Hydrogen energy as a guarantee of energy security

Asia Lariukhina*

RAOS JSC, 115280, Moscow, Russia

Abstract. This article raises the crucial issue of energy security today, particularly in European countries. And the advantages of hydrogen energy, which can contribute to energy security through hydrogen produced in electrolysis plants from renewable energy sources; renewable energy can be built even in countries where oil, gas and coal are not available; and hydrogen can be used for load balancing in the grid as a storage and as a distributed energy source where there is no access to the electricity grid. The conclusion is that hydrogen energy can provide a degree of energy security, but only if costs are reduced.

1 Introduction

Energy security is a state of protection of the country's economy and population against threats to national security in the energy sector, which ensures fulfilment of the requirements for fuel and energy supply to consumers stipulated by the legislation of the Russian Federation, as well as fulfilment of export contracts and international obligations of the Russian Federation.

The current global distribution of forms of energy production is unbalanced even by separately considered regions of the world; the volume of consumption exceeds the volume of production in such regions as Europe and Asia, resulting in a deficit of energy resources.

The world's energy consumption has serious socio-economic and political implications.

In 2021-2023, the world faced an energy crisis: abnormal temperature variations (cold winters and dry summers, especially in Europe and China) led to interruptions in the production of renewable energy plants (HPPs and SES).[1]

At the same time, global demand for energy increased, fuelled by the recovery of the world economy from a covid-19 recession. As a result, the demand for fossil fuels, primarily gas, increased, which could not be promptly met due to underinvestment in the industry in recent years. [2] As a result, prices on world markets have risen significantly, affecting the "affordability" of energy.

An additional incentive for European countries to look for new ways and solutions for energy supply was the voluntary suspension of Russian supplies of hydrocarbons (oil, gas, oil products), which were historically the cheapest fuel alternative on the EU market.

The crisis in Europe has become one of the most pressing issues on the EU's information and political agenda at the end of 2021, calling into question the success and soundness of

* Corresponding author: lariukhina96@mail.ru

the European decarbonisation strategy and giving a new direction to the debate on the role and place of fossil fuels in Europe's energy mix.

According to Table 1, oil accounts for the largest share of European primary energy consumption in 2022 (35.99%), followed by gas (22.5%, almost 2.5% less than in 2021) and renewables (13.88%).

Table 1. Primary energy consumption in European countries, 2021-2022, mln t.o.e. [3].

	2021						2022					
Country	**Oil**	**Natural Gas**	**Coal**	**Nuclear energy**	**Hydro electric**	**Renewables**	**Oil**	**Natural Gas**	**Coal**	**Nuclear energy**	**Hydro electric**	**Renewables**
Austria	17	11	4	0	12	5	17	10	3	0	11	6
Belgium	42	21	4	16	0	9	39	18	4	13	0	9
Czech Republic	14	11	19	9	1	4	14	9	20	10	1	4
Finland	11	3	4	7	5	9	11	1	4	8	4	11
France	100	53	8	117	19	25	99	47	7	91	14	28
Germany	143	113	76	21	6	77	145	95	80	11	6	84
Greece	19	9	2	0	2	6	21	8	2	0	1	6
Hungary	12	13	2	5	0	3	12	11	2	5	0	3
Italy	80	89	8	0	15	25	84	80	10	0	9	26
Netherlands	58	43	8	1	0	15	61	33	8	1	0	17
Norway	13	5	1	0	46	4	12	5	1	0	41	5
Poland	46	27	65	0	1	11	50	22	62	0	1	13
Portugal	14	7	0	0	4	7	16	7	0	0	2	7
Romania	15	14	6	3	6	3	15	12	6	3	4	4
Spain	83	42	4	17	10	33	91	41	6	18	6	35
Sweden	17	1	2	16	24	17	17	1	2	16	22	19
Switzerland	13	4	0	6	12	2	13	4	0	7	9	2
Turkey	69	70	59	0	18	21	72	63	60	0	22	24
Ukraine	15	33	33	27	3	4	13	24	18	19	4	2
United Kingdom	84	96	8	14	2	42	91	88	7	15	2	47
Other Europe	0	0	0	0	0	0	0	0	0	0	0	0
Total Europe	945.3	704.2	354.6	272.2	210.4	345.3	980.2	612.8	343.7	227.9	181.6	377.6
%	33.4	24.87	12.5	9.61	7.43	12.19	35.99	22.50	12.6	8.37	6.67	13.88

Taking into account the fact that the destabilisation of the energy resources market can happen again just as quickly and unpredictably, it is necessary to shift the focus from traditional forms of energy production to hydrogen, whose natural reserves as a chemical element in complex compounds are not scarce. Energy efficiency values of hydrogen are high and level of environmental friendliness is competitive.

2 Current state of the hydrogen energy market

On this basis, the main players in the world arena, taking into account their resource potential, needs and strengths, have adopted hydrogen strategies that define the vectors of development for the near future (Fig.1).

Most of the development strategies focus on the time horizon until 2050. The allocation of roles in the global market is based on the following criteria: geographical and climatic conditions for hydrogen production and technological competences for hydrogen production, transport and consumption.

According to the level of technological potential and the type of hydrogen energy development strategy, countries are divided into the following groups of leaders:

• Focused on technology development and commercialisation activities. USA, China, etc., with climatic and geographical conditions for production, capable of producing hydrogen in large quantities. Japan, Korea, some EU countries, etc., which are more focused on hydrogen imports. Their focus, in addition to hydrogen production, is to create a market and ensure energy security;

• Focused on increasing hydrogen production with subsequent export to the world market: India, Australia, Canada, Russia, Middle Eastern countries (Saudi Arabia, UAE, Qatar).

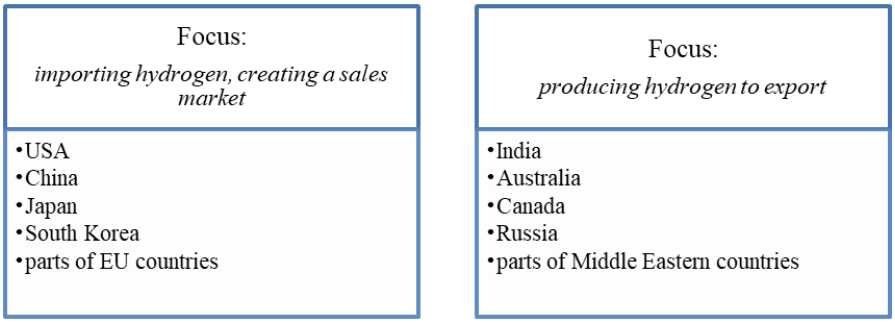

Fig.1. The World Hydrogen Energy Leadership Groups for the year 2023.

At present, collaborations between countries have already been formed to further evaluate the most effective form of cooperation: Japan and Australia, Korea and Australia, Egypt and EU countries, Middle Eastern countries and EU countries, Canada and EU countries. The main criterion for the evaluation of this indicator is the cost of hydrogen, which is structured as follows: the cost of hydrogen production (including the cost of liquefaction, in the case of the liquid aggregate state), the cost of hydrogen storage, the cost of logistics, the cost of hydrogen re-conversion, the cost of fuel cells and the cost of hydrogen.

3 Advantages of hydrogen from an energy security perspective.

The high production cost and consequently high real price (Fig. 2) does not currently allow hydrogen to compete with conventional energy resources (coal, natural gas), especially in the case of "yellow" and "green" hydrogen, but as more countries implement strategies to transition to a low-carbon economy, hydrogen starts to play a more important role in areas such as chemical industry and metallurgy, as well as in sectoral energy consumption, especially in terms of difficult direct electrification. In addition, the need for resources to build RES infrastructure (availability of silicon, cadmium, indium, copper-gallium for SES and steel, concrete and copper for WPP and other materials required for the construction of solar panels and wind farms) remains a relevant issue, which is also a major challenge from an energy security perspective.

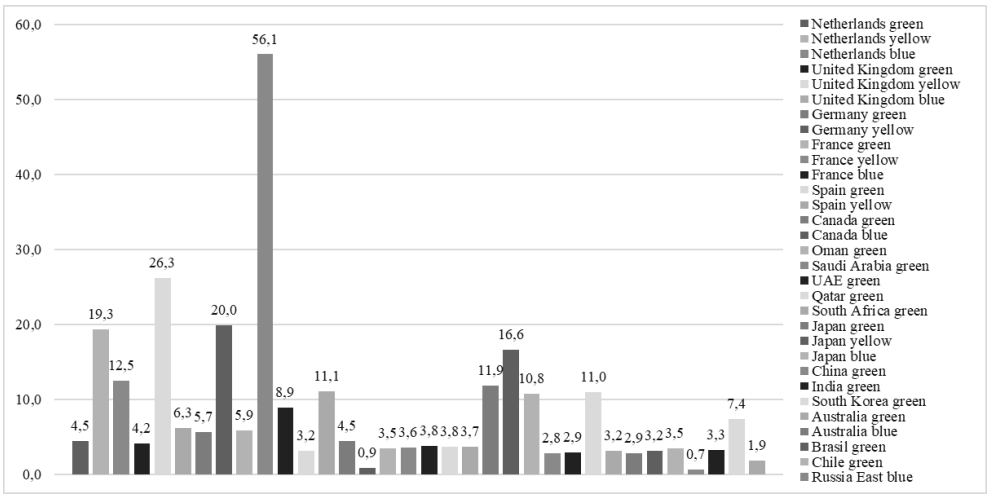

Fig. 2. Actual break-even price of hydrogen in the leading countries at the end of 2022. USD/kg [4].

Hydrogen can be produced from RES in electrolysis plants, RES can be built even in countries where there is no oil, gas or coal, and hydrogen can be used for load balancing on the grid as storage and as a distributed energy source where there is no access to the grid.

The main obstacle to the development of hydrogen energy is its price, which will range from a minimum of 11.9 USD/kg of "green" hydrogen (produced by electrolysis using electricity from renewable energy sources (RES) such as wind, solar or hydro, which means zero CO2 emissions) by the end of 2022, to 12. 5 USD/kg "blue" (produced by steam conversion of methane, but with carbon capture and storage, which roughly doubles carbon emissions), and 56.1 USD/kg "yellow" (like green, produced by electrolysis, but sourced from nuclear power plants, no CO2 emissions). At this real break-even price for hydrogen (Fig. 2), competitiveness can only be achieved by the need to ensure "safety at any costs".

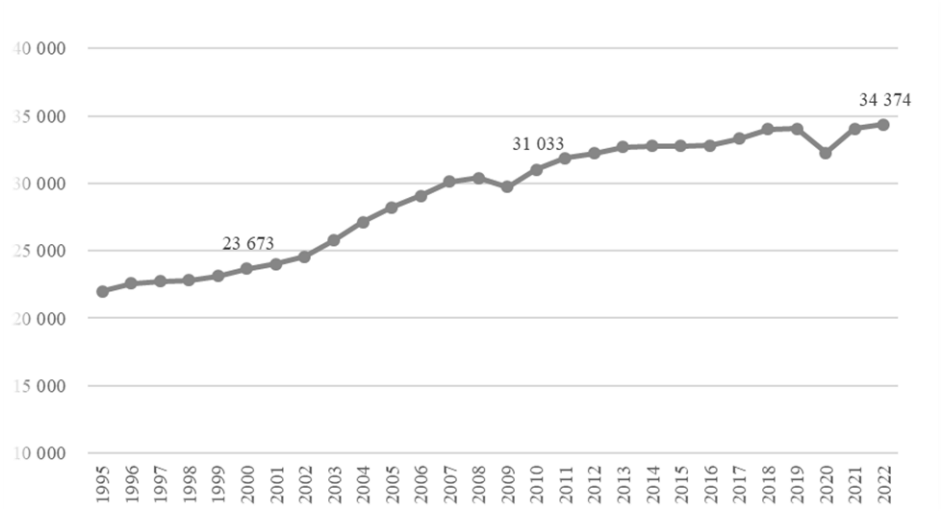

Fig.3. CO^2 emissions from the energy sector, 1995-2022, mln tonnes [1].

Other disadvantages of hydrogen are use is the lack of consumer infrastructure, which limits its large-scale application and need for resources for the establishment of RES infrastructure.

According to European Electricity Review 2023 annual CO^2 emissions from the energy sector have shown an extremely positive trend over the past 25 years (Figure 3). In this context, the cost of conventional energy resources will increase over time by the amount of the CO^2 emission tariff.

4 Conclusions and Results

Over time, the concept of reducing the cost of hydrogen is becoming more accessible, making the goal of reducing the cost of green hydrogen production by up to 85% by 2050 through a combination of cheaper electricity and lower capital costs for electrolysers, along with improving efficiency and optimising electrolyser performance, more realistic to compete with any conventional energy resource and ensure global energy security.

The introduction of sites to monetise GHG emission reductions from the energy sector is also a driver for hydrogen energy development. In view of all the above, the conclusion is that hydrogen energy can provide some degree of energy security, but only if costs are reduced.

Hydrogen energy is the best solution for the competent distribution of forms of energy production for the uninterrupted operation of the energy system, through full or partial transition to a system of storing the generated surplus of renewable electricity in the form of hydrogen and generating electricity on demand.

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