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Research Article

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The role of methane in global climate change

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ABSTRACT

The article gives a scientific analysis of the role of methane in global climate change. The dominant view is that methane, the second most important greenhouse gas, has been considered alongside with the point of view of the non-anthropogenic origin of global climate change. It is shown that the anthropogenic impact is much weaker than the effect of natural processes, among which is the turnover of the 'main greenhouse gas' – H_2O. The view that its concentration does not change does not correspond to reality, since a constant amount of H_2O is maintained by the accelerating and slowing down of the turnover cycle. A similar mechanism of self-regulation is shown in the article for methane. Its content in the atmosphere is regulated by its natural short-period transformation in the atmosphere. Comparison of the degree of methane influence on the climate on the basis of analysis of the global warming potential and the global temperature change potential showed that the methane equivalence coefficient relative to CO_2 can be estimated as 4-11 rather than 25, according to existing assessments. The analysis revealed that methane turnover is a global natural process and anthropogenically caused methane release into the atmosphere has only a slight effect on the climate. The impact of the oil and gas sector is estimated at 0.1% of total global greenhouse gas emissions and 0.004% of the methane of the Russian gas sector.

Keywords: global climate change, greenhouse gases, greenhouse effect, methane, carbon dioxide, climate, atmosphere.

INTRODUCTION

Global climate change has taken a lasting place among the global environmental problems that have seriously threatened the future well-being and even, perhaps, the survival of mankind. It should be recognized, however, that, for example, two other global environmental problems, namely depletion of natural resources and catastrophic pollution of the environment, are no less significant.

Recognition of the urgency of global climate change and the need for collective action to prevent or at least mitigate its consequences was confirmed by the adoption in 1992 of the United Nations Framework Convention on Climate Change (UNFCCC).

The adoption and entry into force of the Kyoto Protocol was a major step in the implementation of the actions envisaged by the Convention. Russia plays an important role in ensuring the successful achievement of the goals of the Convention and the Kyoto Protocol – if Russia had not ratified it, it would not have entered into force.

The Earth's climate is subject to fluctuations at all times. Among the most notable fluctuations are the hundred-thousand-year cycles – the glacial periods when the Earth's climate was mostly colder than the present, and interglacial periods, when the climate was warmer. These cycles happen due to natural causes. In the opinion of a number of scientists we are now in a transition from one glacial period to another, but the change rate is very small – about 0.02°C in 100 years. Since the beginning of the industrial revolution, climate change has come about as a result of human activities that emit greenhouse gases into the atmosphere while burning fossil fuels and also destroy most of the planet's forests which absorb those gases.

According to many, among the greenhouse gases the second place after CO_2 is occupied by CH_4. However, there are contradictory irrefutable data, as the role of the main greenhouse gas (H_2O) is not estimated. This requires analysis and evaluation, and assessment is also needed of the CH_4 role in the global climate change, and especially of the CH_4 of anthropogenic origin.

STATUS OF THE QUESTION

Methane is the most important representative of organic substances in the atmosphere [1, 2]. It was found in the atmosphere relatively recently – in 1947 [2]; its concentration is not large and has stabilized at 1.75 ppm since 1999. For comparison, the concentration of CO_2 in the atmosphere is 400 ppm. It is believed that the contribution of methane to warming is 28% [3].

The UN report acknowledges that rapidly growing livestock herds are the greatest threat to climate, forests and wildlife. Livestock produces 18% of greenhouse gases, more than cars, airplanes and all other means of transport combined. Combustion of fuel to produce fertilizers necessary for growing fodder, for producing meat and for its delivery to consumers and the vegetation destruction for pasture lands gives 9% of the total emissions of carbon dioxide, and livestock intestinal gases and manure provide more than a third of methane emissions [3].

Methane is mainly in the surface layer of the atmosphere – the troposphere, the thickness of which is 11-15 km. The concentration of methane depends little on the height in the interval from the surface of the Earth to the tropopause, which is due to the high rate of mixing at 0-12 km in comparison with methane lifetime in the atmosphere [1]. The methane concentration in the atmosphere (determined by studying the ice cover at Vostok station in Antarctica) showed that the concentration over the last 150,000 years fluctuated with a period of 20,000 years, which proves the naturalness of these fluctuations.

Methane disappears from the atmosphere, mainly in reaction with the OH radical. If the concentration of methane in the atmosphere does not increase, this means that the rate of methane entering the atmosphere is equal to the rate of its release. Methane, unlike CO_2 which ‘places all of its hopes on for forests and other drains’, is self-destructed if its quantity becomes more than necessary for the atmospheric equilibrium. The nature of methane formation in such sources as bogs, lakes, rice fields, ruminants, insects, dumps is approximately the same – the enzymatic processing of fiber [5].

The issue of balance in the atmosphere has not been studied. The concept of ‘noospheric balance’ [6] is especially applicable to the main greenhouse gas H_2O. The noospheric balance is also necessary for the balance of CH_4, since panic appeals [7] without scientific justification, unfortunately, resonate with political and social circles. A reasonable approach to the analysis of processes is very important for solving global environmental problems [8]. The role of methane in the overall picture of the greenhouse problem needs to be considered together with the question of what role the anthropogenic factor plays in climate [9], taking into account not only the prevailing viewpoint.

The discussion on the topic ‘methane and climate’ continues. Yasamanov N.A. [10] writes: "Most of the methane coming into the atmosphere from different sources is ‘guilty’ of the current global warming". However, he immediately indicates the claim is not easy to verify by direct observations, "for the speed of methane movement in the atmosphere is high, and the lifespan is small".

RELEVANCE OF THE TOPIC

The relevance of the topic is due to the fact that solving global environmental problems (one of which is global climate change) is the most important scientific task. Defining the true role of methane in global processes is one of the urgent scientific issues of solving the global problem as a whole.

PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of the study is to determine the true role of methane in global climate change, taking into account its balance in the atmosphere against the overall balance of greenhouse gases and, first of all, H_2O, as well as determining the role and significance of methane of anthropogenic origin.

The objectives of the study are:

1. Analysis of natural and anthropogenic factors of climate change;
2. Study of greenhouse gases balance in the atmosphere and the true share of methane in them;
3. Determination of the role of methane of anthropogenic origin and of its share in the overall balance of greenhouse gases.

METHODOLOGY OF THE STUDY

The methodology is based on fundamental and applied aspects of the origin and balance of methane in the overall balance of greenhouse gases and their impact on climate change. Data on the quantitative indicators of the balance of each of the greenhouse gases are sufficient to produce a systematic analysis of their ‘equity participation’ in global processes. Thus, the main methodological tool is a systematic analysis of the effect of methane on climate change. To determine the contribution of methane to the global temperature change, it is necessary to compare two methods for determining the degree of influence: based on the global warming potential (GWP) and the global temperature change potential (GTP).

RESULTS OF THE RESEARCH AND THEIR DISCUSSION

Analysis of methane formation sources shows [1] that Number 1 source is bogs (21%) and Number 2 is rice fields (20%) – in fact, man-made bogs. This source can be eliminated, but this causes an even more acute food problem. The same pattern is observed with livestock (15% of the total methane emissions), followed by: burning biomass (10%), coal mines and dumps (7%). Methane hydrates ‘blamed’ for the methane release give only 1% of it. Methane from coal mines (7%) is not only threatening people’s lives but adding up to the burning of coal – a significant increase in greenhouse gas emissions. In fact, these 7% should be included in the ‘carbon footprint’ of coal, and the next step should be to prohibit underground coal mining. Nature was ‘hiding’ carbon for millions of years, and mankind, knowing that it is causing global damage, continues to mine for coal, introducing it into the natural balance of the atmosphere in the form of a continuous increase in the concentration of CO_2, which has reached 400 ppm.

According to the IPCC (Intergovernmental Panel on Climate Change) assessment reports [12 - 16], the total methane emissions from natural and anthropogenic sources are shown in Table 1.

Table 1: Sources of methane emissions into the atmosphere, mln t/year

Natural emissions		Anthropogenic emissions	
Sources	mln t/year	*Sources*	mln t/year
Bogs	217	Ruminants	89
Ocean	54	Waste	75
Lakes and rivers	40	Oil and gas industry (including biofuels)	50
Wild animals	15		
Termites	11	Rice fields	36
Hydrates	6	Burning biomass	35
Fires	3	Other	46
Permafrost	1		
Total, mln t/year	347	**Total,** mln t/year	331
Total, %	57,9%	**Total, %**	45,1%

Thus, emissions from natural and anthropogenic sources are distributed approximately 50/50. Given the short survivability of methane and its concentration of just 1.75 ppm in comparison with 400 ppm of CO_2, it is to be expected that even with an equivalent coefficient of 25 t CO_2/t CH_4 its effect is 11 times lower than that of CO_2, and the effect of anthropogenic methane is 24.4 times lower, respectively.

The influence of methane should be considered on the basis of the overall balance of greenhouse gases. However, one should also take into account the point of view that climate change is not of anthropogenic character. This is evidenced by the correlation of the CO_2 content in the atmosphere and temperature variations over the last 500,000 years (Fig. 1).

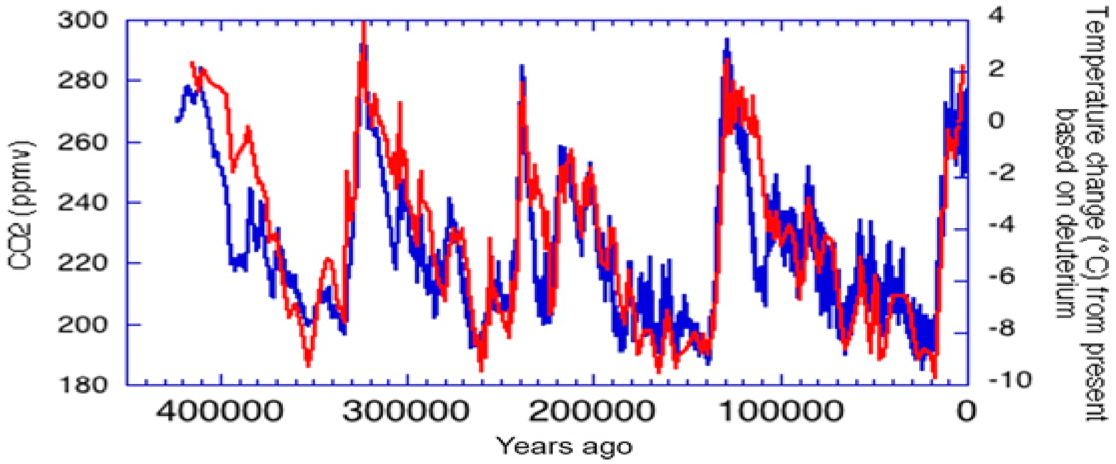

Fig. 1. Change in temperature and in the content of carbon dioxide in the atmosphere Source: National Oceanic and Atmospheric Administration, USA

A study of climatic changes of the last millennium shows that paleoclimatic data based on ice cores, tree rings, lake bottom sediments and coral reefs allow reconstructing the climate of the past. Many millions of years ago, during the time of the dinosaurs, the climate was much warmer, on average 7°C warmer on the global scale. Then the climate gradually became colder, and in the history of the Earth there were many abrupt changes (mainly cooling), when mass extinction of living organisms took place. Since the last retreat of the glaciers from Central Europe, two stages of amazingly rapid natural warming were observed. The first occurred about 15 thousand years ago at the end of the last ice age, the second about 3 thousand years ago. In general, over the past 10 thousand years, the average global temperature has decreased slightly due to volcanic activity and other natural causes, after which it sharply increased in the 20th century.

As the system analysis of the problem shows, the natural causes of climate change are:

1. Earth's orbital eccentricity and axial tilt;
2. Change in solar activity;
3. Volcanic eruptions and changes in the quality of atmospheric aerosols.

The analysis shows that during the last million years the glacial and interglacial periods changed depending on the position of the Earth's orbit. Smaller orbital eccentricity was observed in the last 10 thousand years and the climate became relatively stable. However, in any case, orbital oscillations are quite an inertial phenomenon fundamentally important in the millennial time scale.

In connection with the change in the position of the elliptical orbit, the energy flow from the Sun changes. The change in solar activity is due to the deviation of the solar system mass center from the center of the Sun. According to the Central Aerological Observatory (Moscow), variations in the flux of solar energy received by the Earth fluctuate between ±24 W/m^2. As a result, the anthropogenically caused increase in the greenhouse effect, according to the IPCC, is +2.3 W/m^2.

Comparing -24 W/m^2 and +2.3 W/m^2, the difference will be -20.7 W/m^2, which clearly does not indicate warming. That is, the effect of anthropogenic influence is lower than natural variations. The deviation of the solar system mass center has a quasiperiod of 178 years. In Moscow in 2013 in November, a temperature of +14.8°C was recorded, while the previous record was in 1838 (14.5°C).

Volcanic activity and aerosol release is the third important factor in the natural causality of climate change.

As a result of the eruptions, significant volumes of suspended particles – aerosols – are released into the atmosphere. They are carried by tropospheric and stratospheric winds and do not let part of the incoming solar radiation pass through. However, these changes are not long-term, and the particles settle relatively quickly. Thus, the Santorini volcano eruption in the Mediterranean Sea around 1600 BC significantly cooled the atmosphere, which is seen by the annual growth rings of trees.

The Tambora volcano eruption in Indonesia in 1815 reduced the average global temperature by 3°C. The following year both in Europe and in North America is known as the Year without a Summer, but in a few years everything was straightened out. As a result of the Pinatubo volcano eruption in 1991, in the Philippines at the altitude of 35 km so much ash was released that the average level of solar radiation decreased by 2.5 W/m^2, in other words, the change was approximately equal to all the anthropogenic influence (2.3 W/m^2 according to the IPCC). Thus, the eruption of just one volcano blocks the anthropogenic effect.

Analysis shows that natural causes have a considerably greater effect on the climate than the anthropogenic ones, yet politicians and the public seem oblivious to this. Fig. 2 shows the noospheric balance of 'climate concerns'. 'Noospheric' means 'reasonable', based not on the intelligence of one person (however important), but on the basis of the collective mind formed by the noospheric worldview.

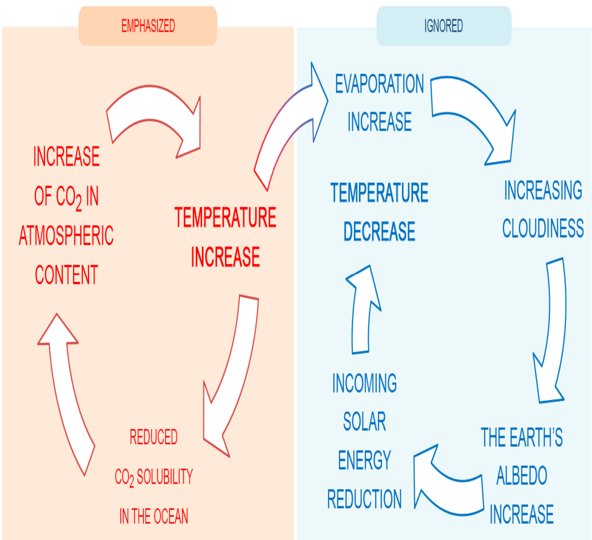

Fig. 2. Noospheric balance of 'climate concerns'

Not only the natural causes of climate change but also factors that compensate naturally for anthropogenic impact on the climate are ignored. With the increase in temperature, evaporation of H_2O increases, cloudiness and the albedo of the Earth increase, which compensates for anthropogenic influence.

In general, the role of the main greenhouse gas is underestimated. The Earth's atmosphere consists of gases and various impurities (dust, aerosols, drops of water, ice crystals). The concentration of gases is practically constant with the exception of water and carbon dioxide: N_2 – 78.084%, O_2 – 20.946%, Ar – 0.9340%, CH_4 – 0.00018%. CO_2 is estimated at 0.0407%, but has been growing steadily lately. Water is in constant motion (circulation with the ocean and land) called the hydrological cycle. The hydrological cycle involves 12-14 thousand km^3 of water (1/2 of Baikal Lake). Annually, there are 45 cycles, and their duration is 7-10 days. Precipitation and evaporation are equal (577 thousand km^3 per year).

This is a natural regulator of the atmospheric processes. Those who do not recognize H_2O as the main greenhouse gas claim its concentration does not change; however, it does so only because it participates in the regulation of global processes: if it becomes warmer, evaporation increases and the cycle of turnover is accelerated.

The contribution of H_2O to the greenhouse effect is estimated at 36-72%, of CO_2 at 9-26% and of CH_4 at 4-9% [12-16]. That is, the above mentioned result (24.4 times) coincides with the estimated data on the contribution of various gases to the warming.

The balance of water, along with the balance of energy, is a fundamental factor of global stability.

In addition, it should be borne in mind that methane is a short-lived greenhouse gas (8-12 years). Fig. 3 shows the forecast of the contribution of greenhouse gases.

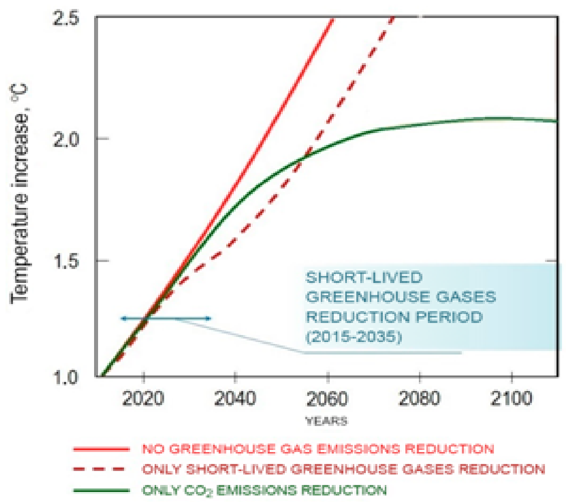

Fig. 3. Contribution of CO_2 and short-lived greenhouse gases to global temperature retention

It can be seen that the focus on the implementation of measures to reduce emissions of short-lived greenhouse gases does not have a long-term trend of long-lived greenhouse gases (CO_2) influence on the Earth's climatic system. This is politically motivated to demonstrate 'light' and fast results, as measures to reduce emissions of short-lived greenhouse gases are less costly and allow demonstrating a rapid estimated reduction in CO_2-equiv. emissions.

Below there is a dynamics chart of the methane concentration change in the atmosphere, which was mentioned above and in the 5th Assessment Report [11 - 16]. Fluctuations sometimes are below the zero level (Fig. 4).

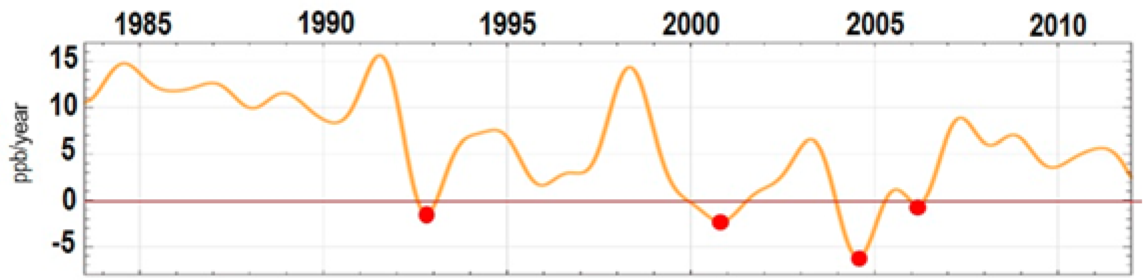

Fig. 4. Dynamics of growth/decrease of methane concentration in the atmosphere

The total content of methane in the atmosphere is about 5 billion tonnes, while annual changes estimated at 592-785 million tonnes are almost equal to emissions (542-852 million tonnes). **The mechanism of change has its own natural character and is analogous to the mechanism for regulating the balance of water vapor.**

A comparison of the methods for assessing the greenhouse effect from the 5th Assessment Report shows that there is no single system of indicators for an accurate comparison of all the consequences. A comparison of the methods for assessing the greenhouse effect of GWP and GTP is shown in Fig. 5.

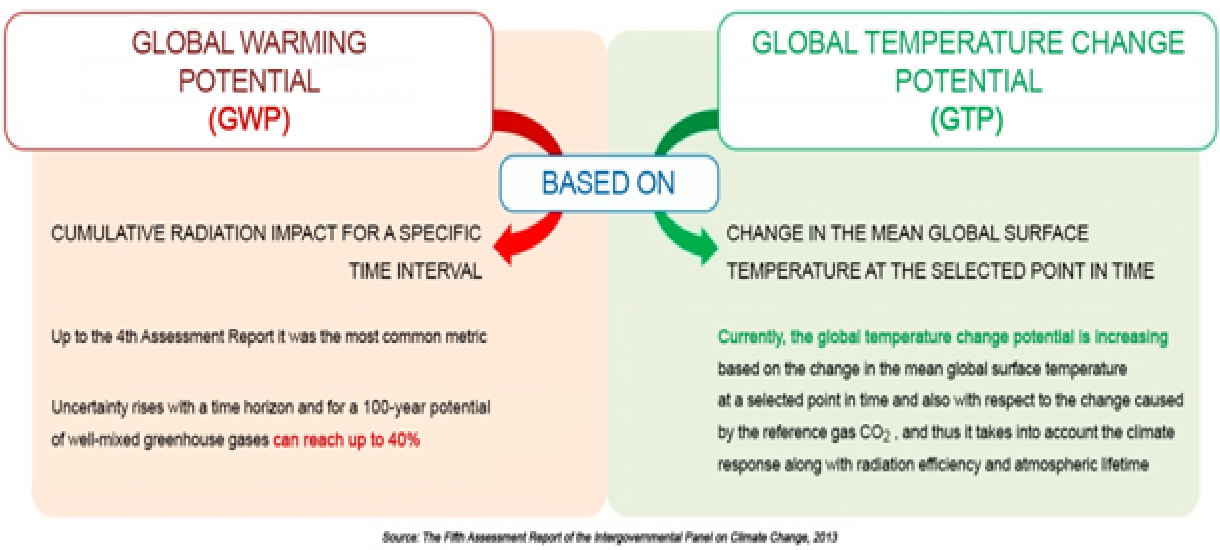

Fig. 5. Comparison of methods for assessing the greenhouse effect of a substance

The results for various methodological approaches are shown in Fig. 6.

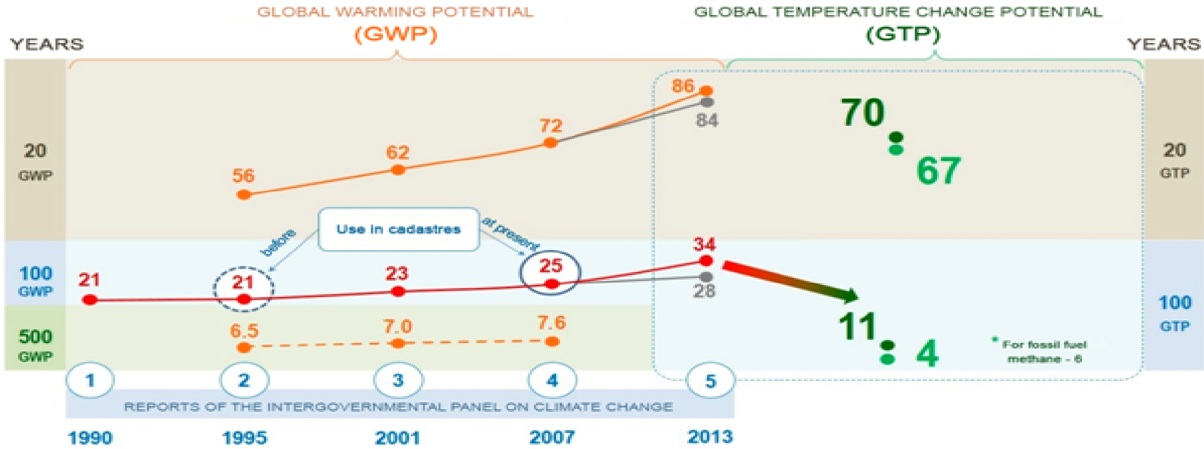

Fig. 6. Comparison of the calculated ratio t. CH_4/ t.CO_2 with different methane assessment methods in climate change

These results allow estimating the degree of methane influence on the climate. Today the most frequently quoted are the conclusions of the consulting company Exergia, made in the ‘Study on actual GHG data for diesel, petrol, kerosene and natural gas’ [11], published in 2015. The study states that methane has the highest greenhouse gas emission factor (25-34 times larger than CO_2).

The entire current discussion is being held around such indicator as the Global Warming Potential (GWP), an indicator that allows experts to compare the impact of methane on the climate with that of another well-known ‘enemy’ – CO_2. The global warming potential is based on the aggregate radiation impact for a specific time interval, and up to the release of the Fourth Assessment Report of the IPCC was considered the most common indicator.

At present, the **Global Temperature Change Potential** is increasing, which is based on the change in the mean global surface temperature at the selected point in time. In other words, this indicator is used in answering the following question: what will be the temperature change in a particular year in response to the radiation impact of certain greenhouse gas emissions? The IPCC report established and confirmed that the potential for changing global temperature is much better suited to the goal-setting policy promoted by the Paris Climate Agreement.

In the case of applying the Global Temperature Change Potential, the CH_4/CO_2 ratio will be between 4 and 11 rather than 25, as currently used in calculations under the Global Warming Potential.

For the first time an alternative point of view is given in the IPCC Fifth Assessment Report ‘The Physical Science Basis’, which is an internationally recognized ‘Climate Bible’. It should be borne in mind that the IPCC was awarded the Nobel Prize for this research in the field of combating climate change. The IPCC states that different indicators can be used to compare the effects of emissions of various substances on climate. The most appropriate indicator and time horizon are selected based on specific aspects of climate change that should be assessed. None of the indicators can be regarded as perfect and cannot be used to accurately compare all the consequences of various types of emissions. All indicators have their limitations and uncertainty which can reach ±40%.

In addition, the IPCC also states one more feature – measures to limit anthropogenic methane emissions to the surface layer with the presence of ozone are defined as a ‘win-win situation’: they can lead to both warming of the climate and its cooling.

For solving the climate problem it is most important to focus on the long-term effects of climate change and to pay more attention to ‘long-lived’ gases, such as CO_2. In reality, carbon dioxide (CO_2) has a very long lifespan in the atmosphere.

Methane is a short-lived gas: a methane molecule is oxidized and converted to water and carbon dioxide for 12 years. By shifting our attention from CO_2 to CH_4, we substitute the trend of global temperature change. The strategy to reduce methane emissions without taking into account the long-term effect of CO_2 emissions gives a quick and cheap result; however, it does not bring us one iota closer to fulfilling the ambitious objectives of the Paris Climate Agreement.

In the study ‘Global biogeochemical cycles of increasing methane content in the atmosphere: growth in 2007-2014 and isotopic shifts’ [17] conducted by fifteen renowned institutions of the United Kingdom, the United States, New Zealand, Canada and South Africa showed that the globally averaged molar fraction of methane in the atmosphere increased from 2007 to 2013 by 5.7 ± 1.2 parts per billion (billion^{-1}) anually. At the same time, the indicator $\delta^{13}C_{CH4}$ (ratio of carbon isotopes $^{13}C/^{12}C$ in methane) has shifted since 2007 to significantly more negative values. The extreme value of growth by 12.5 ± 0.4 billion^{-1} was recorded in 2014; a further shift towards more negative values was observed in most latitudes. The isotope evidence presented here indicates that the most significant increase in methane is due to a significant increase in biogenic methane emissions, especially in the tropics, for example, due to the expansion of tropical wetland areas in years with abnormally high rainfall or in connection with an increase in the number of sources of methane emissions from agriculture, such as ruminants and rice fields. Changes similar to those in the rate of methane removal from the atmosphere in the reaction with the OH radical were not observed in other tracers from the chemical composition of the atmosphere and, as it seems, they do not explain short-term fluctuations in methane concentration. Although there is a possibility of an increase in emissions from fossil fuel combustion, the steady shift to depleted ^{13}C isotope and its significant interannual variability, as well as an increase in methane share in the tropical regions and the Southern Hemisphere after 2007, show that emissions of anthropogenic origin from energy have not become the main cause of methane concentration growth.

Although emissions from fossil fuels in the total methane budget have decreased, the data [17] can not exclude an increase in emissions in absolute terms, especially if the source gas was isotopically highly depleted in ^{13}C. Based on both the analysis [18 - 20] for latitudes and isotope limitations, **the gas of Siberia was excluded** as the cause of methane growth.

Summarizing, it can be argued that isotopic studies confirm the methane content in the atmosphere depends mainly on natural factors and is completely independent of the produced natural gas.

Analyzing this topic, it becomes more and more obvious that today’s politicians and regulators are considering **short-lived ‘contaminants’ such as methane an easy way** to shift the focus of current climate debate from the main obstacles to reducing **CO_2 emissions to the topic of methane emissions – a topic that will actually evaporate in the long run**. Accordingly, the topic of short-lived ‘pollutants’ will have little effect on the warming that will be experienced by the future generation, while shifting the public attention away from CO_2, a much more dangerous greenhouse gas.

Finally, if we estimate the share of methane in the oil and gas industry, the results are presented in Fig. 7.

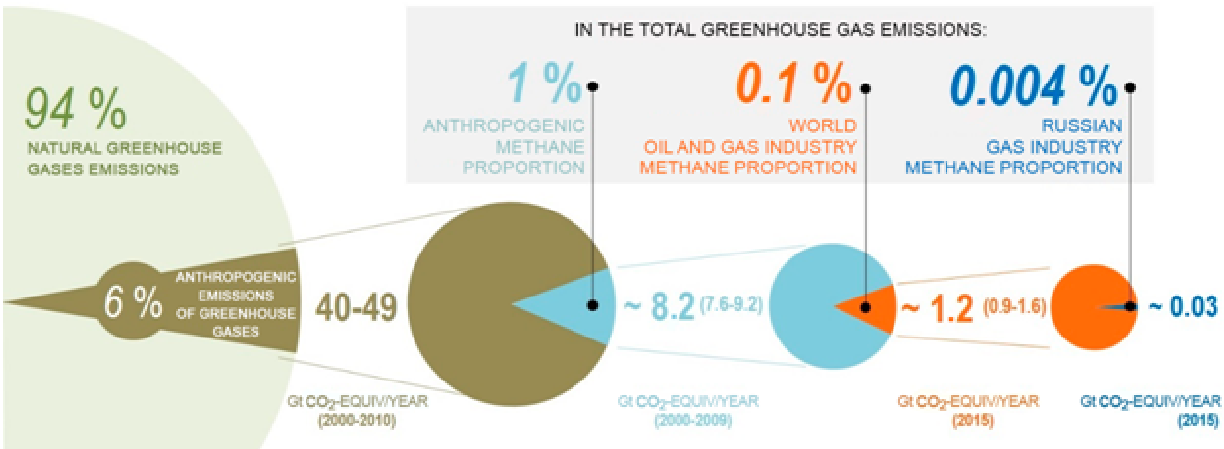

Fig. 7. The share of methane emissions from the gas industry in total greenhouse gas emissions

Thus, with the general slight influence of methane on the climate, the impact of anthropogenic emission of methane from the gas industry in Russia and the world as a whole is negligible and has no effect on the climate.

CONCLUSIONS

1. The anthropogenic impact of methane on the climate in accordance with its share in total methane emissions (45.1%) is 24.4 times lower than that of CO_2. In this case, it is necessary to take into account the anthropogenic impact on the climate as a whole, which is *much smaller* than the natural causes (Earth's orbital eccentricity, changes in solar activity, volcanic phenomena with the release of aerosols) and compensated by natural processes of recovery and self-regulation (natural balance) in the atmosphere.
2. Estimating the contribution of methane to global climate change, it is necessary to take into account that its share in the overall picture of the greenhouse gases influence is 4-9%, while that of the water vapor is 36-72%. It is water vapor that maintains the heat balance and is a natural regulator of atmospheric processes. Analyzing the role of each greenhouse gas confirms that methane impact is 24.4 times smaller than that of CO_2 and, with natural regulation on the part of water vapor and short-lived methane in the atmosphere, *its influence on climate can be considered insignificant.*
3. Analysis of the methane concentration dynamics in the atmosphere shows that the emission of methane is approximately equal to its removal. This process is of natural character and is similar to the natural regulation of the heat balance through water vapor circulation.
4. Comparison of methods for assessing the greenhouse effect of substances showed that there is no single system of indicators for an accurate comparison of all the consequences. Estimates of the role of methane in existing GWP and GTP techniques are discrepant, yet in general show an unimportant role of methane in the process of climate change. The coefficient of methane 'equivalence', now estimated at 25 by the GTP method, is reduced to 4, which is confirmed by radioisotope studies.
5. Analysis of methane emissions share in the gas industry shows the share of greenhouse gas emissions from the oil and gas industry in the world is 0.1%, the share of the Russian gas industry is 0.004%. This makes it possible to draw a conclusion about its insignificant influence, and the emissions of the Russian gas industry in the overall picture should be recognized as absolutely insignificant.

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