Forecasting of the Share of Renewable Sources in the Total Final Energy Consumption for Selected European Union Countries

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Abstract. The development of society requires stable access to electricity at an acceptable price. In order to meet the growing demand in the European Union countries, we are observing a dynamic development of the use of renewable sources in the energy balances of the Member States. The article presents the legal framework resulting from the newly adopted climate strategy, New Green Deal, and the conditions for the development of renewable sources in the process of transforming energy systems. The characteristics of selected energy balances of countries are also presented, which may constitute a knowledge base on the diversity of the Member States in terms of energy resources used, levels of independence and self-sufficiency of raw materials, as well as the levels of current electricity prices. Based on the available statistical data, the Eurostat database presents forecasts of the levels of renewable energy consumption in the 2030 time horizon for selected countries and according to the main types of renewable energy such as wind, solar energy, biofuels, geothermal energy, and hydropower. The statistical analyzes presented in the article are important tools for building a development strategy for the process of integrating energy markets within the European Union. The obtained results of the analyzes constitute a new approach to the study of the diversified energy market in the EU and present potential development scenarios for the surveyed countries.

1. Introduction
The world has abundant renewable energy resources, and the potential sources of renewable energy available worldwide are quite extensive. It is estimated that the total technical potential of renewable energy may exceed 100 times the current global energy demand [1]. Depending on the source, approximately 95% of this potential is generated by solar technologies, ie solar photovoltaics (PV) and concentrated solar energy (CSP), and 2% by wind energy [2]. Geographically, most of this potential is available in Africa (47%), the Asia-Pacific (23%) and the Middle East (12%) [3]. Renewable energy sources in their initial assumption were to be a remedy for the increasing demand for electricity and the increasing use of fossil resources. They are also to be the main element of the new green deal in the energy sector, in which CO2 emissions will be balanced with its absorption [4-9].

2. Energy demand and consumption
The world's energy demand is growing: economic growth has largely driven the world's energy consumption to a large extent in recent years. This is related to the growth of emerging economies, while growth in the Organization for Economic Co-operation and Development (OECD) countries is starting...
to stabilize, while energy consumption remains high. In the United States and China, there was mainly a noticeable increase in world energy production in 2019, recording rising oil and coal production.

In 2019, data on energy production are as follows (figure 1):

- Oil: -0.7% as a result of a decline in production in the Middle East (compared with + 1.2% per annum in 2000-2018)
- Gas: +4% driven by the US, Russia and Australia (compared to + 2.5% pa in 2000-2018)
- Coal: 0%, growth in China (+ 4%) offset by declines in India, US and EU (compared to + 3% / year in 2000-2018)
- Electricity: + 1%, stimulated by China, with declines in Europe, USA and Japan (down from + 3.1% / year in 2000-2018)

Energy production increased also in Russia and Australia (start of new LNG projects), in Brazil (increase in oil production), in South Africa (more coal production) and in Turkey (increase in hydropower). On the contrary, energy production in Europe continued to decline (especially coal production in Germany and Poland, and oil production in Norway and the Netherlands, where oil and gas resources are diminishing). In the Middle East, US sanctions cut Iran's energy production by nearly 15%, while Saudi Arabia cut oil production under the OPEC + agreement. Global growth in energy consumption slowed down in 2019 (+ 0.6%) compared to an average of 2% per year in the period 2000-2018, in a context of slower economic growth, as shown in Figure 2.
Energy consumption grew slower than in previous years in China (+ 3.2%), the largest consumer in the world since 2009, in Russia (+ 1.8%) and India (only + 0.8%). It has decreased in almost all OECD countries, including the US (-1%), EU (-1.9%), Japan (-1.6%), Canada and South Korea. The only exception was Australia, which recorded an increase of 6.3% (due to the sharp increase in gas consumption from LNG installations) well above the historical average. Consumption remained dynamic in Indonesia and Algeria, continued to rise in Saudi Arabia, Nigeria and South Africa, but fell in Latin America (stable in Brazil and a slight decline in Mexico). US sanctions reduced consumption in Venezuela and Iran.

3. Energy and climate package
In the 1980s, the discussion on climate change went beyond the narrow circle of environmental specialists and became a permanent part of the public debate [11]. In 1988, the United Nations and the World Meteorological Organization established the International Panel on Climate Change I (hereinafter IPCC), the most renowned organization dealing with describing climate change, its causes and consequences. The first report prepared and published by the IPCC in 1990 prompted the adoption in Rio de Janeiro in 1992 of the United Nations Framework Convention on Climate Change. The European Union joined the global efforts to curb climate change. One of the most important manifestations of EU activity in this area was the set of multi-sector legal regulations adopted in 2008, known as the first EU energy and climate package (the so-called 3x20 package). It defined the goals that the Community is committed to achieving by 2020. The most important include: reducing greenhouse gas emissions by 20%; increase in the share of energy from renewable sources in final energy consumption by 20%; increasing energy efficiency by 20%. The package included a number of legal acts that set out the paths to achieve the set goals, both at the Community and national level. The legal acts included in the package include:

- Directive 2009/29 / EC of the European Parliament and of the Council 2 (the so-called EU ETS Directive), which modified the system of trading in allocated levels of greenhouse gas...
emissions, introduced in October 2003 by Directive 2003/87 / EC3. The main objective of introducing the greenhouse gas emission allowance trading scheme was to reduce emissions through the introduction of quasi-market rules. The ETS system included: power plants, large industrial installations and air transport, which in total accounted for approx. 45% of EU emissions [12].

- Decision 2009/406 / EC4 of the European Parliament and of the Council (the so-called Non-ETS Decision), which concerned sectors not covered by the ETS, but generating a total of about 55% of all emissions. These sectors include, among others: housing, agriculture, waste management, transport and trade. Non-ETS (as opposed to the EU ETS) concerns domestic emissions, therefore reporting obligations rest with the government administration. The decision was to contribute to the achievement of the first of the main goals of the package, ie the reduction of greenhouse gas emissions. Reduction efforts in the Non-ETS sector were based on the principle of solidarity by the European Union, which meant that countries with relatively high GDP should achieve higher reduction levels than countries with relatively low GDP. The reduction framework was defined between -20 and + 20% and defined for each Member State in Annex II to the Decision. Pursuant to its provisions, Poland could increase the level of greenhouse gas emissions by 14% compared to the 2005 base year[13].

- Directive 2009/31 / EC of the European Parliament and of the Council5 on the storage of carbon dioxide (the so-called CCS – Carbon Capture and Storage Directive). The act related only to demonstration projects of carbon dioxide capture and storage, implemented in order to confirm the possibility of using this technology on an industrial scale. The Act introduced a significant provision on the need to assess the readiness of installations for capturing carbon dioxide, the availability of underground storage sites as well as the technical and economic feasibility of implementing carbon dioxide transport networks in the procedure of obtaining an environmental impact assessment [14].

- Directive 2009/28 / EC of the European Parliament and of the Council8 (the so-called RES Directive), which introduced targets for each of the Member States to increase the share of renewable energy sources in gross final energy consumption in 2020. 20% share of renewable energy sources in gross final energy consumption. Pursuant to Annex I to Directive 2009/28 / EC of the European Parliament and of the Council of the European Union10, Poland has been obliged to produce at least 15% of final energy from renewable sources by 2020 [14].

The energy and climate package adopted in 2008 set goals whose implementation perspective was set for 2020. At the beginning of the decade, the Commission started work on another package that would define goals for the 2020-2030 perspective. In March 2011, the Commission adopted an Action Plan leading to the transition to a competitive low carbon economy in 2050. After analyzing the factors influencing the prices of fossil fuels, as well as various innovation indicators, the Commission developed the assumed reduction levels for individual sectors of the economy, the European Commission assumed proportionally the largest reduction of CO2 emissions in the energy sector by up to 99% in 2050 (compared to the base year 1990). Such large reductions were to be achieved through the increase of low-emission technologies in the energy structure to approx. 60% in 2020, as well as the implementation of the target for the share of renewable energy sources to 75-80% in 2020 and 100% in 2050. In December In 2011, the European Commission adopted the Energy Action Plan to 2050. The Plan was an extension of the Low-Carbon Economy Plan adopted a few months earlier, as well as the deepening of the energy and climate policy objectives adopted under the 2008 energy and climate package. Elements of this study were to identify the challenges of the EU’s decarbonisation target, while ensuring security of supply and competitiveness both in terms of energy generation and the EU economy as a whole. The Commission focused on the energy sector due to the relatively high level of emissions compared to other sectors. The European Commission identified several areas where action should be taken to achieve the assumed goals. The most important were: dekarbonizacja systemu energetycznego;
- increasing the share of energy from renewable sources in final energy consumption;
- creating a single energy market by creating technical infrastructure, but also eliminating regulatory and structural irregularities in local markets;
- development of CCS technology; • development of new energy infrastructure and energy storage capacity.

The European Commission, in its Energy Action Plan to 2050, has developed scenarios for the decarbonisation of the energy sector over the next forty years. In March 2013, the European Commission published the so-called Green Paper, thus starting the consultation process of the 2030 climate and energy policy framework. In February 2014, the European Commission adopted the 2020-2030 energy and climate policy framework. The main objectives were defined as follows: 1) a 40% reduction in GHG emissions compared to the 1990 base year. The reduction level has been broken down by the sector covered by the EU Emissions Trading System (EU ETS), where the target reduction should be 43% in compared to 2005 and the sector not covered by the emission trading system (EU Non-ETS), in which the assumed reduction should amount to 30% compared to 2005. The reduction target proposed by the European Commission to Poland is -7% of the emission level from 2005, which was a major challenge given that by 2020 we were able to increase emissions in this sector by 14%; increase in the share of renewable energy sources in the final consumption balance to 27%; reform of the emissions trading system by creating a market stabilization reserve at the beginning of the emissions trading phase in 2021. In November 2016, the European Commission presented the energy and climate package called Clean Energy for All Europeans Package, better known as Winter package. It contained a recommendation from the European Commission in the field of energy and climate policy until 2030. After more than two years of negotiations, in December 2018, the European Parliament, the Commission and the European Council announced a compromise on the last two components of the Winter Package. The main provisions include the reduction of emissions by at least 40% compared to the base year 1990. The reductions have been divided into entities covered by the European emissions trading system (EU ETS) and those outside this system (non-ETS). The former was assigned a 43% reduction compared to 2005. The non-ETS sector should generate a reduction of 30% compared to 2005 by 2030, with each country assigned a minimum reduction level. Poland should achieve a reduction of -7%. The European Commission, as part of the implementation of the European Green Deal program, plans to increase the reduction target by up to 55% and to increase energy from renewable sources in the final energy consumption to at least 32%. In December 2019, the European Commission adopted the European Green Deal communication, which is a collection of actions in various sectors aimed at climate protection. One of the main goals is to achieve climate neutrality by the middle of the 21st century, i.e. to reduce greenhouse gas emissions to 50-55% (compared to 1990). The European Green Deal would be aligned with the new industrial strategy with the aim of making the EU a world leader in the circular economy and clean technologies and decarbonising energy-intensive industries [15].

4. Energy mixes

Twelve countries dominate the production of electricity in the European Union countries, which together produce 88% of all electricity produced in the European Union. The remaining EU countries produce less than 12% of the total production. The largest producers of electricity among the member states are Germany and France, their share constitutes as much as 37% of the total production in the EU. It is followed by United Kingdom, Italy and Spain, whose production volumes are rounded to half that of Germany or France. These five Member States produce just over 65% of the total energy of the entire European Union. It is followed by Poland and Sweden, whose share in total energy production in the EU is 5%. Other countries, such as the Netherlands, Belgium, the Czech Republic, Finland and Austria, together produce slightly more than 13% of the total energy generated in the EU countries. The European Union member states are diversified in terms of energy raw materials used to produce electricity, as shown in Figure 3.
Fossil fuels dominate energy production in Poland, Germany and the Czech Republic. In addition, the gross available energy in the European Union in 2019 slightly decreased compared to 2018 (-1.7%). Oil (oil and petroleum products) continued to be the most important source of energy for the European economy, despite its long-term decline, while natural gas remained the second largest source of energy. Oil consumption has declined again, following a slight increase in 2014-2017, while natural gas shows some fluctuations, which increased again in 2019. The share of renewables shows steady growth, already surpassing solid fossil fuels in 2018 and reaching further positions in 2019. Solid fossil fuels fell by 19.7% in 2019 and reached their record lowest value since 1990. Poland currently among the largest energy producers in the EU has the lowest level of renewable energy use below 10%. The remaining countries with the share of RES below 20% are France, Great Britain, the Netherlands, Belgium and the Czech Republic (Figure 4).

Figure 3. Gross electricity generation, own study based [16]

Figure 4. Gross electricity generation, own study based [16]
The original Renewable Energy Directive, adopted by co-decision on 23 April 2009 (Directive 2009/28/EC repealing Directives 2001/77/EC and 2003/30/EC), made a mandatory 20% share of energy consumption energy in the EU must come from RES by 2020. Moreover, all Member States are required to source 10% of their transport fuels from RES by 2020. The Directive also specified various mechanisms that Member States can use to achieve their goals (support schemes, Guarantees of Origin, Joint Projects, Cooperation between Member States and Third Countries) as well as the sustainability criteria for biofuels. The revised directive identified two different regulatory regimes: by 2020, it affirmed the existing national renewable energy targets for each country, taking into account its starting point and overall renewable energy potential. These targets range from 10% in Malta to 49% in Sweden. EU countries set out how they plan to meet these targets and the overall roadmap for their renewable energy policy in their national renewable energy action plans. Using the AR class models, the article analyzes whether Poland, the Czech Republic, France, Great Britain, the Netherlands and Belgium will meet the requirements for the share of renewable energy sources in 2030.

5. Autoregressive models (AR)

These models assume that the time sequence is generated by a linear combination of random pulses. These methods are used to forecast stationary sequences, i.e. those with only random fluctuations around the means, or for non-stationary sequences that can be reduced to stationary by calculating successive differences.

Assuming the linearity and stationarity of the dependencies linking the input and output of the object and assuming that all disturbances affecting the object are reduced to the output, we can write [17]:

$$y(i) = G(z^{-1})u(i) + v(i)$$  \hspace{1cm} (1)

Where $z^{-1}$ is the backward shift operator, $G(z^{-1})$ is the transmittance of the input vector, and $v(i)$ is the cumulative random events brought to the output. The randomness is presented as the filtering of the white noise $e(i)$ through the linear filter [17]:

$$v(i) = H(z^{-1})e(i)$$  \hspace{1cm} (2)

White noise is a mathematical construct describing a random event with the expected value $E\{e(i)\} = 0$, variance $\lambda^2$ and independent realizations in consecutive moments of time $i$, i.e. $E\{e(i)e(i + r)\} = 0$ for $r \neq 0$.

It is convenient to parameterize the transmittance $G(z^{-1})$ with the polynomials of the $z^1$ operator, usually marked as [17]:

$$A(z^{-1}) = 1 + a_1z^{-1} + \cdots + a_dz^{-dA}$$  \hspace{1cm} (3)

$$B(z^{-1}) = b_0 + b_1z^{-1} + \cdots + b_dBz^{-dB}$$  \hspace{1cm} (4)

and a discrete delay time $d$ in the input vector.

Depending on the method of parameterization of random events, different types of object models are distinguished. In modeling and forecasting, the so-called the autoregressive process of the $k$ order, abbreviated as AR ($k$) and defined by the formula [17]:

$$y(i) = \varphi_0 + \varphi_1y(i - 1) + \varphi_2y(i - 2) + \cdots + \varphi_ky(i - k) + \varepsilon_i$$  \hspace{1cm} (5)

where:
- $\varphi_0, \varphi_1, \cdots, \varphi_k$ - process parameters,
- $\varepsilon_i$ - random disruption,
The time sequence which is the realization of the autoregressive process is characterized by the fact that its current value is the sum of the finite linear combination of the previous values of this sequence and the random disturbance.

In this paper is adopted two widely used performance metrics: mean absolute error (MAE), root mean square error (RMSE) to assess the prediction accuracy of the proposed methods [18]:

\[
\text{MAE} = \frac{1}{n} \cdot \sum_{i=1}^{n} (y_i - \hat{y}_i)
\]

\[
\text{RMSE} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} (y_i - \hat{y}_i)^2}
\]

where:

\(y_i\) identifies the actual value for sample \(i\); \(\hat{y}_i\) identifies the predicted value for sample \(i\); \(n\) is the testing data.

6. Results and discussions

As part of the new EU energy strategy until 2030, it has been assumed that the share of renewable energy in the EU electricity, heating and transport sectors will total 32%. However, no compulsory targets at the national level were adopted, the implementation of which - as in the case of the 2020 target - will enable the target to be met at the EU level. On the other hand, EU countries are to indicate their own goals in their "National plans for energy and climate for 2021-2030" and will be accounted for by the European Commission for the implementation of these goals. plan for energy and climate for the years 2021-2030 *, by 2030, achieve a 21% share of renewable energy in gross final energy consumption - in total in electricity, heating and cooling, and for transport purposes. France declared 32%, Great Britain 60%, the Czech Republic 22%, the Netherlands 32% and Belgium 40%. In order to analyze whether these countries will achieve their goals in accordance with the current regulations and projects, theoretical models of the share of renewable energy sources in gross final energy consumption were built (the results are presented in Figure 5).

![Figure 5. RES share in gross final Energy consumption, own study](image-url)
The constructed theoretical models were characterized by very high matching coefficients (MAE below 3%). According to the presented forecasts, with the currently applicable measures, it is not possible to achieve the assumed RES targets for all analyzed countries. The analysis of the current situation in the development of renewable energy sources in Europe may lead to the analyzed countries not meeting the target of the share of renewable energy sources in 2030, which was set out in the New Renewable Energy Directive (Directive (EU) 2018/2001). Despite the fact that the dynamics of RES development in relation to other energy carriers is higher in the European Union, there are concerns about meeting the obligations resulting from the current trends, and these trends are steered by investments and financial support to date. The production of energy from renewable sources requires a significant investment effort in the coming years to ensure the required share in the gross final energy consumption of green energy by the end of 2030.

7. Conclusions
The energy and climate policy of the European Union aims at gradual phasing out of fossil fuels in the process of generating electricity and heat and increasing the share of renewable energy sources in final energy mixes. The aim is to build a low and zero carbon economy. Solar energy, onshore and offshore wind, ocean and hydropower, biomass and biofuels are all renewable and available energy sources. The aim of this article was to show the degree of use of renewable energy in the European Union countries. The European Union Member States, which were characterized by a very low share of RES in the final gross energy consumption, were selected for the study in a purposeful manner. The research period covered the years 2004-2019. The sources of the materials were EUROSTAT data, as well as domestic and foreign literature. The article includes the construction of AR class models for forecasting the share of renewable energy sources in the final gross energy consumption. As a result of the developed models, the expected degree of compliance with the obligations for 2030 was achieved. Despite the fact that the dynamics of RES development in relation to other energy carriers is higher in the European Union, there are concerns about meeting these obligations. This means that energy markets alone cannot deliver the desired level of renewable energy in the EU. National support systems and EU funding systems are needed.

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