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Aspects of the introduction of alternative gas fuels and their influence on the quality of natural gas

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Abstract

The paper announces that the Ministry of Energy and Environmental Protection of Ukraine has developed the "Ukrainian Green Deal", the ambitious goal of which is the transition to a climate-neutral economy, reducing greenhouse gas emissions and decarbonizing the economy by 2070. The "European Green Deal" provides for the achievement of similar goals by 2050. It is mentioned that the share of biomethane and "green" methane in the overall system of transmission and consumption of natural gas is planned to increase. The process of biomethane production by biogas enrichment and carbon dioxide separation is described. The perspective course of pure hydrogen production by water electrolysis due to the use of excess "green" energy from solar and wind power plants is noted. The way of complex integration of biomethane and "green" hydrogen production is suggested. The process of "methanation", i.e. the conversion of "green" hydrogen and carbon dioxide as a waste product in the production of biomethane is described. The readiness of the NAAU to accredit verification bodies of greenhouse gas emission due to the introduction of the greenhouse gas emission allowance trading in Ukraine was stated. The calculation of the combustion heat values, density and Wobbe number for natural gas when mixed with pure hydrogen has been simulated. It is pointed that when the heat of combustion decreases and exceeds the permissible limits, the Wobbe number does not exceed the minimum set value, which indicates the absence of the need to replace gas-consuming equipment. It is argued that if it is necessary to increase the combustion heat of a mixture of natural gas with hydrogen, it is necessary to enrich it with "heavy" hydrocarbon gases.

Keywords: biomethane; "green" methane; hydrogen; heat of combustion; density; Wobbe number.

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Introduction

Supporting the initiative of the European Commission, which announced the "European Green Deal" as a roadmap for measures, which will transform the EU into an efficient, sustainable and competitive economy and determine the means of transforming Europe into the world's first climate-neutral continent by 2050, the Ministry of Energy and Environment of Ukraine developed the Concept project of transition to "green" energy, which was called "Ukrainian Green Deal" [1]. The Ukrainian Concept envisages achieving the main goal, which is reducing greenhouse gas emissions, in order to ensure the transition to a climate-neutral economy of Ukraine by 2070. One of the important points is to gradual decarbonize energy in terms of reducing natural gas production by replacing it with energy from renewable sources, including solar and wind energy. In particular, it is expected that the share of synthetic "green methane" and biomethane in pipeline systems of gas transmission to consumers will increase. Furthermore, an important element of the strategy is the development of a hydrogen energy project preparing for the H2Ready programme, i.e. an integrated approach to the possibility of transmitting a mixture of natural gas with hydrogen in pipeline transmission systems, where the content of the latter is up to 20%.

The purpose of the paper is to generalize and analyse the courses of transition to green energy and conduct theoretical research on the possibility of using biomethane, "green methane" and hydrogen in terms of their influence on the quality of "natural gas", the requirements for which are set in regulations.

Ukraine has the potential to increase biomethane production capacity, which in the future may account for a significant share of total gas consumption in Ukraine and play an important role in balancing gas consumption and the energy system as a whole. Moreover, [2] states that by 2050 the consumption of biomethane in Europe may be from 30% to 40% of the total gas consumption by consumers. Biomethane is a prepared and enriched biogas, from the component composition of which carbon dioxide and other gases are extracted, i.e. it is enriched and the methane content is 95–97%. The recently adopted amendments to the Law of Ukraine "On Alternative Fuels" [3] state that "biomethane is a biogas, which in its physical and chemical characteristics meets the requirements

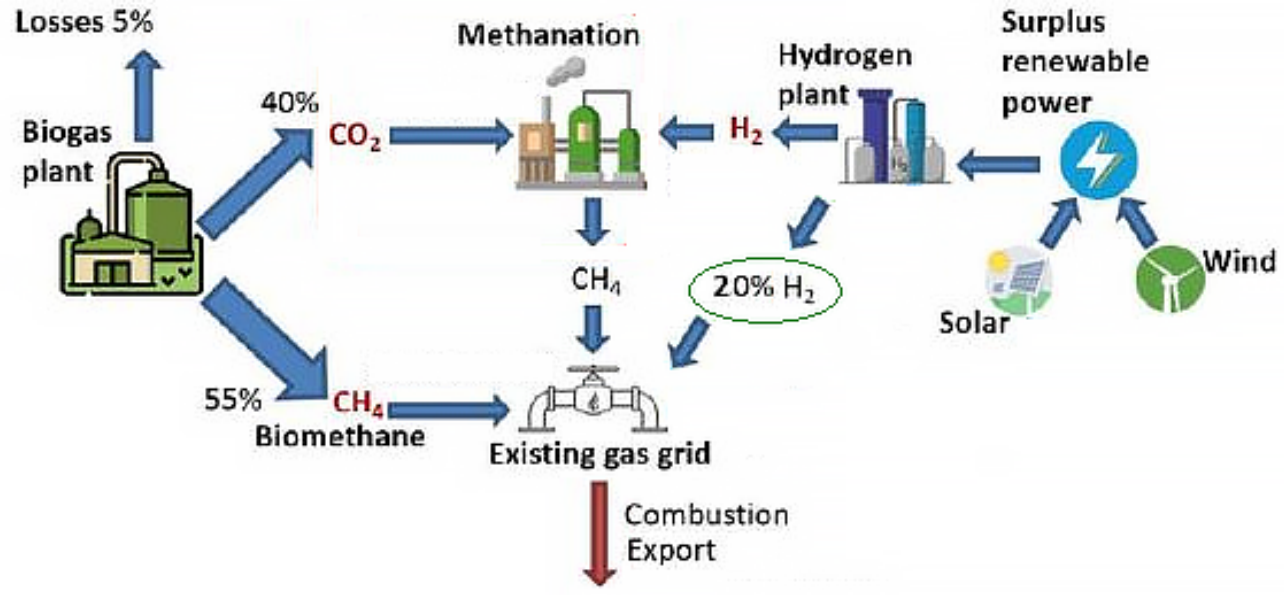

Fig. 1. Stages of the integrated production of biomethane, "green methane" and "green hydrogen"

of regulations on natural gas for supply to the gas transmission or distribution system or for use as motor fuel". That is, the main advantage of biomethane is the ability to pump it into the pipeline without additional costs to change the gas infrastructure. Besides, its physical and chemical parameters will be identical to those of natural gas. Formally, biomethane producers will be subject to similar requirements as mining companies in terms of installation of automated gas metering and control systems and assessment of compliance of these systems with the requirements of the Technical Regulation and the organization of commercial gas metering accordingly. Biomethane will be supplied from biogas production of agricultural and farmland in Ukraine.

LLC "Regional Gas Company" (RGC) announced that it would connect a biomethane plant to the gas distribution networks as early as mid-2022 after the end of the heating season. The company has introduced a "one-stop shop", which allows manufacturers to enter into a direct contract for connection to gas distribution networks on the terms of supply of the necessary equipment from global manufacturers with which RGC cooperates.

It should be noted that biomethane is classified as a climate-neutral gas, because the cycle of its formation involves the amount of carbon dioxide absorbed by plants during their growth, which is identical to the total emissions from burning biomethane to the final consumer without changing the overall balance of harmful emissions. Thus, biomethane production should become one of the key elements of the strategy of transition to a climate-neutral economy of Ukraine.

The next element of the strategy is the production and transmission of pure hydrogen. In the course of implementing this element, Ukraine has been identified as one of the priority partners in the supply of hydrogen to Europe. Ukraine has successfully launched the Hydrogen Project, which provides for two stages. The first stage is the production of pure hydrogen ("green" hydrogen in the electrolysis of water with renewable energy, "black" hydrogen in the combustion of coal, "yellow" hydrogen in the electrolysis of water from nuclear power plants, "blue" hydrogen from natural gas). The second stage is the transmission of hydrogen through pipelines. In addition, the issue of this transmission studied in two directions: the supply of pure hydrogen to the pipeline and mixing hydrogen with natural gas in the ratio of 20% / 80%. The most promising is the production of "green" hydrogen, which is *a priori* environmentally friendly and meets all the requirements of the green course strategy. A separate component of the implementation is manufacturing and testing of gas equipment, which must work and come into direct contact with hydrogen. Currently, the equipment that has successfully passed all stages of testing is identified as H2Ready.

However, in order to fully implement the green strategy in Ukraine, it is advisable to apply an integrated approach, which involves attracting surplus energy from renewable sources (wind farms, solar power plants and others) and biomethane plants for production synthetic "green methane" and "green hydrogen". Thus, it is possible to significantly increase the efficiency of both processes, in particular, the use of carbon dioxide, which is actually a "waste" product in the enrichment of biomethane [4]. Currently, such an integrated approach differs from the roadmap of the European Green Course and is the result of practical experience in Ukraine. Fig. 1 schematically shows an integrated approach to the production of biomethane, "green methane" and "green hydrogen".

Technologically, the process will be as follows: during the peak surplus of electricity from wind and solar power plants, it will be consumed for the process of water electrolysis to produce "green hydrogen" H_2. Moreover, the produced hydrogen will be used in three ways. Firstly, it will be transmitted for methane production. Secondly, the part of the hydrogen will be sent to the gas transmission system for mixing with natural gas in a limited proportion, not exceeding 80%/20%. Thirdly, pure hydrogen will be pumped into cylinders for storage and sale in various types of chemical processes and for replacement of technical hydrogen, which is currently produced from natural gas. What is more, "green hydrogen" will be added to natural gas in pipeline transmission systems to reduce carbon dioxide emissions from its combustion to the consumer, i.e. decarbonization will be promoted.

The raw materials of the biomethane plant are: biomethane (55%) and carbon dioxide (40%), the remaining 5% are technological losses of the initial volume of biogas. Biomethane, with the methane content of 95–97%, will also be supplied directly to gas distribution networks. Thus, the extracted carbon dioxide CO_2 can be effectively used in the "methanation" reaction, i.e. in the conversion of "green hydrogen" and in the production of synthetic "green methane" accordingly. The reaction of "methanation" has the following form [5]:

$$4H_2 + CO_2 \rightarrow {}^{p,\,T\,^\circ C} \rightarrow CH_4 + 2H_2O - 164\ \text{kJ/mol}. \quad (1)$$

In addition to hydrogen and carbon dioxide for the reaction to take place, catalysts are required, the most common of which is nickel. Furthermore, the reaction is exothermic and requires creating conditions of high overpressure and high temperature.

It should be noted that to achieve climate neutrality in the framework of decarbonization, the European Commission aims to introduce a carbon tax to be paid by producers and exporters who will use fossil energy sources. That is, manufacturers will have to prove that their products are made using green energy. In addition, it will protect consumers from carbon footprint products, i.e. the production has been moved to a country where greenhouse gas emission requirements are not regulated.

In Ukraine, the emission trading will be introduced in 2021 as one of the requirements of the Association Agreement with the EU, according to which the Directive 2003/87/EC on the establishment of a scheme for greenhouse gas emission allowance trading should be implemented [6]. This Directive introduces a system of selling a limited number of allowable permits ("caps") for greenhouse gas emissions in order to stimulate the reduction of greenhouse gas emissions from large stationary sources in a cost-effective and low-cost way. That is, for some sectors of the economy the requirements will be set to reduce CO_2 emissions. To carry out appropriate supervision at the legislative level, the National Accreditation Agency of Ukraine (NAAU) accredits bodies for verification of greenhouse gas emissions in accordance with the DSTU ISO 14065:2015 [7] under the Law of Ukraine "On Principles of Monitoring, Reporting and Verification of Greenhouse Gas Emissions" [8].

The next stage will be a study on the possibility of using a mixture of natural gas with hydrogen and the compliance of its physical and chemical parameters with the requirements of current regulations in Ukraine. According to the GTS Code [9], higher and lower heat of combustion are standardized for natural gas, in particular the range of values

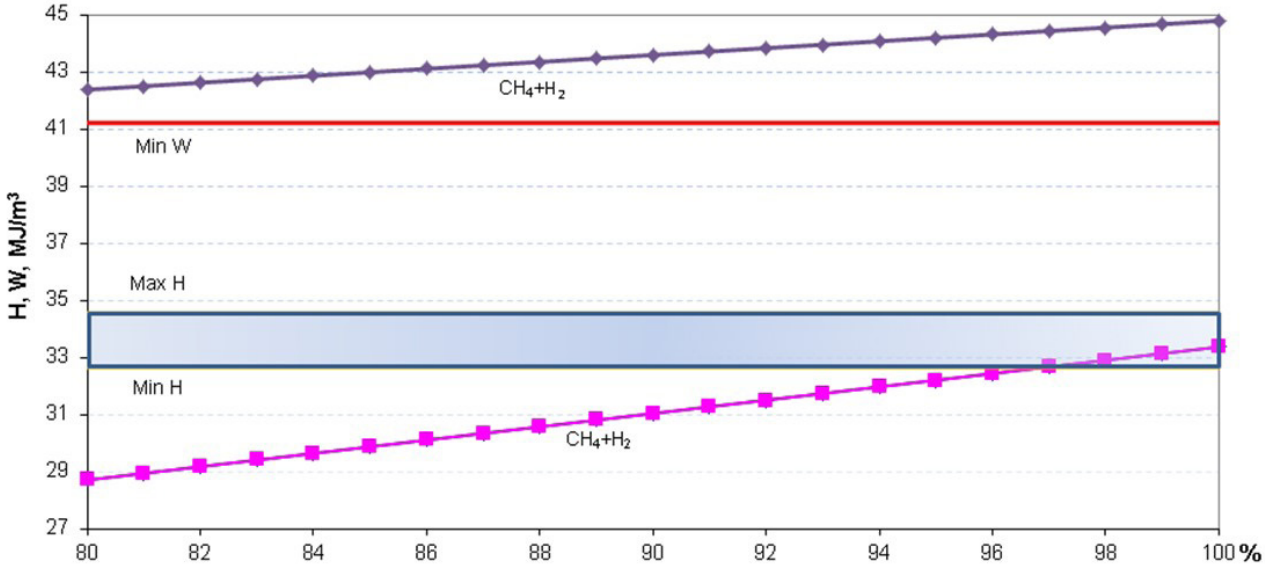

Fig. 2. The results of simulating the influence of the hydrogen on natural gas: Max H, Min H are the maximum and minimum normalized value of the combustion heat for natural gas; Min W is the minimum normalized value of the Wobbe number for natural gas

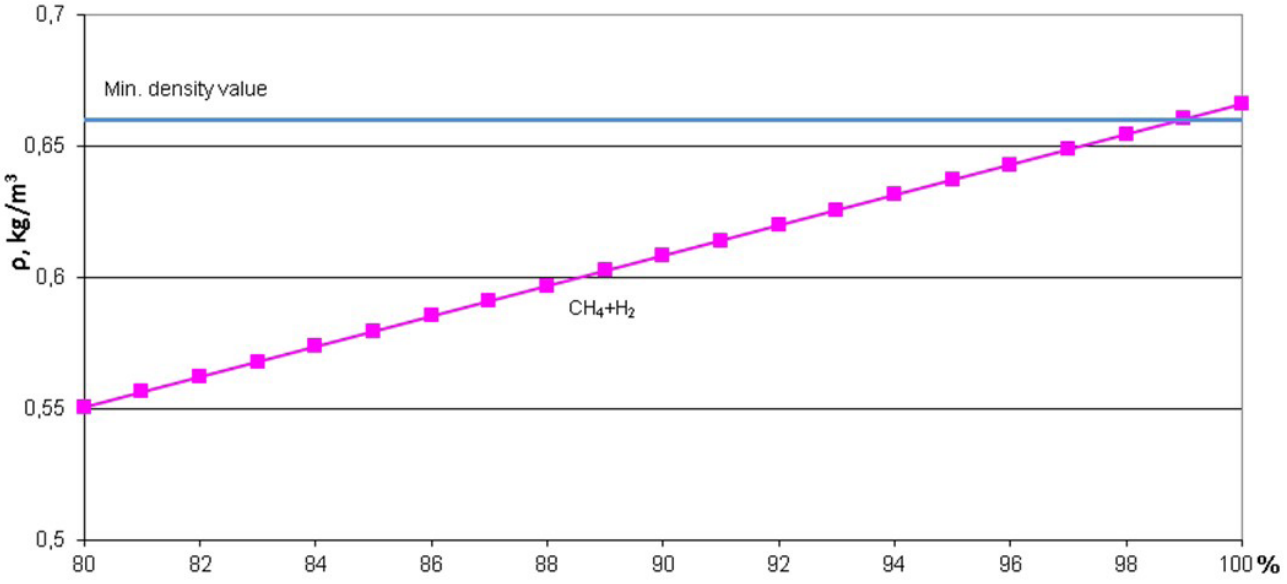

Fig. 3. The results of simulating the effect of hydrogen on the natural gas density

of lower combustion heat is from 32.66 MJ/m^3 to 34.54 MJ/m^3. The range of natural gas density values is not standardized, however when calculating the compressibility coefficient according to [10], it is indicated that the scope of calculation methods is limited from 0.66 kg/m^3 to 1.05 kg/m^3. In addition, the Wobbe number, which is a complex indicator because it is determined taking into account the analytical dependence connecting two separate indicators: the heat for gas combustion and its relative density [11], and its range is from 41.2 MJ/m^3 up to 54.5 MJ/m^3. The Wobbe number is in its physical nature a criterion for the similarity of gases and determines their possibility of interchangeability and characterizes the constancy and stability of thermal energy coming from the gas as a result of its combustion, regardless of component composition. That is, gases with the same Wobbe number under equivalent overpressure and combustion conditions can usually be replaced without additional replacement or adjustment of burners or gas injectors of gas-consuming equipment.

It is currently suggested to add hydrogen to natural gas with a maximum content of up to 20%. It should be noted that the normative document [12] concerning the testing of gas-burning appliances sets the reference gas type G 222 "saturated gas for flame leakage", the component composition of which provides CH_4= 77%, H_2 = 23%.

Based on the above data and limit ranges, simulations of combustion heat values and the Wobbe number values for gas with the methane content from 100% to 80% and the hydrogen content from 0% to 20%, respectively, were simulated. Fig. 2 shows the simulation results.

According to the results of the analysis of Fig. 2, the value of the combustion heat with the addition of the hydrogen decreases and releases when the hydrogen content is more than 3% beyond permissible limits. The situation is similar with the value of density, which according to the simulation results is from 0.55 kg/m^3 to 0.66 kg/m^3 and immediately exceeds the limits normalized for the calculation of the compressibility coefficient (Fig. 3). However, the calculated values of the Wobbe number do not fall below the minimum set value, which indicates that the gas with such a component composition will be burned in conventional gas-consuming appliances without additional replacement of injectors.

However, [9] normalizes the maximum content of other components of natural gas, particularly ethane, propane, butane, etc. Thereafter, to ensure the value of combustion heat at the level of the minimum permissible value of 32.66 MJ/m^3, it is necessary to add "heavy" gases with a higher value of combustion heat to the composition of natural gas. According to the simulation results, it is calculated that the following component composition of the gas will meet the above requirements for combustion heat and gas density: CH_4 = 74%; H_2 = 20%; C_3H_8 = 3%; C_4H_{10} = 2%; C_5H_{12} = 1%, the combustion heat is 32.82 MJ/m^3. Moreover, the Wobbe number is also within permissible limits and is 44.8 MJ/m^3. That is, with the addition of the hydrogen to the maximum amount of 20%, it is possible to achieve the regulated values of combustion heat, density and the Wobbe number by enriching the gas by adding "heavy" hydrocarbon gases.

Conclusion

The Ukrainian economy has set itself an ambitious goal to ensure climate neutrality by 2070, i.e. to transit to green energy. Particularly, in terms of reducing the number of fossil energy sources, it is planned to increase the amount of energy from renewable sources, including a promising area, which is a comprehensive

solution for the production of biomethane, "green methane" and "green" hydrogen. In addition, the implementation of the hydrogen project involves the production and transmission of pure hydrogen and the addition of the hydrogen to natural gas not exceeding 20% of the content. The simulation is carried out in terms of changing the quality of gas depending on the increase in the hydrogen content. It is pointed out that the value of combustion heat and density decreases below the normalized minimum value, while the Wobbe number does not fall below the minimum permissible value. It is calculated that to improve the quality of gas, it is necessary to enrich it by adding "heavy" hydrocarbon gases.

Аспекти запровадження альтернативних газових палив та їхній вплив на якісні показники природного газу

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Анотація

У статті анонсовано, що Міністерство енергетики та захисту довкілля України розробило "Український зелений курс", амбітною ціллю якого є перехід до кліматично нейтральної економіки, зменшення викидів парникових газів, декарбонізація економіки до 2070 року. Слід відзначити, що "Європейський зелений курс" передбачає досягнення аналогічних цілей до 2050 року. Відзначено, що планується збільшення частки біометану, "зеленого" метану в загальній системі транспортування та споживання природного газу. Описано процес виробництва біометану шляхом збагачення біогазу та відділення діоксиду вуглецю. Показані переваги біометану та відзначено про готовність РГК до приєднання виробників біометану в газорозподільчі мережі та подачі його споживачам. Відзначено перспективний напрямок виробництва чистого водню шляхом електролізу води за рахунок використання надлишку "зеленої" енергії від сонячних та вітрових електростанцій. Запропоновано шлях комплексного об'єднання виробництва біометану та "зеленого" водню. Відзначено про підвищення ефективності обох процесів. Описано процес "метанації", тобто конверсії "зеленого" водню та діоксиду вуглецю, як відхідного продукту при виробництві біометану. Відзначено готовність НААУ до акредитації органів із верифікації викидів парникових газів у зв'язку із запровадженням ринку квот на парникові гази в Україні. Проведено моделювання розрахунку значень теплоти згоряння, густини та числа Воббе для природного газу при змішуванні його з чистим воднем. Показано, що при зменшенні теплоти згоряння та виходу за допустимі межі число Воббе не виходить за мінімально встановлене значення, що свідчить про відсутність необхідності заміни газоспоживчого обладнання. Аргументовано, що при необхідності збільшення теплоти згоряння суміші природного газу з воднем необхідно збагачувати її "важкими" вуглеводневими газами.

Ключові слова: біометан; "зелений" метан; водень; теплота згоряння; густина; число Воббе.

Аспекты внедрения альтернативных газовых топлив и их влияние на качественные показатели природного газа

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Аннотация

В статье анонсировано, что Министерство энергетики Украины разработало “Украинский зеленый курс”, целью которого является переход к климатически нейтральной экономике. Отмечено, что планируется увеличение части биометана, “зеленого” метана в системе транспортировки природного газа. Описан процесс производства биометана путем обогащения биогаза. Отмечено перспективное направление производства водорода за счет использования избытка зеленой энергии. Предложен путь комплексного объединения производства биометана и водорода. Отмечена готовность НААУ к аккредитации органов по верификации выбросов парниковых газов. Проведено моделирование расчета значений теплоты сгорания, плотности и числа Воббе природного газа при смешивании его с водородом. Показано, что при уменьшении теплоты сгорания и выходе за допустимые пределы число Воббе не выходит за минимально установленное значение, что свидетельствует об отсутствии необходимости замены газопотребляющего оборудования. Аргументировано, что при необходимости увеличения теплоты сгорания смеси природного газа с водородом необходимо обогащать ее “тяжелыми” углеводородными газами.

Ключевые слова: биометан; “зеленый” метан; водород; теплота сгорания; плотность; число Воббе.

References

1. Ukraine 2050 Green Energy Transition Concept – Ukraine Green Deal. Available at: https://mepr.gov.ua/files/images/news_2020/14022020/eng_pdf_%D0%B7%D0%B5%D0%BB%D0%B5%D0%BD%D0%B0%20%D0%BA%D0%BE%D0%BD%D1%86%D0%B5%D0%BF%D1%86%D1%96%D1%8F%20(1).pdf
2. EBA Statistical Report 2020. Available at: https://www.europeanbiogas.eu/eba-statistical-report-2020/
3. Law of Ukraine “On Alternative Fuels”. *Vidomosti Verkhovnoi Rady Ukrainy* (*VVR*), 2000, no. 12, p. 94 (in Ukrainian).
4. Geletyha G.G., Zhelezna T.A., Matveev Yu.B., Kucheruk P.P., Kramar V.G. Roadmap for the development of bioenergy in Ukraine until 2050. *Analytical Note*, 2020, no. 26. 54 p. (in Ukrainian). Available at: https://uabio.org/wp-content/uploads/2020/11/PP-UABIO-26_UA_26-11-2020.pdf
5. Rönsch S., Schneider J., Matthischke S., Schlüter M., Götz M., Lefebvre J., Prabhakaran P., Bajohr S. Review on methanation – From fundamentals to current projects. *Fuel*, 2016, vol. 166, pp. 276–296.
6. Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. *Official Journal of the European Union*, 2003, L 275, pp. 32–41.
7. DSTU ISO 14065:2015. Greenhouse gases. Requirements for bodies for validation and verification of GHG claims for use in the case of accreditation or other forms of recognition (ISO 14065:2013, IDT). Kyiv, 2015 (in Ukrainian).
8. Law of Ukraine “On Principles of Monitoring, Reporting and Verification of Greenhouse Gas Emissions”. *Vidomosti Verkhovnoi Rady Ukrainy* (*VVR*), 2020, no. 22, p. 150 (in Ukrainian).
9. Code of the gas transmission system, approved by the Resolution of the National Commission for State Regulation of Energy and Utilities No. 2493 of 30.09.2015 (in Ukrainian).
10. GOST 30319.2-96. Natural gas. Methods for calculating physical properties. Determination of the compressibility factor. Minsk, 1996 (in Russian).
11. GOST 5542-2014. Natural combustible gases for industrial and municipal purposes. Technical conditions (in Russian).
12. DSTU EN 437:2018. Test gases. Test pressure. Categories of devices (EN 437:2018, IDT).