Strategy for the Energy Transition to a Carbon-free Economy: Real Opportunities and Prospects

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Abstract: The topical issues of the Russian economy development focused on the prospect of producing new types of energy resources and new types of «green» fuel for eco-transportation, providing the highest environmental standards, have been considered. The program «Carbon-free economy-2030» adopted by the European Union, according to which hydrocarbon fuel is supposed to be abandoned by 2036, has been analysed from the standpoint of challenges for the Russian economy and determining the strategic prospects for its development. Russia has chances to become a leader of the «blue hydrogen» market, and in the top five countries developing the production of eco-fuel, Russia is not in the last positions. The main requirement for the realization of opportunities for the Russian economy are overcoming the stereotype of a resource power and taking a course towards the development of innovative «green» technologies. The Khanty-Mansi Autonomous Okrug - Yugra, the Far East, the Leningrad Region and the Republic of Tatarstan can become promising regions for the implementation of the «carbon-free economy» strategy as regions with high-tech industries, technological capabilities and a unique base for the effective development of new production complexes and ecosystems.

1 INTRODUCTION

The environmental problems of modern reality, which include such systemic areas as the conservation and management of ecosystems on the efficiency principles, environment cleanliness, improvement of the water resources management at the system level, introduction of the renewable energy sources and etc., currently remain relevant. A lot of resources of the world advanced countries are aimed at solving these problems. Global warming, abnormally warm winters in the northern part of the globe and abnormally hot summer months in the equatorial parts of the globe, the huge atmospheric concentration of carbon dioxide and associated with it tsunami have become increasingly threatening to civilization. In most cases this is due to the high concentration of carbon dioxide in the atmosphere that prevents the cyclical exchange of air masses. During the World Climate Forum in Glasgow the ESG concept and the energy transition strategy were adopted. In essence, ESG is a new concept that reflects the three main principles of modern companies: environmental principles, social responsibility principles and management efficiency principles. The energy transition is a strategy the content of which is the transition to carbon-free renewable energy sources. This strategy formed the basis of the “Carbon-Free Economy” program adopted by the European Union, which is focused on abandoning hydrocarbon fuels by 2036 (Kaveshnikov, 2014).

For Russia, as the largest producer of carbon-based energy resources, this is both a serious challenge and great opportunities.

So, for example, a new energy carrier «blue hydrogen», which does not leave a carbon footprint, can become an alternative energy carrier. In the coming years, the global blue hydrogen market will reach about $2.5 billion. The top five countries developing the production of "blue hydrogen" include

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Russia that has every chance of becoming a leader in it.

Nowadays, the demand for hydrogen reaches 70 million tons per year. The main raw material component in the production of hydrogen is natural gas used in the technological process of the methane conversion vapor phase. This technology is applied to the production of ammonia and methanol. Annually, 205 billion cubic meters are spent on hydrogen production. Most enterprises that use hydrogen produce it themselves using specialized facilities. It should be noted that hydrogen is not an energy resource and therefore there is no global market for its production. However, it is important to note that hydrogen is a secondary energy carrier, and its production will require additional energy costs that will certainly affect the growth of costs and prime cost. The main areas of hydrogen application are transportation and energy. According to Hydrogen Consulting (Association of Hydrogen Producers), the share of hydrogen in the global energy market by 2050 will be up to 25% (Grib, www.ngv.ru).

Global environmental problems have many directions for their solution. Equally important of these are the problems associated with greenhouse gases destroying the Earth's ozone layer that can lead to catastrophic consequences. In this regard, another direction of the systemic approach of the «green» economy is the comprehensive development of «clean» transportation (Aniskov, plus-one.ru).

Thus, in modern conditions, the strategic issues of unlocking the potential of the Russian economy and its development in the direction of creating a carbon-free economy with the prospect of switching to the production of a new energy carrier and eco-transport are being updated.

2 MATERIALS AND METHODS (MODEL)

In the course of the study, methods of statistical analysis, economic and mathematical modeling, analysis and synthesis tools have been used. At the system level using the materials of the State Statistics Committee of the Russian Federation, the Republic of Tatarstan and other Internet materials, an analysis has been made of the opportunities and prospects for the development of a carbon-free economy in two directions: the development of hydrogen energy and the development of the Russian automotive industry using environmentally friendly fuel and vehicles from the standpoint of eliminating emissions into the atmosphere. The prospects for the development of a carbon-free economy are dictated by time and the speedy solution of global environmental problems.

3 RESULTS AND DISCUSSION

The European Commission, which published its strategy for the development of hydrogen energy resources [Building a hydrogen economy for a climate-neutral Europe] in July 2020, announced the creation of the Clean Hydrogen Alliance. The presented strategy outlines the main stages and directions for the hydrogen energy development (European Commission, ec.europa.eu).

If we return to the origins, there are three types of hydrogen: «gray», «blue» and «green». This is the same hydrogen, the difference lies only in the production methods.

Coal is the main raw material for producing «gray» hydrogen. However, its production doesn't use technologies for capturing or storing carbon dioxide generated during the production process, that is, it doesn't use effective encapsulation methods, and, as a result, carbon dioxide enters the atmosphere and pollutes it.

Methane is used in the production of «blue» hydrogen. However, this production method has not found wide application due to the explosive nature of the raw material, but remains promising for the industrial hydrogen production.

The safest and most common method for producing hydrogen is water electrolysis. This method produces «yellow» and «green» hydrogen. But even here there are subtleties, for example, in the case of «yellow» hydrogen, nuclear energy serves as an energy source, and in the case of «green» hydrogen, energy obtained from renewable sources, that is, from sources of recycled energy.

According to the strategy for the development of hydrogen energy resources, at the first stage, by 2024, it is planned to reach the goal of producing one million tons of renewable hydrogen using an electro laser with a capacity of at least 6 GW. At the second stage, from 2025 to 2030, it is planned to increase productivity to 10 million tons per year using a capacity of 40 GW. According to the German hydrogen strategy, the demand for hydrogen will increase to 100 TWh, of which 14 TWh (about 0.4 million tons) is planned to be produced by the electrolysis, and the rest (76 TWh) is proposed to be produced from natural gas. The main consumer of German hydrogen will be the metallurgical industry with demand up to 10 TWh by 2030 and up to 80

TWh by 2050. «Thyssenkrupp Steel Europe» company in January 2021 published a feasibility study on the possibility of providing a steel-casting factory with hydrogen generation based on blue hydrogen. The generation price will be 58 EUR/MWh (BMWi, www.bmwi.de).

The main indicator that determines the economic feasibility of the technology for the production of «blue hydrogen» is the cost of its production.

Let's conduct an expert assessment of the cost of «blue» hydrogen according to the formula (1):

$$(Цact•Qact)/P + CsQact + Qen•Цen = Цav \quad (1)$$

where: P – density ≈ from 1.5 $/kg to 2 $/kg

The mass of 1 litre of hydrogen or hydrogen vapor at a temperature of 0 degrees C and a pressure of 760 mm. = 0.1 kg ⇒ production cost of 1 litre of hydrogen = 0.2 $. This indicator convincingly proves the economic feasibility of the production of «blue» hydrogen in Russia.

Today, hydrogen energy is actively developing in five countries of the world, which include, first of all, The UK, Germany, the USA, and China. Russia closes the top five countries developing the production of blue hydrogen. The cost of yellow hydrogen (the least environmentally friendly) in Germany is 9.50€ ≈ 11.21$.

Today, the global hydrogen market is 1.8 trillion euros, and in the coming years it will reach 2.5 trillion euros. According to the optimistic assessment scenario of the Hydrogen Council (an association of large international companies, which includes Total, Toyota, BP, Shell and other corporations, mainly European and Japanese), in 2050 the share of hydrogen in energy consumption will be 18%.

Summing up, we can say that Russia has every chance to take a leading position in the «blue hydrogen» market, having raw materials for this.

Let's consider the features and prospects of hydrogen energy in Russia and its regions, especially in those regions where high-tech industries are concentrated, there are technological capabilities and a unique base for the effective development of new production complexes and systems (Strekalova, 2020).

In connection with the global trend towards ESG, as well as the global change in demand from the main Russian importers of energy resources - the European Union, the Russian Federation has put forward its strategy until 2035 - «Energy Strategy of the Russian Federation - 2035». The strategy considers Russia's global energy transition and its role in this process. According to the strategy, already in 2014, the Russian Federation was able to export 200 thousand tons of hydrogen energy, and by 2035 it is able to increase the export volume to the level of 2000 thousand tons of hydrogen energy. In the domestic market, hydrogen consumers will be environmentally friendly vehicles, including hydrogen cars, electric vehicles and many other companies that have adopted the ESG strategy. The development of production chains of hydrogen energy provides for the creation of «hydrogen clusters».

Three regions of Russia expressed interest in the hydrogen production: the Khanty-Mansi Autonomous Okrug - Yugra (KhMAO-Yugra), the Far East and the Leningrad Region.

There are two gas processing plants in Khanty-Mansi Autonomous Okrug - Yugra: Balyksky (Sibur) and Yuzhno-Priobsky (Gazprom). Both of these plants underwent modernization in 2020. In Khanty-Mansi Autonomous Okrug - Yugra, 40% of all Russian oil is produced by the three largest energy companies in Russia: Rosneft, Lukoil and Gazpromneft. Until recently, oil itself was the main extracted raw material, but recently the production of associated raw materials (associated petroleum gas) has begun. In addition, in Siberia, of which Yugra is an integral part, the main production of natural gas is carried out. The combination of these factors makes the region very convenient for creating a hydrogen production plant in it. Technically, this can be done on the basis of two gas processing plants, and in the future, ready-made hydrogen will be delivered to the consumer through pipelines. The construction of gas pipelines is similar in cost to the construction of a hydrogen pipeline, that is, it is possible to create a production cluster almost directly on the production site.

The second promising region for creating a hydrogen cluster is the Far East.

The convenience of this region lies in the fact that there are two large industrial countries next to it - Japan and China with a huge consumer market.

The third promising region is the Leningrad region. A huge gas cluster, which combines gas processing, gas chemistry and natural gas liquefaction, has been built in the Leningrad Region in Ust-Luga. This region is promising both in terms of the existing infrastructure and in terms of consumers.

Firstly, the hydrogen production in this region can cover with its products the two most densely populated districts of our country - the North-Western and Central, as well as the two largest metropolitan areas - St. Petersburg and Moscow.

Secondly, a large volume of industrial production is concentrated in St. Petersburg, as well as large financial and exchange organizations, such as VTB, the St. Petersburg Stock Exchange, which indicates a large number of people with an income above the average (population - 5,376,672 people, regional gross product - 4.478 trillion rubles). The average salary, according to Rosstat, is 61,572 rubles. There are more than 60 higher educational institutions in the city, which testifies to the high level of people education. At the same time, the ecological situation in the city, as in any metropolis, is not the most favorable; there is a large number of emissions of harmful substances into the atmosphere, soil and hydrosphere (Rosstat, petrostat.gks.ru).

The situation is similar in Moscow. The population of Moscow is 12 632 409 people, the gross regional product is 20000,5 billion rubles. There are 118 universities in Moscow that also indicates a large number of educated people and, like in St. Petersburg, there are many environmental problems. The combination of these factors gives reason to believe that the popularity of environmentally friendly cars will be high, and the Russian government is already creating conditions for this. The development strategy published by the government states that from 2030, every fifth imported car in Russia must be environmentally friendly (N 1523-p, 2020).

Among the promising regions, in addition to those listed, are Tatarstan.

The Republic of Tatarstan has the most diversified economy - the petrochemical industry, mechanical engineering, agriculture, information and telecommunication hubs - this is not a complete list of industries that the Republic has and in which it occupies a leading position in Russia. The petrochemical complex is represented by a full cycle - from production to processing. The basis of the republic's oil refining is the Taneco plant in Nizhnekamsk, which is a petrochemical cluster that produces gasoline of all grades, aviation fuel, sulfur, petroleum coke and many other products. In July 2021, the launch of new technological units took place: gas fractionation, catalytic isodewaxing of diesel fuel, the second delayed coking unit in a row, which gives huge advantages in creating a hydrogen cluster and switching to ecological fuel in Tatarstan.

Looking ahead, we note that there are two main types of electric vehicles: charging directly from the grid and using hydrogen as fuel. The plug-in electric car runs on large on-board batteries, while Tesla's most advanced electric car currently charges in about 6 hours to a full charge (with the right infrastructure in place). The device of a hydrogen electric car is in many ways similar to the device of a standard electric car: the same engine is of an electric type, but the engine battery is powered not from the grid, but from hydrogen released as a result of a chemical reaction. Hydrogen filling stations can potentially be created on the basis of Tatneft's infrastructure, which has a developed grid of filling stations in the Republic. However, this will require the development of appropriate projects focused on ensuring the safety of transportation and storage of hydrogen fuel, since it is explosive. If we consider from a technological point of view the reality of obtaining any of the listed hydrogens, then the most promising for Russian practice is «blue» hydrogen from methane. A successful solution to the production of «blue» hydrogen will require the development of technologies and the choice of the most efficient and less costly alternatives. There are gas processing plants in Russia, for which a decision can be made regarding the organization of the production of «blue» hydrogen. The most profitable option is a gas processing plant in the Khanty-Mansi Autonomous Okrug. The advantage of these plants is that associated petroleum gas is also formed during oil production. It is from associated petroleum gas that hydrogen can be produced and delivered directly through pipelines to distribution grids, including export to other countries.

The Republic of Tatarstan is the best region to start the energy transition process in Russia. The average salary in Tatarstan is 31,543 rubles, the GRP of Tatarstan for 2020 amounted to 2.4 trillion rubles. There are more than 60 universities in the Republic, which indicates the education of the population, but most importantly, the leadership of the Republic supports the trend towards environmental education of residents, especially children. The Ministry of Ecology of the Tatarstan Republic has created such projects as «It will be Clean», which is aimed at attracting young people to study the environmental problems of their native land, environmental clean-up days are held, residents take an active part in environmental reviews of any major project in the Republic. Nowadays, electric cars can already be seen on the roads of Kazan that indicates the desire of residents to purchase environmentally friendly cars (tatstat.gks.ru).

Let's consider a possible transition of the Russian automotive industry to an electric car that is environmentally friendly in terms of eliminating emissions into the atmosphere and dwell on its advantages from an economic point of view. Let's use the Avtostat data, according to which the average car

mileage per year in Russia is about 18.000 kilometers ("Avtostat", www.autostat.ru).

Let's carry out a comparative analysis on the example of two vehicles of the same manufacturer: Nissan Note (gasoline) and Nissan Leaf (electric car) according to the maximum similarity of objects.

A car with a gasoline engine in the urban cycle consumes approximately 8.8 litres of gasoline per 100 kilometers. With the cost of gasoline on average 60 rubles per litre, the cost of refueling per year will be: $8.8 \cdot (18{,}000 / 100) \cdot 60 = 95{,}040$ rubles.

An electric car consumes approximately 35 kWh of electricity per 120 km in buildup areas, that is, in this scenario, the average consumption of "eco-fuel" will be 42 kWh per 100 km. Taking into account the cost of a kilowatt of electricity in Kazan equal to 4.11 rubles, the cost of charging an electric car per year will be: $42 \cdot 180 \cdot 4.11 = 31071.6$ rubles.

The difference of 63,968.4 rubles testifies in favor of an electric car, refueling of which, all other things being equal, is 3 times cheaper. Of course, the calculations are preliminary, and if we took them into account, we would have switched to the production and operation of electric cars as an environmentally friendly mode of transport long ago. The following figures can be added: CO2 emissions from an electric car will be 2 times lower than from a gasoline car after 200 thousand km of run (Maltseva, www.vedomosti.ru).

Thus, in terms of cost, an electric car is preferable to a car with a gasoline engine.

Other benefits of an electric vehicle include:

- Safety for the environment: zero exhaust means that the surrounding air is not polluted by exhaust gases and becomes cleaner;
- The noise level is minimal: an electric car produces much less noise than a conventional car and it becomes more comfortable to live in densely populated cities;
- Repair and maintenance of electric cars are less labor-intensive, cheaper and take less time;
- Safety: the center of gravity of the electric car is shifted down to where the battery is located, electric cars are more stable and better controlled during sharp maneuvers.

Of these advantages, one question arises, why, with such advantages, the conditions for replacing gasoline cars with eco-cars have not yet been created?

Let's dwell on a number of disadvantages of electric vehicles:

- The power reserve before recharging is limited: an average of 210 - 260 kilometers, which indicates the priority of using only within the city. Of course, there are models such as the Tesla Model S and Jaguar F-Pace with more than 550 kilometers on a single charge, but this is still not enough;
- High cost: even the average budget version of an electric car has a cost equal to 2.3-2.5 million rubles, which is 1.5-2 times higher than the cost of inexpensive Japanese-made cars with a gasoline engine;
- Dependence on the ambient temperature: the battery capacity decreases when the ambient temperature changes, for example, at an air temperature of 5 °C, the battery capacity decreases by 20%, at -5 °C the decrease is 35–40%, and at -12 °C by 50%. For the Russian automotive industry this indicator is important, since low temperatures in Russia are observed for about seven months;
- Optimization of the microclimate in the cabin: the air conditioning and heating are powered by a battery that reduces its capacity. By optimizing the microclimate in the cabin, battery consumption increases that leads to a decrease in the power reserve by 20-25%.

There are also problems associated with the production of electric batteries, which is quite environmentally unsafe and economically expensive, but the decision whether or not to be a «people's» electric car depends not only on economic feasibility, but also on the creation of decent living conditions and the quality of life for the planet's population as well.

4 CONCLUSIONS

1. Environmental problems are forcing humanity to switch to new types of energy resources, to radically reduce harmful emissions into the atmosphere. Today, hydrogen energy is becoming a reality and one of the promising areas for the development of a carbon-free economy. The global hydrogen market today is 1.8 trillion euros, in the long term it will reach the level of 2.5 trillion euros. According to the optimistic assessment scenario, the share of hydrogen in energy consumption will be 18% in 2050. The cost of hydrogen production according to preliminary calculations ranges from $1.5 to $2 per kilogram. This indicator convincingly proves the economic feasibility of the production of «blue» hydrogen in Russia, which has every chance of taking a leading position in the «blue hydrogen» market, having raw materials for this.
2. Russia has the necessary opportunities and conditions: a resource base, a developed fuel

and energy complex, a large number of specialists in order to take a leading position in this direction, despite geopolitical difficulties. The Khanty-Mansi Autonomous Okrug - Yugra, the Far East, the Leningrad Region and the Republic of Tatarstan can become promising regions for the implementation of the «carbon-free economy» strategy as regions, which have high-tech industries, technological capabilities and a unique base for the effective development of new production complexes and ecosystems.

3. Most of the emissions are produced by road transport, in this regard it is necessary to develop manufacturing related to the production of electric vehicles both on electric and hydrogen fuels, especially there are examples of advanced industrial countries that create conditions for the production and transition to environmentally friendly fuel, including hydrogen. According to preliminary calculations, refueling an electric car costs three times less than a car with a gasoline engine, CO2 emissions from eco-transport are 2 times lower than from a gasoline car after a run of 200,000 km, all other things being equal, which indicates the prospects for the development of environmentally friendly vehicles on «green» fuel.

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