CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

E-ISSN 2450-8594

CEER 2023; 33 (3): 0111-0128
DOI: 10.59440/ceer/175466
Original Research Article

COMPARISON OF THE USE OF RENEWABLE ENERGY SOURCES (RES) BY POLAND AND LATVIA IN THE PERSPECTIVE OF THE ENVIRONMENTAL OBJECTIVES SET BY THE EUROPEAN UNION

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A b s t r a c t

The objective of this article is to present an analysis of the utilization of renewable energy sources in Latvia and Poland since their accession to the European Union (EU), and to evaluate the progress made in meeting the environmental targets established by the EU through the implementation of Directive 2009/28/EC. The analysis is based on data obtained from the "Our World in Data" database as well as government documents. The findings reveal that while Latvia has successfully met the EU requirements, Poland has yet to achieve the set targets. However, Poland efforts in the development of renewable energy sources indicate a promising trajectory, mirroring those undertaken by Latvia. These implemented measures can serve as a valuable reference for other countries in their pursuit of a greener future.

Keywords: renewable energy, targets, greenhouse gas emissions, European Union

1. INTRODUCTION

Alternative energy sources such as wind power, solar power, hydroelectric power, ocean energy, geothermal energy, biomass, and biofuels offer a sustainable and eco-friendly solution to traditional fossil fuels. By embracing these renewable sources, we can effectively curtail greenhouse gas emissions, foster energy diversification, and diminish our reliance on volatile and insecure fossil fuel markets, particularly oil and gas [1]. Fossil fuels continue to dominate the global energy landscape, representing over 80% of our overall energy consumption [2]. Fortunately, fossil fuel consumption increases slower than renewable energy consumption [3-4]. Coal is the dirtiest fuel in the world, it not only emits the highest carbon dioxide emissions per unit of energy, but it has serious impacts on health through air pollution. Therefore, many countries are committed to eliminating coal power from their

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electricity mix. The use of gas and oil in energy production also emits carbon dioxide and promotes climate change and air pollution, which is the main reason why the world should reduce fossil fuels [3]. According to the main problem of the 21st century, climate change, the depletion of underground resources, people must change their usual way of life, promote the reuse of resources, and reduce greenhouse gas emissions as much as possible [5]. To curb climate change already at the end of the 20th century, the Kyoto Protocol entered into force on 11 December 1997 and was replaced on 22 April 2016 by the Paris agreement of the United Nations, which established regulations to prevent global warming of the planet above 2 °C (recommended at 1.5 °C) and reduce carbon dioxide (CO_2) emissions to their neutrality in 2050 [6]. One of the most important measures to achieve the goal is to completely abandon the use of fossil fuels and switch to renewable energy sources.

The global demand for renewable energy and energy-efficient solutions is witnessing a significant surge (Fig. 1). This trend stems from the fact that the production and adoption of renewable energy and efficient technologies play a vital role in reducing greenhouse gas emissions while fostering economic growth. Renewable energy sources enable the generation of clean electricity without compromising the environment. Consequently, there is typically a negative correlation between the use of renewable energy and carbon emissions [7]. In 2009, the European Union adopted Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources. One of the main objectives of the directive is to control energy consumption in Europe and increase the use of renewable energy, along with energy savings and increased energy efficiency. One of the primary objectives is to mitigate greenhouse gas emissions and fulfill the obligations outlined in the Kyoto Protocol of the United Nations Framework Convention on Climate Change, along with other commitments made by the international community and various nations to decrease greenhouse gas emissions post 2012. Currently, the main goal is to achieve the use of renewable energy by 40 % by 2030, in addition, the greater use of fuels obtained from renewable energy resources, such as hydrogen, is promoted in the industrial and transport sectors [8].

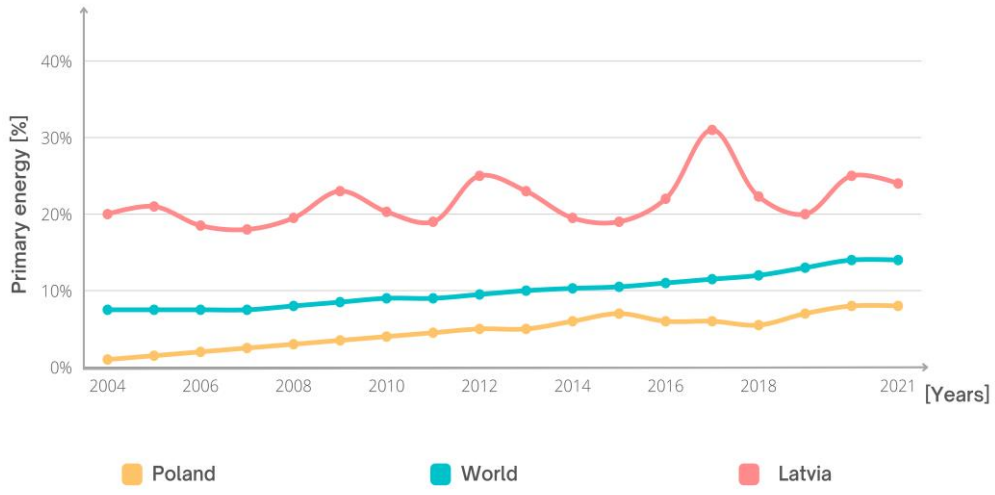

Fig. 1. Primary energy using the substitution method from renewable sources (don't include biofuels). Source: based on OurWorldInData.org/energy CC BY [9]

This paper discussed the tendency of Latvia and Poland, two member states of the European Union (since 2004), to use renewable energy resources. Comparing the two countries is important for three reasons. First, both countries have committed to increasing the use of renewable energy under Directive 2009/28/EC of the European Parliament. Second, both countries have favorable conditions for the development of renewable sources. Third, these countries have had varying degrees of success in attracting investment in clean technologies. Their main sources of renewable energy are contrasting. Latvia can be an example for Poland as one of the 3 European countries with the largest renewable energy production. In Poland, on the other hand, wind energy is the dominant RE source. In turn, Latvia points to the rapid development of wind farms as one of the most urgent areas that requires action. A closer look at the directions of renewable energy development for these two countries will allow us to better understand their choice and indicate the directions of their mutual cooperation in the development of the Green Deal and the fulfillment of EU directives.
Therefore, presented here is the article that discusses the use of renewable energy sources in the perspective of the objectives assigned by the European Union. The structure of review consists of six sections - Sections 1 and 2 - Introduction and Methods; Sections 3 and 4 - Information on renewable energy in Latvia and Poland, measures that countries have implemented to increase the use of renewable energy, Section 5 - Discussion on the consumption of renewable energy in both countries and future targets, and Section 6- Conclusions.

2. METHODS

Each section will be based on the literature review. Literature was searched in databases web of science, scopus, ebsco, sciencedirect, researchgate, google scholar, eurostat, among others, based on keywords included in the following phrases: renewable energy, benefits, hydropower energy, solar energy, wind energy. Statistic databases, government websites, and laws from Latvian and Poland will also be used.

For non-fossil based electricity sources (hydro, wind, solar, biomass in power, and other renewable sources), bp's generation (in TWh- terawatt-hour)
corresponds to gross generation and does not account for cross-border electricity supply. Also, for non-fossil based electricity, there are two ways to define primary energy:
* one is "direct primary energy", which corresponds to the electricity generation (in TWh). * The other is the "input-equivalent primary energy" (also called the "primary energy using the substitution method") [9, 10].

Primary energy using the substitution method- this is the amount of fuel that would be required by thermal power stations to generate the reported electricity, as explained in bp's methodology document. For example, if a country's nuclear power generated 100 TWh of electricity, and assuming that the efficiency of a standard thermal power plant is 38%, the equivalent primary input energy for this country would be 100 TWh / 0.38 = 263 TWh = 0.95 ej. This input-equivalent primary energy takes into account inefficiencies in fossil fuel production and provides a better approximation of each source's share of "final energy" consumption [9, 11].

Additional metrics have been calculated based on Our World In Data database: ‘annual change in energy consumption by source’: This is calculated as the difference from the previous year. ‘% of total primary energy’: calculated as the share of primary energy (direct energy and primary energy using the substitution method) from all sources. Energy per capita by source: calculated as primary energy consumption by source, divided by population. To determine per capita figures, we rely on a

population dataset meticulously compiled and maintained by Our World in Data, drawing upon various reputable sources [9].

3. RES IN LATVIA

Situated along the eastern coast of the Baltic Sea, Latvia is a Northern European country and one of the three Baltic states. It joined the European Union in 2004 and has been an active member ever since. The total land area of the country is 64 589 km2, and the population in 2021 is 2.801 millions [12].

The total consumption of energy resources in 2021 was 193 petajoules (PJ), which is 4.9% higher than in 2020. According to Our World In Data in 2021 energy use per person was 22.610 kWh, which is 4.5%, more than in 2020, when energy consumption per person was 21.575 kWh. In the structure of the total consumption of energy resources, the share of renewable energy resources (RES) continues to increase in recent years, while the share of fossil energy resources in total consumption is decreasing. During the decade (2012−2021), the share of natural gas consumption decreased by 5.7 percentage points and in 2021 it was 21%, while the consumption of renewable energy in total consumption during the decade (2012-2021) increased by 14.9 percentage points and in 2021 it was 42.13% [13].

The main sources of renewable energy in Latvia are hydropower (2708 GWh), biomass production (570 GWh), biogas (292 GWh), wind energy (141 GWh), solar energy (7 GWh) (Figure 2).

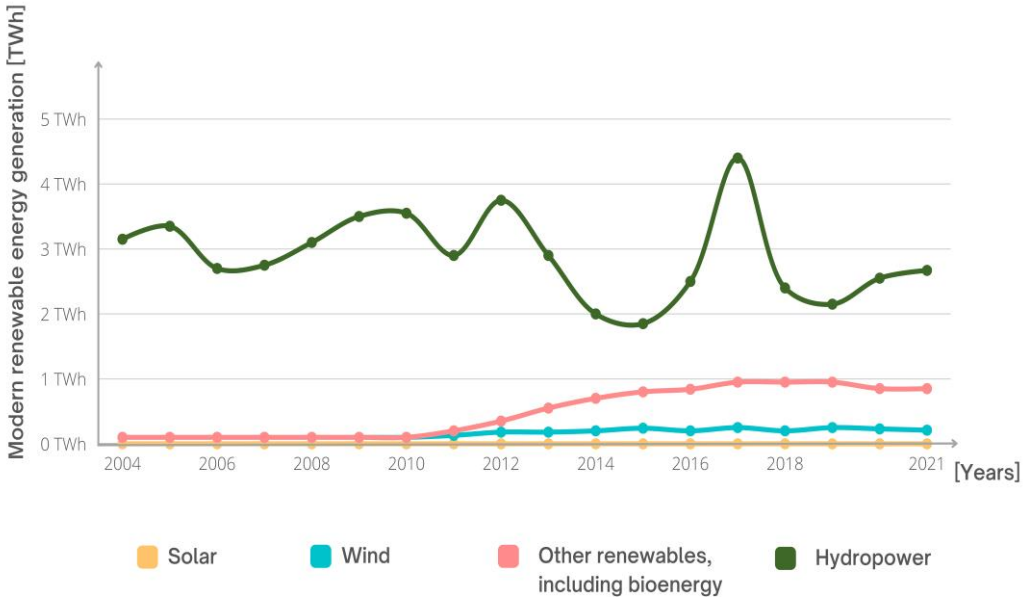

Fig. 2. Generation of contemporary renewable energy by energy source in Latvia. Source: based on OurWorldInData.org/energy.CC BY [9]

Comparing renewable energy source used in electricity generation, since 2004 – 2021 when Latvia join European Union the share of renewable energy has increased. Since 2004 the share of energy produced from renewable energy resources in gross final energy consumption has increased to 42.13% (an increase of 32.26%). According to the target of the European Union and Latvia, until 2020, Latvia should have increased renewable energy in total consumption to 40% [14]. According to the data, Latvia successfully achieved this target.

3.1. Hydropower

Today, the primary source of energy in Latvia is hydroelectric power generation. Latvia boasts three major hydroelectric power plants (HPPs), namely Riga HPP, Plavinu HPP, and Keguma HPP, with the latter located along the Daugava River. These three power plants collectively produced 2.50 terawatt-hours (TWh) of energy in 2020, and this figure increased to 2.6 TWh in 2021. According to data from these hydroelectric power plants, 58% of all hydroelectric power production in Latvia comes from the Daugava River HPPs.

Additionally, there are 147 smaller hydroelectric power plants scattered throughout Latvia. However, it's important to note that the number of these smaller power plants is expected to decrease in the future. This is due to the country's ongoing efforts to implement more stringent regulations aimed at protecting the environment and biodiversity. Various environmental protection organizations are actively working to reduce the number of hydroelectric power plants in Latvia as part of their conservation efforts.

3.2. Energy from biomass

Along with hydroelectric power plants, the use of biomass and wood chips - mainly to obtain heat energy - is an important resource that is not only binding on the Latvian state, but is also a renewable energy resource. In 2020, the total amount of electricity produced in wood chip cogeneration stations was 499 GWh, while the amount of heat energy produced was 7673 TJ. In 2021, the amount of electricity produced increased by 11.8% and amounted to 552 GWh, while the amount of heat energy produced increased by 17.15% and amounted to 8989 TJ [14]. According to the Latvian National Energy and Climate Plan for 2021-2030, Latvia plans to increase the share of renewable energy in electricity production by increasing the installed capacity of wind generators and solar photovoltaic cells. The capacity of Latvia's electricity transmission networks currently allows for an increase in the amount of electricity transmitted to the grid by 800 MW. Latvia does not plan to increase the capacity for biomass and biogas for electricity production. Latvia plans to increase the share of RES in heating and cooling by modernizing the capacities of installed biomass utilization equipment, increasing the capacities of installed heat pumps and cooling pumps, and increasing the use of solar energy in heat energy production [16].

3.3. Wind and solar energy

In Latvia, wind energy and the creation of wind parks are only the beginning of the road. Currently, wind energy accounts for 3% of the total volume of the internal electricity market. In 2021, the total installed capacity of wind farms reached 17.4 GW, of which 14 GW were obtained from offshore wind farms. In Latvia, the development of wind farms is actively being worked on. 2022 On 22 July, a joint venture between JSC "Latvenergo" and JSC "Latvijas valsts meži'' to implement the wind park project in state forests by 2030. Furthermore, work continues on the creation of a joint Latvian and Estonian wind farm in the Baltic Sea [17]. Similarly to wind energy, solar power is relatively new in Latvia, and the existing installed capacity remains limited. However, the untapped potential of solar energy in the country is significant. To harness and promote the use of solar energy, Latvia has initiated support programs for the installation of solar panels. In the following sections, we will delve into these support programs and their associated funding mechanisms.

3.4. RES in the perspective of the environmental objectives set by the European Union

According to the National Energy and climate plan of Latvia 2021-2030, Latvia should increase renewable energy in total energy consumption (Table 1).

Table 1. Overview of Latvia objectives, targets, and contributions 2021-2030 [16].

National targets and contributions	Latest available data	2020	2030
Binding target for greenhouse gas emissions compared to 2005 under the Effort Sharing Regulation (ESR) [%]	8	+17	-6
National target/contribution for renewable energy: Share of energy from renewable sources in the final gross consumption of energy [%]	40%	40%	50%
National contribution for energy efficiency:			
Primary energy consumption [Mtoe]	4.7	5.4	4.1
Final energy consumption [Mtoe]	4.2	4.5	3.6
Level of electricity interconnectivity [%]	50	10	60

Note: [Mtoe] - million tonnes of equivalent oil, 1toe = 11.63 MWh

Table 1 contains information about the set goal, about this indicator in 2020, the Latvia goal until 2020 and the Latvia goal until 2030.

To achieve the set of goals, Latvia not only takes various measures at the national level, but also motivates citizens to get involved in the implementation of the plan. The following are the measures implemented to increase the use of renewable energy resources and energy efficiency in Latvia (Table 2).

According to all measured uses of Latvia to increase renewable energy consumption, Latvia can reach the goal, increase renewable energy consumption, up to 50% in 2030. The government of Latvia requires citizens to replace the consumption of fossil fuel energy in households with renewable energy from solar panels and to use an electric or hybrid vehicle to reduce gas consumption and CO_2 emissions.

Table 2. Steps taken by Latvia to increase the use of renewable energy sources

Steps	Details
1. March 2022 the regulations of the open tender of the projects financed by the emission allowance auction instrument have been approved. Support program for residents to reduce the prices of adult energy resources and compensate for them - the total available support is 30,000,000 euros [18].	Transition from existing fossil energy resources (natural gas, coal, diesel) heating equipment to new renewable energy resources heating equipment (biomass pellet boilers, solar collectors, heat pumps); Purchase of new renewable energy equipment for electricity production (solar panels, wind generators) (not taking into account the current heating type of the residential house); Designing and creating a connection for a centralized heat supply system (not taking into account the current heating type of the residential house) The amount of financing for new electric cars is set at 4,500 EUR, for used electric cars and new externally chargeable hybrid cars - 2,250 EUR;
2. Rules have been developed for state support for the purchase of electric cars [18].	Normatively, the purchase price limit for a low-emission and zero-emission vehicle in the basic configuration is set at 60,000 EUR The rules provide for additional support in the amount of 1,000 EUR for the write-off of a vehicle owned by the beneficiary by handing it over to a processing company
3. Support for local governments to switch central heating boiler houses from fossil fuel to renewable energy sources [19].	Total support EUR 68.81 million
4. In the period from 01.10.2021. - 30.04.2022, legal entities were fully compensated for the electricity system service fee, i.e., the distribution and transmission tariff costs of all system operators [20]	Compensation for legal entities will be applied automatically to their invoices Total support 123 577 867 EUR
5. Increasing the energy efficiency of multi-apartment and private houses - building insulation [21, 22].	Support for increasing the energy efficiency of private houses - 2 373 521 EUR Support for increasing the energy efficiency of multi-apartment buildings - 57 282 000 EUR
6. A draft law is being developed, which will make it possible to significantly accelerate the possibilities of using wind energy by developing large wind farms on the territory of Latvia [23].	

4. RES IN POLAND

Poland is a country in central Europe, a member of the European Union since 2004. The total land area of the country is 312 696 km2, and the population in 2021 is 37.797 millions. The total energy consumption in 2021 was the highest in Polish history, 645.84 petajoules [PJ]. The energy use per person in 2021 was 32.645 kWh, which is 8.2% more than in 2020, when the energy consumption per person was 29.968 kWh [24].

The main renewable energy sources in Poland (Fig. 3) are wind energy, second is biogas, third is solar energy, fourth geothermal energy, waste energy and biomass, and fifth is hydropower.

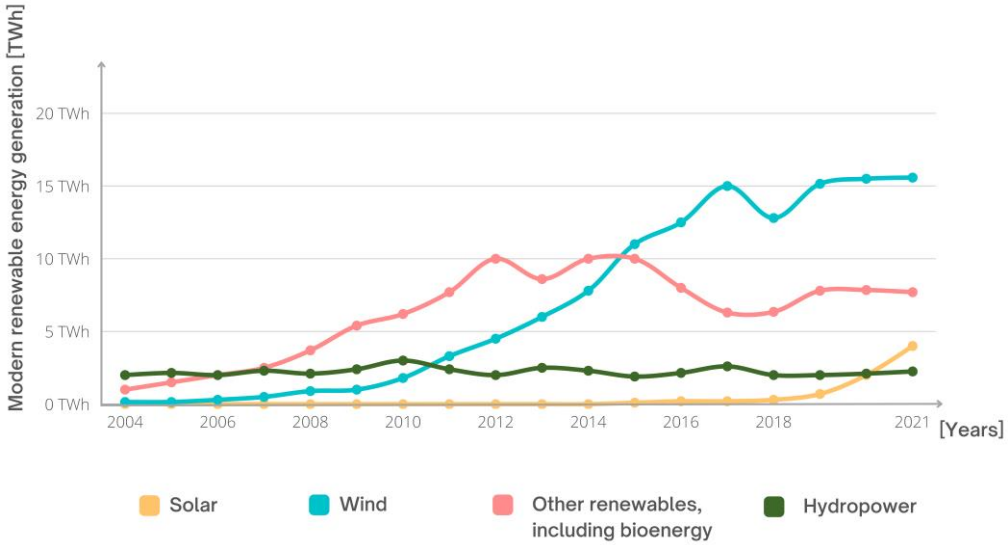

Fig. 3. Modern renewable energy generation by source, Poland. Source: based on OurWorldInData.org/energy.CC BY [9]

Wind energy and solar energy consumption are growing, as these are both new technologies that only started to be used in the early 1990s, and now the usage of these renewable energy sources is only beginning to increase. Unlike the other renewable energy sources, traditional biomass consumption from 1994 until 2021 is reduced by 4.6%.

The share of renewable energy in total energy consumption in Poland increases every year, but the number of renewable energy shares is not as good as it should be. In 2020 when every EU country should reach a minimum 15% share of renewable energy, Poland did not exceed and balance renewable energy, and the country did not achieve the 2020 goal, only producing 12.2% of RES. According to the assumptions of the National Plan for Energy and Climate for 2021-2030, Poland's share of renewable energy is expected to increase from 17.6% in 2025 to 21% in 2030 [24] In 2021, the share of coal in electricity generation increased to 72%. Comparing renewable energy sources used in electricity generation, since 2004 - 2021, when Poland joined the European Union, the share of renewable energy has increased. In 2004, Poland's renewable energy consumption was 1.99% and until 2021 renewable energy consumption in total energy consumption increased by 14.74% [24].

4.1. Wind energy

The first windmills were constructed in Poland in 2001. The years 2008−2016 were the period of constant growth of wind power and the share of primary wind energy increased by 2.69% [25]. In 2016, the so-called (distance act) entered into force, which established the 10H rule. According to the act, wind farms cannot be located less than 10 times the total height of the turbine in residential buildings. After the act came into force, the installation of wind turbines and the energy obtained from the wind did not increase significantly. Wind power plant can only be built on the basis of the local spatial development plan [26]. Despite the 'Distance Act', the installed wind energy capacity in 2021 increased by 1.21GWh since 2016. Poland also has offshore wind energy potential. According to the project "Offshore wind energy and maritime development program taking into account the available area of the Polish exclusive economic zone", the theoretical potential of wind conditions was estimated at 12GWh, with a generation potential of approximately 48-56TWh [26].

4.2. Bioenergy

Poland has one of the largest bioenergy potentials in Europe, which also helps Poland achieve its independence in energy. Recently, co-firing of biomass with coal has been widely used in Poland, but imported biomass has become increasingly used for this purpose, causing the collapse of the green certificate market. Today, co-firing of biomass with coals is used when biomass resources are located about 50-70 km from the place of its combustion. The low investment and operating costs of co-firing alternative fuels with coal in heat blocks compared to thermal systems that use only biomass are the main reasons for the popularity of co-firing in Poland and around the world. In addition to energy and heat, bioethanol, biodiesel, biofuel, and biohydrogen are also produced. In 2021, the total volume of bioethanol produced in 13 factories was 789.4 million dm^3, the total volume of diesel fuel produced in 8 factories was 1674.5 million dm^3, the total volume of biofuel produced in 9 factories was 603.7 million dm^3, the volume of biohydrogen produced in one factory was 1.120 million dm^3 [26].

4.3. Solar energy

Referring to the above that Poland did not achieve the 2020 goal and did not reach 15% renewable energy in total consumption, Poland made important changes, and in 2020 Poland took the first place in the EU-27 in terms of the rate of increase in the power of photovoltaic installations, calculated on the basis of the cumulative annual growth rate. In 2020, 1.5% of the electricity produced in the country came from solar PV sources [26]. In 2020, it was predicted that the electricity produced from PV sources in 2021 will be 2.29%. In 2022, the electricity produced from photovoltaic sources in 2021 was 3.5%. In 2022 the sector broke a new record, providing more than 1TWh of energy during the month of July.

4.4. Geothermal energy

Poland also has great potential for geothermal energy. Currently, thousands of heat pumps were installed in Poland every year. Most of them are ground-to-water, air-to-water, and water-to-water pumps [27]. Geothermal energy is increasingly replacing old coal stoves with heat pumps. In 2020 Poland produces 1073 TJh of geothermal energy [26].

4.5. Hydropower energy

Despite having significant hydroelectric power potential, Poland currently utilizes only 17% of its hydroelectric capacity. The country faces limitations in terms of its variable and limited water resources. The development of hydropower is also criticized due to potential negative impacts on aquatic biodiversity. Various factors contribute to the constraints on hydropower development in Poland and other nations, including political and institutional barriers arising from the definition of development goals and inadequate institutional infrastructure [28]. As of 2021, the total capacity of water turbines in Poland reached approximately 1,000 MWh. The largest pumped-storage power plant in the country is the Żarnowiec power plant, boasting a capacity of 716 MWh [26].

4.6. Res in the perspective of the environmental objectives set by the European Union

Poland is one of the European countries that is currently strongly dependent on primary energy sources, such as hard coal and lignite. Compared to other EU member states, Poland has much larger reserves and makes good use of hard coal and lignite for electricity production, the Belchatow Power Plant, which is the largest power plant in Poland and the largest lignite power plant in the world. With

a capacity of 5102 MW [29]. Coal is of strategic importance to the Polish economy. Despite the economic factor, the development of the RES sector in Poland is important for the continuation of social-economic development, as well as for the implementation of the European Green Deal [30].
Since Poland is a member of the European Union, Poland, like other member states, must take decarbonization measures to reduce CO2 emissions, increase the use of renewable energy sources, and move the country towards climate neutrality. The European Union target will inevitably lead to a reduction in domestic coal exploitation and, consequently, to mine closures [31]. In 2020 in Brussels, the national energy and climate plan of Poland was approved 2021−2030. The main goals set by Poland will be discussed in Table 3 (contains information about the set goal, about this indicator in 2020, Poland's goal until 2020 and Poland's goal until 2030).

Table 3. Overview of Poland's objectives, targets, and contributions 2021-2030 [32].

National targets and contributions	Latest available data	2020	2030
Binding target for greenhouse gas emissions compared to 2005 under the Effort Sharing Regulation (ESR) [%]	21	14	-7
National target/contribution for renewable energy: Share of energy from renewable sources in the final gross consumption of energy [%]	11.3	15	21−23
National contribution for energy efficiency:			
Primary energy consumption [Mtoe]	100.9	96.4	91.3
Final energy consumption [Mtoe]	71.8	71.6	67.1
Level of electricity interconnectivity [%]	4	4	8.7

Note: [Mtoe] - million tonnes of equivalent oil, 1toe = 11.63 MWh

According to the information in Table 3, Poland has not achieved only one target until 2020. The share of renewable energy sources in the gross energy consumption of energy in 2020 was 11.3%, but the 2020 target was 15%. Now, a new target has been set, reaching 21-23% of the energy from renewable energy sources in the final gross consumption.
When evaluating the Polish goals set by the Energy Policy until 2040, an important step toward the use of renewable energy and the reduction of emissions is the use of coal in energy production. However, despite the established goal of reducing greenhouse gas emissions by 30% compared to 1990, Poland will reduce the use of coal in the energy sector to only 56% and the share of renewable energy in the energy sector will not be less than 23%. The use of coal for energy production is the main form of energy production today, both coal mines, coal mining, and energy production companies employ a large number of people, which slows down the closing of coal mines to energy production companies. In 2019, 83,000 people were employed in hard coal mining in Poland. Various solutions are currently being developed and offered to prevent high unemployment in the industry after the closure of coal mines and to reduce state costs for unemployment benefits [33]. Some of the solutions are: no longer hire new employees; educational institutions abandon study programs that train coal miners, focusing on training electricians, factories and machine operators and construction workers, not miners; early retirement benefits; retraining programs for employees related to the introduction of renewable energy resources, as the energy transition will provide 300,000 new jobs [32].

In 2021 the Council of Ministers adopted the Energy policy of Poland until 2040. These documents show Poland's goals to reach the low carbon emission targets of the European Union, increase renewable energy use, and reach a climate-neutral Europe until 2050. The targets until 2040 include the targets of the national energy and climate plan 2021-2030 and present more targets. The main

goals set by Poland in energy policy until 2040 will be discussed below (Table 4). In light of the above, Poland has taken the right decisions regarding the grant of aid to increase the use of renewable energy.

Table 4. Goals and steps taken by Poland to increase the use of renewable energy sources until 2040.

Goals	Ex. Steps
1. Energy transition including power self-sufficiency; Energy efficiency will increase with a target of a 23% reduction in primary energy consumption. By 2040, the heating needs of all households will be covered by district heating and individual zero or low-emission sources [34].	In January 2023, the "Energy for the Village total cost PLN 1 million" The program was launched. The support Provide applies to investments such as Biogas plants, hydroelectric power plants, photovoltaic installations, wind turbines and energy storage integrated with these sources [35]. The 'distance Act' is slightly mitigated by the legislator. The Polish court assesses, whilst taking into account the necessity and proportionality of the regulation, whether the Act has directly contributed to the slowdown of wind energy development in Poland. Moreover, there is a new draft law liberalizing this requirement [36].
2. Development of wind power. The installed capacity of offshore wind energy will reach approximately 5.9 GW in 2030 and 11 GW in 2040 [36].	In 2020 was approved the law about promoting electricity generation in offshore wind farms. The offshore Act provides public assistance in the form of the right to cover the negative balance, a type of difference contract, for wind farms located in the Baltic Sea for a period of 25 years [36]. There are storage projects in development in Poland. In 2018, construction started on the largest energy storage facility in Poland with a capacity of 27 MWh, near the Bystra wind farm. The goal is to build a system for the protection of the electrical network, which will ultimately enable the appropriate management of a large number of wind farms [37].
3. There will be a significant increase in installed capacity in photovoltaics of approximately 5-7 GW in 2030 and 10-16 GW in 2040 [34].	In 2019, Poland's 'My Electricity' program was created to support the photovoltaic microinstallation segment (PV). Total support in 2019 235 millions EUR [38].
4. Increase in the share of RES in all sectors and technologies. In 2030, the share of RES in gross final energy consumption will be at least 23% (not less than 32% in the power industry, 28% in the heating sector, 14% in transport). Several actions will be aimed at improving air quality: development of district heating, low-emission direction of the transition of individual sources, abandonment of coal use in households, increasing the energy efficiency of buildings, and development of low-emission transport. By 2030, there will be a reduction	In 2021, the support program "My Electrician" was developed, supporting the purchase/leasing of electric cars. Implementation period 2021-2026. The total amount of support is 106.15 milions EUR [37].

in greenhouse gas emissions of approximately 30% compared to 1990 [34].	
5. In 2030, the share of coal in electricity generation will not exceed 56%. The reduction of the use of coal in the economy will be carried out in a way that ensures a just transition. Reduction of the phenomenon of energy poverty to a maximum of 6% of households [39].	In 2021 Poland's government and unions signed an agreement with the coal mining industry, to phase out coal production by 2049. The agreement provides for a support program for workers from closed mines. Additional benefits for laid-off workers, as well as other information related to working in coal mines [40]. In mid-2020, the Minister of Climate restarted work on the set of provisions dedicated to energy storage, which will cover a new definition of energy storage, as well as licensing aspects. However, at this time, it is still a new draft regulation [39].
6. The most anticipated development in energy technology and R&D investments includes energy storage technologies, smart metering and energy management systems, electromobility and alternative fuels, and hydrogen technologies. The first nuclear power plant power unit with a capacity of approximately 1-1.6 GW will be completed in 2033 [39].	Since February 24, 2021, entered into force the agreement on the development of nuclear energy signed between Poland and the United States, which includes ongoing programs and projects under development to: advance innovative, secure, and safe nuclear technologies such as small modular reactors ; advance large-scale, clean, and modern nuclear power generation; demonstrate the potential of nuclear-produced hydrogen to fuel the transition to clean energy, and first nuclear unit in a proposed set of six 1150 MW AP1000 PWRs as planned for 2033, with the rest to follow throughout the 2030s and into the early 2040s. The total amount of support within the project is 25 million US dollars for all six countries who are project partners, including Poland [41].
7. TSOe (The electricity transmission system operator) and DSOe (Electricity distribution system operators) will focus on the development of active RES consumers and the local balancing of RES [39].	
8. Natural gas will be a bridge fuel in the energy transition. In 2030, the ability to transport a gas mixture containing approximately 10% decarbonized gases through gas networks will be achieved. The natural gas, crude oil, and liquid fuel infrastructure will be expanded and also diversification of supply directions will be ensured [39].	

5. DISCUSSION

5.1. Comparison of RES use in Latvia and Poland

Compared to Poland, Latvia has 4.8 times smaller in area and 20.2 times fewer inhabitants. Both numbers are key pieces of information that defines the amount of energy needed for the country to be able to meet the needs of the population. Based on the studies, the energy consumption per person in Poland was 31.645 kWh in 2021 almost one and a half times higher than in Latvia, 22.610 kWh [12-15]. The share of electric cars is one of the reasons why energy consumption varies dramatically. In Poland, the number of electric cars per person is 1.59 times more than in Latvia [37].

The main objective of the article was to evaluate and compare the use of renewable energy in Latvia and Poland. Thus, based on the data, the consumption of renewable energy in Poland and Latvia was established. In Poland, the total share of renewable energy consumption in total energy consumption in 2021 was 16.73%, while in Latvia 41.3%, which is 2.5 times higher than in Poland

[24]. The main renewable energy resources from which renewable energy is derived in both Poland and Latvia are hydropower, wind energy, solar energy, biogas, biomass energy. In addition to these renewable energy sources, geothermal and waste energy are also used in Poland [24].

In Latvia, however, the amount of energy extracted from waste is negligible and only one company in Latvia, Schwenk ltd, uses the energy extracted from waste, but only for its own needs. In assessing Poland's practice of burning energy waste, several waste incinerators have been set up in Poland. Białystok, Szczecin, Konin, Bydgoszcz, Zabrze, Rzeszów, Warszawa, Poznań [42]. In addition, new waste incineration plants are currently being worked on in Gdańsk and Olsztyn to reduce the amount of waste to be disposed of in landfills, make sustainable use of available resources and develop a circular economy. Compared to Poland, Latvia has a much more complex authorization process to start burning waste for energy production. Furthermore, Latvian residents are more skeptical of the construction of these stations, which is mostly related to fears about air pollution [42]. In terms of geothermal energy, Latvia is estimated to have several underground water horizons from which it is possible to extract heat from the depths of the earth, but this type of energy is not obtained in Latvia [39]. Poland, on the other hand, has the potential to develop geothermal energy due to the formation of Mesozoic sediment, which the country is also using successfully. Based on the Ministry of Climate and Environment of Poland, 2022. A decision was made per year to invest 250 million PLN (around 60 million EUR) in the development of geothermal energy in municipalities, which will increase the share of renewable energy in the total energy consumption [39].

When evaluating the renewable energy sources used in Poland and Latvia, the use of hydropower dominates in Latvia. Hydropower has been widely used in Latvia since the twentieth century. The use of hydropower in Latvia is related to the number of rivers in the country. Approximately 12.5 thousand larger and smaller rivers and streams flow into the territory of Latvia, the total length of which is 37.5 thousand kilometers - almost as much as the length of the longest parallel or equator of the land. Latvia has an average river flow of approximately 0.60 km per square kilometer of its territory. Larger or smaller hydroelectric power plants are being built on rivers to generate energy [43]. However, as has already been mentioned over time, hydroelectric power plants are increasingly starting to attract the attention of environmental organizations, as hydroelectric power plants can reduce biodiversity, the viability of living organisms in rivers, and cause eutrophication. In Poland, the hydropower potential is not maximized and, against the backdrop of other renewable energy sources, is the least used resource, which is a complete contrast to the situation in Latvia. This situation has occurred mainly because Poland has limited water resources that are highly variable in time and space, and, similarly to Latvia, the development of hydroelectric plants is also hampered by various environmental protection and biodiversity-related issues [13, 26].

5.2. Comparison of energy independence and pursuit of renewable energy development in Latvia and Poland

Despite the green course and the need to increase the share of renewable energy in total energy consumption, Poland is looking for new cooperation partners to cover the necessary coal and natural gas shortage, as it abandons Russian coal and natural gas. In addition to fossil energy, the use of renewable energy, the share of solar panels, wind turbines, and the development of nuclear energy in Poland are also actively increasing, as has been highlighted in previous sections. Coal is the largest energy resource in Poland. About 50 million tonnes of coal are mined annually in Poland, while 10 million tonnes are used annually to heat households. 60% of the Polish coal is left in the inland and the rest is largely escorted to the Czech Republic, Austria, Slovakia, Germany [13]. In addition to domestically mined coal, 40% of the necessary volume was imported from Russia until April 2022,

because imported coal was much cheaper than domestically mined coal, because it is quite deep in Polish mines, which requires more investment in coal mining [13, 44]. Currently, Poland has completely stopped importing coal from Russia and is looking for opportunities to import coal from Colombia, Australia, South Africa, and Indonesia [45]. In addition to domestically produced resources, Poland has been importing natural gas from Russia for many years, but since 2016, Poland has been looking for solutions to disconnect from the Russian natural gas connection [44]. The baltic pipeline project is currently being implemented. The baltic pipe project is a strategic gas infrastructure project that aims to create a new gas supply corridor in the European market. The Baltic Pipe project will allow the transport of gas from Norway to the Danish and Polish markets, as well as to end-users in neighboring countries. At the same time, the Baltic Pipe project will allow the supply of gas from Poland to the Danish market [46].

Evaluating the situation in Latvia related to the need to give up on Russian natural gas, in April 2022 Latvia stated that solutions are being sought to completely give up on Russian natural gas. The energy law was amended and entered into force on 11 August 2022 and stated that importing natural gas from Russia is prohibited, but based on the fact that it is difficult to compensate for the necessary energy resource in a relatively short period of time, the Latvian company 'Latvia's gáze' indirectly imported from Russia 10% of Latvia's gas consumption in the first half of 2022. Furthermore, Latvia has decided to purchase gas from Norway to increase the volumes of Latvian inčulkalnas gas storage, the total capacity of which is 2.3. Billion m of active gas. On 13 November 2022, the total amount of natural gas reached 14.34 tWh [47].

Compared with the approach of Poland and Latvia in the field of energy independence, Latvia is constantly looking for new solutions to compensate for the Russian gas shortage with renewable energy resources, while simultaneously increasing the share of renewable energy in the total energy consumption, while Poland, despite the relatively low share of renewable energy in the total energy consumption, is looking for new ways of supplying coal and natural gas, which not only will not increase the use of renewable energy, but as for the use of coal for energy production, will increase air pollution in the country [3]. On the basis of the above, in comparison to Poland and other European union countries, Latvia is considered one of the greenest countries in the European union, taking the third place among all European union member countries. On the other hand, Poland's percentage of renewable energy is relatively low and has not achieved the previously established goals related to increasing the share of renewable energy by 2020. After 2020, Poland has committed to seriously reduce the use of fossil resources and to completely stop using coal for energy production by 2049, as well as concluded an agreement with the United States on the development of nuclear power plants in Poland. In 2020, a study was conducted in which, based on the "asr" prediction method, it was predicted that Poland would be able to fulfill its promise and reduce the use of coal in energy production in the period from 2019 to 2030. Based on the results of the method, with a probability of 95%, Poland will still be able to implement the current set goals - to reduce the use of coal in energy production [35].

6. CONCLUSIONS

Latvia has successfully achieved the environmental objectives set by the European Union, while Poland is still working towards meeting them. However, Poland is actively taking concrete steps to develop renewable energy sources and can serve as an example for other countries pursuing a green deal.

The Polish government is actively supporting its citizens in transitioning to renewable energy. This includes offering incentives for installing solar panels in homes and businesses, providing

subsidies for electric car purchases, and collaborating with Baltic Sea countries to build national-level wind farms. These efforts are aimed at moving Poland towards climate neutrality and increasing reliance on renewable energy.

Similarly, Latvia is implementing similar support mechanisms to increase the share of renewable energy. This includes promoting solar panel installations, supporting the adoption of electric cars, exploring nuclear power options, and actively fostering cooperation to expand wind farm projects. These measures ensure future production of green energy and enable Latvia to meet its growing energy demands independently.

When comparing the renewable energy usage of Poland and Latvia, it is important to consider the different energy resources available in each country, which significantly impact their national economies. Poland has historically relied heavily on coal for energy and export revenue, posing challenges in completely phasing out coal and closing coal mines. Economic implications, such as potential job losses, present significant obstacles. However, Poland is fully aware of the goals to be achieved and the associated challenges. The national energy and climate plan for Poland 2021-2030, along with the energy policy until 2040, outline goals to close coal mines and eliminate coal usage for energy production. Efforts are being made to retrain coal mine workers to mitigate unemployment risks.

Considering all these factors, Poland is on a rapid trajectory towards achieving its set goals. By adhering to the established plan, Poland can successfully fulfill the objectives outlined by the European Union and achieve climate neutrality by 2050.

ACKNOWLEDGEMENTS

This research was funded by the Faculty of Environmental Engineering, Geomatics and Renewable Energy of the Kielce University of Technology. No SUBB.IKGT 05.0.12.00/1.02.001/SUBB.IKGT.23.002.

REFERENCES

1. Khan, Y et al. 2022. The effect of renewable energy sources on carbon dioxide emissions: Evaluating the role of governance, and ICT in Morocco. *Renewable energy* **190**, 752-763.
2. Ritchie, H and Roser, M 2022. Energy Mix [electronic resource: https://ourworldindata.org/energy-mix], [Access 04.03.2023]
3. Ritchie, H and Roser, M 2022. CO_2 emissions by fuel [electronic resource: https://ourworldindata.org/emissions-by-fuel] [Access 04.03.2023]
4. Ritchie, H Rossado, P and Roser, M 2022. Fossil Fuels [electronic resource: https://ourworldindata.org/fossil-fuels] [Access 04.03.2023]
5. Olujobi, OJet al. 2022. Carbon emission, solid waste management, and electricity generation: a legal and empirical perspective for renewable energy in Nigeria. *International Environmental Agreements* **22**, 599–619.
6. Depledge. J 2022. The “top-down” Kyoto Protocol Exploring caricature and misrepresentation in literature on global climate change governance. *International Environmental Agreements* **22**, 673–692.
7. Wang, Cet al. 2022. Renewable energy output, energy efficiency and cleaner energy: Evidence from non-parametric approach for emerging seven economies. *Renewable energy* **198**, 91-99.

8. European Union: Directive (EU) 2018/2001 Of The European Parliament And Of The Council of 11 December 2018 on the promotion of the use of energy from renewable sources, in: Official Journal of the European Union, L328/82.
9. Our World in Data database 2022. Annual change in primary energy consumption [electronic resource: https://ourworldindata.org/grapher/change-energy-consumption, [Access 11.03.2023]
10. Wimmer L, Kluge J, Zenz H, Kimmich C 2023. Predicting structural changes of the energy sector in an input-output framework. *Energy* **265**, 126178.
11. Chen, Cet al. 2023. Effect of equivalent heat input on WAAM Al-Si alloy. *International Journal of Mechanical Sciences* **238**, 107831.
12. Central Statistical Office, (Latvia), 2022. Population at the beginning of the year, its changes and main indicators of natural movement, [electronic resource: https://stat.gov.lv/lv/statistikas-temas/iedzivotaji/iedzivotaju-skaits/tabulas/irs010-iedzivotaju-skaits-gada-sakuma-ta?themeCode=IR], [Access 12.11.2022]
13. Central Statistical Office, (Latvia), 2022. Latvia's energy balance in 2022, [electronic resource: https://admin.stat.gov.lv/system/files/publication/2022-08/Nr_23_Latvijas_energobilance_2021_gada_%2822_00%29_LV_1.pdf], [Access 12.11.2022]
14. Central Statistical Office, 2022. Fuel consumed in cogeneration plants, thermal energy and electricity produced, [electronic resource: https://stat.gov.lv/lv/statistikas-temas/noz/energetika/tabulas/enb140-kogeneracijas-stacijas-pateretais-kurinamais?themeCode=EN
15. Central Statistical Office, 2022. Production, import, export and consumption of electricity, [electronic resource: https://stat.gov.lv/lv/statistikas-temas/noz/energetika/tabulas/enb010m-elektroenergijas-razosana-imports-eksports-un?themeCode=EN], [Access 21.11.2022]
16. European Commision, 2020. Assessments of the final national energy and climate plan of Latvia, [electronic resource: https://energy.ec.europa.eu/system/files/2021-01/staff_working_document_assessment_necp_latvia_en_0.pdf], [Access 20.11.2022]
17. Ministry of Economics, 2022. Strengthening energy independence, [electronic resource: https://www.em.gov.lv/lv/energetiskas-neatkaribas-stiprinasana], [Access 21.11.2022]
18. Regulations of the Cabinet of Ministers of the Republic of Latvia No. 150, Latvia), 2022. Regulations of the open competition "Reduction of greenhouse gas emissions in households - support for the use of renewable energy resources" of the project financed by the emission allowance auction instrument, [electronic resource: https://likumi.lv/ta/id/330568-emisijas-kvotu-izsolisanas-instrumenta-finanseto-projektu-atklata-konkursa-siltumnicefekta-gazu-emisiju-samazinasana-majsaimniecibas
19. Construction State Control Office (Latvia), 2022. Already in April, local governments will have access to support for switching central heating boiler houses from gas to renewable energy sources. [Electronic resource: https://www.bvkb.gov.lv/lv/jaunums/pasvaldibam-jau-aprili-bus-pieejams-atbalsts-centralizetas-siltumapgades-katlumaju-parslegsanai-no-gazes-uz-atjaunojamo-energoresursu-kurinamo?utm_source=https%3A%2F%2Fwww.google.com%2F],[Access 12.11.2022]
20. Law of the Republic of Latvia on measures to reduce the extraordinary increase in energy resource prices, (Latvia), 2022, [Electronic resource https://likumi.lv/ta/id/329532-energoresursu-cenu-arkarteja-pieauguma-samazinajuma-pasakumu-likums], [Access 12.11.2022]
21. Ministry of Economics, 2022b. Approves a new support program for renovation of multi-apartment buildings, [electronic resource: https://www.em.gov.lv/lv/jaunums/apstiprina-jaunu-atbalsta-programmu-daudzdzivoklu-eku-atjaunosanai], [Access 20.11.2022]

22. Regulations on the support program for renovation of one-apartment residential houses and two-apartment residential houses and increasing energy efficiency (2021),[electronic resource: https://likumi.lv/ta/id/321021-noteikumi-par-atbalsta-programmu-viena-dzivokla-dzivojamo-maju-atjaunosanai-un-energoefektivitates-paaugstinasanai], [Access 20.11.2022]
23. State Chancellery of the Republic of Latvia, (Latvia), 2022. Bill, [Electronic resource: https://tapportals.mk.gov.lv/structuralizer/data/nodes/9c9500c4-9702-4d4c-b274-949d7e811b78/preview], [Access 12.11.2022]
24. Poland: Energy country Profile, 20 22[Electronic resource: https://ourworldindata.org/energy/country/poland], [Access 15.11.2022].
25. Talarek, Ket al. 2022. Wind Parks in Poland—New Challenges and Perspectives. *Energies* **15**, 7004.
26. Igliński, Bet al. 2022. The assessment of renewable energy in Poland on the background of the world renewable energy sector. *Energy* **261.**
27. Nartowska, Eet al 2022. Assessment of the thermal power of groundwater intakes in the Kielce district. *Civil and environmental engineering reports* **32**, 0025-0049.
28. Kałuża, Tet al. 2022. The hydropower sector in Poland: Barriers and the outlook for the future. *Renewable and Sustainable Energy Reviews* **163**,112150.
29. Tylman, M, Sawicki, J and Vosteen, B 2022. *Bromine-Enhanced Mercury Oxidation at the PGE GiEK lignite fired power plant Belchatów (Poland)*. 54th Power Plant Colloquium at October 18th and 19th International Congress Center Dresden.
30. Kujawska, Jet al. 2022. Analysis of the Energy Parameters of Selected Biomass and Biochar Types and the Environmental Impact of Their Ashes. *Civil and Environmental Engineering Reports* **32**, 147-166.
31. Malec, M. 2022. The prospects for decarbonisation in the context of reported resources and energy policy goals: the case of Poland. *Energy Policy* **161**, 112763.
32. European Commision, 2020b. Assessments of the final national energy and climate plan of Poland, [electronic resource: https://energy.ec.europa.eu/system/files/202101/staff_working_document_assessment_necp_poland_en_0.pdf], [Access: 20.11.2022]
33. Sokołowski, J et al. 2022. Hard coal phase-out and the labour market transition pathways: the case of Poland. *Environmental Innovation and Societal Transitions* **43**, 80-98.
34. Ministry of Climate and Environment, 2021, Energy policy of Poland until 2040, [electronic resource: https://www.gov.pl/web/climate/energy-policy-of-poland-until-2040epp2040#:~:text=The%20Energy%20Policy%20of%20Poland%20until%202040%20takes%20into%20account,optimum%20use%20of%20Poland's%20own], [Access 20.11.2020]
35. Li, Y et al. 2020. Will Poland fulfill its coal commitment by 2030? An answer based on a novel time series prediction method. *Energy reports* **6**, 1760-1767.
36. Chancellery of the Seym, 2021, On promoting electricity generation in offshore wind farms, [Electronic resource: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20210000234/T/D20210234L.pdf], [Access 22.11.2022].
37. Service of the Republic of Poland, 2021. Electromobility, [Electronic resource: https://www.gov.pl/web/elektromobilnosc/o-programie], [Access 22.11.2022].
38. Cader, J et al 2021. Regional dependencies of interest in the “My Electricity” photovoltaic subsidy program in Poland. *Energy Policy Journal* **24**, 97-116.

39. Ministry of Climate and Environment, 2022, PLN 250 million for the development of geothermal energy in Polish municipalities, [electronic resource: https://www.gov.pl/web/climate/pln-250-million-for-the-development-of-geothermal-energy-in-polish-municipalities], [Access 07.12.2022]
40. Ministry of State Assets, 2021. Social contract for mining signed, [electronic resource: https://www.gov.pl/web/aktywa-panstwowe/umowa-spoleczna-dla-gornictwa-podpisana], [Access 21.01.2023]
41. United states of America, Department of States, 2020. Agreement between the United States of America and Poland about Nuclear energy, [electronic resource: https://www.state.gov/wp-content/uploads/2021/05/21-224-Poland-Nuclear-Energy.pdf], [Access 06.12.2022]
42. Starzyk, A et al. 2023. Environmental and Architectural Solutions in the Problem of Waste Incineration Plants in Poland: A Comparative Analysis. *Sustainability* **15**, 2599.
43. Chomać-Pierzecka, E et al. 2022. Hydropower in the Energy Market in Poland and the Baltic States in the Light of the Challenges of Sustainable Development-An Overview of the Current State and Development Potential. *Energies* **15**, 7427.
44. Value of coal imports from Russia to Poland from 2000 to 2020, 2022, [electronic resource: https://www.statista.com/statistics/1295086/poland-coal-imports-value-from-russia/], [Access: 14.12.2022]
45. Stala-Szlugaj, K and Grudzinski, Z 2022. Alternative directions of coal supply to Poland as a result of the Russian-Ukrainian war. *Mineral Resources Management* **38**, 31–47.
46. About the Baltic pipe project, 2022, [electronic resource: https://www.baltic-pipe.eu/about/], [Access 14.12.2022]
47. Information about reserves, 2022, [electronic resource: https://www.conexus.lv/pazemes-dabasgazes-kratuve], [Access 14.12.2022]