GRADUAL TRANSITION TOWARDS THE LOW-CARBON POWER INDUSTRY IN THE REPUBLIC OF BELARUS

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Abstract

In the Republic of Belarus, due to limits of its own natural reserves of fossil fuels, almost 80 percent of energy consumption in real sector and social sphere is provided by the import of energy resources that significantly reduces the energy security of the country. Under these conditions, one of the priority areas for increasing stability and security of Belarusian power engineering complex is gradual replacement of imported crude oil and natural gas with local energy resources, including renewable energy and nuclear power. Both resources if properly balanced, scheduled and utilized in the National United Energy System along with gradual decommission of fossil fuel facilities should also help Belarus in meeting and strengthening the country's climate commitments. The recent developments in this area included construction and commercial operation of the Belarusian nuclear power plant and sufficient progress in extending renewable energy resources and improving energy efficiency. This allowed, since 2010, to achieve the twofold reduction of the share of hydrocarbon imports in GDP and increase the ratio of the own primary energy production to the gross consumption of fuel and energy resources from 14.0% to 22.5%. As a result, during the last ten years, the energy production facilities reduced their greenhouse gas emissions by more than 8%. The analysis of energy supply indicators, the current state and medium-term forecasts of the development of the national energy industry, in the structure of which nuclear energy begins to play a significant role, indicate about a number of achievements that include gradual elimination of threats and uncertainties for the sustainable, reliable and efficient development of the energy sector in the Republic of Belarus.

Keywords: *power engineering, fossil fuel, nuclear power plant, renewable energy, low-carbon development, energy security*

INTRODUCTION

Reliable, secure and efficient functioning of the national fuel and energy complex (hereinafter referred to as FEC) is one of the most relevant and important tasks for the current economy of the Republic of Belarus [1]. To ensure the essential development level of FEC and its further improvement, it is necessary to identify and eliminate the factors (actual or potential) that pose a threat to the sustainable and safe growth of the energy industry. The most important threats, their sources, indicators of the level of hazard, methods for their assessment and monitoring standards, as well as the main directions for their elimination are set out in the Energy Security Concept of the Republic of Belarus [2].

The Republic of Belarus is a net importer of fuel and energy resources (hereinafter referred to as FER), providing today about 77.5% of gross domestic energy consumption through imports of crude oil and natural gas. In this regard, the strategic objectives of the development of the national FEC, the implementation of which will increase energy security, should include reduction of the dependence on hydrocarbon imports. These objectives can be achieved by increasing local fuel share, enlarging capacity of low-carbon power sources, including those of nuclear origin, and renewables, as well as by efficiency improvement of FER production and use. Progress is needed in terms of diversifying suppliers of primary energy carriers to the country and bringing the energy intensity of gross domestic product (hereinafter referred to as GDP) closer to the world average value of this indicator that will also increase the energy security.

Since 2020, the list of energy security threats that Belarus faces due to objective political, resource, geographic and economic constraints and circumstances has been supplemented by high uncertainty in

key indicators of the development of world economies associated with the COVID-19 pandemic and the aggravation of a number of international and regional conflicts. All this, in turn, leads to an increase in vulnerability and the risk of unsustainable development of FEC in many countries, including the Republic of Belarus, whose enterprises, moreover, meet with significant sanction pressure from the influential foreign economic partners of the country and experience respective challenges of sharp fluctuations in the import-export balance. In addition, if no measures are applied lowering the FEC's carbon intensity, the current cross-border carbon regulation strengthening will soon impact negatively on the export of a national product dependent on the activities of companies in the energy sector.

For the Republic of Belarus, the above circumstances have significantly aggravated the issues of ensuring the safe, stable and efficient operation of the national FEC. Under these conditions, one of the priority areas for its further secure development is gradual replacement of imported crude oil and natural gas with renewable energy and nuclear power. Both energy sources belong to the local types of low- or zero-carbon FER and will contribute a certain amount of diversification, energy self-sufficiency, carbon neutrality and reliability to the FEC's structure.

The task for this work is to review and analyze the state and changes in the primary energy gross consumption balance of Belarus based on the results of the functioning of the country's economy over the past 5 years. The aim is to develop with a focus on the challenges met during that period the recommendations for further proceeding to the low-carbon power industry in the country. The authors take into account the today's international energy policy trends and consider the Belarusian nuclear power plant (hereinafter referred to as BelNPP) as an important instrument for the energy transition.

PRESENT-DAY ENERGY DEVELOPMENT TRENDS

As the world moves towards decarbonization, there is no shortage of climate change commitments. At COP27 in Egypt in November 2022, an international agreement reinforced commitments to limit global temperature rise to no more than 1.5 degrees above pre-industrial levels. There are about 130 countries [3] with commitments to achieve zero carbon emissions before 2060 adopted either by lows or policy documents (70 countries) or by formal proposals/declarations. But even if all of these countries meet their current commitments, global emissions will be still far from the 1.5-degree target.

Therefore, an important trend in world energy policy is the significant reduction of the GDP carbon intensity [4] that provides for a gradual transition to the low-carbon FER used in production and consumption of energy. The low-carbon FER include renewable energy sources (hereinafter referred to as RES), as well as the nuclear energy. Since natural renewable sources are characterized by large fluctuations in capacity and generated energy and are difficult to regulate depending on the load, the voltage in networks with a high content of renewable sources will be unstable. In some cases, such a network will not be able to provide the main parameters of the load curves. To minimize grid fluctuations and ensure a reliable supply of energy for consumers some of energy sources is to provide the base load. In the conditions of decarbonization, the modern energy policy considers the nuclear energy as one of such sources, which is to perform 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 was 389.5 GW, and 58.1 GW were under construction [5].

Analysts note the growth of investments in reducing the carbon intensity of the global energy sector, which in 2021 increased by 27% compared to 2020, reaching $755 billion [6] while amounting to about $50 billion only 15 years ago. Through these investments, the largest energy companies are decommissioning carbon-intensive energy sources, replacing them with more efficient low-carbon facilities, including nuclear (for example, in Belarus), and via accelerating the RES introduction. The corresponding trends in the development of the low-carbon global energy sector can be confirmed by the dynamics of some key indices in the electric power industry [7] (see Fig. 1).

As a result, the primary FER gross consumption per unit of world GDP over the past 20 years has been declining by an average of 1.5% per year with GDP growth of about 3.1% per year [8]. At the same time, the levels, dynamics and trends in reducing energy intensity differ markedly by countries and

regions (see examples in Fig. 2) that reflects the characteristics of the respective climatic zones and differences in economic and technological development as well as in structures of national economy and energy policy. The high energy intensity and its growth in some countries is explained by the predominance of low-efficiency industries, a raw material export economy and low prices for natural fuel and energy resources, which do not stimulate a reduction in specific energy consumption.

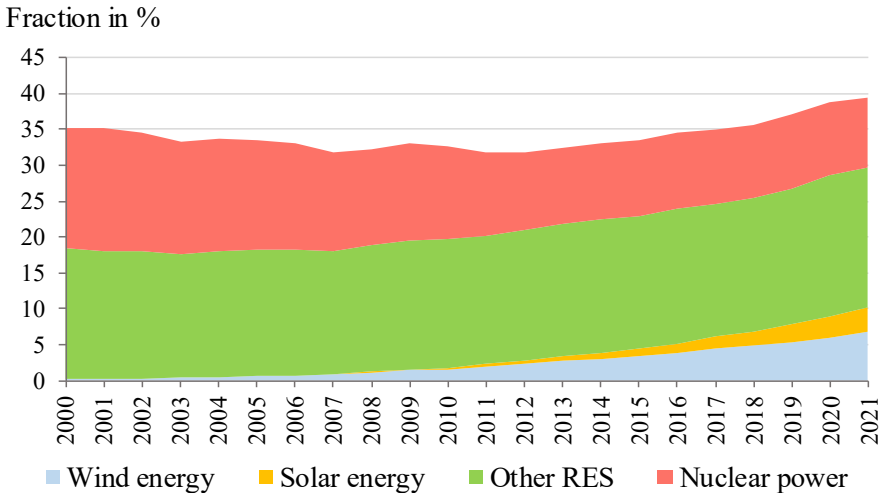

Figure 1. The structure of consumption of low-carbon FER in the global electricity production

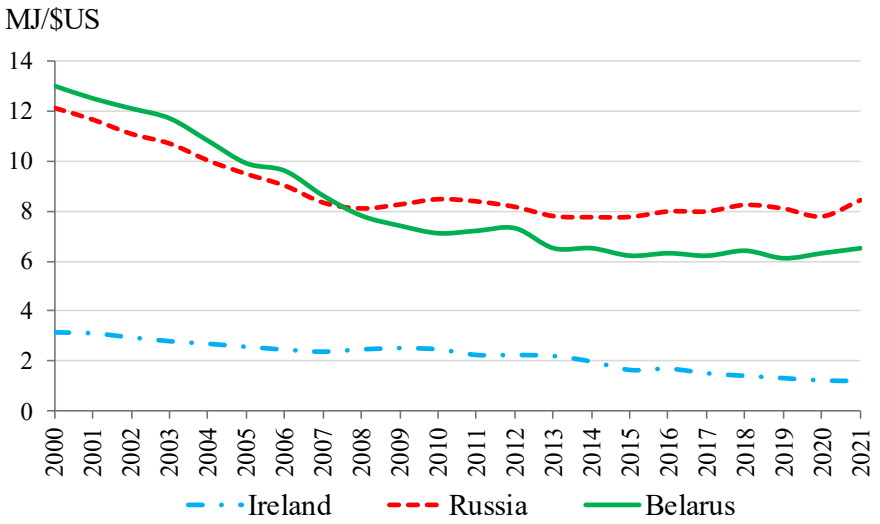

Figure 2. Examples of trends of the energy intensity of national products

It should be noted that in the last four-year period, the indicators of the development of the world energy system were not stable due to the high uncertainty of energy policy at the regional and national levels. During 2020, this was related to the consequences of the COVID-19 pandemic (a 3.4% drop in global GDP) that led, for example, to a reduction in the daily increase in oil consumption by 41% followed by a decrease in the oil refining sector's capacities by 0.5 million barrels per day with related drop of prices in oil exchanges. Then, from 2021, consumers began a rather sharp post-pandemic economic growth that in 2022 matched with one of the most difficult international conflicts involving the Russian Federation, which led to an increase with subsequent sharp fluctuations in prices for the main primary FER. According to the exchange data [9], oil prices in 2021-2022 compared to January 2021 rose up to

150%, natural gas prices - up to 310%, falling sharply by the end of March 2023, respectively, to 75% and 30% of January 2021 prices.

In the next 5 years, the energy sector of the leading countries will continue to gradually move from direct budget support measures and implicit subsidies for fossil fuels to the competitive schemes in favor of low-carbon energy, such as auctions, green certificate systems, direct contracts between producers and consumers for FER supply. The purpose of these decisions is to reduce the dependence of the economy on the production and consumption of fossil fuels and diversify the FER balance. These measures together with the growing role of a consumer to choose and expanding competition between various types of energy and fuel will lead to greater stability, predictability and security of energy development. At the same time, the reduction in the specific consumption of fossil fuels for production of a commodity will become a direct competitive advantage for the participants in such schemes and construct a basis for energy transition towards the zero-carbon future.

MAIN PARAMETERS AND PRIORITIES FOR ENERGY INDUSTRY DEVELOPMENT IN BELARUS

Ensuring the safety, reliability and efficiency of the energy industry while improving its financial stability are the important priorities of the national economy of Belarus. Based on these priorities, which are in line with global trends, and also taking into account the unbalanced structure of primary FER in the national FEC, the strategic tasks for the development of the energy industry include as follows:

- reduction of dependence on hydrocarbon imports;
- convergence of energy intensity of GDP closer to the world average value;
- cut of gross consumption of fossil fuels; and
- increase of capacity of low-carbon energy sources, including BelNPP.

According to national statistics [10], the gross consumption of primary energy in Belarus during the last 10 years is varying around 38.6 (±1.5) million tons of coal equivalent annually. The recent trend of this index reflecting transformation of primary FER into thermal and electric energy in the national FEC is shown in Fig. 3 that is in line with the tasks listed above.

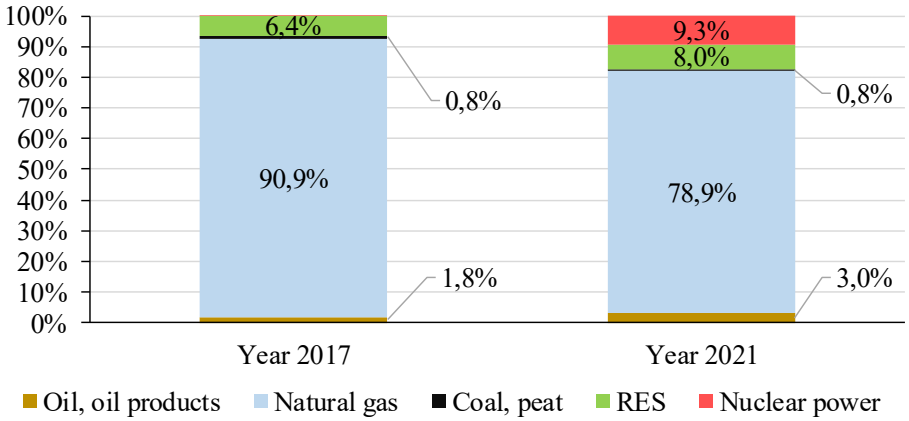

Figure 3. Share of primary FER in thermal and electric energy production [10]

The country has always actively planned and fully implemented programs to improve energy efficiency, and to date, the energy intensity of the country's economy has decreased by 3.5 times compared to the level of 1990 [11]. At the same time, when analyzing the rate of decrease in energy intensity, one should note that in the last 10 years it has slowed down significantly (the trend line can be seen in Fig. 2 above).

This leads to the conclusion that low-cost measures to improve the energy efficiency of the national economy have already been exhausted. New political and managerial decisions are required to motivate the subjects of the energy industry, both producers and consumers, to reduce the specific consumption of FER and, first of all, fossil fuels.

In view of the possibility of diversifying primary FER, the government of the country in the medium term (until 2025) focuses on increasing energy self-sufficiency by expanding nuclear energy sources, local FER and RES and on reducing energy intensity by at least 7%.

According to the Ministry of Energy, the total installed capacity in the FEC's organizations of the Republic of Belarus as of January 1, 2023 amounted to 11.5 GW (Table 1). The main part (10.2 GW) is included in the National Integrated Energy System. The rest (1.3 GW) refers to power installations used by various organizations. Most energy sources (9.7 GW) use gaseous or liquid hydrocarbon fuels converted from fossil primary FER.

Table 1. Installed capacity of FEC's power resources in operation as of January 1, 2023

Facility of the Integrated Energy System	Capacity, MW	Power installation of separate block-stations	Capacity, MW
SPA “Belenergo” / other facility, total, including:	10,202.49	Block stations, total, including those using:	1,295.49
SE “BelNPP”	1,170.00	associated petroleum gas	42.26
Condensing power plants, including:	4,704.22	natural gas	690.51
Berezovskaya SRPS	1,095.12	biogas	41.45
Lukomlskaya SRPS	2,889.50	biomass	76.04
Minsk CHPP-5	719.60	wind	109.27
CHPs, including:	3,579.55	water resources	7.57
Novopolotsk CHPP	270.00	secondary energy resources	51.61
Mozyr CHPP	206.00	solar	272.77
Svetlogorsk CHPP	155.00	firewood and wood fuel	3.51
Gomel CHPP-2	544.00	other RES	0.50
Grodno CHPP-2	312.45		
Minsk CHPP-3	557.00		
Minsk CHPP-4	1,035.00		
Mogilev CHPP-2	317.50		
Bobruisk CHPP-2	182.60		
TPP up to 140 ata	651.62		
RES	97.11		

As it follows from Table 1, the total capacity of power plants using RES and secondary energy resources is 659.9 MW, which is more than 10 times higher than five years ago. The trend of increase of installed capacity of RES is shown in Fig. 4.

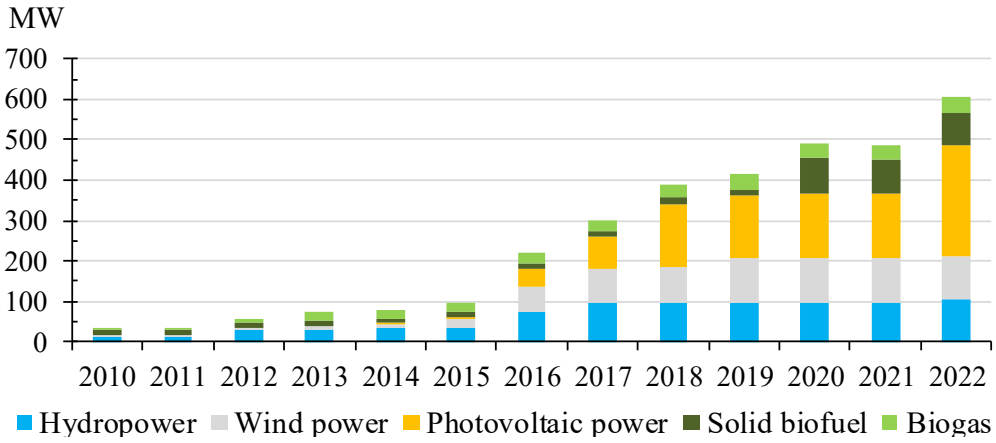

Figure 4. The development of installed capacities of RES in the national FEC [12]

Ten years ago, in the Belarusian electricity production sector, 99.6% of electrical power was produced from fossil fuels, and only 0.4% of energy was generated in RES facilities. Since November 2020, when the first nuclear power unit of 1.17 GW installed capacity was included in the country's Integrated Energy System, and until December 2022, the electricity produced from fossil fuels constituted 88.2% of total electrical power generated in the system. The remaining 3.0% and 8.8% of electrical power was generated in RES facilities and BelNPP respectively. In Fig. 5, the sources of electrical power produced from RES during the last 10 year are listed [12].

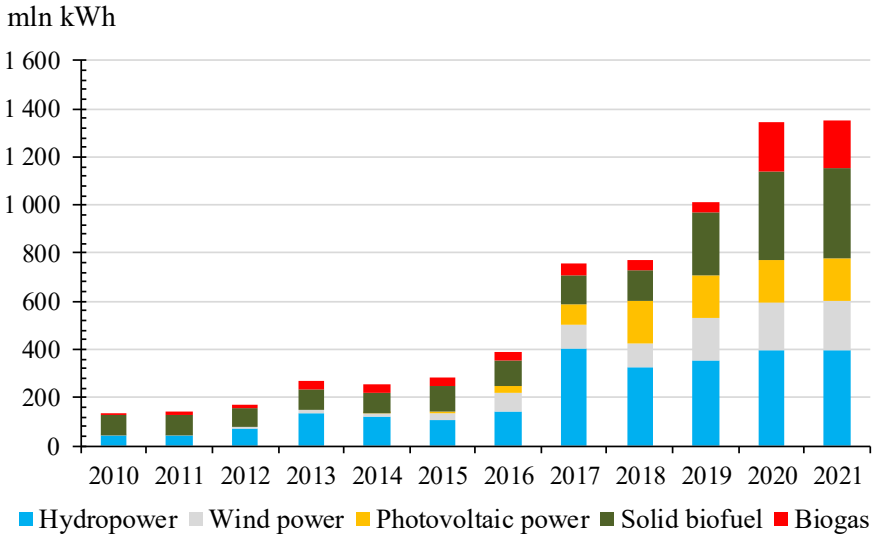

Figure 5. The electrical power produced with RES in the national FEC

DEVELOPMENT OF NUCLEAR ENERGY AND ENERGY TRANSITION IN THE REPUBLIC OF BELARUS

The decision to build a nuclear power plant in Belarus was made on January 15, 2008 at a meeting of the Security Council of the Republic of Belarus. The adoption of this decision was preceded by a complex and lengthy dialogue between the public, scientists and technical specialists, the main issue of which was the choice of a site and ensuring the safety of the operation of the proposed nuclear units. The construction of BelNPP started at the end of 2011 at the Ostrovets site. The installation of the reactor of the first power unit with a capacity of 1.17 GW was started on January 27, 2016, and on November

3, 2020 it was included in the country's Integrated Energy System. The acceptance act and the corresponding license were issued on June 2, 2021, and on June 10, the first power unit was put into commercial operation.

In the period from July 12 to October 4, 2021, the station was disconnected from the network due to the actuation of the automatic protection of the turbine generator and the implementation of diagnosis of technological systems and components. Until December 31, 2021, the station generated 6,120 million kWh of electricity. BelNPP electricity generation in 2022 was also well below the planned 13,807 million kWh. This was due to the scheduled maintenance work from April 26 to November 9, 2022, the first partial refueling of nuclear fuel and additional tests. As a result, the plant's output in 2022 amounted to 4,685.4 million kWh, or 12% of the total electricity generated in the country in 2022. According to the Ministry of Energy, starting from the date of commercial operation of the BelNPP, its total generation by April 14, 2023 amounted to 13,720.8 million kWh. By December 27, 2021, the second power unit of the BelNPP with a capacity of 1.17 GW was refueled with nuclear fuel and on April 26, 2022 its reactor was physically launched. The commercial commissioning will be carried out at the end of 2023.

The implementation of the BelNPP construction project will provide for about a third of the country's domestic electricity needs, replacing 4.5 billion cubic meters of imported natural gas annually, as well as reducing greenhouse gas emissions every year by more than 7 million tons. However, in order to integrate the BelNPP into the country's energy system and maintain the operation of nuclear units in the basic mode, it is necessary to ensure the appropriate value and modes of power consumption. Therefore, considering the prospects for the development of nuclear energy in the Republic of Belarus, one should dwell separately on the state policy that determines the final consumption of electricity in the country. Over the past three years, a number of government decisions have been devoted to this issue (Table 2), including resolutions of the Council of Ministers of the Republic of Belarus (hereinafter referred to as CM RB).

Table 2. Policies and measures for the integration of BelNPP into the energy system

Decree Title	Decree Number and Date. Brief Description
Ministry of Energy: «On the approval of the Concept for the development of electric generating capacities and electric networks for the period up to 2030»	No.7 of 25.02.2020 It includes an analysis of the current state of the energy system, the structure and changes in its installed capacities and the efficiency of power transmission systems. It also determines the predicted balance of electrical and thermal energy, the further development of power generating facilities and power grids. For the organizations of the State Production Association “Belenergo”, it gives a forecast of the balance of production and consumption of electricity and heat, as well as the total installed capacity of energy sources until 2030.
CM RB: «About the State Program “Comfortable Housing and Favorable Environment” for 2021–2025»	No.50 of 28.01.2021 It ncludes measures to create and further develop a comfortable and safe living environment, consumer services, to increase the availability of energy supply in settlements. It also initiates the sub-program “Development of the electric power industry and gasification of settlements”, the implementation of which will increase electricity consumption by 2.8 billion kWh per year.

CM RB: «On approval of the State Program "Energy Saving" for 2021–2025»	No.103 of 24.02.2021 It is aimed at increasing the energy efficiency of the national economy and strengthening the energy security of the country, including reducing dependence on imported FER, bringing the energy intensity of GDP closer to the world average value of this indicator. It establishes energy intensity targets, relevant targets and controls by industry and region, and funding principles.
Ministry of Energy: «On approval of the Program for the Comprehensive Modernization of Energy Sector Production for 2021–2025»	No.19 of 05.04.2021 It is aimed at the comprehensive modernization of power plants and boiler houses, electric and heat networks of the organizations of the State Production Association "Belenergo", taking into account the commissioning of nuclear power plants. It also presents and justifies a set of measures to achieve the energy system development indicators, the implementation of which will increase the availability of electricity for heating and hot water supply both in the existing housing stock and in the construction of new electrified housing. As a result, electricity consumption is supposed to increase by 900 million kWh per year.
CM RB: «On approval of a comprehensive plan for the development of the electric power sector until 2025»	No.169 of 01.03.2016 (reduction: No.714 of 20.10.2022) It approves the changes made to the Comprehensive Plan for the Electricity Sector Development until 2025, taking into account the commissioning of the BelNPP and the Intersectoral Set of Measures to Increase Electricity Consumption until 2025. The changes relate mainly to the deadlines and the list of responsible executors, which have been adjusted based on the results of the commercial operation of the first BelNPP unit.

These government decisions are aimed at increasing electricity consumption in various areas of the national economy, namely, in industry, housing and communal services, construction, and transport. They also concern the construction and reconstruction of electrical networks and substations of various voltage classes. At the same time, the measures envisaged in these decrees will lead to a reduction in the final consumption of fossil fuels, and the declared/forecast volumes of such a reduction can reach about 1 million tons of coal equivalent per year that will almost halve annual greenhouse gas emissions in the energy sector.

Measures are also being taken for promoting the consumers active in the economy real sector to increase electricity consumption. Since January 1, 2021, the category "energy-intensive consumers" has been introduced that provides for the use of a stimulating tariff plan. Given the fact that population is one of the main energy consumers, accounting for approximately 45% and 21% of the heat and electricity supplied to the market, respectively, a special system of discounts to energy tariffs for households has been introduced. In general, since the start of commercial operation of nuclear power plants, direct and indirect subsidies in support of low-carbon energy have amounted to 46.7 million US dollars [16].

An important and necessary element in the emerging power supply infrastructure, aimed at improving the stability and reliability of BelNPP equipment, and equalizing the daily load schedule, 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. Currently, 170 MW and 26 MW have been put into operation, respectively. It also provides for the construction and commissioning of additional network equipment and new substations.

An accelerated transit on to replacing the main volumes of secondary FER with electricity to achieve the required consumption of this resource has become an important priority of the state's energy policy. However, as follows from the analysis of the data (Fig. 6), the positive growth in electricity consumption, which has been outlined over the past 5 years, showed a negative trend in 2022, which is a decrease by 6%. At the same time, there is a noticeable trend in the growth by 2.1% of electricity consumption by the population. Thus, the electrification of the housing sector and the service sector can become an important direction for increasing the electric intensity of the economy in the context of the commissioning of the BelNPP. It is planned that electrified houses and electric transport will account for more than 30% of the commissioned power consumption facilities.

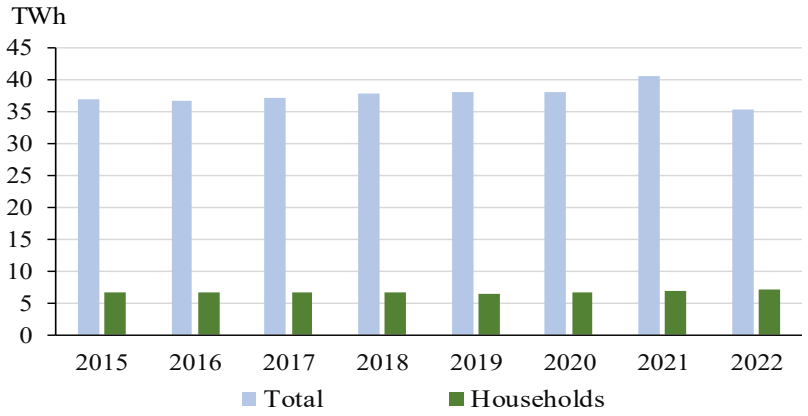

Figure 6. Annual final electricity consumption in the period of 2015-2022

According to the collected data, the country's energy self-sufficiency indicator shows that the volume of own production (extraction) of primary energy in 2022, taking into account the energy generated by the BelNPP, amounted to 8,213 thousand tons of coal equivalent. This satisfied 22.5% of national needs of gross consumption of FER, which amounted that time to 36,559 thousand tons of coal equivalent. An analysis of the change in the values of this indicator during the period of 2015-2022 (Fig. 7) demonstrates its significant growth after the start of commercial operation of the BelNPP in 2021. The BelNPP's operation created the conditions when the total installed capacity of power generating plants significantly exceeds the maximum actual load. The backup power resources reached 180.4% that makes it possible to gradually decommission outdated thermal power plant units, provides an opportunity to expand the use of RES and increases the country's export potential in the field of electric power industry.

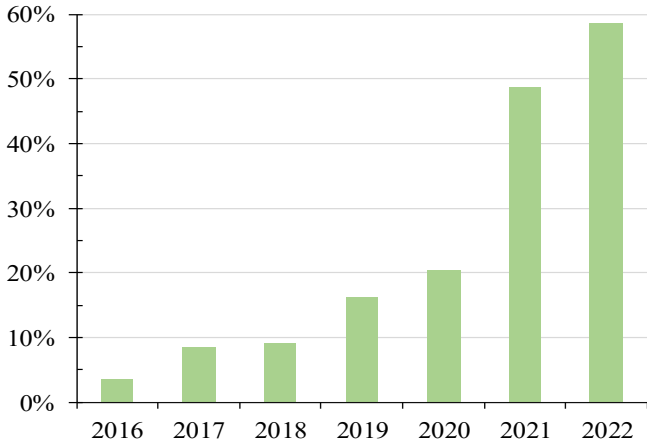

Figure 7. The ratio of production (extraction) of primary energy to gross consumption of FER, as a percentage of this parameter in 2015

While developing the low-carbon energy sector policy, the attention is paid to greenhouse gas emissions in the Republic of Belarus [13]. Here, in the last 5–10 years, their stagnation and growth per unit of gross consumption of primary energy has been observed, in contrast to the most of global trends [14] (Fig. 8), where a decrease in carbon emission intensity prevails in the energy sector. In this regard, it must be emphasized that export products with a high carbon intensity will no longer be able to compete in the international market due to the restrictions of transboundary carbon regulation (e.g., the Carbon Border Adjustment Mechanism [15]). This circumstance poses a certain risk to sustainable development and must be taken into account in the plans for the development of the energy industry, where the increase in low-carbon capacities, including nuclear, is becoming one of the decisive directions for implementing the Energy Security Concept of the Republic of Belarus and approaching climate neutrality indicators.

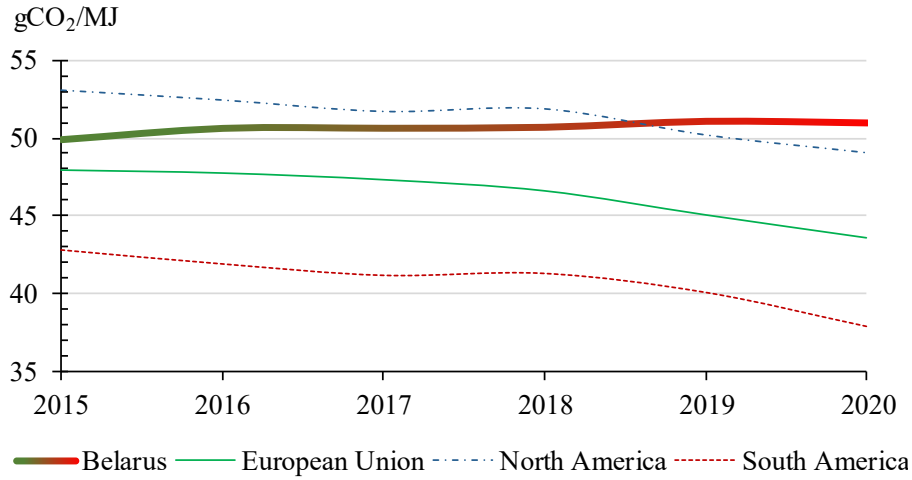

Figure 8. Specific greenhouse gas emissions per unit of FER gross consumption

In the future, by 2035, the launch of both BelNPP power units at full capacity (2 x 1.17 GW), which is expected by the end of 2023, as well as the expansion of the use of RES, will improve energy efficiency and energy security of the national FEC as follows:

- Energy independence. The volume of own production (extraction) of primary energy in the volume of gross consumption of FER will be increased from current 22.5% to 70%.
- Diversification of energy resources. The share of natural gas (the dominant type of fuel) in the gross consumption of FER will be reduced from current 59.5% to 40%.
- Power reservation. The ratio of the total installed capacity of power plants to the maximum actual load in the energy system will increase from current 180.4% to 200%.

CONCLUSIONS

An analysis of the results of almost two-year operation of the first nuclear power plant in the Republic of Belarus allows us to conclude that the inclusion of this low-carbon energy source in the Unified Electric Grid of the national FEC has significantly improved the energy efficiency and energy security of the country.

First of all, the BelNPP, together with RES, guarantees a stable and consistent growth of the energy self-sufficiency of the national economy.

Secondly, the operation of the BelNPP contributes to the diversification of the structure of the balance of primary FER and the final consumption of FER with a reduction in the share of fossil fuels that

contributes to the fulfillment of the country's international obligations under the Paris Agreement, and also corresponds to modern trends and programs for the development of world economies.

Thirdly, nuclear energy contributes to the growth in demand for electricity that, in turn, will initiate an increase in the share of renewable energy and other low-carbon sources in final energy consumption, accelerate the development of decentralized electricity generation, including the search for solutions in the field of its accumulation.

Fourthly, the BelNPP not only minimizes or eliminates the threat of lack of energy resources, other risks and uncertainties faced by the energy system of Belarus, while creating conditions for sustainable energy supply to the economy and the social sphere for the effective development of the country, but also promotes the participation of the national FEC in international and regional energy markets and integrated energy systems.

In addition, the operation of the BelNPP as part of the FEC contributes to an increase in the availability of primary FER in the form of electricity for the final consumer, makes the infrastructure for the production, transformation, transmission and consumption of FER more reliable, sustainable and efficient, reduces the energy intensity and carbon intensity of the national GDP, attracts investments in the further development of the industry's infrastructure.

Taking into account the role of the BelNPP in improving the energy security of the Republic of Belarus, the necessary work should be carried out in the near future to ensure the stable operation of the first unit of the station, to complete the construction of the second unit and put it into operation. It is also necessary to carry out a technical and economic assessment of the feasibility of further development of this area, including a forecast of long-term demand for electricity in the country and the subsequent calculation of the level of energy security according to the relevant indicators.

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