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Hydrogen Economy as a Driver of Synergetic Technological Development: Policy and Application Evidence from Russia

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ABSTRACT

Hydrogen energy is still at an early stage of development: Nevertheless, national and international strategies are used to boost its development by all kinds of incentives, subsidies, tax instruments and R&D financing of pilot projects in order to achieve the main goals: Decarbonization of the energy sector, ensuring the reliability of supply of energy systems. The technical capabilities of decarbonization are still coexisting with high production costs, difficulties in storing and delivering hydrogen to consumers. Shift to hydrogen economy is not possible without thorough consideration of policies at different levels as well as technological advances. In this article the author analyses current situation of Russian hydrogen economics from strategic and technological point of view. The main agenda-setting documents and contributors in the field of technical deployment of hydrogen projects have been analyzed by applying content-analysis. Main policy implications and recommendations have also been given.

Keywords: Hydrogen, Hydrogen Economy, Hydrogen Energy, Hydrogen Policy, Russia
JEL Classifications: Q4, Q42, O14

1. INTRODUCTION

Reducing the greenhouse effect has become one of the highlights of the global energy agenda, if not the most important. Thus, in order to hold back the rise of global average temperature below 2°C compared to pre-industrial level, the 2015 Paris Agreement suggests a reduction in total emissions to zero between 2045 and 2060. The document has been ratified in 174 countries. However, industrial markets are experiencing extended political pressure today, pushing for the earliest possible achievement of the environmental objectives (United Nations, 2015).

In 2017, as a result of titanic efforts and colossal capital investments, it was possible to increase the share of renewable electricity in the energy sector to 25%, but this success did not practically affect the amount of carbon dioxide emissions in the world (Balashova et al., 2020). This is because energy is responsible for only 40% of global CO_2 emissions, while reducing the remaining 60% is a commitment from other sectors, mainly transport, construction, industry and utilities. In fact, greenhouse gas pollution is increasing every year, with a record 1.7% increase in emissions in 2018 (Falcone et al., 2021).

In a resource-based economy based on fossil fuels, decarbonization of industry sectors, energy, heat power, gas production and transport, as a rule, are preceded as separate processes. In order to achieve zero CO_2 emissions by the middle of the XXI century, it is necessary to accomplish mutual integration of these industries, which will allow the energy sector to supply them with clean energy, without which the transition to a carbon-free business model is impossible. The synergetic (co-directed) development of technologies is becoming more important due to the continuous increase of the installed capacity of green power plants (Iosifov, 2016).

2. HYDROGEN ENABLING TECHNOLOGIES

In light of the above, research aimed at finding opportunities to maximize positive economic effects of carbon-free technologies development, in particular, due to their synergistic development, becomes relevant. Synergetic development of two technologies is a state of socio-technical system, when the development of one technology creates technical, infrastructural, economic and/or social conditions favorable to the development of other technologies (Iosifov and Ratner, 2020). In such situations, government support for the development of the first technology indirectly stimulates the development of another, co-directed technology, which can significantly reduce the required funding for the development of carbon-free technologies in general.

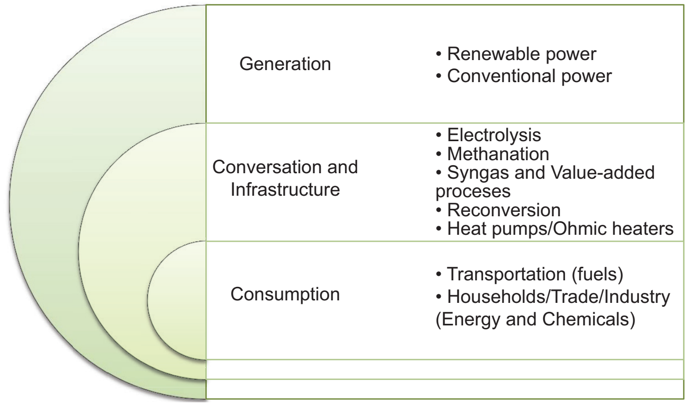
One of the promising examples of a natural development of dependent technologies within hydrogen economy is Power-to-X. According to IRENA, "Power-to-X technologies are able to address the short-term variability of renewable energy generation and also can help address seasonal variability, providing the option to store energy over longer periods of time. The process of converting the power generated from solar and wind sources to different types of energy carriers for use across multiple sectors, or to be reconverted back into power, has the potential to greatly increase the flexibility of the power grid." Solution XI: Power-to-X solutions, 2021. Combined power and heat production based on CCGT (closed-cycle gas turbine) has been successfully used for many decades due to the maximum efficiency and coefficient of fossil fuels. The technology for converting electricity to heat (Power-to-Heat) using heat pumps or heating rods is innovative and environmentally friendly way to heat buildings and even provide industrial plants with process heat. Today, electric transport, which provides the direct consumption of electrical energy from batteries, is receiving support in various countries. But electric drive is hardly worth considering as a viable solution for long-haul freight transport by land, sea and air. In this case, instead of fossil fuels, it is necessary to actively introduce an energy-intensive synthetic fuel called e-Fuel, produced on the basis of electricity from renewable sources (Iosifov and Ratner, 2020). These fuels are similar to conventional fuels and can be mixed with them to gradually reduce the carbon content of the fuel mixture without the need to replace a vehicle or refueling infrastructure (Ratner et al., 2019; Chehade e al., 2019; Chukwudi and Nnabuife, 2021). Thus, the transition to a carbon-free economy can be accomplished without spikes and shocks, while reducing emissions at the same time. General description of Power-to X technologies is presented in Figure 1.

Integration and sustainable utilization of a complex of hydrogen-based technologies tightly align with well-timed deployment of policies and strategies at different level.

3. STRATEGIC GUIDELINES FOR THE DEVELOPMENT OF HYDROGEN TECHNOLOGIES

According to the IEA, the number of measures aimed at stimulating hydrogen technologies and the number of sectors that they cover

Figure 1: Power-to-X technologies application



Source: Turbomachinery International, 2021

are increasing. As of 2018, there were about 50 measures in the world that directly support the energy use of hydrogen - mainly in transport (passenger transport, refueling infrastructure, buses, and freight transport). In 2019-2020, there is a shift in the emphasis of state policy from individual measures to comprehensive strategies for the development of hydrogen energy. It reflects the renewed interest in the simultaneous disclosure of the potential of hydrogen in various sectors of the economy: Not only in transport, but also in industry, heat and power engineering, etc. (IEA, 2021).

Japan was the first country to formulate its own national hydrogen strategy. Its strategy emerged in December 2017, followed in 2019 by the Strategic Roadmap for Hydrogen and Fuel Cells. In 2019, the Republic of Korea disclosed strategic plans for the development of hydrogen. The views of these largest developed importers of energy resources in the APR on the role of hydrogen are similar:Increasing energy security through diversifying energy sources, focusing on hydrogen imports, developing technologies for export, and fulfilling climate obligations (Table 1).

In the context of the crisis associated with the spread of Covid-19, it is important not to miss the moment to promote hydrogen technologies and not to reduce support. The growing number of hydrogen strategies (at least in the European region) makes it possible to expect that hydrogen technologies will continue to develop dynamically. In particular, the strategy of the Netherlands was approved in March 2020, Germany and Norway in June, Portugal and the EU as a whole in July, and France's strategy followed in September. It is noteworthy that European strategies (for example, Germany and France) are presented in the context of plans for economic recovery (Brada et al., 2021).

4. HYDROGEN TECHNOLOGIES IN RUSSIA: POLICY STATE-OF-ART

Interest for the development of hydrogen energy in Russia is growing. As declared in the Energy Strategy of the Russian Federation for the period up to 2035, hydrogen energy is designated as one of the promising areas of energy development (Energy Strategy of the Russian Federation up to 2035, 2020). In October 2020, an action plan ("roadmap") of hydrogen energy development in the Russian Federation until 2024 was approved,

Table 1: Comparative analysis of existing hydrogen strategies

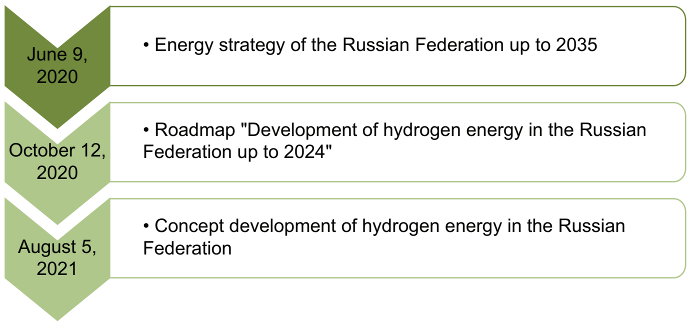
Country	Strategy title/key landmarks	Funding	Management
Japan	*2017 Basic Hydrogen Strategy* • Achievement of a "hydrogen society" to improve energy security and decarbonization • Focus on hydrogen import (with an emphasis on "green" hydrogen after 2040) • Primary use in the electric power industry • -Development of export of fuel cell vehicles (e.g. Toyota)	USD 664 million in FY2020	Ministerial Council on RES, Hydrogen and Related Matters
South Korea	*2019 Hydrogen Economy Roadmap and 2019 National Hydrogen Technology Roadmap* • Leadership in the production of fuel cells for cars and power plants • Focus on the import of hydrogen • - Development of the export of fuel cell vehicles (for example, Hyundai) and fuel cells for power plants	2.6 trillion won (US $2.2 billion) in industrial ecosystem for hydrogen cars by 2022	Ministry of Trade and Energy, H2KOREA - public-private partnership
Australia	*2019 National Hydrogen Strategy* • Development of the export direction • Creation of hydrogen energy supply chains based on solar, wind and water energy and large-scale export-oriented production infrastructure and the use of CCS to obtain low-carbon hydrogen from fossil resources	US $297 million at various levels of government in 2015-2019 with an emphasis on R&D, demonstration and pilot projects	Australian Hydrogen Council, uniting representatives of the fuel and energy complex, transport, consulting and innovation - with the support of the Government of Australia
EU	2020 Hydrogen Strategy for Climate Neutral Europe • Achieve climate neutrality and zero pollution • Use hydrogen from wind and solar energy	€145 billion ($170 billion) by 2030 in grants and subsidies	European Alliance for Clean Hydrogen, including representatives of government, business and civil society
Germany	*2020 National Hydrogen Strategy* • Achieve climate neutrality • Focus on imports and domestic production of "green" hydrogen • Main application in transport and industry • Development of Power-to-X technologies	€1.4 billion ($1.7 billion) in 2016-2026 for innovation; 1.1 billion euros (1.3 billion US dollars) in 2020-2023 for R&D and technology transfer; € 9 billion (US $ 10.6 billion) - Recovery Plan	State Committee for Hydrogen; Government Hydrogen Coordination Office; National Hydrogen Council
France	*2020 National Strategy for the Development of Pure Hydrogen* • Achieve Climate Neutrality • Expansion of Electrolysis Capacities and Domestic Production of Green Hydrogen • Main Application in Transport and Industry	€ 7.2 billion ($ 8.5 billion) by 2030 - Recovery plan	National Committee for Hydrogen; French Association for Hydrogen and Fuel Cells
The Netherlands	*2020 State Hydrogen Strategy* • Achievement of climate neutrality • Expansion of electrolysis capacities and internal production of "green" hydrogen, incl. using CCS • Strengthening the role of the energy hub	35 million euros (41 million USD) annually from 2021 for green hydrogen	Government
Portugal	*2020 National Hydrogen Strategy* • Achieve Climate Neutrality	7 billion euros (8.3 billion US dollars) by 2030 - investment	Government
Norway	*2020 Hydrogen Strategy* • Achievement of climate neutrality • Expansion of electrolysis capacities and internal production of "green" hydrogen, incl. using CCS • Main application in transport and industry	NOK 120 Million (USD 13 Billion) - Recovery Plan	Government

Source: Adapted from (Hydrogen Energy-Energy Bulletin #89, 2020)

which provides the improvement of the regulatory framework, the formation and implementation of measures of state support for projects in the field of hydrogen energy, strengthening the positions of Russian companies in the hydrogen sales markets and conducting R&D (Roadmap, 2021). With the participation of Rosatom State Corporation and Gazprom, it is planned to implement a number of pilot projects, including the creation of pilot plants for low-carbon hydrogen production, the development and testing of gas turbines running on methane-hydrogen fuel, the creation of a prototype railway transport using hydrogen, and the production of hydrogen on the basis of a nuclear power plant. According to the Roadmap, in August 2021, a Concept for the development of hydrogen energy in the Russian Federation was designed, in which, according to the Ministry of Energy of Russia, priorities for the development of hydrogen energy in the country should be formulated in the short, medium and long term. The timeline of current governing strategic documents is presented in the Figure 2.

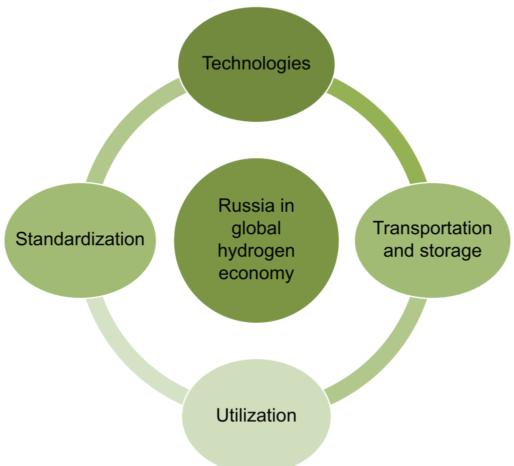
The possibilities of hydrogen energy development in Russia are mainly associated with the export of hydrogen, which is reflected in Energy Strategy-2035 (ES-2035) and Roadmap. Concept development of hydrogen energy in the Russian Federation sets the task of joining Russia among the world leaders in the export

Figure 2: Strategic hydrogen economy documents timeline



Source: Authoring

Figure 3: Focus areas of Russian hydrogen development



Source: Adapted from (Skolkovo, 2019)

of hydrogen and sets the corresponding targets: 0.2 million tons in 2024, 2-12 million tons in 2035 and 15-50 million tons in 2050. The export orientation of hydrogen energy in Russia is associated with competitive advantages. First, it is a geographical proximity to potential hydrogen sales markets (Asia-Pacific and EU-countries). Second, large reserves of resources (gas, coal and water), a significant reserve of generating capacities in the Unified Energy System of Russia and a huge potential in the field of green energy make it possible to develop hydrogen production in Russia by various methods (steam reforming of methane, incl. combination with carbon capture and storage technologies (CCS); electrolysis, including energy production from renewable energy sources and nuclear power plants).

Russian Ministry of Energy estimates the potential for hydrogen production in Russia only by loading unused reserve generating capacities at 3.5 million tons (capacity reserve - 45 GW, ICUF - 40%), the CSR Fund - 5-6 million tons (reserve capacities - 45 GW, ICUF - 70-80%), Infrastructure Center EnergyNet - 1.9-3.5 million tons (with ICUF 46-85%) (Prospects for Russia in the global hydrogen fuel market, 2018). This will make it possible to increase the efficiency of capacities use in Russian electric power industry. Decarbonization and energy transition in potential sales markets will form certain requirements for the export of hydrogen from Russia (in particular, in the EU Hydrogen Strategy, priority is given to "green" hydrogen produced using renewable energy). In this regard, Russia is interested in the production of "carbon-free" or "carbon-neutral" hydrogen based on electricity from hydroelectric power plants, nuclear power plants, renewable energy sources and traditional energy sources in combination with CCS technologies. However, due to the insignificant capacities of renewable energy sources and the relatively high present value of electricity production (LCoE), the production of "green" hydrogen in Russia in the near future will not be widespread. Thirdly, it is the existing gas transportation infrastructure in Russia and the growing liquid gas industry, which create preconditions for the development of hydrogen production from natural gas and its export via pipelines and in a liquefied form. At the current stage, mixing hydrogen with natural gas in main gas pipelines is difficult (due to the lower permissible level of hydrogen concentration in the mixture for industrial consumers). However, such pilot projects are being implemented in the world, in particular, the Italian company Snam has proven the technical feasibility of mixing up to 10% hydrogen into main gas pipelines. At the same time, according to Gazprom Export estimates, hydrogen supplies via export gas pipelines entail risks of violation of long-term contractual obligations for gas quality and the need for additional investments in the gas transportation infrastructure, in connection with which the company is considering an alternative - the production of hydrogen from natural gas after its transportation through the main gas pipeline using the methane cracking method. Along with the export direction, hydrogen energy demonstrates possibilities of development within the country. Firstly, it is the ability to reduce emissions of pollutants into the atmosphere, primarily from transport, which is important primarily for large cities. However, hydrogen will have to compete with natural gas vehicles and electric vehicles based on lithium batteries. ES-2035 considers transport as one of the priority directions for using hydrogen in the domestic market. Secondly, it is the provision of energy supply to isolated and remote territories. The power industry in mentioned territories in Russia is characterized by costs increase and cost of electricity due to the obsolescence of equipment and technologies and an increase in prices for imported fuel. The solution to the problem can be a partial replacement of energy capacities (diesel power plants) with energy facilities based on renewable energy sources and small nuclear energy. However, unlocking the potential of renewable energy sources in these territories requires large-capacity energy storage systems (ESS).

5. HYDROGEN TECHNOLOGIES IN RUSSIA: TECHNOLOGY STATE-OF-ART

According to Russian Federal State Statistics Service, since 2010 hydrogen production in Russia has tripled and amounted to 1.95 billion cubic meters in 2019. According to CENEF (Center for Energy Efficiency, Moscow), hydrogen is mainly produced and used in the oil refining, chemical and petrochemical industries, which corresponds to the global structure of demand for hydrogen.

Russia for the time being (with minor exceptions) remains on the sidelines from international centers and partnerships developing hydrogen technologies, although universities and scientific hubs of the Russian Academy of Sciences have strong cooperation with their colleagues from different countries. First of all, this is due to the fact that the climate agenda and decarbonization still play an insignificant role in the country's energy strategy. Nevertheless, there are groundwork and scientific developments in the production, storage and transportation of hydrogen, as well as its use in mobile transport. In addition, Russia has enormous potential for the production and export of hydrogen on a global scale. Therefore, hydrogen technologies are discussed in a positive way both at the largest Russian forums and in the discussion of innovative strategies of the largest Russian companies.

At the stage of *production* Russia has proven technologies for «gray» hydrogen production. It is used in oil and gas refineries (methane conversion), power plants (electrolysis) - all of the hydrogen produced is used locally - for example, to improve the quality of hydrocarbon processing or in the cooling systems of generators in power plants.

The largest producer of electrolyzes, Uralkhimmash (Yekaterinburg, Russia), produces units with a capacity of 4 to 300 cubic meters of hydrogen per hour. Major Russian energy companies – Gazprom and Rosatom – are working on hydrogen production technologies with a minimum carbon footprint – based on adiabatic methane conversion (Aksyutin et al., 2017) and high-temperature nuclear reactors (Ponomarev-Stepnoy et al., 2018) Technologies are now at preliminary stages of scientific development and are being tested at the pilot laboratory facility. The Table 2 demonstrates the ongoing hydrogen energy-related projects run by Russian companies.

At the stage *of laboratory testing*, Russian developers accelerate the following technologies:

- Obtaining hydrogen by oxidizing aluminum in water (Joint Institute for High Temperatures of the Russian Academy of Sciences, JIHT RAS)
- Fuel processors for natural gas and diesel fuel conversion into a hydrogen-rich fuel mixture and pure hydrogen separation of out of it (Krylov State Research Centre - Branch of The Ship Electric Engineering & Technology Institute).

Scientific developments in the field of electrolysis are carried out by Kurchatov Institute and Research Centers of the Russian Academy of Sciences, for example, the Institute of High-Temperature Electrochemistry of the Ural Branch of the Russian Academy of Sciences.

The stage of *transport and storage* of hydrogen is less developed, since it is consumed at the place of production. Gazprom, the owner and operator of the Russian gas transmission system, has carried out studies showing the possibility of adding hydrogen to transported natural gas in the range of 20-70% - but real experiments have yet to be carried out. Scientific and experimental developments in the field of liquefaction and transport of hydrogen in a liquefied state were carried out by NPO Geliymash for the space program of Russia and PJSC Cryogenmash.

In the field of hydrogen use, several research centers and companies develop fuel cell technologies:

- Institute of Problems of Chemical Physics of RAS (hydrogen proton exchange air fuel cells membrane)

Table 2: Hydrogen energy projects of large Russian energy companies

Companies/Agencies	Initiation date	Project description
Rosatom, Russian Railways and Transmash-holding	September, 2019	Railway communication using trains on hydrogen fuel cells. Rosatom is a supplier of hydrogen, fuel cells and other key equipment
Rosatom, Rusatom Overseas and the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry of Japan	September, 2019	Hydrogen production by the electrolysis method
Rosenergoatom Concern, Afrikantov OKB Mechanical Engineering	August, 2018	Energy efficient and environmentally friendly industrial hydrogen production at nuclear power engineering plant (NPEP). The construction of the head NPEN is expected to be completed by 2030
Gazprom	2018-2020	Methane-hydrogen fuel as a fuel gas for gas-pumping units based on adiabatic methane conversion – two projects in Samara and Ufa. The next step is the production of methane-hydrogen fuel (its unification) for serial production and replication of the technology at Gazprom facilities Carbon-free technologies for the production of hydrogen from natural gas. An innovative technology for the decomposition of natural gas in a nonequilibrium low-temperature plasma into hydrogen and carbon is considered promising An international scientific and technical project is being implemented jointly with German and Austrian companies to test the possibility of safe storage of methane-hydrogen mixtures in UGS facilities
RusHydro, H_2 Clean Energy	September, 2021	Cooperation agreement aiming to implement joint projects in the field of hydrogen energy. The parties will study the possibility of building new hydroelectric power plants to provide energy for the production of hydrogen and hydrogen-based chemical compounds. It is planned to conduct research in the field of hydrogen energy, including advanced technologies of fuel cells and energy storage systems based on hydrogen

Source: Adapted from (Hydrogen Energy - Energy Bulletin #89, 2020)

- Center for Autonomous Energy of the Moscow Physics Technical Institute (solid oxide fuel elements)
- Institute of High-Temperature Electrochemistry of the Ural departments of the Russian Academy of Sciences (solid oxide fuel elements)
- Rosatom Fuel Company «TVEL» (including Electrochemical Converters Plant and NPO Centrotech) - solid oxide fuel elements for autonomous power supply of remote from the infrastructure of the objects.

At the stage of *standardization* of hydrogen technologies Technical Committee for Standardization (TK-29) "Hydrogen Technologies" was created in 2008. Its main goal is to adapt international hydrogen technology-related standards at national level documents and regulations. The list of current standards is presented in the Table 3.

6. FINDINGS AND POLICY IMPLICATIONS

Russia has substantial stocks of resources for integration into a new global market. Emerging global hydrogen market will compete with the hydrocarbon market in which the positions of Russia now seem unshakable. In the long term, ignoring hydrogen technologies will create risks of a setback of the national economy - not only due to a drop in demand for fossil fuels, but also due to a slowdown in the development of the innovative sector in industry.

Table 3: National standards fostering the hydrogen energy production

Notation	Title
GOST R 54110-2010	Hydrogen generators using fuel processing technologies Part 1. Safety
GOST R 54111.1-2010	Fuel cell road vehicles — Safety specifications Part 1. Vehicle functional safety
GOST R 54111.2-2010	Fuel cell road vehicles. Safety specifications. Part 2. Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
GOST R 54111.3-2011	Fuel cell road vehicles. Safety specifications. Part 3. Protection of persons against electric shock
GOST R 54113-2010	Compressed hydrogen surface vehicle refueling connecting devices
GOST R 54114-2010	Transportable gas storage devices. Hydrogen absorbed in reversible metal hydride
GOST R 55226-2012	Gaseous hydrogen. Fuelling stations
GOST R ISO 14687-1-2012	Hydrogen fuel. Product specification. Part 1. All applications except proton exchange membrane (PEM) fuel cell for road vehicles
GOST R ISO 146687-2-2013	Hydrogen fuel. Product specification. Part 2. Proton exchange membrane (PEM) fuel cell applications for road vehicle
GOST R ISO 227342-2-2013	Hydrogen generators using water electrolysis process. Part 1. Industrial and commercial applications
GOST R ISO 13985-2013	Liquid hydrogen. Land vehicle fuel tanks

Source: Technical Committee "Hydrogen Technologies," 2021

It is possible to distinguish three main pillars on which the global hydrogen market can develop sustainably. These principles can be applied in order to shape Russian national hydrogen policy (Frontier Economics, 2018).

First, it is important to ensure *technological development* - mastering and reducing the cost of all elements of the chains monetization of "green" hydrogen, as well as complementary technologies - CO_2 capture and storage, steam methane reforming, etc. Second, *market support and sustainable demand for hydrogen* - primarily for consumers who are interested in buying "green" hydrogen. Third, the key to success is attracting *international investment*, creating compensation mechanisms commercial, currency, cross-cultural and domestic risks.

The Russian policy, based on these three pillars, can also include the following items (Table 4).

Determination of the state's position on this issue is largely will determine the attitude of large companies towards it, many of which already have plans and developments in the field of hydrogen technologies, but do not give them priority yet.

Table 4: Policy elements to include in National Hydrogen Energy Strategy

Policy element	Detailed description
Development of pilot projects for the export of hydrogen	Export of hydrogen to Japan, Europe Launch of international projects with the participation of Russia
Development of hydrogen clusters in the domestic market	Creation of several reference "hydrogen clusters" - with a focus on sales markets and centers of competence, Moscow, St. Petersburg, Novosibirsk, Krasnoyarsk, Yekaterinburg, etc.
Development of hydrogen-based fundamental and applied research	Inventory of existing stocks and coordination R&D Specialization in those areas in which Russia already has know-how's, and those that are paid less attention in other national programs Focus on the markets of the future - on the basis of preliminary analysis of the status of hydrogen technologies and forecast their development abroad
Coordination at the state level	Management and coordination at the highest political level, leading role of the federal ministry Key performance indicators by redistribution and the years of implementation of the program with the mechanisms of their adjustments Creation of a unified information platform Creation of a system of incentives for large and small businesses (taxes, benefits, orders) and localization technologies
International cooperation	Technology partnerships Joining international hydrogen organizations and platforms

Source: Adapted from (Skolkovo, 2019)

7. CONCLUSION

In the modern world, energy transition is taking place in completely different conditions in terms of a set of own (less expensive) resources, with different combinations of use in the economy, different delivery distances, storage needs, different degrees of concern of countries with energy and climate problems. Hydrogen energy is becoming an important component of the energy complex at first on a local scale, but it can expand significantly due to transportation through pipelines, replacing traditional gas or using it as a resource. Thus, the effective use of hydrogen energy potential tightly depends on synergetic technologies, which need to be developed in accordance with the main technology.

This article has analyzed the state-of-art of hydrogen economy in Russia from policy and technology point of view. The limited description of the technological parameters of pilot projects is due to the lack of open data. Although, the analysis has shown the energy strategy of Russia takes into account the potential opportunities mainly for the export of hydrogen, and the scientific and engineering resources of Rosatom and Gazprom are keeping the role of Russian science and energy in the near future.

8. ACKNOWLEDGMENTS

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