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HYDROGEN ENERGY DEVELOPMENT TRENDS IN FOREIGN COUNTRIES

Narzullaev Olim Khomamatovich
Doctor in Law, Tashkent State University of Law,
Department of Ecological Law, Professor
Alimnarzullayev@yahoo.com

Madaminov Dilshadbek Imidjanovich
Master's Degree, Tashkent State University of Law
e-mail: dimamsn@mail.ru

ABSTRACT

In recent decades, with the emergence of problems associated with consistent decrease in non-renewable energy sources, such as hydrocarbons, the term "hydrogen energy" is being increasingly used in mass media, economics, politics, and science. The analysis of numerous articles on this subject, however, shows that the authors of these publications often mean several programs that differ from each other when using this term. The article provides a comparative analysis of national strategies for the development of hydrogen energy in countries that seek to play the main roles in the emerging market for the production, storage and транспортation of hydrogen, as well as secure a legal support for hydrogen energy, which is also релевant at this moment in the context of the emergence of a new energy industry. It discusses the main positions of strategic documents in the field of hydrogen energy in such countries as Japan, South Korea, the EU (in particular, Germany) and Russia. This article states that the plans of countries in the field of the development of hydrogen energy within a short period took the form of strategic programs, which cannot be said about the processes of formation of national regulatory frameworks governing the use of hydrogen, which are developing very slowly impeding the general process of implementation of hydrogen technologies in варious industries.

Keywords: Hydrogen, hydrogen energy, international cooperation, fuel cell, energy policy, strategy for the development of hydrogen energy, Roadmap.

MATERIAL AND METHODS

Philosophy, economic and legal doctrines on the right to use and protect natural resources, the mutual unity of subjectivity and objectivity in the regulation of social relations, taking into account the environmental factor in the socio-economic development of society. In writing this article, the author used such methods as comparative-legal, logical analysis, generalization of practical materials/

RESEARCH RESULTS

By the 21st century, the environmental problems facing humanity began to have an increasingly strong influence on the energy policy conducted on a global scale. Decarbonization policy, considered one of the main ways to combat global climate change, is the most important driver of the quality change in the energy sector that continues around the world. In this case,

renewable energy sources and hydrogen technologies play the role of a locomotive of changes in this field. It is difficult to imagine the chemical and food industry, oil refining, and metallurgy without hydrogen, and hydrogen is increasingly used as an especially environmentally friendly car fuel.

Today, the demand for energy resources is structurally changing, in particular, in the transition from hydrocarbon resources to renewable resources, the development of hydrogen energy is becoming an urgent issue.

At the same time, the analysis of the state of the industry shows that there are problems related to ensuring an efficient, resource-efficient and ecologically safe economy in the republic in the face of climate change. In particular, accelerating industrialization and population growth are significantly increasing the economy's need for energy resources, as well as intensifying the negative anthropogenic impact on the environment.

In order to strengthen the energy security of the Republic of Uzbekistan, it is necessary to expand the possibilities of using renewable energy sources and create the necessary conditions for the sustainable development of hydrogen energy, including strengthening the scientific potential of this field. PQ-5063 of the President of the Republic of Uzbekistan on April 9, 2021 in order to establish the hydrogen energy infrastructure in Uzbekistan, increase the effectiveness of scientific and practical research in the fields of renewable and hydrogen energy, widely introduce innovative technologies into production, and also ensure the transition of the Republic of Uzbekistan to a "green" economy. Decision No. "On measures to develop renewable and hydrogen energy in the Republic of Uzbekistan" [1]. was also accepted. According to the International Renewable Energy Agency (IRENA)[2] in 2019, in 30 years, "green hydrogen" will provide 18% of the world's gross energy. In turn, it is predicted that 16% of all electricity in the world will be used for the production of this hydrogen. Widespread adoption of hydrogen technologies is also expected to significantly reduce the carbon footprint of a number of industries.

In some scientific literature, "hydrogen energy" is used as a substitute for "hydrocarbon energy". However, it should be noted that the field of hydrogen energy is not related to the extraction of the original source of energy, but only includes the transportation, processing and use of energy. In this, it is a field that complements conventional and alternative (renewable) energy and is not considered a separate, new or independent source of energy. In other words, hydrogen energy is a method of efficient use of existing energy sources, increasing their useful efficiency or obtaining benefits in the energy sense in another form. The fight against climate change, the release of carbon dioxide (SO2) and other greenhouse gases into the atmosphere, and the reduction of the share of energy sources based on hydrocarbons, the establishment of an energy supply system based on "clean energy", the rapid development of advanced technologies and the possibility of their wide application in various industries. will provide unprecedented opportunities for hydrogen energy. The report of the International Energy Agency (IEA) entitled "The future of hydrogen" [3] states that today is the era of widespread use of hydrogen.

Acknowledging the universality of hydrogen, experts suggest its use not only in oil refining or fertilizer production, but also in industries and sectors where hydrogen has not yet penetrated. This, in turn, is a reliable step towards the transition to environmentally friendly energy.

Currently, hydrogen is produced by three main methods and classified by different colors. Including:

First, steam conversion of methane gas (SMR). In this case, hydrogen is obtained from natural gas or gasified coal. This hydrogen is called "gray" because of the large amount of SO2 that is released during the production of hydrogen in this way. This hydrogen is not considered environmentally friendly hydrogen. If carbon capture and storage (CCUS) technology is applied to this process, the hydrogen produced is called "blue" (SO2 neutral) hydrogen (second method).

The most environmentally friendly "green" hydrogen is obtained in the third way, that is, by electrolysis of water. The electricity consumed in this process is obtained from renewable energy sources[4]. The analysis of strategic planning documents, as well as the development of the legal basis of hydrogen energy, is an extremely urgent issue in the context of the emergence of a new field of energy, the rapid growth of the number of countries that are developing their strategies and projects and strive to take a leading position in the developing hydrogen energy market. Since it was not possible to analyze all the national programs related to the development of hydrogen energy of more than 20 countries within the framework of this material, a comparative analysis of some of them was given as an example of the level of possibility. In particular, the concept of hydrogen energy development in South Korea was first proposed by President Moon Jae-in. According to this concept, the main focus is on the mass production of hydrogen-powered vehicles, the development of fuel cells, and the construction of hydrogen production, storage and distribution infrastructure. Although President Moon Jae-in's administration adopted a Road Map aimed at developing all areas of the hydrogen economy, its implementation was closely related to the sale of fuel cell vehicles, first in the domestic market, and later in foreign markets. If this plan is successfully implemented in South Korea, it will demonstrate the viability of these technologies while showing other countries the most effective ways to transition to a hydrogen-based economy.

It should be noted that the tragedy of the nuclear power plant "Fukushima-1" was a great impetus for the development of renewable energy sources and hydrogen technologies in Japan. The main focus was on concrete and promising technical solutions for the use of hydrogen in the power supply of high-rise buildings, automotive and shipbuilding industries, abandoning abstract concepts. It is planned to intensively fund basic research that forms the basis of technologies aimed at obtaining hydrogen from various sources using renewable energy sources (QTEM). The main task was to turn it into a source of cheap electricity for the population by supplying hydrogen not only to large industrial enterprises, but also to household appliances that work on compact and long-life fuel cells that work on fuel cells [5].

European Commission President Romano Prodi(2004) announced the adoption and launch of the European Technology Platform (ETP) on hydrogen and hydrogen fuel cells. Based on this platform, a single mechanism has been developed that unites researchers, manufacturers and policymakers. This mechanism was intended to help define the perspective of any project related to hydrogen and hydrogen-based fuel cells, and to help find the most effective ways to implement this project.

Currently, two associations for hydrogen energy and fuel cells are active in the European Union:

– European Fuel Cell Group (EFCG) – Founded in 1989 as a non-profit organization, this group publishes informational publications on fuel cells and organizes various seminars on this topic. Each EU country sends one or more manufacturers as representatives to this group.
– The European Hydrogen Association (EHA) was launched in 2000 and includes existing national associations, including AFH2 (France), DWV (Germany), Norsk Hydrogen Forum (Norway), H2Forum (Sweden) . It also includes representatives of countries where national hydrogen associations are now being established.

Among the countries of the European Union, the strategy for the development of hydrogen energy and fuel cells is rapidly being pursued in Germany. The main reason for this is the adoption of the policy of phasing out the use of nuclear energy.

The new stage of hydrogen energy development in Russia corresponds to the 2000s [6]. In 2003, the National Association of Hydrogen Energy (NAVE), a non-profit organization, was established. The main task of the association was to promote the development of hydrogen technology and the industry of fuel elements and the use of hydrogen energy.

Support for the development of hydrogen technologies, including the discovery of new methods and technologies for its production, storage and delivery, is reflected in several documents of strategic importance. The most important of these is the Energy Strategy of Russia until 2035 (ES-2035), adopted in June 2020[7]. In response to the state's new hydrogen policy, major companies such as Gazprom, Rosatom, Rostex, and the Russian Academy of Sciences have significantly increased the amount of scientific research aimed at hydrogen production and export. Under the chairmanship of the Minister of Energy of Russia, an interdepartmental working group on the development of hydrogen energy will be formed, and a project office that will provide information and analytical support for the implementation of the Plan adopted in 2020 on the basis of the Russian Energy Agency will start its work. It is planned to pay special attention to the training of highly qualified personnel for the new industry, including the organization of internship programs for graduate students and scientists conducting scientific research in the field of hydrogen energy in advanced experience centers around the world.

It should be noted that according to the Energy Strategy (ES-2035) adopted in Russia until 2035, the task of hydrogen energy is to develop the production and consumption of hydrogen and to strive for the Russian Federation to take a strong place among the world's leading countries that produce and export hydrogen. Among the important measures aimed at the implementation of this task are the following. Including: supporting the construction of the infrastructure for the consumption and supply of hydrogen and fuel mixtures based on it by the state, as well as the legal provision of hydrogen production; further expansion of the scale of hydrogen production from natural gas, including a further increase in the use of renewable energy sources and nuclear energy; creation of national technologies that produce low amounts of carbon harmful to the environment in the production process through hydrogen conversion, methane gas pyrolysis, electrolysis and other methods, including localization of advanced technologies available abroad; stimulate the domestic market demand for hydrogen fuel cells by the transport sector, as well as the use of hydrogen and fuel mixtures based on it as energy storage and redistribution to increase the efficiency of centralized energy supply systems; creation of a regulatory framework for the safety of hydrogen energy; activation of

international cooperation on the development of hydrogen energy and access to foreign markets.

According to the Energy Strategy-2035, the solution to the challenges of hydrogen energy is to increase the export of hydrogen to 2 million tons by 2035.

In order to realize the potential of the country related to hydrogen energy and to achieve the goals set in the Energy Strategy (EU-2035), various ministries have developed a single plan (roadmap) of special actions for the development of hydrogen energy in Russia until 2024 [8]. This plan was approved by the Russian government on October 12, 2020. The plan consists of eight targeted sections: strategic planning and monitoring of hydrogen energy development; measures to encourage the development of hydrogen energy and its state support; formation and raising of hydrogen production capacity; identification and implementation of priority pilot projects in the field of hydrogen energy; development of scientific and technical potential and development of high-tech methods and solutions; improvement of the regulatory framework and national standardization system; improvement of the mechanism of training of mature personnel; development of international cooperation.

Therefore, in January 2019, the government of the Republic of Korea announced the "Roadmap" for the development of the hydrogen economy, which includes three priority areas. These are: the mass production of vehicles equipped with fuel cells, the creation of hydrogen batteries that satisfy household needs and industrial purposes, and thirdly, the construction of a comprehensive infrastructure for the production, storage and delivery of hydrogen.

Despite the fact that the total number of hydrogen-powered vehicles sold worldwide in 2019 was 7,500[9], the Roadmap focuses heavily on the transportation sector.

The Korean government plans to achieve the following indicators within the "Road Map".

In the field of transportation: production of 100,000 units of such vehicles by 2025, of which 40,000 will be exported, despite the low sales volume of fuel cell vehicles (FCV). By 2030, hydrogen and electric vehicles will make up a third of all cars sold in the country; transfer of public transport to hydrogen fuel: by 2040, 80,000 hydrogen-powered taxis, 40,000 buses and 30,000 trucks will be on the road. Carrying out research aimed at the use of hydrogen in ships, trains and drones; Establish a network of 1,200 hydrogen filling stations by 2040.

In the direction of production of hydrogen fuel cells to meet industrial sector and household needs: mass production of hydrogen fuel cells with a current capacity of 307 MW in order to provide electricity to industrial enterprises, public and office buildings. By 2040, bringing the total capacity of these elements to 15 GW (8 GW for the domestic market, 7 GW for export); By 2040, providing 940,000 households with hydrogen fuel cells with a total capacity of not less than 2.1 GW; Construction of an extensive network of pipelines in places where hydrogen is imported. In addition, the creation and production of gas trucks that transport hydrogen in tanks with a capacity of 1 ton[10]. As part of this strategy, in October 2019, Korea's Ministry of Land Resources, Infrastructure and Transport announced its intention to implement a pilot project of "hydrogen cities" in which utility (electricity, heating and cooling) and transportation needs are covered by hydrogen fuel. Ansan, Ulsan and Wanju were chosen as the first "hydrogen cities". At the same time, the mechanism of allocation of state subsidies remains the main means of stimulating the development and production of new hydrogen technologies. In the Republic of Korea, the issuance of "green" certificates (Renewable Energy Certificates) is

an additional means of promoting the use of hydrogen fuel cells. With the help of these certificates, any enterprise confirms that it has produced and delivered to the market a certain amount of renewable or "green" energy[11].

It is worth noting that energy security has always been a serious problem for South Korea. Scarcity of natural resources has made the economy and industry dependent on imported energy sources. Therefore, ensuring technological superiority, reducing the country's dependence on energy imports, and creating high-tech jobs is a priority. Currently, South Korea's hydrogen needs are met by using the economically viable "grey" hydrogen produced by refining natural gas and oil. In the long term, South Korea is analyzing options for replacing "grey" hydrogen with "green" hydrogen, which is produced mainly by water electrolysis, relying on renewable energy sources. The reduction in the cost of production of "green" hydrogen and the implementation of new technologies can make this hydrogen the basis for creating an environmentally friendly future. Perhaps in the next decade, we will see the remarkable results of the South Korean government's hard work in cooperation with various ministries, agencies and private enterprises to comprehensively develop the field of new and renewable energy sources.

It should be noted that in 2014, the Roadmap for the Development of Hydrogen Energy and Transportation was adopted as an addendum to the current version of Japan's Energy Master Plan (EAR). At the end of 2017, along with the development of a new version of the EAR, relevant additions were made to the "Road Map", and this document was named the Basic Strategy for the Development of Hydrogen Energy. It should be noted that Japan was the first country in the world to officially adopt such a document[12]. The main strategy defines the most important directions for the development of hydrogen energy, and the quantitative indicators of hydrogen needed in industry and energy consumption until 2050 are determined. This strategy includes four main areas: first, to provide consumers with energy and significantly increase the role of hydrogen in the production of vehicles. This direction is to provide hydrogen fuel not only for cars, but also for cargo and lifting vehicles, locomotives and even small ships. Second, the development of hydrogen delivery infrastructure, both by sea and through a network of pipelines passing through Japan's territory. Establishment of hydrogen clusters, that is, special areas where hydrogen is of primary importance as a source of energy. Thirdly, to create priority opportunities for the development of hydrogen energy and increase its share in the country's energy sector to 25-30% (taking into account the share of renewable energy sources). Widespread implementation of carbon capture and storage systems. Later, this carbon is used to create synthesis gas, which is a raw material for the production of "green" hydrogen[13]. One of the important issues is the development of international cooperation mechanisms on hydrogen supply and storage, as well as the creation and adoption of common standards for models of equipment working on hydrogen fuel cells (VYoE). Undoubtedly, the policy of the Japanese state in the field of hydrogen energy development has a consistent and systematic character, and it is based on a number of regulatory legal documents. Specifically: High Pressure Gas Safety Act (High Pressure Gas Safety Act). Industrial Safety and Health Act. Act on Prevention of Disasters in Petroleum Industrial Complexes and Other Petroleum Facilities. Act on Port Regulation [14].

Although the financing of hydrogen energy projects is constantly increasing, the amount remains limited and low for the potential of the Japanese market[15]. The prospect of hydrogen taking a significant place in the energy supply system is causing some doubts both in Japan and in other countries of the world[16]. Currently, almost all existing technologies related to the production of hydrogen and fuel cells based on it are financed by the government, and in general, private business is not interested in these technologies. The main reason for this is the huge amount of financial resources spent on building infrastructure for hydrogen production, supply and storage. In this case, the constantly changing and unstable demand for hydrogen energy by consumers has a negative impact on hydrogen energy. However, this situation may change. The implementation of the hydrogen energy development strategy adopted by the Japanese government may lead to the emergence of a new sector in the international energy trade market and the creation of cooperation in the international financial and industrial systems that did not exist before.

The main strategy for the development of hydrogen energy in Europe is a comprehensive document, in fact, which emphasizes the importance of developing this field together with "traditional" QTEMs based on geothermal sources, solar, and wind energy. Taking into account world trends, European countries are actively participating in activities aimed at reducing environmental pollution within the framework of sustainable development strategy. Until recently, efforts to integrate research resources and economic programs in different European Union (EU) countries have met with some resistance. With the actions of the EU leadership, the aspirations of the member states of the union are being combined in the framework of common programs, but at the moment they are far from each other and not sufficiently coordinated.

Some EU countries have been conducting their own research on alternative energy sources for a long time. However, most of these studies repeat each other. Realizing this, the European Commissioners formed a group of experts at the highest level. As a result of the work of this group, the European technological platform for hydrogen and fuel cells was established. This platform has several goals, including: 1) the adoption of political decisions that will support the development of hydrogen technologies in the energy and transport sectors; 2) significantly increase the funding of fundamental and applied scientific work related to hydrogen; 3) creation of a system for showing and demonstrating the advantages of hydrogen energy; 4) work with entrepreneurs to bring financial organizations closer to developers of new technologies; 5) establishing a center for promotion of the above initiatives.

It should also be noted that in recent times, European countries have seen unprecedented activity in the field of hydrogen energy and hydrogen-based fuel cells. According to experts in this field, in the near future, the process of "connecting" local networks of hydrogen distribution pipelines in this area will begin. In this case, most of the hydrogen in pipelines will be produced using QTEMs. By 2030, there will be equipment that will allow hydrogen to be stored for a long time, and the electricity produced with the help of hydrogen will be consumed in this place. There are also views on establishing the hegemony of hydrogen energy in European countries after 2040.

Based on the above issues, it is considered important to implement the following in the national framework instead of the conclusion. Including:

First, develop a national strategy for the development of hydrogen energy;
Secondly, to ensure the development of projects of normative legal documents on the development of hydrogen energy, as well as the implementation of promising projects in these areas;
Thirdly, to conduct necessary researches in the fields of hydrogen energy and to assist ministries and agencies in issues of personnel training, retraining and improvement of their qualifications;
Fourth, to conduct fundamental, practical and innovative research in the field of hydrogen energy, and to support the implementation of scientific and technical projects and the introduction of scientific research and experimental design developments.
Fifth, establishing cooperation with scientific institutions, centers and experts in these fields and organizing research with their participation;
Sixth, together with local and foreign higher education organizations, to form an integrated system connecting the processes from scientific research to production and to train highly qualified scientific personnel.

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