Current state and perspectives of the gas industry of Russia

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Abstract. The dynamics of energy consumption in the world market is analyzed. The natural gas demand growth forecast is provided. Gas will be the most crucial energy source in the next 30 years which can be considered to be the “era of gas”. It is shown that natural gas is a promising source of energy and raw materials of petrochemical chemistry. Unlike oil and coal, gas will have strengthened its position by increasing its share in the total balance of primary energy carriers from 22 to 24-26% by 2035. By the middle of the 21st century, its share will have been 25 -27% in the world and 56% in Russia. The use of natural and associated petroleum gas in Russia is compared with global trends. In Russia, the use of useful gas components does not meet potential capabilities of the raw material base and does not comply with the world practice. The rational use of hydrocarbons can be organized through the cooperation of gas processing. The backlog of Russian gas processing is described. Currently, global gas processing is in the GTL era. In order to increase the profitability of producing synthetic liquid hydrocarbons, a combination of existing and GTL enterprises is promising. Developments of Russian scientists and world experience allow us to create GTL-production in almost all developed regions of Russia. The conclusion about the possibility and necessity to develop GTL-production is drawn.

1. Introduction
Natural gas plays an important role in the global energy balance due to its environmental friendliness, economy and technological effectiveness. Compared to other mass energy resources (coal, oil), gas produces less harmful emissions, its reserves are significant, production and transportation are relatively cheap, and its processing into chemical products requires less expensive.

However, Russia, which is a powerful gas power with huge reserves of natural gases and gas condensates, does not use all the potential resources of the raw material base, and useful gas components are processed worse than in developed countries. There is an urgent need to formulate priority areas for increasing the efficiency of production and use of natural gas. It is relevant to carry out a scientific analysis of the gas industry by comparing it with global trends. The purpose of this study is to assess the current state of the gas industry in Russia and determine effective directions of processing natural and associated petroleum gases to produce valuable chemical products.

2. The role of natural gas in the fuel and energy industry
In the Russian economy, the fuel and energy complex (FEC) and exports of its products occupy a unique position, their dynamics affects the stability of the national economy. “Gas will be the most crucial energy source in the next 30 years which can be considered to be the “era of gas” [1].

The annual world energy consumption will grow by 1.3% in the next 20 years. Natural gas, unlike oil and coal, will strengthen its position by increasing its share in the total balance of primary energy carriers from 22 to 24-26% by 2035 [2]. By the middle of the 21st century, it could reach 25-27% in the world, and 56% in Russia. Until 2035, world gas consumption will continue to grow by 1.8% per year [1].

Data on world gas production for 2011-2017 (billion m$^3$) are given in Table 1.

According to the estimates of [4], in 2017 in Russia, natural gas production grew by 8.1% and reached 690.9 billion m$^3$, which was high for the post-Soviet period. In 2018, it was 727.6 billion m$^3$ [5], in 2019 - 739 billion m$^3$ [6] and increased by 1.8% compared to the previous year, which was facilitated by an increase in global demand and domestic consumption. About 13% or 95 billion m$^3$ fell to the share of petroleum gas.

An analysis of the data shows that Russia ranks second after the United States, which produced more than 1000 billion m$^3$ of marketable gas in 2019 [7].

Table 1. Data on gas production in the leading gas producing countries for 2011-2017 (billion m$^3$) (according to [3])

| Countries         | Years | 2011 |
|-------------------|-------|------|
| USA               |       | 648,5|
| Russia            |       | 607,0|
| Canada            |       | 144,4|
| Iran              |       | 159,9|
| Qatar             |       | 145,3|
| Norway            |       | 101,4|
| China             |       | 109,0|
| Saudi Arabia      |       | 92,3 |
| Other             |       | 1282,8|
| World gas production |     | 3290,2|

In Russia, current reserves of natural gas are 48.805 trillion m$^3$, and the volume of exploration of undeveloped raw materials is 24.6% [8]. The regional structure of gas production is presented in Table 2.

Table 2. The regional structure of gas production in Russia in 2018 (according to [9])

| Regions                        | Volume of gas extraction |
|--------------------------------|--------------------------|
| Yamal-Nenets Autonomous District | 591,2 81,2 |
| Khanty-Mansi Autonomous District | 34,9 4,8 |
| Sakhalin region                | 32,4 4,5 |
| Orenburg region                | 16,2 2,2 |
| Astrakhan region               | 14,2 2,0 |
| Krasnodr region                | 9,4 1,2 |
| Other                          | 30,1 4,1 |

The largest oil and gas company is Gazprom of Russia, which has the richest natural gas reserves (33.4 trillion m$^3$). Its share in the world gas reserves is 17%, in the Russian gas reserves - 72%. Gazprom accounts for 12% of global and 66% of Russian gas production. Currently, the company is
implementing large-scale projects for the development of gas resources of the Yamal Peninsula, the Arctic shelf, Eastern Siberia and the Far East, as well as a number of hydrocarbon exploration and production projects abroad [9]. Thus, the volumes of natural gas production in the world, including in Russia, tend to increase, which indicates the relevance of gas as a source of high-quality fuel and gas chemistry raw materials.

The situation with associated petroleum gas is somewhat more complicated. This is due to the fact that the resources of associated petroleum gas are more limited - they are determined by the scale of oil production and its low content in the oil produced. Accordingly, the gross volume of associated petroleum gas produced with oil is less by 10 times [10]. The energy costs of associated petroleum gas processing are significantly higher, since, unlike high-pressure natural gas, associated petroleum gas is released from oil at a low pressure. Associated petroleum gas is much more complicated than natural gas, which complicates the technology of its processing, but increases its value as a raw material.

3. Comparative analysis of the use of gas hydrocarbon feedstock for gas chemistry

In Russia, the use of useful gas components does not meet potential capabilities of the raw material base and comply with world trends. For example, over the past 25 years, gas condensate reserves have increased 100 times, and its extraction does not exceed 3-6 million tons per year [11].

The rational use of hydrocarbons can be organized through the cooperation of the gas processing and petrochemical industries [2, 5, 11, 12].

Modern large oil and gas companies have well-developed gas-chemical industries. The share of petrochemical products and profits of the largest oil and gas companies (Exxon Mobil, Shell, Total, etc.) are 8-10% of the total production [12].

The global petrochemical industries have different raw material orientations. Japan, South Korea, most European countries use liquid hydrocarbon feedstock, mainly straight-run gasoline fractions (naphtha). These countries cooperate in the oil refining and petrochemical industries. Other countries (USA, Canada, the Middle East, primarily Saudi Arabia, Venezuela) use gaseous raw materials (ethane, propane, butanes and other hydrocarbons). These countries are building cooperative ties between the gas processing and petrochemical industries. Some of these countries (e.g., the United States) produce ethane and other shale gas hydrocarbons. In the countries of the Middle East, gas condensate is used as a raw material [13, 14].

The problem of supply of Russian petrochemical and chemical industry enterprises with hydrocarbon raw materials can be solved by using natural and associated petroleum gases and gas condensates, which are not used rationally.

In the total volume of natural gas produced, methane is mainly used as furnace and household fuel. The share of ethane, propane, butanes and heavier hydrocarbons is much smaller [15].

Natural gas exported from Russia is processed into extract valuable hydrocarbons used to produce petrochemical products. The development of high-tech gas chemistry would make it possible to obtain high value-added products and increase export revenues, which is especially important in the conditions of instability of the world energy markets and relatively low prices for hydrocarbons.

For 2013, there is information on 2,000 gas processing plants and plants that process more than 4 billion m³ of gas per day [2]. The largest number of gas processing plants are located in the USA and Canada –700 and 979, respectively (with a total capacity of 840,2 and 554,0 billion m³ / year) [10], 36 gas processing enterprises are located in Russia, which is incommensurable with Russian reserves of natural and oil gas. Large gas processing facilities are located in Saudi Arabia, Mexico, Kuwait, Iran and other countries. In these countries, liquid products extracted from natural and associated gases are raw materials for the petrochemical industry [14].

Only 7.5% of natural gas is processed in Russia. IN 2005 in the USA, about 90% of natural gas was processed. Russia is losing at least 19–20 million tons of light hydrocarbons per year [16].

The unifying of oil and gas refining and petrochemical industries led to the creation of the largest centers for the production of petrochemical products (petrochemical clusters) in Texas and Louisiana.
In these states, there are 263 out of 700 American gas processing plants and 46% of gas processing capacities of the USA [15]. In the USA, small units of shallow gas processing are located at the fields preparing gas for transportation to large gas processing plants for subsequent deep processing [17].

In Russia, 0.4 million tons of ethane have been extracted from natural and associated petroleum gas, and in the United States, this volume is 9 million tons per year. In 1977, a 3,000-kilometer pipeline was built to transport ethane, ethylene, propane and butane from western Canada to the United States; ethane is used to produce ethylene, its production volume and consumption structure determine the level of development of the organic synthesis industry. About 65% of propane are produced from petroleum and natural gases, which are used as a pyrolysis feedstock. In addition to ethane and propane, n-butane, isobutane, n-pentane and isopentane are extracted from natural and petroleum gases, which are used in the production of many valuable products: synthetic rubber, communal butane and motor fuels. When cleaning and processing natural and associated gases, large quantities of cheap sulfur, helium and other inorganic products are produced. In the production of helium, the USA ranks first. Helium is used in space rocket technologies. Canada is the second largest sulfur producer in the world. For Russia, it is promising to extract helium from gas-helium raw materials of Eastern Siberia and Yakutia, which contain large amounts of helium - up to 1 percent or more [15].

Recently, the process of liquefying and transporting liquefied natural gas by water has been developing rapidly, which makes it accessible to almost any country in the world. It is expected that in the USA, an increase in imports of liquefied natural gas will increase 2-3 times [18-21].

The results of a comparative analysis of gas industries in different countries confirm that Russia lags in the gas processing.

Currently, global gas processing is at a stage called the “GTL era” (conversion of natural gas into higher hydrocarbons, fuels and chemical products).

The main products of the synthetic liquid fuel production are: high-quality environmentally friendly diesel fuel, which fully complies with Euro-5 requirements; synthetic light naphtha, which can be used as an environmentally friendly component of motor fuels (an analog of the straight-run gasoline fraction) and high-quality raw materials for petrochemical industries; synthetic oil (instead of synthetic motor fuels) [22, 23].

Currently, there are four large-tonnage GTL plants: Mossel Bay (South Africa); Bintulu (Malaysia); Oryx (Qatar); Pearl (Qatar). New GTL plants are going to be constructed in the future [24, 25].

Various foreign companies have created GTL pilot plants in the USA, Brazil, Great Britain, South Africa, and Japan. 55 projects of GTL technologies with a total capacity of about 2 million bar with a total gas consumption of 166 billion m$^3$/year are being implemented [26]. Technological solutions for producing liquid hydrocarbons from natural gas directly from synthesis gas according to the Fischer-Tropsch reaction and through the methanol production stage have been developed and implemented.

There is no similar production in Russia, and leading developments are mainly based on the use of the second variant of synthesis through methanol. However, the accumulated world experience allows us to create GTL-production in almost all developed regions of Russia.

According to experts of the All-Russian Scientific Research Institute of Natural Gases and Gas Technologies, the use of natural gas from remote fields by converting it to synthetic liquid fuels is a more promising area [27].

The creation of GTL-production in Russia is relevant for the following five reasons:
- oil independence of energy;
- GTL product - environmentally friendly fuel;
- GTL is an alternative way of exporting natural gas and pipeline independence;
- possibility of utilizing associated gas;
- profit from the production of synthetic fuels. In Russia, Gazprom, Rosneft and Lukoil officially announced plans to develop this new technology [25].
Over the past decade, a number of Russian energy companies (Gazprom PJSC, Irkutsk Oil Company LLC, etc.) have evaluated the possibilities of creating large-capacity GTL plants in Russia using the technologies of Western companies (Shell, Japan GTL, Syntroleum) [24, 28]. However, due to the calculated risks of the GTL business, plans to build Russian plants have not been implemented.

Currently, there are a number of innovative organizations in Russia: LLC Gazohim Techno, LLC Energosynotop-Engineering, LLC Infratechnologies, Institute of Petrochemical Synthesis of the Russian Academy of Sciences, LLC CITIS, etc. GTL technologies are being developed, but most of the projects are at the stages of theoretical development or pilot implementation and require additional research [28-34].

In order to increase the profitability of producing synthetic liquid hydrocarbons, it is necessary to unite existing enterprises and new GTL ones.

On the basis of Novokuybyshevsk Oil Refinery of Rosneft, a pilot industrial unit for the production of synthetic oil is going to be launched for the first time. The plant capacity will be 300 tons of synthetic hydrocarbons per year. It is planned to use the technology for converting natural and associated petroleum gas into high-quality synthetic liquid and solid hydrocarbons by the Fischer-Tropsch technology.

Novomoskovsk Institute of Nitrogen Industry began to manufacture plants for the production of methanol from gas. In 2010, Russia's first pilot plant for producing methanol from natural gas with a capacity of 40 thousand tons per year was installed at the Yurkharovskoye gas condensate field in Western Siberia [32].

The GTL industry can be considered in two key aspects: large-capacity and small-capacity production. Given the capital intensity and risks of GTL large-scale production, as well as its competition with LNG projects and gas pipeline transport, small-scale production is a promising direction for the GTL industry. In this area, GTL micro- and minichannel technologies, which have been developed in recent years [35], are of interest.

Thus, in Russia there is no industrial GTL production, and developments of Russian scientists and accumulated world experience allow us to create GTL production industries in almost all developed regions of Russia.

4. Conclusion
It is important for Russia to choose industrial development areas where it has competitive advantages and potential and natural prerequisites for the innovative development. This potential exists in the gas industry, since Russia has the largest world reserves of natural gas. However, the use of useful components of natural and associated gas does not meet potential capabilities of the raw material base and does not comply with the world trends. At the same time, world experience shows the effectiveness of small installations for shallow gas processing directly at the fields, preparing it for transportation to large gas processing plants for subsequent processing.

Developed and implemented technological solutions for the production of liquid hydrocarbons from natural gas will allow the use of gas from remote fields through its conversion and solve the problem of reliable supply of petrochemical and chemical industries with hydrocarbon raw materials. To do this, it is advisable to develop a GTL-production industry in Russia and combine it with gas processing enterprises. These are an alternative way of exporting natural gas, pipeline independence and a possibility of utilizing associated gas from oil production.

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