The Role of Nuclear Energy in Enhancing Energy Security of the Republic of Belarus

A.A. Mikhalevich*, A.Zh. Grebenkov

Institute of Power Engineering, National Academy of Sciences of Belarus, Minsk, Republic of Belarus

***Abstract* — The paper highlights and examines the issues related to the limited natural reserves of fossil fuels in the Republic of Belarus. Almost 80 percent of the demand for energy in the economy and social sector of the country is met through the import of energy resources. In this context, one of the priority objectives for the energy development in Belarus is the gradual replacement of imported oil and natural gas with local fuel and energy resources, including nuclear energy. The world's experience in the development of this area is shown. Analysis is made of the measures to achieve the necessary indicators of energy supply to the national economy and the development of the energy sector, in the structure of which the nuclear power plant is beginning to play a significant role. The activities on strengthening the national energy system in Belarus began in June 2021, when the first unit of the Belarusian nuclear power plant was put into commercial operation. The findings show that since then there has been a gradual decline in the shortage of necessary energy resources, reduction in reliance on imported hydrocarbons, and elimination of other threats and uncertainties for sustainable, reliable, and efficient advancement of the energy sector aiming to achieve carbon neutrality of the economy of the Republic of Belarus in the near future.**

***Index Terms* — fuel, energy, energy sector, nuclear power plant, sustainable development, energy security.**

I. Introduction

Reliable and efficient functioning of the energy sector is one of the overriding and essential objectives of the modern economy in the Republic of Belarus [1]. It can be accomplished by identifying and eliminating factors that pose risks to the sustainable and safe development of the sector. The most important threats, their sources, risk level indicators, methods for their assessment and monitoring standards, as well as the main directions for their elimination are set out in the Concept of Energy Security of the Republic of Belarus [2].

The Republic of Belarus provides about 77.5 percent of domestic gross energy consumption through the import of crude oil and natural gas. The significant reliance of the country's economy on the import of hydrocarbons and the low degree of diversification of primary energy resources represent elements of risk for sustainable development. Since 2020, the republic has faced numerous energy security threats resulting from various political, resource-related, geographical, and economic limitations and circumstances. Moreover, new threats have emerged, including high uncertainty to key indicators of global economic development, which are associated with the COVID-19 pandemic and the escalation of several international and regional conflicts, due to which the enterprises in the country encounter immense pressure from their influential foreign economic partners and experience large fluctuations in the import-export balance. Belarus has also lost the benefits of its strategically

* Corresponding author.
E-mail: amikhal@bas-net.by

http://dx.doi.org/10.25729/esr.2023.04.0005

Received September 29, 2023. Revised October 25, 2023. Accepted December 11, 2023. Available online December 27, 2023.

advantageous geographical position between large exporters of hydrocarbons and their consumers, which the country enjoyed by attracting investments in the development of the energy sector, including in interregional transport enterprises. There is a noticeable delay in creating conditions for the development of a circular economy and there is no assessment of the impact of carbon border adjustment on the export of a national product dependent on the activities of companies in the energy sector.

In this regard, the strategic objectives of the national energy development should focus on reducing the economy's reliance on the import of fossil fuel and energy resources by increasing the share of local fuels, expanding the capacity of low-carbon and renewable energy sources, and bringing the energy intensity of the gross domestic product (GDP) closer to the world average value of this indicator. In this context, the role of nuclear energy is growing since it belongs to the local types of low-carbon energy resources and contributes to diversification, energy independence, and reliability of the energy sector.

This study aims to comprehensively examine and assess the indicators and risks related to the energy security of Belarus. This assessment is based on the performance of the country's economy over the past 5 years, given the commissioning of the Belarusian Nuclear Power Plant (the BelNPP) in June 2021. The objective is to formulate recommendations that will enhance the national energy security, considering the current trends in international energy policy.

II. Key Features of Contemporary Energy Development

An important trend in global energy policy is the reduction in the carbon intensity of GDP [3]. This fact is evidenced by the changing consumption patterns of low-carbon fuel and energy resources [4] (see Fig. 1). There is also fundamental restructuring of global energy markets with a more diversified balance of energy resources, increased competition between energy producers, an increased role of the energy consumers and their choice in shaping energy policy and in reducing the energy-to-GDP ratio. Major energy companies are actively adopting the modern global energy transition toward renewable energy sources (RES) and nuclear power. The share of the latter in final energy consumption has remained at about 4.4% for ten years due to the commissioning of new nuclear power plants [5], which are considered as a necessary component of the transition period towards a climate-neutral economy. At the end of 2021, the installed capacity of operating nuclear units were 389.5 GW and 58.1 GW was under construction.

Gross consumption of primary fuel and energy resources per unit of world GDP has decreased over the past 20 years

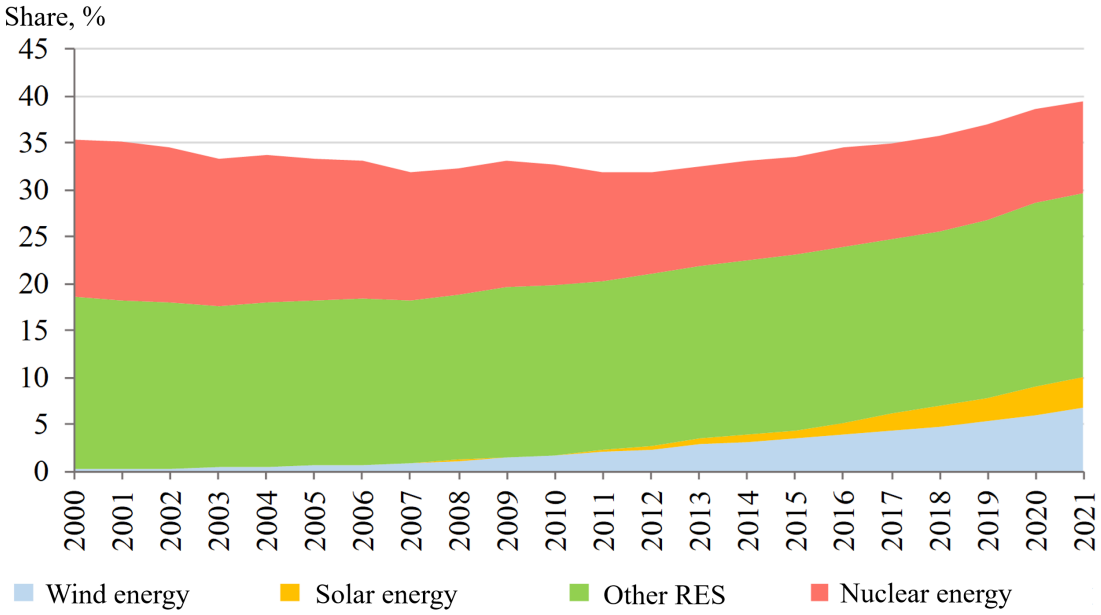

Fig. 1. Consumption of low-carbon energy resources in the world's electricity industry.

annually by an average of 1.5 %, with GDP growing by 3.1% per year [6]. At the same time, the structure and balance of this consumption, as well as the levels, dynamics, and trends in the reduction in energy intensity differ markedly across countries and regions (see examples in Fig. 2 and 3, presented on the basis of data from [7, 8]).

The given examples illustrate the characteristics of the respective climatic zones, the availability and type of primary energy sources, differences in technological development, the structure of the economy, and factors in national energy policy. High energy intensity and its growth in some countries is explained by the presence of inefficient industries, the predominance of a raw material export economy, and low prices for natural energy resources, which do not stimulate a reduction in specific energy consumption.

In the energy sector of leading countries, there is a gradual transition from measures of direct budget support

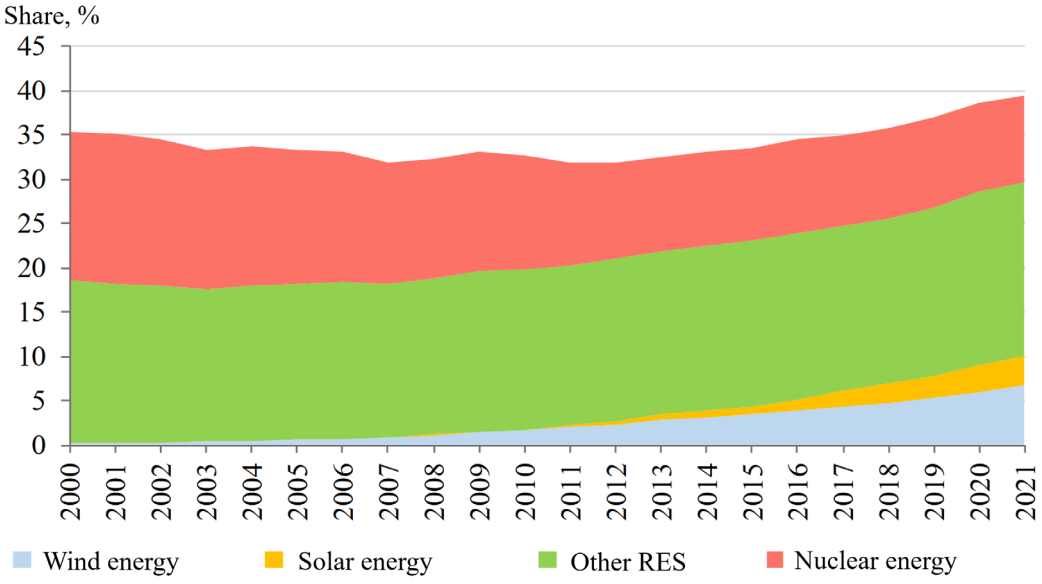

Fig. 2. Examples of changes in energy-to-GDP ratio.

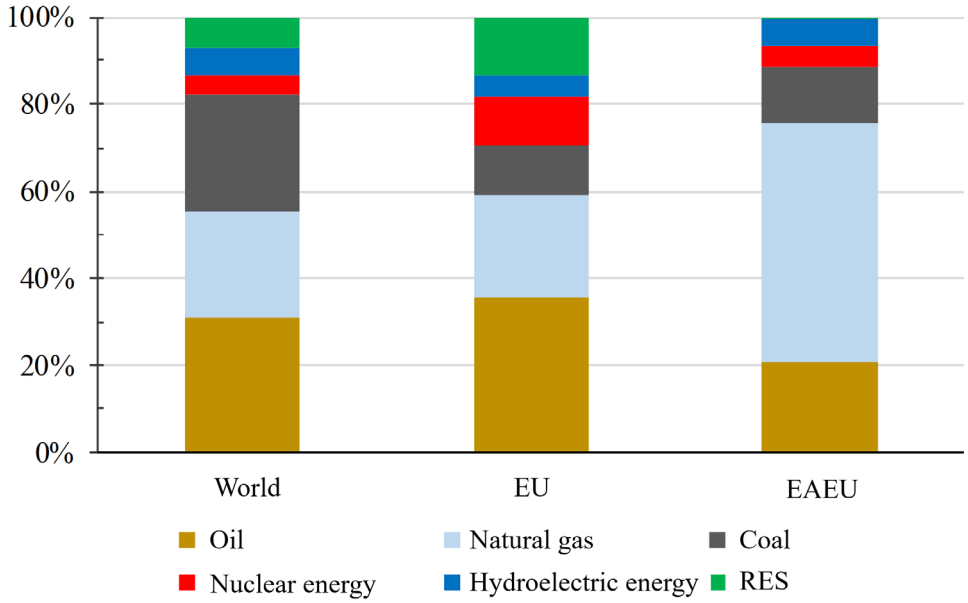

Fig.3. Examples of the structure and balance of consumption of primary energy resources by region (EU – European Union; EAEU – Eurasian Economic Union).

for fossil fuels and implicit subsidies to competitive schemes in favor of nuclear and renewable energy, i.e., auctions, green certificate systems, direct contracts for the supply of energy resources between producers and consumers. These solutions aim to reduce the economy's dependence on the production and consumption of fossil fuels, to diversify the balance of energy resources, which, together with the growing role of consumer choice and expanding competition between different types of energy and fuel, will lead to greater sustainability, predictability, and security of energy development. At the same time, cutting down the fossil fuel consumption per unit product output will become a direct competitive advantage for participants in such schemes.

Analysis of the above trends and existing development programs of the world's leading economies, including their legislation in the field of energy security, allows making the following medium-term forecast regarding the evolution of global energy policy and its target indicators:

• Starting in 2030, the growth of gross primary energy consumption will slow down significantly, in particular due to the enhancement of energy efficiency and the introduction of circular principles of economic development;

• According to all forecast scenarios, the share of fossil fuels in the structure of primary energy resources will begin to decline due to restrictions on the demand side, which will lead to a reduction in their share in primary energy resources by 2050 from the current 82% to approximately 60%, and some scenarios assume such a reduction to their share below 20-30%;

• Among fossil fuels, only natural gas will be able to increase its share in the global energy balance from 22% to 24–26% by 2050, the share of coal will go down from 28% to 19–23%, and oil - from 32% to 25–27%;

• Final energy consumption in the member states of the Organization for Economic Cooperation and Development will be reduced by at least 25% by 2050, and according to some scenarios – by approximately 50%;

• In the rest of the world, final energy consumption will significantly slow down its growth and will be on average no more than 0.3% per year compared to the current 1.9%;

• The overall growth in energy consumption in developing economies will be achieved not through the growth in the fossil fuel and energy production, but through the introduction of new low-carbon energy sources and renewable energy sources;

• The demand for electricity will grow along with the share of electricity in final energy consumption which will exceed 20% by 2040. Moreover, the rapid development of renewable and other low-carbon sources will provide 35–50% of global electricity production by that time;

• The development of distributed electricity generation will accelerate, involving the search for electricity storage solutions;

• Electricity markets will continue to develop to diminish price distortions and foster competition;

• Mobilization of additional investments in sustainable energy, related to technological innovation and energy efficiency, will continue and the amount of $300 billion reached in 2021 is expected to triple by 2030;

• Expansion of international cooperation will persist with a focus on the transfer of technology and the enhancement of human and institutional capacity in developing countries.

III. Parameters and priorities for energy development in Belarus

Important priorities of the national economy of Belarus are to ensure the security, reliability, and efficiency of the energy sector, while simultaneously increasing its financial stability. Following these priorities, which correspond to global trends, and taking into account the unbalanced structure of gross primary energy consumption in the national energy sector (Fig. 4), the strategic objectives of the sector development aim to reduce reliance on imports of hydrocarbons, bring the energy-to-GDP ratio closer to the world average value of this indicator, cut down the gross energy consumption, and increase the capacity of low-carbon energy sources, including nuclear power plants.

The country has always actively planned and fully implemented programs designed to improve energy efficiency, and to date, energy intensity of the country's economy has decreased by 3.5 times compared to the 1990 level. At the same time, the analysis of the rate of decrease in energy intensity reveals that it has decelerated significantly in the last 10 years (Fig. 2). The conclusion follows that low-cost measures to improve the energy efficiency of the national economy have already been exhausted. New political and management decisions are required to motivate the energy sector entities (both

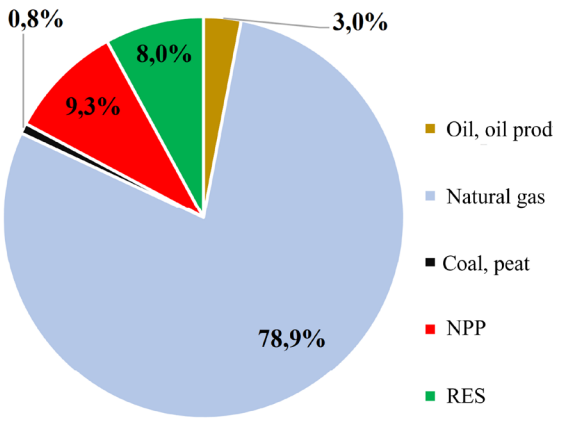

Fig. 4. Gross primary energy consumption in the energy sector of Belarus

producers and consumers) to reduce specific consumption of energy, including fossil fuels.

Over the past 20 years, the gross primary energy consumption has remained virtually unchanged. However, an analysis of the structure of the current balance of primary energy and its comparison with last year's data indicates a good trend in import reduction: imports of electricity decreased by almost 15 times, oil – by 39%, natural gas – by 5.3%, and coal – by 54%. At the same time, in 2022, it became evident that the diversification of imported energy supplies still faces a critical threat. The share of electricity, crude oil, and coal coming from the Russian Federation in the total volume of imports in physical terms continues to grow, replacing supplies of these resources from Lithuania and Ukraine (electricity), Azerbaijan (crude oil), and Kazakhstan (coal).

The government of the country is committed to enhancing energy independence by diversifying primary energy sources, which involves expanding nuclear energy sources, promoting local fuel and renewable energy sources, and reducing energy intensity by a minimum of 7% by 2025.Today, according to the Ministry of Energy, the total installed capacity in energy companies is 11 498 MW. The main part (10 202.5 MW) is connected to the Integrated power grid. The rest of the capacity (1 295.5 MW) are installations operating at various entities. Most energy sources (9 668.2 MW) use gaseous or liquid hydrocarbon fuels converted from primary energy sources. The total capacity of energy plants using renewable energy sources and secondary energy resources is 659.9 MW, which is more than 10 times higher than the figure five years ago. The capacity of each of the two BelNPP units is 1 170 MW.

We must prioritize our attention to the greenhouse gas emissions in the energy sector [9], especially considering their significant growth in the past 5 years, which goes against the global trends observed. In this regard, it must be emphasized that high carbon-intensive export products will no longer be able to compete in the international market due to the restrictions of cross-border carbon regulation. This circumstance poses a certain risk to sustainable development and must be taken into consideration in plans for the development of the energy sector.

IV. Development of Nuclear Energy in the Republic of Belarus

The decision to build the BelNPP was made on January 15, 2008 at a meeting of the Security Council of the Republic of Belarus. This project is expected to provide about a third of the country's domestic electricity needs, replacing annually 4.5 billion m^3 of imported natural gas and reducing greenhouse gas emissions by more than 7 million tons. The installation of the first generator unit began on January 27, 2016, at the Ostrovets site. On November 3, 2020, it was connected to the Integrated power grid and on June 10, 2021, it was put into operation.

Since the beginning of the commercial operation of the BelNPP, its total output has reached about 14 136 million kWh as of the end of April 2023, which was lower than planned. This was due to the operation of automatic protection of the turbogenerator, diagnostics of technological systems and components, routine maintenance, the first partial reloading of nuclear fuel, and additional tests. On December 27, 2021, the reactor of the second generator unit of the BelNPP was filled with fuel and its physical start-up was carried out on April 26, 2022. Commercial operation is planned to start in the second half of 2023.

To integrate the BelNPP into the country's power system and maintain the baseline operating conditions of nuclear units, it is necessary to ensure the appropriate value and patterns of power consumption. Over the past three years, several decisions have been dedicated to addressing this issue (Table 1).

TABLE 1. Policies and Measures for the Integration of the BelNPP into the Power System

Name of the Resolution	Number and date. Short description
On approval of the Concept for the Development of Electricity Generating Capacities and Electrical Networks until 2030	Resolution of the Ministry of Energy No. 7 of 25.02.2020 includes an analysis of the current state of the power system, the structure and changes in the installed capacity of generating sources, the efficiency of electricity transmission systems, the current and planned energy balance, measures for the further development of electricity generating facilities and electrical networks. The document provides a forecast of the balance of electricity and heat production and consumption, as well as the total installed capacity of energy sources until 2030 for organizations of State Production Association (SPA) "Belenergo."
About the State Program "Comfortable Housing and Favorable Environment" for 2021–2025	Resolution of the Council of Ministers No. 50 of 28.01.2021 includes measures to create and further develop a comfortable and safe living environment and the consumer services sector; to increase the availability of energy supply in populated areas. It also includes the subprogram "Development of the Electric Power Industry and Transition to Gas in Populated Areas," the implementation of which will increase electricity consumption by 2.8 billion kWh a year.
On approval of the State Program "Energy Saving" for 2021–2025	Resolution of the Council of Ministers No. 103 of 24.02. 2021 is aimed at boosting the efficiency of the national economy and strengthening the country's energy security by reducing the reliance on imported fuel and energy resources, bringing the energy-to-GDP ratio closer to the world average value of this indicator. This document establishes energy intensity targets, related objectives and control mechanisms by industry and region, as well as financing principles.
On approval of the Program for Comprehensive Modernization of Energy Production Facilities for 2021–2025	Resolution of the Ministry of Energy No. 19 of 05.04.2021 is aimed at modernizing power plants and boiler houses, electrical and heat networks of the entities of the SPA "Belenergo," given the commissioning of the nuclear power plant. The document presents and justifies a set of measures to achieve power system development indicators, which will increase the availability of electricity for heating and hot water supply both in the existing housing stock and during the construction of new electrified housing. As a result, there will be an increase of 900 million kWh per year in electricity consumption for these needs.
On approval of a Comprehensive Plan for the Development of the Electric Power Sector until 2025, with the BelNPP Put into Service	Resolution of the Council of Ministers No. 169 of 01.03.2016 approves changes (Amendments No. 714 dated October 20, 2022) included in the Comprehensive Plan for the Development of the Electric Power Sector until 2025, with the BelNPP Put into Service and the Cross-sectoral Set of Measures to Increase Electricity Consumption until 2025. The changes concern the deadlines and the list of performers, which were adjusted based on the results of the commercial operation of the first unit of the nuclear power plant.

These measures were aimed at increasing power consumption in various areas, such as industry, housing and utilities sector, construction, and transport. They also concerned the construction and reconstruction of networks and substations of various voltage classes. The increase in electricity consumption is also facilitated by the introduction of the category of "energy-intensive consumers" on January 1, 2021, which involves using a special incentive tariff plan and a system of discounts. Given the fact that households are the main energy consumers, which account for approximately 45% and 21% of the heat and electricity supplied to the market respectively, a special discount system was introduced to encourage them to boost electricity consumption for heating, hot water supply, and cooking. In general, since the beginning of the BelNPP operation, direct and indirect subsidies in support of low-carbon energy have amounted to 46.7 million US dollars [10].

An important and necessary component in the emerging power supply infrastructure, which is aimed at increasing the stability and reliability of the BelNPP equipment and leveling the daily load curve, is the construction of peak-backup sources and electric boilers. The total installed capacity of electric boilers planned by 2025 is 1.12 GW, of which 0.76 GW will be installed at power plants and 0.16 GW – at boiler houses. To date, 170 MW and 26 MW respectively have been put into operation. The construction and commissioning of additional network equipment and new substations are also planned.

To maintain the base-load operation of the nuclear units of the BelNPP, it is necessary to ensure the appropriate value of the final electricity consumption in the country. An accelerated transition to replacing the main volumes of secondary energy resources with electricity in order to achieve the required level of consumption of this resource has become an important priority of the national energy

TABLE 2. Energy Security Indicators of the Republic of Belarus

Name of the indicator and its characteristics	Index of security level		
	Normal	Critical	2022
Energy independence			
1. The ratio of primary energy production (extraction) to gross consumption of fuel and energy resources, %	30	16	22,5
2. The ratio of primary energy production (extraction) from renewable sources to gross consumption of fuel and energy resources, %	14	5	8,0
Diversification of suppliers and types of energy resources			
3. The share of the dominant supplier of energy resources in total imports of fuel and energy resources, %	65	85	98.6
4. The share of the dominant fuel type in gross consumption of fuel and energy resources, %	50	70	59.5
Reliability of supplies, redundancy, processing and distribution of fuel and energy resources			
5. The ratio of the total installed capacity of power plants to the maximum actual load in the power system (redundancy), %	140	95	180.4
6. The share of accumulated depreciation in the initial cost of fixed assets of energy entities, %	45	75	43.4
7. The ratio of the capital investment made in the development of the energy sector to the initial cost of fixed assets of the energy entities, %	6	4	4.7
8. The share of the dominant energy resource (natural gas) in the production of thermal and electrical energy, %	50	80	84.2
9. The ratio of the average daily number of power supply failures in populated areas to the total number of populated settlements, %	0.5	2	0.3
Energy efficiency of final energy consumption and economic sustainability of the energy sector			
10. Energy-to-GDP ratio, kg c.e./million rub.	160	485	361
11. Ratio of the cost of energy commodity imports to GDP, %	15	30	10.4

policy. However, as follows from data analysis, the positive growth in electricity consumption that has emerged over the past 5 years showed negative dynamics in 2022 (a reduction of 6%). At the same time, there is a noticeable trend in the increase in electricity consumption by the population (by 2.1% in 2022). Thus, electrification of the housing sector, service sector, and urban transport holds great potential to enhance the electricity intensity of the economy in the context of commissioning the BelNPP. By 2030, more than 30% of electricity is expected to be consumed by electric houses and electric vehicles.

V. ENERGY SECURITY AND NUCLEAR ENERGY

According to the Energy Security Concept of the Republic of Belarus, in March 2023, the data on monitoring of the energy sector in 2022 were analyzed, and the main risks for its sustainable development in general and for individual sectoral areas were identified. Furthermore, trends in changes in the relevant indices were clarified for the period of 2015–2022 and recommendations were prepared to minimize the risks and ensure the country's energy security in 2023.

Table 2 presents energy security indicators of the Republic of Belarus that cover some characteristics and indices of the energy sector development.

One of the two indicators characterizing the country's energy self-sufficiency (indicator No. 1) shows that the volume of its primary energy production (extraction) in 2022, given the energy generated by the BelNPP, was 8 213 thousand t.c.e. This satisfies 22.5% of national needs (gross consumption of fuel and energy resources), which amounted to 36 559 thousand t.c.e. Analysis of changes in this indicator for the period of 2015-2022 (Fig. 5) demonstrates its significant growth after the commercial operation of the BelNPP started in 2021. This indicator approached the normal level and was noticeably better than the value that was planned to be reached only by 2030. However, it must be taken into account that it still remains within the values of the precritical range.

The second indicator, which represents the share of primary energy produced from renewable energy sources (indicator No. 2), also shows positive dynamics. The ratio of the primary energy production (extraction) from renewable energy sources (2 027 thousand t.c.e.) to the gross fuel and energy consumption in 2022 was 8.0%, which is equal to the value of indicator that was planned to be achieved by 2030.

The commissioning of the first unit of the BelNPP significantly improved the redundancy indicator (indicator No. 5), which is in the range of the normal threshold level. Thus, it becomes possible to gradually decommission

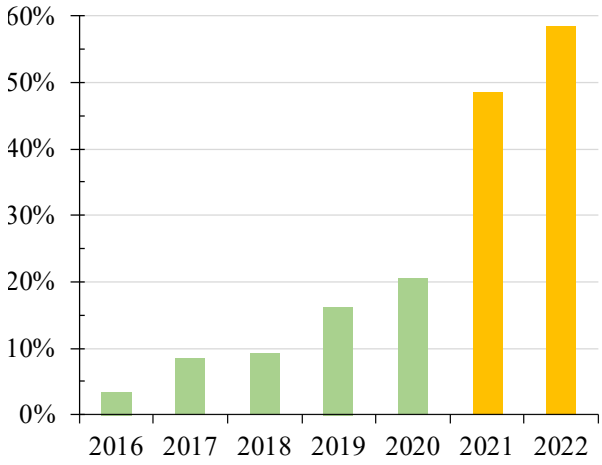

Fig. 5. Change in the indicator "Ratio of primary energy production (extraction) to gross energy consumption," as a percentage of the 2015 level.

obsolete power units of thermal power plants, thereby expanding the room for the utilization of renewable energy sources and increasing the country's electric power export potential.

Furthermore, given the cost of fixed assets of the BelNPP and the upgrade of technical equipment at some enterprises of the SPA "Belenergo," the calculations suggest that the accumulated depreciation accounts for 43.4% of the initial cost of fixed assets, which indicates that the corresponding indicator (indicator No. 6) is within the normal threshold level.

Natural gas is still the dominant primary energy source. Its share in energy production is 84.2%. Compared to the 2015 level, this share decreased by 7.1%, which is the result of the commissioning and gradual increase in the load of the BelNPP and the development of renewable energy sources. This indicator (indicator No. 8), however, still remains at a critical level.

VI. Conclusion

The launch of both BelNPP power units at full capacity, anticipated by the end of 2023, along with the expansion of renewable energy sources will enhance our energy security indicators by 2035 as follows:

• The share of primary energy production in the volume of gross consumption of fuel and energy resources will rise from the current 22.5% to 70%;

• The share of natural gas in gross fuel and energy consumption will decrease from the current 59.5% to 40%;

• The ratio of the installed capacity of power plants to the maximum actual load will increase from the current 180.4% to 200%.

The connection of the BelNPP to the Integrated power grid of the national energy sector significantly improved the country's energy security indicators, providing, together with renewable energy sources, a guarantee of a sustainable and consistent increase in the energy independence of the national economy.

The operation of the BelNPP contributes to the diversification of the balance and final consumption of fuel and energy resources, thereby reducing the share of fossil fuels. In doing so, the country not only fulfills its international obligations under the Paris Agreement, but also stays in line with the latest trends and development programs of global economies.

Putting the BelNPP into service boosts the availability of electricity for the end consumer, which, in turn, will provide the corresponding demand for electricity and initiate an increase in the share of renewable energy sources and other low-carbon sources in final energy consumption. This will also accelerate the development of decentralized electricity generation, including search for storage solutions, motivation of the participation of the national energy sector in international and regional energy markets and integrated power systems.

The BelNPP as part of the energy sector makes the infrastructure for the production, conversion, transmission, and consumption of energy resources more reliable, sustainable, and efficient. With this plant, we can reduce the carbon intensity of the national GDP and attract investments in the further development of the energy sector infrastructure.

On the other hand, there are some certain aspects of the current economic and energy development, both internal and external, which could potentially hinder the future progress of nuclear energy and jeopardize the energy security of the Republic of Belarus. These are as follows:

• Potential disruption of financial stability and decline in the financial health of end energy consumers;

• Increased inflation and devaluation risks jeopardizing the ability to finance investment programs, modernization and ongoing maintenance of the energy infrastructure;

• Reduction in the possibility of concluding long-term agreements on the export of electricity from the Republic of Belarus, given its low competitiveness compared to

neighboring countries, where, significant electricity surpluses are growing;

• Sanctions impose restrictions on the import of crucial equipment and technology, which may pose a threat to the planned maintenance and repair of the existing energy infrastructure due to its high reliance on imports and credit financing, with the BelNPP being no exception.

Therefore, given the significance of the BelNPP in enhancing the energy security of the Republic of Belarus, it becomes imperative to conduct a comprehensive technical and economic feasibility analysis to determine the future progress in this area, make a projection of long-term demand for electricity in the country, and perform a subsequent calculation of the energy security level based on relevant indicators.

REFERENCES

[1] Concept of the National Security of the Republic of Belarus. Decree of the President of the Republic of Belarus dated Nov. 9, 2010, No. 575.

[2] Concept of the Energy Security of the Republic of Belarus. Resolution of the Council of Ministers of the Republic of Belarus dated Dec. 23, 2015, No. 1084.

[3] A.A. Mikhalevich, A. Zh. Grebenkov, "Modern energy policy: global and regional aspects," *Problems of energy and resource conservation*, no. 3, pp. 28–53, 2022.

[4] Statistical Review of World Energy 2022, 71st edition. BP p.l.c.: Centre for Energy Economics Research and Policy, June 2022.

[5] Nuclear Power Reactor in the World. International Atomic Energy Agency, IAEA-RDS-2/42, June 2022.

[6] World Energy & Climate Statistics – Yearbook 2022. Energy intensity. Enerdata. Jul. 05, 2022.

[7] World Bank: Sustainable Energy for All (SE4ALL) database, Jun. 30, 2022. [Online] Available: https://energydata.info/dataset/se4all-database. Accessed on Aug 12, 2023.

[8] BP p.l.c.: Statistical Review of World Energy, June 2022. [Online] Available: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. Accessed on Jan. 23, 2023.

[9] Belarus. 2022 Common Reporting Format (CRF) Table. [Online] Available: https://unfccc.int/documents/461954. Accessed on Jan. 23, 2023.

[10] OECD/IISD: Fossil Fuel Subsidy Tracker, Supplementary datasheet to Fossil Fuel Subsidy Tracker platform, 2022. [Online] Available: https://fossilfuelsubsidytracker.org/country/. Accessed on Jan. 23, 2023.