Laws of Ukraine on Improving the Conditions of Support for Electricity Production from Alternative Energy Sources" of 21.07.2020, the "feed-in" tariff will be provided only for plants put into operation before January 1, 2023. This innovation means that from 2023 all biogas plants, including small ones, will have to participate in auctions to receive state support. As of April 2021, there remains a significant debt to producers of energy from renewable sources for commercial product and not even pilot auctions were held, which were initially scheduled for 2019, and then postponed to 2020. According to the above-mentioned Law of Ukraine No 810-IX, the auction price for non-wind power plant and non-solar power plant projects may not exceed 0.12 EUR/kWh, including for small producers.

As of 2021, biomethane is more expensive than natural gas, which is fully consistent with available world practice; however, a reduction of the cost of its production is expected [14]. In some countries, state support is introduced to increase the role of biomethane in the energy mix. Financial state support in the EU countries exists either in the form of a separate tariff for biomethane, or in the form of "feed-in" tariff for electricity from biomethane (Table 1).

Table 1

Financial incentives for biomethane production in EU countries

Type of support	Country	Amount
Tariff for biomethane	Denmark	Premium to the price of natural gas. Tariff for biomethane - EUR 0.735 per cubic meter
	Netherlands	Tariff for biomethane EUR 0.483–1.035 per cubic meter
	France	Tariff for biomethane from municipal solid waste (MSW): EUR 0.450-0.950 per cubic meter; from agricultural raw materials - EUR 0.850–1.250 per cubic meter; from wastewater: EUR 0.650–1.350 per cubic meter
	Italy	Premium to the price of natural gas. Tariff for biomethane - EUR 0.796 per cubic meter
"Feed-in" tariff for electricity from biomethane	Germany	EUR 0.134-0.237/kWh, bonus for biomethane EUR 0.03/kWh
	United Kingdom	EUR 0.1–0.116/kWh surcharge to the market price
	France	EUR 0.150-0.175 /kWh
	Switzerland	EUR 0.146–0.233 /kWh

Source: [21].

The availability of economic incentives in European countries made it possible to generate 20 billion kWh of electricity from biomethane in 500 biogas plants in 2017 [3]. The lion's share of biomethane was produced using vegetable raw materials and waste (13 billion kWh), biological waste (5 billion kWh) and sewage sludge (1.2 billion kWh) [22]. According to the Scientific-Engineering Center "Biomass", the cost of biomethane in the EU is EUR 0.3-0.9 per cubic meter, and the average cost - EUR 0.55 per cubic meter. The potential for biomethane production in Ukraine is 7.8 billion cubic meters, equal to a quarter of the country's natural gas consumption.

The main obstacle to the large-scale production of biogas (and, consequently, biomethane) is the high cost of equipment. Let us calculate the minimum amount of state support for the production of biogas from post-treatment to biomethane and supplying the latter to the gas transportation and gas distribution network. For this purpose, we use data on the projected development of bioenergy in Ukraine until 2050 - the draft roadmap for bioenergy development in Ukraine until 2050, which was developed by Bioenergy Association of Ukraine (Fig. 1).

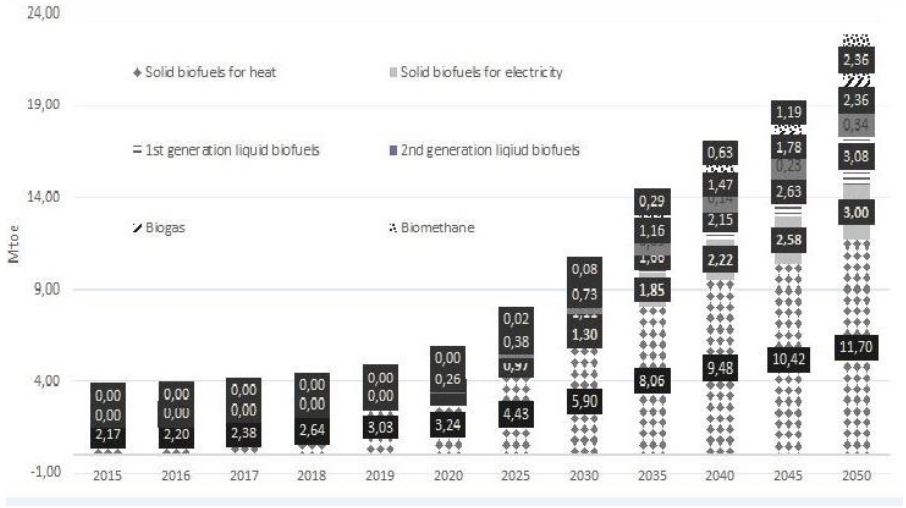

Figure 1. The structure of biofuels by area of use, *Mtoe*

Source: [23].

As can be seen in Figure 1, biomethane output and use are expected to increase starting with 2025 (0.02 million toe) to 2.36 toe in 2050.

For further calculation, we use the data that 1 million toe is equal to 11.63 TWh, or 1.21 cubic meters of natural gas equivalent [14]. Accordingly, before 2040, the natural gas equivalent of biomethane output will be 0.024 cubic meters in 2025, 0.01 cubic meters in 2030, 0.35 cubic meters in 2035, and 0.76 cubic meters in 2040 (Figure 2).

In June 2021, natural gas prices in Ukraine averaged 8 UAH/cubic meter (excluding transportation), or 0.24 EUR/cubic meter. Thus, NJSC Naftogaz's fixed annual tariff is 7.96 UAH/cubic meter including VAT excluding delivery. The calculation of the necessary subsidies for biomethane production for different production costs of the latter (EUR 0.3-0.9/cubic meter) is shown in Table 2. It

should be noted that this calculation is not exact, as it is not yet known at what pace the price of natural gas will change and how rapidly the biogas production technologies will become cheaper.

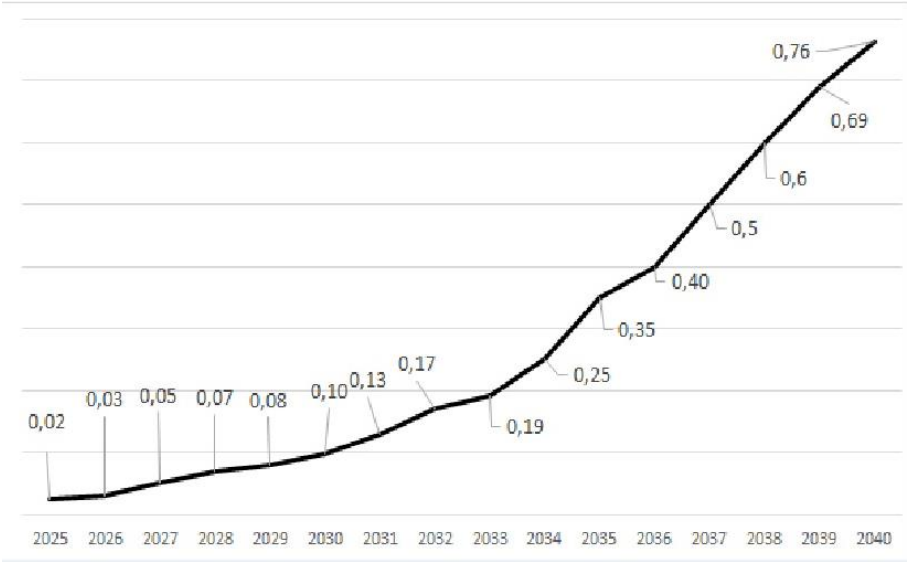

Figure 2. Natural gas equivalent of biomethane output, *billion cubic meters of natural gas equivalent*

Source: author's own calculations [23].

Table 2

Required subsidies for biomethane production in Ukraine in 2025-2040

Years	**Natural gas equi-valent,** *billion cubic meters*	**The cost of corresponding volume of natural gas,** *EUR million*	**Biomethane production costs**, *EUR million*			**Need for compensation**, *EUR million*		
			EUR 0.3/*cubic meter*	*EUR* 0.55/*cubic meter*	*EUR* 0.9/*cubic meter*	*EUR* 0.3/*cubic meter*	*EUR* 0.55/*cubic meter*	*EUR* 0.9/*cubic meter*
2025	0.02	5.79	7.23	13.26	21.70	1.45	7.47	15.91
2026	0.03	7.20	9.00	16.50	27.00	1.80	9.30	26.97
2027	0.05	12.00	15.00	27.50	45.00	3.00	15.50	33.00
2028	0.07	16.80	21.00	38.50	63.00	4.20	21.70	62.93
2029	0.08	19.20	24.00	44.00	72.00	4.80	24.80	52.80
2030	0.10	23.64	29.55	54.18	88.65	5.91	30.54	88.55
2031	0.13	31.20	39.00	71.50	117.00	7.80	40.30	85.80
2032	0.17	40.80	51.00	93.50	153.00	10.20	52.70	152.83
2033	0.19	45.60	57.00	104.50	171.00	11.40	58.90	125.40
2034	0.25	60.00	75.00	137.50	225.00	15.00	77.50	224.75
2035	0.35	84.12	105.15	192.77	315.44	21.03	108.65	231.32
2036	0.40	96.00	120.00	220.00	360.00	24.00	124.00	359.60
2037	0.5	120.00	150.00	275.00	450.00	30.00	155.00	330.00
2038	0.6	144.00	180.00	330.00	540.00	36.00	186.00	539.40
2039	0.69	165.60	207.00	379.50	621.00	41.40	213.90	455.40
2040	0.76	182.87	228.59	419.08	685.77	45.72	236.21	685.01
	Total	1054.81	1318.52	2417.28	3955.55	263.70	1362.47	3469.67

Source: author's own calculations.

As can be seen from Table 2, the need for subsidies for biomethane production from 2025 to 2040 cumulatively might be in the range of EUR 0.263 to 3.5 billion or on average EUR 16.5 to 217 million per year if the gas price remains at 2021 level (EUR 0.24 /m3). In comparison, Ukraine spent EUR 5.7 billion in 2014, EUR 4.5 billion in 2015, EUR 2.2 billion in 2016, EUR 3.2 billion in 2017, EUR 3.1 billion in 2018 and EUR 2.3 billion in 2019 [24]. Undoubtedly, it is unlikely that the current price level for natural gas will be maintained until 2040. In addition, renewable energy technologies are gradually becoming cheaper (although biomass energy technologies are not as cheap as solar energy technologies [25]). It should be noted that measures are needed to reduce the production cost of biomethane to raise the market saturation with the latter. Investments in research and development should play a major role here. In the initial stages of implementation of the technology, subsidies are possible to agricultural producers for the production of biomethane in case of its production from agricultural waste, or to the housing and communal services sector, in case of its production from waste water.

This calculation did not take into account the costs of infrastructure, which are significant: the vertically integrated holding MHP in 2020 built a more than 10 km length biogas pipeline on Separate Division "Biogas Ladyzhyn", whose construction cost EUR 1 million [13].

Also, we do not consider electricity production from biomethane, as electricity can be sold to the grid either at a "feed-in" tariff or at an auction price. The purification of biogas to biomethane quality requires additional funds, and the available "feed-in" tariff of EUR 0.1239/kWh or the auction price (that cannot exceed EUR 0.12 /kWh) are only sufficient for certain raw materials and for large biogas plants. Moreover, biomethane cogeneration units are by 20-30% more expensive than biogas cogeneration units, and if the heat from such a unit is sold, the "feed-in" tariff coefficient (or auction price) should be EUR 0.196-0.239/kWh [26].

In addition, during 2020, a situation unfavorable for the development of this economic activity emerged in Ukraine, in particular during the transition to a full-scale competitive market of bilateral contracts no financing sources were identified for those producers of electricity from renewable sources, who sell it at the "feed-in" tariff. As a result, during 2020 the State Enterprise "Guaranteed Buyer" paid only 37% (UAH 15.97 billion) of the required costs for the sold electricity [27]. The energy use of biomass is an activity that requires timely settlements, as electricity producers have to pay for the delivered raw materials. As of April 2021, the problem of non-payment has not been solved. The lion's share of investment in renewable electricity generation projects comes from leading international organizations. The latter, due to the debts, mostly refuse to grant loans for new projects that aim specifically at producing electricity from renewable sources. In addition, the "feed-in" tariff expires in 2029, and auctions for electricity from renewables have not even taken place yet because no sources were found to pay for electricity from renewables. In addition, biomethane can be stored and consumed exactly when needed, while electricity storage devices have not yet become commercially available in Ukraine either.

Over time, the use of biomethane may also be feasible in the transport sector. Biomethane as fuel for transport belongs to the so-called "advanced biofuels" [3], in other words, it does not compete with food products and does not deepen the problem of food security. Ukraine is a Contracting Party in the Energy Community, so our country will have a new requirement for the share of renewables in the transport sector (expected to be 9% in 2030), and first-generation biofuels based on plant raw materials cannot exceed 2%. It is noticeable that a small amount of motor biofuels produced, imported and consumed in Ukraine are first-generation biofuels, which do not meet the requirements for GHG reduction, and therefore such biofuels are not counted for Ukraine as part of the renewable sources energy used in the transport sector and hence are considered non-compliant biofuels [28] (Fig. 3).

But so called renewable electricity in railways, road transport (electric vehicles) and other forms of transport is included in the above category. Research [28] indicates that Ukraine could achieve even 13.8% of energy from RES in the transport sector in 2030, with the following contribution of the energy carriers:

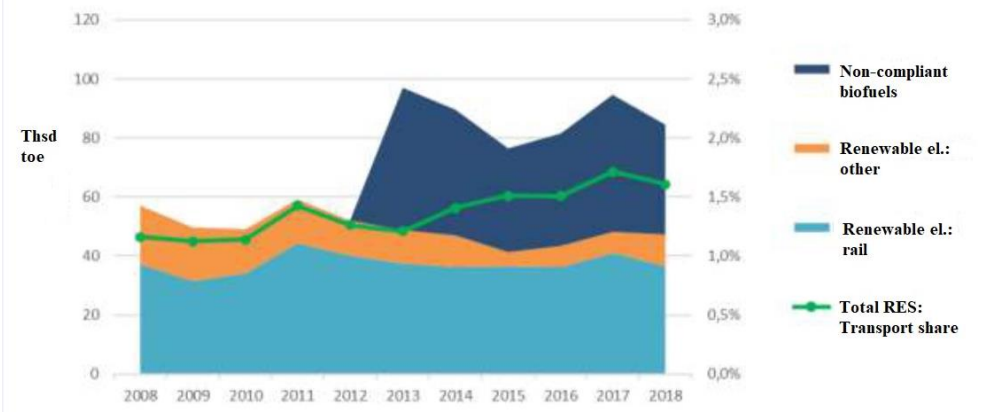

Figure 3. Consumption of energy from renewable sources in Ukraine's transport sector before 2019

Source: [28].

- crop-based biofuels – 2%;
- liquid fuels from raw materials specified in Annex IX B of Directive (EC) 2018/2001 in road transport - 3.4%;
- liquid advanced biofuels (based on raw materials from Annex IX A of Directive (EC) 2018/2001) in road transport;
- non-biomass liquid hydrogen in road transport - 0.03% (e.g. hydrogen from solar or wind energy);
- **biomethane in road transport - 1.2%;**
- electricity on railways - 3.45%;
- electric public transport (bus, trolleybus, tram, metro) - 1.12%;
- electric vehicles (passenger and freight ones) - 0.19%;
- hydrogen railways - 0.01%;
- hydrogen buses - 0.006%;
- hydrogen-powered cars and trucks - 0.05% [28].

The use of biomethane in road transport is supported by the already existing relatively extensive network of methane filling stations: as of 2021, there were more than 600 of such stations. In addition, biomethane can be produced domestically, whereas liquefied petroleum gas (LPG) is imported to Ukraine.

Ukraine imports from the Republic of Belarus about 40% of all oil-based fuel consumed in the country. The suspension of liquid fuel supplies from the Republic of Belarus for political or economic reasons negatively affects the economic security of Ukraine.

In order to be able to produce biomethane on an industrial scale, a special financial program needs to be developed to help reduce the cost of biomethane production. The use of relatively new financial instruments, such as green certificates or investment funds, is advisable. Almost all areas of the use of biomethane need to be stimulated: both the use of bio-methane in transport and its feeding into the gas transport system, and the production of electricity from biomethane [29]. To increase the production and use of biomethane and to synchronize the trade of biogas in Europe in the framework of Horizon 2020 project, the all-European project REGATRACE: Renewable Gas Trade Centre in Europe (06.2019-05.2022) is under way, where the Bioenergy Association of Ukraine also participates [30]. In addition to incentives, the role of enforcement measures is expected to grow, including the introduction of biomethane blending requirements for gas distribution networks. Due to this, the demand for biomethane is expected to increase more than fourfold (from 2 EJ in 2020 to 8.5 EJ in 2050), and the amount of blended biomethane will exceed 80% in many regions of the world. Half of the biomethane is used in industry and 25% in the transport and buildings sectors [31].

Additional factors that will make biomethane more economically attractive in Ukraine are the expected increase in the CO_2 tax in 2022 that will make natural gas more expensive, the potential decline in the role of natural gas for economic sectors and households and achieving economies of scale in biomethane production, as the role of natural gas is reduced in the EU due to the introduction of the Green Deal [32][2]. Ukraine intends to become part of the European Green Deal, so a drop in demand for natural gas is hypothetically possible also for Ukraine in the long term.

In summary, biomethane has certain prospects for use as an alternative to natural gas in the gas distribution and transmission networks and as an advanced fuel for transport in Ukraine. At current production costs, if biomethane is used in the gas grid at the April 2021 natural gas price level, then in 2025-2040, a compensation in the amount of EUR 263 million to EUR 3.47 billion on, or on average EUR 16.5 million to 247 million per year (depending on the price of natural gas as well as on the cost of biomethane production) will be needed. It is difficult to predict at this time the rate at which the cost of natural gas will rise and the rate at which the cost of biomethane production will fall. However, it is clear that government support, in

[2] Executive Vice-President Timmermans' Speech for the Eurogas Annual Meeting 2021. 25.03.2021. URL: https://ec.europa.eu/commission/commissioners/2019-2024/timmermans/announcements/executive-vice-president-timmermans-speech-eurogas-annual-meeting-2021_en

the form of direct subsidies to biomethane producers (in the form of a premium on the price of natural gas), will be necessary to commercialize this technology. State support in the form of a premium on the auction price (similar to the EU experience) is also possible, but requires not only a revision of the maximum auction price, but also the identification of payment sources for the electricity supplied from RES, which are presently missing.

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ПЕРСПЕКТИВИ ДЕРЖАВНОЇ ПІДТРИМКИ РОЗВИТКУ ГАЛУЗІ БІОМЕТАНУ В УКРАЇНІ ДО 2040 РОКУ

У статті розглянуто перспективи державної підтримки розвитку галузі біометану в Україні з 2025 р. по 2040 р. Основними фінансовими стимулами для використання енергії з біомаси є спеціальний тариф на тепло не з природного газу, а також "зелений" тариф (у майбутньому аукціонна ціна). В країнах ЄС виробництво біометану набуває розповсюдження завдяки наявним

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фінансовим стимулам (надбавки до ціни на природний газ, а також надбавка до "зеленого" тарифу). Основною перешкодою для широкомасштабного виробництва біогазу (і, відповідно, біометану) є висока вартість обладнання. Було розраховано обсяги державної підтримки для виробництва біогазу з доочищенням його до біометану та подачі останнього до газотранспортної та газорозподільчої мереж за умови виробництва біометану в обсягах, передбачених проєктом Дорожньої карти розвитку біоенергетики в Україні до 2050 року. За збереження вартості газу на рівні цін 2021 р. (0,24 євро/куб. м), необхідність у субсидуванні виробництва біометану з 2025 по 2040 рр. сумарно може становити від 0,263 до 3,5 млрд євро, або в середньому від 16,5 до 217 млн євро на рік. У розрахунку не бралися до уваги видатки на формування інфраструктури. Можливість виробництва електроенергії з біометану не розглядалась, оскільки доочищення біогазу до якості біометану потребує додаткових коштів, а законодавчо передбачена аукціонна ціна може бути достатньою лише для певних видів сировини та для великих біогазових установок. Використання біометану може бути доцільним у транспортному секторі, адже біометан є вдосконаленим біопаливом (advanced biofuel), і в Україні вже наявна порівняно розгалужена мережа метанових заправних станцій. Для виробництва біометану в Україні буде необхідна державна підтримка, зокрема у формі прямих субсидій виробникам біометану (у вигляді надбавки до ціни на природний газ), а також у вигляді надбавки до аукціонної ціни. Використання біометану дозволить частково зменшити залежність від імпортованого викопного палива, а також виступає важливим елементом декарбонізації секторів, де використовується природний газ, дозволивши його заміщення у 2040 р. у обсягах до 0,76 млрд куб. м, що відповідає провідним світовим тенденціям з декарбонізації економік.

Ключові слова: *біометан, біогаз, біоенергетика, Україна*