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THE CARBON FOOTPRINT OF NATURAL GAS AND ITS ROLE IN THE CARBON FOOTPRINT OF ENERGY PRODUCTION

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ABSTRACT: The study of the carbon footprint of natural gas in order to assess its impact on global climatic processes has shown that the carbon footprint of natural gas at the stages of production, transportation, storage, and distribution amounts to not more than 17 kg CO_2-eq./GJ (16.5 – in 2012; 15 – in 2013; and 12.2 – in 2014) and is reduced yearly by 1 CO_2-eq./GJ. The comparative study has revealed that its value is less than that of gasoline, kerosene, and diesel fuel. When delivering to Europe through various corridors, carbon footprint varies from 18 kg CO_2-eq./GJ for the Ukrainian Corridor to 9 kg CO_2-eq./GJ for the "Nord Stream". The proportion of the methane (CH_4) carbon footprint prior to use in a particular power generating process is 30 g CO_2-eq./kWh of a generation that amounts to 4.5-7.5% of the total carbon footprint at natural gas-fired power generation (398-662 g CO_2-eq./kWh), and to 2.8% of the carbon footprint at coal-fired generation. This indicates the high efficiency of gas fuel in terms of its positive impact on reducing the global climate change

Keywords: Natural gas, Carbon footprint, Ecological aspects of energy production

1. INTRODUCTION AND STATE-OF-THE-ART

Sensitivity in the perception of the problem concerning global climate change affects competitive struggle between energy producers. The impact of greenhouse gases on climate, although not a conclusively proven fact, is the subject of ongoing discussions, and in recent years the so-called "carbon footprint" issue is discussed especially actively.

The term "carbon footprint" is a conditional designation, which allows the brief estimation of what we can get by climate change with regard to something. This "something" can be anything, namely a certain activity, a way of life, a company, a country, or even the whole world.

The carbon footprint includes direct and indirect emissions of greenhouse gases (usually expressed in g CO_2-eq./product unit).

Therefore, the calculation of carbon footprint must be carried out very carefully and based necessarily on the reliability of the source data.

Climate change is an issue under discussion at all levels. The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) gives a comprehensive assessment of climate change [1], as well as do the previous similar SRREN [2] and SREX [3] documents. These documents provide comprehensive assessments, though the debates on this issue are still continuing. At that, especially many different opinions concern "carbon footprint". This issue is being considered in a large number of works.

The article [4] analyzes the growing concern about environmental problems. The authors state that the number of regulations and legislation aimed at limiting carbon emissions has significantly increased.

The role of biomass in carbon footprint is discussed in [5].

The study [6] provides a method of quantitative determination of the carbon footprint. Manufactures with a low amount of waste (emissions), based on wastes' identification and reduction, represent a growing trend in the manufacturing sector [6]. Growing environmental concerns encourage the government to regulate greenhouse gas or carbon dioxide emissions, as provided for in the American Clean Energy and Security Act of 2009 [6].

The question is raised about the carbon footprint of business processes [7]. The issues of the carbon footprint for sustainable improvement of supply chains are discussed as well [8].

The carbon footprint of solar energy is estimated by the British Parliamentary Office of Science and Technology to be equal to 110 g CO_2-eq./kWh. However, according to the European Committee for Standardization (Climate & Energy Department) this figure for 2016 amounts to 978 g CO_2-eq./kWh. Such essential difference is caused by the fact that solar panels are made in China and their transportation to the place of destination leads to a great increase in carbon footprint.

Such differences give rise to paradoxical judgments. For example, C. Nunez writes [9] that according to her research, switch to natural gas won't reduce carbon emissions much. Though, what means "much" in terms of science is not explained.

The carbon footprint is also explored on the scale of particular entire countries. So, [10] provides an overview of the construction methods and techniques used to calculate greenhouse gases' emissions for industry sectors, as well as the use of input-output analysis for the subsequent calculation of the carbon footprint of Australia.

The authors of the article entitled "Carbon footprint of the knowledge sector: What's the future?" [11], have conducted an extensive literature search and environmental scan to obtain data relating to CO_2 emissions in various industry sectors and activities.

Of course, everyone is interested in reducing carbon footprint [12].

Accounting for carbon footprint [13] is also an important issue in which evaluation standards play a significant role. The article "A comparative study of carbon footprint and assessment standards" [14] focuses on the research methods and stages associated with research on various types of carbon footprints. In addition, a comparative study of different carbon emission standards has been conducted.

In the article "A geospatial approach to measuring surface disturbance related to oil and gas activities in West Florida" [15], American colleagues analyze the fact that the oil and gas exploration and production activities can lead to surface violations that are caused by the construction of roads, wells, oil wells, pipelines, production facilities.

Along with this, there are emerging studies showing that the carbon footprint of natural gas is higher than that of gasoline and diesel fuel.

2. URGENCY AND OBJECTIVES OF THE RESEARCH

In connection with the foregoing, it seems relevant to investigate the issue of the carbon footprint in all aspects of its definition, ranging from the source data to role of the carbon footprint in the power generation.

The purpose of the present study is determining the actual values of the carbon footprint based on the comprehensive system analysis of the issue and its role (and proportion) in the carbon footprint of energy production.

Research objectives include:

1. Analysis of initial data to determine the carbon footprint in the context of their reliability taking into account the greenhouse gases' balance in the atmosphere, and the contribution of greenhouse gas emissions from different sources.
2. Calculation of actual amount of the carbon footprint with the assistance of independent party and further analysis of the obtained data by "independent estimators".
3. Analysis of the data about the carbon footprint of natural gas from the viewpoint of its contribution to energy production.

3. METHODS

The global carbon balance is the balance of carbon fluxes in the process of the carbon cycle between three natural reservoirs: land ↔ atmosphere ↔ ocean.

Global anthropogenic carbon emission and its migration into the atmosphere, the ocean, and land are in equilibrium:

$$E_F + E_L = G_A + S_O + S_L,$$

Where E_F – is the emissions resulting from the burning of fossil fuels;

E_L – is the emissions resulting from human activities related to the land management and land use, change in land-use and woodland management;

G_A – is the content of carbon in the atmosphere;

S_O – is the absorption of carbon by the ocean;

S_L – is the carbon uptake by the land biota.

At the beginning of the world economy industrialization, the increase of the carbon dioxide concentration in the atmosphere was caused by the emission of carbon to the atmosphere due to deforestation and other ways of economic use of land. Since about 1920s, the CO_2 emissions from the combustion of fossil fuels became the dominant source of anthropogenic emissions to the atmosphere.

When analyzing balances and calculating the carbon footprint, first, it is necessary choosing reliable initial data. With regard to Russia, such information includes data of the Ministry of Energy of the Russian Federation [16], Federal State Statistics Service "Rosstat" [17], the Ministry of Natural Resources [18], Environmental Protection Bulletin of Russian Federal State Statistics Service [19], as well as Ukrtransgaz [20], and the IEA [21, 22]. And because EXERGIA presents also data on Norway, Germany and the Netherlands, these data must be taken also from the original sources, i.e. the Norwegian Environment Agency [23], the Norwegian Oil and Gas Association [24], and the Norwegian Statistics Bureau [25]. The same concerns Germany [26].

4. RESULTS AND DISCUSSIONS

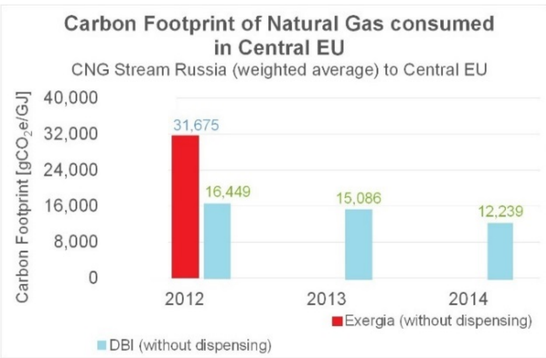
The calculations performed by independent scientists based on the data presented in methodology are given in the DBI report [27]. Based on these data it can be stated that the conclusion drawn by EXERGIA is not true. A comparison of the initial data is given in Table 1.

Table 1 Comparison of the initial data presented in the assessment made by EXERGIA, and the actual source data based on state statistics

	Assumptions in the EXERGIA study		**Actual source data**
Natural gas output	2,375,880 100%	*Absolute emissions of methane, t*	69,949 74% of the total production volume
Transportation	4,823,670 100%	*Absolute emissions of methane, t*	1,329,294 100%
Power consumption	0.000045	*Power consumption, J/J·km*	0.000024
Rate of gas compression	1.45 (Russia)	1.3 – 1.35 (Foreign systems)	1.3 – 1.36 (Russia)

Comparison of EXERGIA and DBI results for 2012 for natural gas supplied to Central EU is given in Fig. 1.

a)



b)

Fig.1 The carbon footprint of natural gas consumed in Central EU: a) delivery scheme; b) carbon footprint

Taking into account the updated data and recalculating, the carbon footprint of Russian natural gas flow amounted in 2012 to 16,449 g CO_2-eq./GJ.

The difference is explained by the following reasons:

- updated values for methane emissions and energy consumption;
- reduced values of the carbon footprint of natural gas due to the implementation of energy efficiency measures, and switch to best available technology.

Comparison of various natural gas delivery corridors is shown in Fig. 2. Result for Russian export flow is a weighted average for the 3 different delivery corridors.

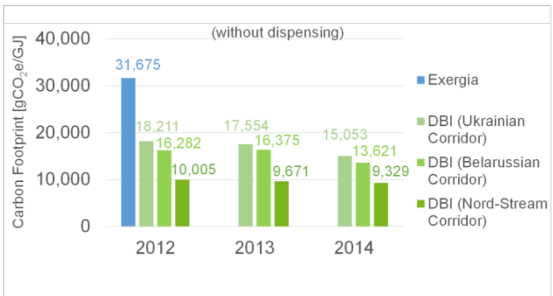


Fig.2 Comparison of export corridors

New technologies implemented in the Northern corridor reduce gas consumption for auxiliary needs at transportation by 6 times in comparison with that of the gas transportation system (GTS) of 5.5 MPa, and by 3 times in comparison with GTS of 7.5 MPa. This is clearly illustrated by the data shown in Fig. 3.

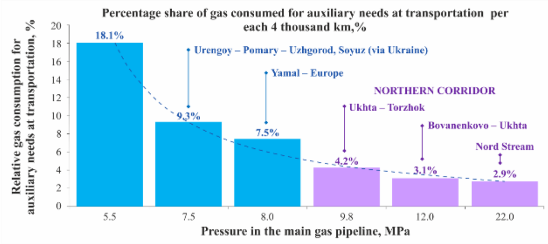
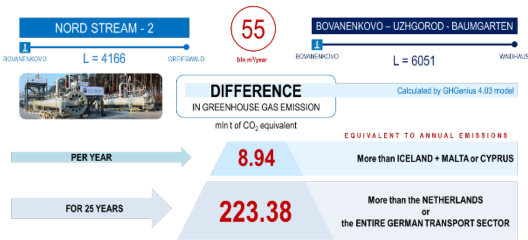


Fig.3 The energy efficiency of the Russian export gas flows

The least gas consumption for auxiliary needs at transportation was revealed for the "Nord Stream 2". Comparison of the carbon footprint of the "Nord Stream 2" and "Bovanenkovo – Uzhgorod – Baumgarten" pipeline is given in Fig. 4.



The fig.4 Carbon footprint of "Nord Stream 2"

All the above pertained to compressed natural gas (CNG). But there is also liquefied natural gas (LNG) for Qatar, the country, which is the richest in terms of gas, as well as for the USA and Russia.

And finally, the third task to be solved consists in determining the proportion of natural gas in energy production. The study conducted by the Parliamentary Office of Science and Technology (Great Britain) [28] presents quite detailed data on carbon footprint. On a global scale, they make up:

for coal 766-1070 g CO_2-eq./kWh
for gas 398-662 g CO_2-eq./kWh

The carbon footprint of natural gas averaged over the three years amounts to 30 g CO_2-eq./kWh, that is 4.5-7.5% of the total carbon footprint of natural gas in electricity production, and just 2.8% of the carbon footprint of coal, that is confirmed by the studies of the European Institute for Climate and Energy which has assessed the carbon footprint of solar energy as being equal to 978 g CO_2-eq./kWh.

When using compressed gas for purposes of vehicles, the carbon footprint of natural gas itself should be supplemented by carbon footprint of refill (4 kg CO_2-eq./GJ). This is according to EXERGIA. But here it must be borne in mind that the major carbon footprint of the vehicle is not that caused by the fuel.

In the article "The carbon footprint of the vehicle" [29] it is indicated that the carbon footprint of the new Citroen C1 equals to 6 t of carbon expressed in CO_2 equivalent, while that for Ford Mondeo amounts to 17 tons. The authors [29] write that "the best thing that can be done is the so-called "input and output" analysis, which will allow splitting the known total emissions between the world or particular country between different industries and economy sectors, taking into account data describing how each industry consumes goods and services of all other industry sectors. If we do this, and further divide the total emissions of the automobile industry by the amount of money spent on new cars, we get the carbon footprint in the amount of 720 kg of CO_2 equivalent per 1,000 pounds spent on the purchase of the car. Car replacement will reduce these figures just slightly.

Nevertheless, the use of CNG in vehicles will undoubtedly reduce carbon footprint. According to EXERGIA, the carbon footprint of diesel is 18.17 kg CO_2-eq./GJ that is twice higher than CNG from the "Nord Stream". But no one will refuse the car, although it is believed that "giving up meat will reduce carbon footprint more essentially, than giving up the car" [30]. Though, in this joke, there is a very serious share of the truth. Animal industry and other sources of greenhouse gases are not less serious than the use of vehicles or natural gas in all economy sectors, which have significant advantages in both energy [28] and metallurgy [31], and everyday life. The consequences are obvious to everybody and nobody is going to abandon it.

5. CONCLUSIONS

1. The calculation of the carbon footprint of natural gas based on the reliable data of the state statistics of Russia and the Central EU countries has shown that the carbon footprint of natural gas during its extraction, transportation, and storage excluding fueling amounted in 2012 to 16.5 kg of CO_2-eq./GJ, in 2013 – to 15 kg of CO_2-eq./GJ, and in 2014 – to 12.2 kg of CO_2-eq./GJ, i.e., what is meant here is natural gas and its use not only in transport sector.

2. The natural gas delivered to Europe via the Nord Stream is characterized by the smallest

carbon footprint (9 kg CO_2-eq./GJ), that is twice lower than for the gas shipped through the "Ukrainian Corridor".

3. The proportion of the carbon footprint of the pure natural gas itself in electricity generation is 4.5-7.5% of the total carbon footprint of natural gas-fired electricity production, and 2.8% compared to that for coal. This testifies the fact that the main contribution in electricity generation belongs not to the fuel, but to the process of generation. This is supported also by data on solar energy (according to the European Institute for Climate and Energy).

So the role of natural gas in energy generation is enormous, whether it is electric energy, vehicle motion energy, or the energy of the household. Therefore the development of the gas industry sector is expedient not only in terms of economy but in terms of ecology as well. A combination of economic, environmental and social factors is the essence of sustainable development.

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