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LESHCHENKO, I. Ch. (<https://orcid.org/0000-0003-3382-4762>)

Institute of General Energy, the NAS of Ukraine,
172, Antonovycha St., Kyiv, 03150, Ukraine,
+380 44 294 6701, info@ienergy.kiev.ua

ESTIMATES OF METHANE EMISSIONS IN THE OIL-AND-GAS INDUSTRY OF UKRAINE: PROBLEMS AND WORLD EXPERIENCE IN THEIR SOLUTION

Introduction. *Given the possible impact of economy decarbonisation policy decisions on the future of the oil-and-gas industry, it is necessary to develop a strategy for its further development, taking into account both carbon dioxide and methane emissions.*

Problem Statement. *In recent years, many countries have been making efforts for reducing methane emissions in the oil-and-gas industry, several national and international initiatives have been formed. In Ukraine, not enough attention is paid to this matter.*

Purpose. *The purpose is to analyze the state of monitoring of methane emissions from the oil-and-gas industry of Ukraine and to generalize experience of other countries in this field.*

Materials and Methods. *Analysis of official estimates of methane emissions from the oil-and-gas industry of Ukraine. Review of authoritative literature sources and documents of international organizations on the estimate of methane emissions from the industry, technological and institutional measures for monitoring and verification of these emissions.*

Results. *Comparative analysis of estimates of greenhouse gas emissions in the oil-and-gas industry based on the National GHG Inventory annual reports of the Naftogaz of Ukraine Group has been made. The peculiarities of methane emission sources in the industry and the problems of quantification of its emissions have been considered. Technological means and measures implemented in different countries to solve the problems of methane emissions monitoring have been analyzed.*

Conclusions. *It has been concluded that there is a wide range of available technologies for detection and quantification of methane emissions in the industry. The need to use national coefficients for estimating fugitive emissions from oil-and-gas industry for the National GHG Inventory has been shown. An important factor in reducing methane emissions from the industry shall be government policy that aims at developing and implementing regulatory standards and special economic tools.*

Keywords: *greenhouse gases, oil-and-gas industry, identification of methane emission sources, methane emission estimation, and technology.*

Much of the world's attention has been paid to climate change that is associated with greenhouse gas (GHG) emissions. Ukraine has been an official party to Annex I of the United Nations Framework Convention on Climate Change (UNFCCC), since 1997; a party to

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Annex B to the Kyoto Protocol, since 2004; and a party to the Paris Agreement that amends the Kyoto Protocol and defines its commitment to reduce GHG emissions, since 2016. As part of the climate process, the Cabinet of Ministers of Ukraine by its order of 16.09.2015 no. 980 approved the expected national contribution to the draft of the new global climate agreement, which is not to exceed 60% greenhouse gas emissions of 1990 in 2030 [1]. In 2018, GHG emissions (excluding the sector *Land use, rezoning, and forestry*) accounted for only 31.6% of 1990 [2]. At the same time, according to the Paris Agreement, every five years, the member countries shall report on their contributions to the UNFCCC Secretariat and set new, more ambitious goals. The first such report is to be submitted in 2023.

Another important argument in favor of strengthening GHG emission reduction in the oil-and-gas industry is a significant transformation of approaches to energy development in the world, the so-called green energy transition that is accompanied by a reduction in the share of extractive industries in economy. According to [3], political decisions regarding decarbonization, which are made in the next 5–10 years, will irreversibly affect the future of not only oil but also natural gas. To ensure that natural gas is included in Europe's energy balance after 2030 and remains competitive with other low- or zero-carbon energy sources, gas companies need to develop appropriate strategies for further development over the next five years. If the situation in the gas sector remains unchanged, it will be the beginning of its decline in the future after 2030, as options for the formation of non-methane energy may be adopted.

Today, the only widely available document that contains official information on GHG emissions in our country is the National Inventory of Anthropogenic Emissions from Sources and Absorption of Greenhouse Gases in Ukraine (hereinafter referred to as the National Inventory). According to the National Inventory for 1990–2018 [2], in 2018, methane (CH_4) emissions in Ukraine amounted to 67.54 million tons of CO_2 -eq, which was

about 20% of total GHG emissions. The largest sources of methane emissions are power engineering (65.1% of total emissions), agriculture (13.9%), and waste management (16.4%). In the Energy sector, according to the Intergovernmental Panel on Climate Change (IPCC), the largest fugitive emissions are from coal, oil and natural gas. Thus, in the oil-and-gas industry of Ukraine, it is necessary to pay attention to reducing emissions of both carbon dioxide (CO_2) and methane.

In recent years, much attention has been paid to reducing methane leaks and emissions in the oil-and-gas industry, and several national and international initiatives have been launched to this end. First and foremost, the United States Environmental Protection Agency's Natural Gas STAR Program that encourages oil-and-gas corporations to use proven, cost-effective technologies and practices that improve performance and reduce methane emissions [4]. Reducing methane emissions from the oil-and-gas sector has attracted focused attention of the UN [5–7], the International Energy Agency [8], the European Commission [9], and many non-governmental organizations. At the same time, there have been almost no publications on this important subject in Ukraine, and when it comes to reducing GHG emissions, first of all, we mean carbon dioxide. Even in such an important document as the Strategy for Low Carbon Development of Ukraine until 2050, measures for reducing greenhouse gas emissions other than carbon dioxide are presented very formally [10].

Table 1 shows the amount of carbon dioxide and methane emissions in 2017–2018 from the oil-and-gas industry (excluding oil refining) along the entire technological chain from exploration to consumption.

From Table 1 shows that the main GHGs generated in the industry are carbon dioxide and methane, as their shares made up 2.6% and 43.8% of the total emissions of these GHGs across the country, in 2017, and 2.4% and 45%, in 2018, respectively. The main part of carbon dioxide emissions is generated from hydrocarbon extraction and fuel combustion operations by gas-compress-

sor units of main gas pipelines. The main sources of methane emissions are natural gas production, distribution, and consumption in the residential and commercial sectors. This structure of methane emissions suggests, in particular, that in contrast to the country's gas transportation system, the conditions of gas distribution networks require much attention.

In Ukraine, information on GHG emissions from oil-and-gas facilities in addition to the National Inventory is provided in the annual reports of *Naftogaz of Ukraine* Group (Table 2).

The data given in Table 2 differ significantly from the data of the National Inventory, especially with regard to methane emissions. Thus, in 2017, according to the inventory, methane emissions from hydrocarbon production amounted to 356.5 thousand tons, and according to *Naftogaz*, the total methane emissions of JSC *Ukrnafta* and JSC *Ukrgezvydobuvannya* came to only 14.4 thousand

tons. According to the National Inventory, methane emissions from these operations amounted to 371.98 thousand tons, while according to *Naftogaz*, they totaled 24.9 thousand tons. In 2017, JSC *Ukrnafta* and JSC *Ukrgezvydobuvannya* extracted 16.4 billion m³, and in 2018, 16.6 billion m³, which accounted for about 80% of gas production in Ukraine. Since in accordance with the Law of Ukraine on *Environmental Impact Assessment* [12], at each stage and project of the technological chain of the development of hydrocarbon resources, both public and private corporations shall develop Environmental Impact Assessment given the norms defined in the laws of Ukraine, industry regulations, and standards of enterprises, the emissions from extraction by private corporations may be taken similar to methane emissions by *Naftogaz of Ukraine* Group corporations. Hence, according to *Naftogaz* estimates, the total annual methane emissions from hydrocarbon pro-

Table 1. GHG Emissions in the Oil-and-Gas Industry of Ukraine in 2017–2018

Operation	GHG, thousand tons			
	2017		2018	
	CO ₂	CH ₄	CO ₂	CH ₄
Exploration and production of oil and condensate	150.72	56.13	162.50	60.53
Flaring in oil operations	88.55	0.05	95.47	0.06
Venting in oil operations	0.21	1.56	0.22	1.68
Exploration and production of natural gas	1751.69	281.53	1815.89	291.84
Flaring in natural gas operations	77.25	0.05	80.08	0.05
Processing of natural gas	5.44	17.19	5.64	17.82
<i>Total extraction of hydrocarbons</i>	<i>2073.86</i>	<i>356.51</i>	<i>2159.80</i>	<i>371.98</i>
Pipeline transportation of oil	0.01	0.10	0.01	0.10
Pipeline transportation and storage of natural gas, including:	3730.46	26.61	3473.99	26.05
fugitive emissions	0.31	26.54	0.30	25.99
combustion of fuel by gas-compressor units	3730.15	0.07	3473.69	0.06
Natural gas distribution	5.72	496.74	6.50	568.11
Natural gas consumption by the residential and commercial sectors	0.91	236.58	0.94	249.94
<i>Total transportation, distribution, and consumption of hydrocarbons</i>	<i>3737.10</i>	<i>760.03</i>	<i>3481.44</i>	<i>844.20</i>
<i>Total oil-and-gas industry</i>	<i>5811</i>	<i>1117</i>	<i>5641</i>	<i>1216</i>
Total GHG emissions (without capture)	223200	2548	231700	2700
<i>The share of emissions from the oil-and-gas industry from total GHG emissions in the country</i>	<i>2.6</i>	<i>43.8</i>	<i>2.4</i>	<i>45.0</i>

Source: based on the data of Ukraine's Greenhouse Gas Inventory 1990–2018 [2].

duction may be estimated at 20 thousand tons, in 2017, and 32 thousand tons, in 2018, which is an order of magnitude higher than the data given in the National Inventory. At the same time, methane emissions from the transportation of natural gas through main gas pipelines differ much less.

The significant difference in estimates of methane emissions in the industry is explained by several factors. First, to date, both in Ukraine and in other countries, the problem of determining the sources and amount of methane emissions in the oil-and-gas industry has not been addressed. This is due to the following features that are clearly defined in [5, 6]:

- ◆ a large number of emission sources. For example, studies in Canada have shown that compressor stations have an average of 6 leakage points, while gas extraction plants comprise several ten thousand components, a few percent of which typically has leakages, assuming an average of 19 leakage points;
- ◆ geographical dispersion of emission sources. Equipment at fields, compressor stations, pipelines are located on a large area and in remote places, which increases the cost of measurements, often physical availability of emission sources for measurements is limited;
- ◆ variability of emissions. Emission indicators from equipment and processes vary significantly depending on the type and age of the equipment, its technical condition, operating condi-

tions and maintenance practices, climatic conditions. In addition, many emission points are intermittent sources. Therefore, the widespread use of emission factors from a limited number of sites or equipment may lead to significant uncertainties;

- ◆ Methane emissions are invisible and in most cases odorless, which makes it difficult to determine and to estimate emissions without the use of specialized equipment. This leads to additional costs of monitoring, reporting, and verification.

Second, according to the authors of the National Inventory, the Tier 1 simplest methodological approach and the average default emission factors according to the IPCC recommendations of 1996 and 2006 are used to estimate emissions in category 1.B.2 *Fugitive emissions* [13]. The Tier 2 approach recommended by the IPCC is similar to Tier 1, but instead of default emission factors, it uses national factors determined on the basis of research and analysis of the results of special measurements. The National Inventory of 2019 states that a “national method” based on the use of state statistical reporting, namely, the 4-MTP form, was developed to assess GHG leakage during the transportation of natural gas through main gas pipelines [2]. The 2-step approach was also used to estimate leakage during natural gas distribution with the use of gas distribution networks (GDN). It seems, the authors of the document mean the application of the Tier 2 approach, but readers do not understand this. In particular, in [5, 6] it is noted that for the National Inventory, in 2019, in Ukraine, only the Tier 1 approach was used to estimate emissions from hydrocarbons.

In addition, the application of the 2-step approach proposed by the authors of the National Inventory leads to the fact that the natural gas leak rates during transportation and distribution differ significantly for neighboring years, which has not been justified by the authors of the document and raises doubts about their correctness (Table 3).

Table 2. GHG Emissions by Corporations of Naftogaz of Ukraine Group in 2017–2018, thousand

Corporations of <i>Naftogaz of Ukraine Group</i>	2017		2018	
	CO ₂	CH ₄	CO ₂	CH ₄
Ukrgezvydobuvannia	862.7	10.0	1 715.2	20.3
Ukrnafta	1 022.8	4.4	631.1	4.6
Ukrtransgaz	3 818.5	30.4	3 707.9	30.2
Ukrtransnafta	1.7	0.1	2.9	0.1
Other corporations	1.5	0.6	1.9	0.6
Total emissions	5 707	45.5	6 059	55.7

Source: annual reports of *Naftogaz of Ukraine Group* for 2017 and 2018 [11].

It should be noted that both Tier 2 and Tier 3 approaches as well as Tier 1 approaches are used in the inventory of methane emissions from oil and natural gas operations in different countries. According to the National Inventory 2019 Reports [14], the USA and Canada applied the Tier 2 and Tier 3 approaches, and so did Australia for most categories of emission sources. While preparing National Inventories 2019, twelve EU member states used Tier 1 approaches, whereas the others applied coefficients from different tiers for different operations with hydrocarbons. Kazakhstan used Tier 1 for the preparation of the National Inventory for 2019; in 2019, the Russian Federation applied Tier 2 for natural gas production and transportation operations and Tier 1 for other operations with hydrocarbons. It should be noted that in 2016, in this country, upon the request of the Ministry of Power Engineering of the Russian Federation, a survey was conducted and national factors for carbon dioxide and methane emissions from certain categories of sources of the oil-and-gas industry were developed [15]. These coefficients were used to estimate methane and carbon dioxide emissions during the production and processing of natural gas, as well as during its transportation through main gas pipelines. Because of the use of national Tier 2 emission factors instead of the Tier 1 default factors, the estimate of methane emissions from the oil-and-gas sector, for example, in 2016 decreased from 24.9 million tons to 6.3 million tons.

So, Ukraine shall move to Tier 2, while preparing National Inventories.

Third, it cannot be said that the methane emission estimates given by *Naftogaz* in its annual reports are more accurate than the estimates of the National Inventory. Today, in Ukraine, even at the level of industry corporations, the quantitative estimates of methane leaks are rarely based on direct measurements, more often they are derived from the estimates or requirements of industry standards (so-called “certified” or “nominal” value of leaks).

Thus, until the system of monitoring, reporting, and verification of GHG emissions start operating

in Ukraine, it is impossible to talk about the development of national methane emission factors.

It should be noted that, in 2019, the process of improving the 2006 IPCC Guidelines was completed [7]. In the Energy sector, all methodological updates concern the categories of fugitive emissions, including those from the oil-and-gas industry. In particular, methods and coefficients for determining emissions from liquidated wells were added. The introduction of this source in the inventories may significantly increase estimates of methane emissions from the oil-and-gas industry, as in Ukraine, especially in the Carpathian Region, there are many liquidated and abandoned wells in many old oil fields. Another important amendment in the Guidelines is that there is no longer a difference between Tier 1 emission factors for advanced economies and developing countries.

With regard to the system of monitoring, reporting, and verification of GHG emissions, Verkhovna Rada of Ukraine adopted the Law of Ukraine on the *Principles for Monitoring, Reporting, and Verification of Greenhouse Gas Emissions* in compliance with international obligations under the Association Agreement with the European Union [16]. The law is expected to be introduced since 01.01.2021. However, this law is a framework, the methods and procedures for preparing a monitoring plan, as well as emission calculation methodologies will be determined by bylaws to be app-

Table 3. Natural Gas Leak Rates During Transportation and Distribution in Ukraine

Year	Natural gas leak rate during transportation, billion m ³ /million tons	Natural gas leak rate during distribution, billion m ³ / billion m ³
2012	0.00071	0.01151
2013	0.00101	0.00893
2014	0.00150	0.01042
2015	0.00057	0.01386
2016	0.00140	0.01623
2017	0.00039	0.01984
2018	0.00040	0.02386

Source: Ukraine's Greenhouse Gas Inventory 1990–2018 [2].

roved by the relevant resolutions of the Cabinet of Ministers of Ukraine. According to the draft resolution of the Cabinet of Ministers of Ukraine on Approval of the List of Operations Covered by Monitoring, Reporting, and Verification of Greenhouse Gas Emissions, and Specific Features of Its Application [17], at the first stage of implementation, this system will apply only to operations

Table 4. Methods for Detection and Quantification of Methane Leaks in the Oil-and-Gas Industry

Method	Principle of the method	Capital expenses, USD	Analysis of price factors
Leak detection methods			
Optical video recording system (infrared cameras)	Hydrocarbon emissions absorb infrared light with a certain wavelength, the camera uses this feature to detect the presence of hydrocarbon emissions in real time	85 000 – 115 000 for portable device	High cost and labor expenses
Laser Leak Detector	Uses an adjustable infrared LED tuned to a frequency that is absorbed by methane	15 000	Relatively cheap equipment, but high labor expenses
Soap bubble screening	Soap solution is applied to the place where there is a suspicion of leakage. In the case of leakage, bubbles are formed, which are observed visually	Less than 100	Relatively low costs, but high labor inputs
Organic vapor analyzers and toxic vapor analyzers	Portable hydrocarbon detectors are generally capable of measuring organic vapor concentrations in the range from 9 to 10,000 ppm	Less than 10 000	Limited use, complexity. May require expensive software
Acoustic Leak Detectors	Record the acoustic signal that is generated when a gas leaks under pressure. Most detectors have the ability to adjust the frequency, which allows adjusting the sensor to the leaks of specific objects	1 000–20 000, depending on sensitivity, size, and availability of additional equipment	Limited use and high complexity when using a hand-held device
Leak quantification methods			
Calibrated vent bag	Measures the time to complete the bag of the calibrated volume. The gas temperature is measured to adjust the volume to standard conditions. The gas composition shall be analyzed to determine the methane content	50	Low cost method, major costs are labor expenses (requires 2 operators)
High-volume sampler	Absorbs atmospheric air and hydrocarbon gas leaks. The thermal anemometer monitors the mass flow rate of the air-hydrocarbon mix. Two-element hydrocarbon detector measures the concentration of combustible hydrocarbons in the captured stream.	17 500, additional 1.200 (calibration kit)	Relatively expensive method given labor costs
Gas flowmeters	There are different technical versions of flowmeters: volumetric, thermal, rotary, ultrasonic, vortex, etc.	4 000–8 500, depending on the type and size of the meter	Cost-effective, especially for measuring large and long-term leaks
Vane anemometers	Consist of a paddle speed sensor and a hand-held unit that displays the measured speed of the gas passing through the device	1 400–5 500	Low cost and cheap maintenance
Hotwire anemometer	A heated wire inserted into the gas stream is used to measure its speed. The hotwire anemometer measures the electric current passing through the wire, as the heat is dissipated due to the gas flow, and the heat lost as a result of convection is proportional to the gas flow.	1 400–5 500	Low cost and cheap maintenance

Source: based on [4–6, 20].

that lead to emissions of carbon dioxide: fuel combustion in plants with a total rated thermal capacity of more than 20 MW, oil refining, metallurgy, production of coke, building materials, nitric acid, and ammonia. Monitoring and verification of methane emissions has not been implemented yet.

At the same time, given the structure of GHG emissions from the oil-and-gas industry, the main priority is to reduce methane emissions from natural gas, which is typical for the gas industries of other countries as well. Preventing and reducing methane emissions is first and foremost a safety requirement. In addition, the global warming potential of methane is 28 times higher than that of carbon dioxide, but it has a shorter life, averaging up to 12 years, as compared with CO₂, that is stored in the atmosphere for centuries. Thus, methane emissions have a much greater impact on the climate in the short term [18]. It is also possible, in many cases, to sell the captured methane in the natural gas market, thereby avoiding emissions and making a profit.

Today, in the world, there is a wide range of methods and measures for timely detection and quantification of methane leaks in the gas industry [4–6, 8, 9, 19, 20] (Table 4).

The analysis of the characteristics of methane emission sources and methods for their detection has shown that continuous monitoring of a large number of emission sources in the oil-and-gas industry is currently impossible. However, many new methods that will allow it in the near future, primarily, through remote sensing have been being developed.

Quantitative estimation of methane emissions requires a combination of operational measurements and calculation methods. Currently, there are two groups of the calculation methods: the bottom – up and the top – down ones [4–6, 8]. The former provides a quantitative estimate of emissions from individual sources directly at the emission site. These methods give the most accurate information on specific emission sources at the equipment level, but are costly and time con-

suming as compared with the computational or top – down approaches. The top – down estimation methods measure methane concentrations in the atmosphere with the use of, for example, satellites, aircraft, or drones. These methods use the values of the measured environment parameters and weather conditions and mathematical models to determine emissions from a specific facility or from a specific region. Scaling such data to a corporation or a regional level is cheaper and may be more accurate than the use of bottom – up approaches. Such estimation methods can provide more frequent quantification of methane emissions and identify the largest sources of emissions. Although according to research [6], one of the key problems related to the top – down methods is that they do not allow the identification of specific equipment that is a source of emissions, but today analytical methods for building emission distributions are developing very rapidly.

Also in research [6] it is noted that today no country may completely deviate from the general methods for estimating individual emission sources. Therefore, it is important to involve research institutions for independent verification of emissions through actual measurement programs.

The studies conducted in different countries [5, 6, 8, 19] allow us to identify several key measures that can contribute to the formation of reliable national estimates of methane emissions:

- ◆ organization of qualitative direct measurement of emissions, which is critical for the localization of emission sources and estimates of their reduction levels;
- ◆ clear formulation of the emission reduction target, which shall be expressed both in broad, qualitative and in specific, quantitative and time terms;
- ◆ attraction of innovative technologies, first of all, low-cost technological solutions, and use of advanced digital technologies;
- ◆ ensuring of maximum transparency through the exchange of measurement protocols and their analysis by industry corporations and national regulator;

- ◆ encouragement of cooperation with international and national oil companies, which facilitates the introduction of best practices;
- ◆ ensuring of effective control over the implementation of established legal norms governing the organization of supervision and regulation, determination of institution entrusted with regulation or control, provision of powers and resources for this institution, determination of penalties for non-compliance with legal norms.

The world experience summarized in [6, 8] also has shown that the main government policies and regulations important for the reduction of methane emissions in the oil-and-gas industry are as follows:

1. Standards that require the use of specific technologies and / or operational practices and quantify emission limits. The most common are technical standards. For example, this category includes the requirement to implement regular programs to detect and to eliminate methane leaks.

2. Economic tools covering emissions charges, taxes, and penalties for exceeding the permitted level of emissions, emissions trading systems, tax rebates and financial subsidies for specific investments in emission reductions. However, the introduction of a methane emission charge requires confidence in the accuracy of a certain amount of emissions, as there may be situations in the industry where the reliability of the estimated emissions are not verifiable.

3. Public-private partnership and agreements between industry and political authorities or the regulator, which may take various forms: from a weakly defined partnership with voluntary objectives to formalized agreements with the subsequent introduction of mandatory rules if specific quantitative targets are not met.

At the same time, there is no single best practice for regulating methane emissions. Each country shall develop its own rules, given world experience and its own institutional conditions and economic opportunities.

In recent years, several countries have developed policies to reduce methane emissions, in parti-

cular, the report of the International Energy Agency for 2020 [8] refers to the following examples:

- ◆ Canada has introduced standards to reduce methane emissions by 40–45%, by 2025, as compared with the reference year 2012. In the provinces of Alberta, British Columbia, and Saskatchewan, additional regulatory measures have been being taken to address ventilation and flare leaks in oil and natural gas production;
- ◆ In the United States, several states (California, Colorado, Ohio, Pennsylvania, Utah, and Wyoming) have their own regulations and standards for methane emissions that accompany or reinforce federal obligations. They vary in terms of scale, but all require mandatory control of objects at different intervals;
- ◆ Several European countries have provisions on reporting and limiting methane emissions. For example, in Norway, each oil-and-gas complex shall annually give report on methane emissions with the use of a common estimation methodology based on standard emission factors; methane emissions from ventilation are taxed.

An example of public-private partnership is the commitment to reduce methane emissions, which is assumed by oil-and-gas corporations. Some companies have set a target of reducing methane emissions from oil-and-gas production by 2025, depending on the amount of natural gas supplied to the market. For example, *British Petroleum* aims to achieve methane emissions of 0.2% of natural gas sales during this period; *Shell* and *Total* have similar targets; *Pemex* and *OGCI* aim to achieve 0.2–0.25% methane emissions from the total amount of natural gas released to the market [19]. Other companies have set as a target reducing in methane emissions by a percentage of a given reference year. For example, *Eni* aims to reduce methane emissions from extraction by 80% by 2025 as compared with 2014; *ExxonMobil* aims to reduce methane emissions from operating activities in 2020 by 15% as compared with 2016; the Netherlands Oil and Gas Exploration and Production Association undertakes to reduce methane emissions from offshore production by 50%, as com-

pared with 2017 [19], in 2020–2024. These commitments can be a guide for other companies that have not yet set their methane reduction targets.

It should be noted that NJSC *Naftogaz of Ukraine* declares its participation in reducing greenhouse gas emissions. However, so far, the official documents of *Naftogaz* and its subsidiaries, which are available to the general public [21–25], have not contained any specific commitments to reduce GHG emissions in general or methane in particular.

At the same time, according to the information contained in the annual reports of *Naftogaz of Ukraine* [11], the company has applied some measures and technologies to reduce methane emissions, in particular, detection of natural gas leaks is carried out by electronic indication and acoustic leak detection. In 2019, within the framework of the tripartite Memorandum between NJSC *Naftogaz of Ukraine*, the European Bank for Reconstruction and Development, and the Ministry of Environment and Natural Resources of Ukraine [26], the first detection and measurement of methane leaks into the atmosphere with the use of drones were implemented at the facilities of JSC *Ukrgezvydobuvannia* and JSC *Ukrtransgaz*. The contractor was *Carbon Limits* (Kingdom of Norway). It was this company that, in 2017, conducted a study for reducing methane emissions at the industrial facilities of JSC *Ukrgezvydobuvannia*, but no information about the results of this study has been published in open sources.

With regard to gas distribution networks and gas consumers in the residential and commercial sectors, which are the main sources of methane emissions from the oil-and-gas industry, the efforts for reducing emissions are not sufficient. To estimate methane emissions, gas distribution companies use the Methodology approved by the Ministry of Energy and Coal Industry of Ukraine in 2003 [27]. This Methodology defines production-related (normalized) gas losses as “the maximum gas leakage which does not prevent ensuring reliable operation and conditional standard tightness of gas pipelines, connecting parts, fittings, compensators, gas equipment, appliances, etc.” How-

ever, the current technical condition of the GDN equipment is significantly different from the state of “conditional standard tightness”. Also, it should be noted that the Methodology covers only the regular operation leaks of the equipment, while the unforeseen leaks of methane from the GDN equipment are not estimated at all. Given the fact that as of 2017, in Ukraine 1% of the total length of GDN and 8% of gas control points were in a critical condition [28], and the entire gas distribution system is suboptimal because of reduced natural gas consumption, the most relevant is the use of advanced technologies for detecting natural gas leaks in these networks. However, today, most often, both GDN and consumers use the soaping method and the calibrated ventilation bag technique for detecting gas leaks and for measuring the amount of leakage, respectively.

Thus, the analysis of greenhouse gas emissions in the oil-and-gas industry has shown that it is a major source of methane emissions that, in 2018, according to the National Inventory, accounted for 45% of emissions of this greenhouse gas in the country as a whole. Hence, the main priority for the industry is to reduce methane emissions, which is typical for oil-and-gas industries in other countries.

It has been shown that the oil-and-gas industry is very difficult in terms of identification and quantification of methane leaks and emissions because of a large number of emission points, their geographical dispersion, physical inaccessibility, variability of emission levels. Quantifying methane emissions is a global problem that has not yet been addressed so far. Today, it is advisable to use a combination of measurements, computational methods, and simulation. It has been established that technologies that facilitate the detection and quantification of methane leaks are available and shall be used by corporations and authorities for monitoring, reporting, and verification of emissions.

It has been established that until the system of monitoring, reporting, and verification of methane emissions starts operating in Ukraine, it is impossible to say which of the estimates, the National Inventory or the reports of the *Naftogaz of*

Ukraine group, are more accurate and reliable. Meanwhile, it is necessary to move to Tier 2 (use of national coefficients) while forming the National Inventory in terms of estimating fugitive emissions from oil and natural gas operations.

An important measure to reduce methane emissions from the oil-and-gas industry shall be government policy that aims at developing and implementing regulatory standards, economic tools,

agreements between industry and government, and promoting the exchange of best practices.

Extensive implementation of measures to reduce methane emissions from the oil-and-gas industry may allow Ukraine to achieve more ambitious GHG emission reduction targets under the Paris Agreement and to prepare the industry for operation in the context of energy decarbonization.

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І.Ч. Лещенко (<https://orcid.org/0000-0003-3382-4762>),

Інститут загальної енергетики НАН України,
вул. Антоновича, 172, Київ, 03150, Україна,
+380 44 294 6701, info@ienergy.kiev.ua

ОЦІНКИ ВИКИДІВ МЕТАНУ В НАФТОГАЗОВІЙ ГАЛУЗІ УКРАЇНИ: ПРОБЛЕМИ ТА СВІТОВИЙ ДОСВІД ЇХ ВИРІШЕННЯ

Вступ. Враховуючи можливий вплив на майбутнє нафтогазової галузі політичних рішень стосовно декарбонізації економіки, потрібно розробити стратегію її подальшого розвитку з урахуванням необхідності зменшення викидів не тільки двоокису вуглецю, а й метану.

Проблематика. Останніми роками у багатьох країнах ведеться активна діяльність зі скорочення викидів метану у нафтогазовій галузі. Для вирішення цієї проблеми сформовано низку національних та міжнародних ініціатив. В Україні зазначеному питанню не приділяється достатньо уваги.

Мета. Проаналізувати стан моніторингу викидів метану від нафтогазової галузі України та узагальнити досвід інших країн з цього питання.

Матеріали й методи. Аналіз офіційних даних щодо викидів метану від нафтогазової галузі України; огляд авторитетних літературних джерел та документів міжнародних організацій щодо оцінки викидів метану від підприємств галузі, технологічних та інституціональних заходів, спрямованих на вирішення проблем моніторингу та верифікації цих викидів.

Результати. Виконано порівняльний аналіз оцінок викидів парникових газів у нафтогазовій галузі відповідно до Національного кадастру парникових газів та річних звітів групи «Нафтогаз України». Розглянуто особливості джерел викидів метану в галузі та проблеми кількісного визначення обсягів його викидів. Проаналізовано технологічні засоби та заходи, які запроваджуються в різних країнах для вирішення проблем моніторингу викидів метану.

Висновки. Встановлено, що існує широкий спектр доступних технологій для виявлення та кількісного оцінювання викидів метану в галузі. Визначено необхідність переходу до використання національних коефіцієнтів при формуванні Національного кадастру парникових газів в частині оцінки летучих викидів від діяльності з вуглеводнями. Важливим чинником зменшення викидів метану від галузі має стати політика держави, акцентована на розробленні та запровадженні регуляторних стандартів і спеціальних економічних інструментів.

Ключові слова: парникові гази, нафтогазова галузь, ідентифікація джерел викидів метану, оцінка викидів метану, технологія.