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FORECASTING THE DEVELOPMENT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES IN POLAND AGAINST THE BACKGROUND OF THE EUROPEAN UNION COUNTRIES

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ABSTRACT: One of the key elements in the development of countries is energy stability particularly related to ensuring, among other things, continuity of power supply. The European Commission is trying to protect the security of energy supply by introducing internal conditions regarding the share of RES in everyday life. The aim of this article is to forecast the share of RES in electricity production for all the EU member states. The study covers the years 1985-2021, the research is based on two models: the autoregressive (AR) model and the Holt-Winters model, whereas the prediction values were determined for the period 2022-2030. The prediction values showed that Denmark, as the only one of the community countries, may turn out to be self-sufficient in terms of electricity production from RES already at the turn of 2026-2027. In the case of Poland, there is a high probability that the projected RES share for 2030 will not be met. Potentially, for most EU countries, the energy produced from RES will satisfy at least 50% of electricity demand by 2030. A projection of the chances of meeting the commitments presented in the National Energy and Climate Plans regarding the share of renewable energy sources in electricity production in the EU member states in 2030 indicates that they will not be met in most EU economies.

KEYWORDS: electricity, forecasting, RES in the European Union, Holt-Winters model, autoregressive model

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Introduction

Electricity is vital to the productive sector and society's life (Sokulski et al., 2022, p. 1). The electricity supply determines productivity and economic development, as well as influences the well-being of society (Raugei, 2020, p. 1). Electricity is one of the most important energy carriers for several production processes and therefore has a significant impact on resource consumption. Furthermore, the generation of electricity by fossil fuel power plants produces harmful waste and greenhouse gases, which have a devastating impact on environmental well-being (Stanek et al., 2018, p. 87). The increase in electricity demand and dwindling fossil fuel resources determine the need to work towards the decarbonisation of electricity systems (Sokulski et al., 2022, p. 1), which should contribute to the reduction of greenhouse gas emissions into the atmosphere (Mac Domhnaill & Ryan, 2020, p. 954).

Global concerns about the climate crisis have prompted efforts to shift to renewable electricity (Yang & Kim, 2020, p. 1). Due to its specificity, renewable electricity plays a key role in reducing the mentioned emissions, mainly because of its potential to be used in other consumption sectors. The decarbonisation of the energy supply makes electrification of both heating and transport necessary. Such a shift would make no economic sense if electricity generation itself relied on fossil fuels (Mac Domhnaill & Ryan, 2020, p. 963). Renewable sources used for electricity generation include solar, hydro, wind, geothermal, tidal and biomass (Sokulski et al., 2022, p. 3).

Russia's military invasion of Ukraine has caused serious consequences for the functioning of the global energy system. Energy prices have risen, and energy security has been disturbed, which has clearly highlighted the EU's excessive dependence on imports of conventional energy sources from Russia (European Commission, 2022). In this situation, the European Commission reacted quickly and announced the REPowerEU strategy in March 2022. This strategy aims to reduce Russian gas imports by two-thirds by the end of 2022 and entirely by 2030. It considers three key aspects: ensuring gas and oil imports from outside Russia, improving energy efficiency and increasing the use of renewable energy (IRENA, 2022). In the current situation of the energy crisis, RES can support the energy security of individual EU Member States. The use of natural resources for the environment and energy is a matter of sustainable development of each country (Kurzak, 2010); therefore, renewable energy will play a vital role in the future development of EU countries. In addition, ensuring clean and accessible power for all is a focus of the UN Sustainable Development Goal 7 (Tomala et al., 2021). The European Union uses selected indicators to verify progress in the implementation of all sustainable development goals (Pleśniarska, 2019), including the aforemen-

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tioned seventh goal – the most related to the development of RES. For this reason, the authors of this study decided to analyse an indispensable element of the functioning of society, which is electricity, the future of which is based on renewable energy sources.

The aim of the article is an attempt at preliminary verification of the accepted declarations of European Union Member States regarding the share of RES in electricity production. A literature query on the subject indicates a high interest in research on the development of RES in the European Union. In the context of this organisation, works forecasting the share of RES in energy consumption in its member states were presented (e.g. Manowska, 2021; Utkucan, 2021; Firlej & Stanuch, 2022). Several studies concerned the forecast of the share of RES in electricity consumption in individual EU countries (Table 1). To the knowledge of the authors, no research has been carried out so far forecasting the possibility of fulfilling national declarations in terms of the share of RES in electricity production (included in the national energy and climate plans) separately by each EU member state until 2030. This study fills this research gap in the literature. In order to determine the possibility of shaping this share, the study was based on two predictive models: the autoregressive model and the Holt-Winters model. On their basis, predictive values for the years 2022-2030 were determined.

In connection with the implementation of the research objective, a research methodology was formulated, including successive steps, which were illustrated in Figure 1.

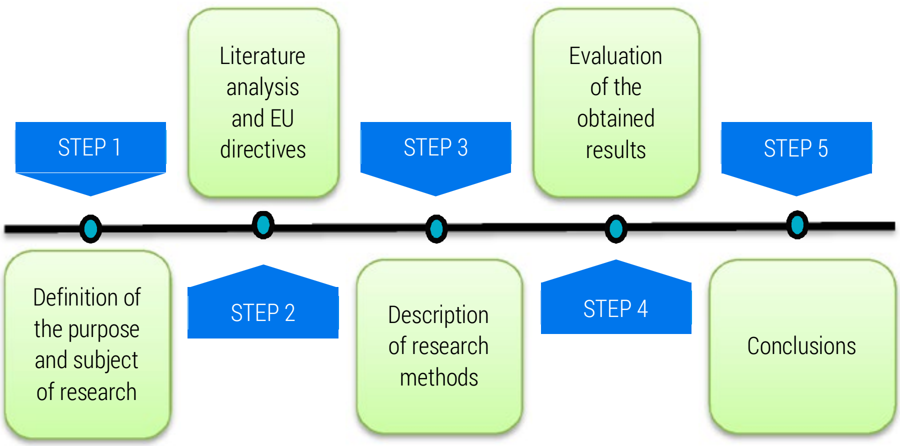

Figure 1. Research methodology

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Electricity and renewable energy sources in the energy policy of the European Union

The European Union aims to create a secure, sustainable, competitive energy market. It is pointed out that electricity from renewable energy sources (RES-E) has a special role to play in shaping this market, the development of which is the cornerstone of the energy policy pursued in the EU member states (De Jonghe et al., 2009, p. 4743). Electricity from renewable sources plays an important role in the context of ensuring the energy security of the European Union, which is of particular importance in an era of war conflict in Ukraine and reduced cooperation in the supply of energy resources from Russia. A greater diversity of energy sources enhances energy security, which comes from considering the security of supply and demand for energy, as well as monitoring energy shortages and surpluses (Blum & Legey, 2012, p. 1986). However, ensuring a sustainable energy supply is subject to a number of requirements, such as climate compatibility, reasonable exploitation of sources, low investment risk, equity and social acceptance. At the same time, the deployment of renewable energy sources should support innovation and growth of the economy and generate new jobs (Paska & Surma, 2014, p. 293).

In 2018. European Union adopted the Renewable Energy Directive (Directive (EU) 2018/2001) (European Parliament and Council, 2018). It targets that at least 32% of the final energy consumed in the European Union should be obtained from renewable sources by 2030. Furthermore, the 2018 Regulation (EU) 2018/1999 of the European Parliament and of the Council on Governance of the Energy Union and Climate Action obliged member states to submit National Energy and Climate Plans (NEEAPs) to the European Commission by the end of 2019. These plans should set out ways to meet targets in the area of greenhouse gas emissions reductions, which should contribute to the European Union's goal of consuming 32% of energy from renewable sources in the global energy mix by 2030 (Institute for Sustainable Development Foundation, 2020). The aforementioned documents also indicate, among other things, declarations regarding the share of renewable sources in electricity production.

In 2019, the European Commission presented the 'Clean Energy for All Europeans' package (European Commission, 2019), which contains a number of proposals for the energy development strategy in the European Union. The crucial and strategic importance of electricity for the future of the European Union was identified. Furthermore, electricity is projected to supply more than half of the European Union's energy needs by 2050. At the same time, renewable energy sources and nuclear energy are expected to account for 80% of the European Union's electricity generation (Matuszewska-Janica, 2021, p. 3).

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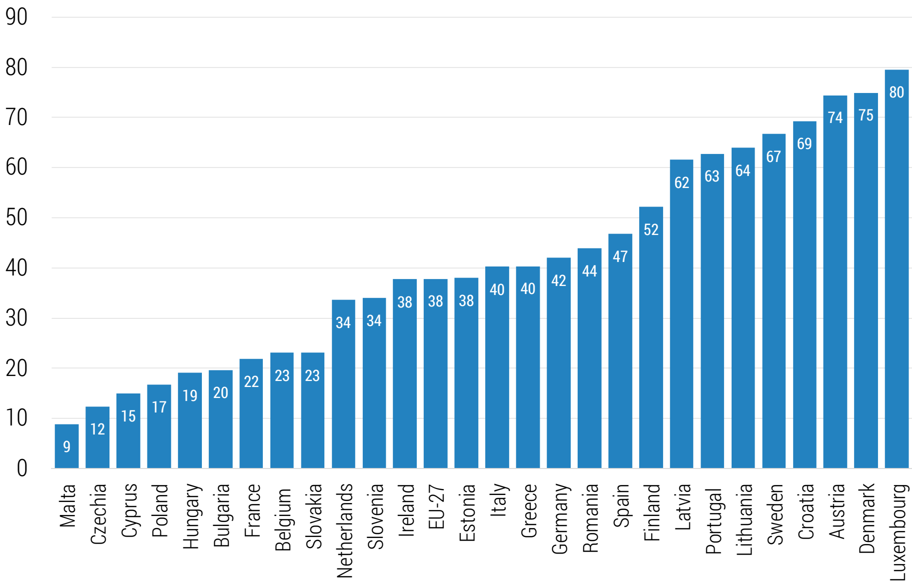

Figure 2. Electricity from renewables in 2021 [%]

Source: authors' work based on Our World in Data, 2022a.

The European Union member states are characterised by varying levels of renewable electricity generation, with an average of 38% in 2021 for the EU-27. Compared to the aforementioned average, a higher level of electricity generation from renewable energy sources was recorded in 15 member countries, of which as many as 10 were EU-15 economies. 12 member countries were below the EU-27 average, with the EU-10 dominating (8 economies) (Figure 2).

Forecasting the development of electricity from renewable sources is a tool for assessing the chances of achieving the targets proposed in the European Union documents and national energy and climate plans and enabling their possible adjustment. In the literature, one can find studies that include renewable electricity development forecasts that have been carried out for selected areas using various econometric methods. Among studies on the selected EU (and other) member states, one can point to those containing forecasts of, among others, the share of renewable energy sources in total electricity production in France, Germany, Spain, Turkey and the UK by 2021 (Şahin et al., 2021); the share of renewables in electricity consumption in the European Union and Romania by 2030 (Mehedintu et al., 2021). Multidimensional projections of the development of renewable energy sources that also include their share of electricity consumption in Poland (IRENA, 2015) and the European Union (IRENA, 2018) in 2030 are presented in the International Renewable Energy Agency reports.

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Table 1. Selected forecasts for electricity from renewable sources

Author	Publication year	Projected years	Forecast	Method	Results
International Renewable Energy Agency (IRENA)	2015	2020, 2030	Share of renewables in electricity consumption	Original program IRENA's REmap	The share of RES in electricity generation (for Poland) in the case of REmap for 2020 was supposed to be 27% and for 2030 it was estimated at 37.7%.
International Renewable Energy Agency (IRENA)	2018	2030	Share of renewables in electricity consumption	Original program IRENA's REmap	The overall share of renewable energy generation in the power sector could reach 50% by 2030.
Şahin, U., Ballı, S., & Chen, Y.	2021	From the third quarter of 2020 to the end of 2021	Share of renewable energy sources in total electricity production	Time regression model and autoregression model	All forecasting models estimate an increase in the share of annual renewable electricity production in total electricity production compared to previous years for the analyzed countries.
Mehedintu, A., Soava, G., Sterpu, M., & Grecu, E.	2021	2030	Share of renewables in electricity consumption	Genetic algorithm based-seasonal fractional nonlinear grey Bernoulli model	All four evolution scenarios for the share of renewable energy consumption in electricity prefigures values close to the desired one 50% in UE.

Source: authors' work based on: IRENA, 2015; IRENA, 2018; Mehedintu et al., 2021; Şahin et al., 2021.

Research methods

The study focused on trying to predict the share of renewable energy sources (RES) in electricity production in the European Union Member States. The study uses the statistical data resources of the electronic scientific publication "Our World in Data" (Our World in Data, 2022b), where the period of study is based on the data from 1985 to 2021. For seven countries, the period of study is shorter, due to the lack of statistical data that may result, inter alia, from the collapse of the USSR, and they are as follows: Estonia since 1995, Croatia 1991, Cyprus 2003, Latvia, Lithuania, Slovenia 1990 and Malta 2012. In order to obtain the prediction values of RES share in electricity production, two models were used: the Holt-Winters model and the autoregressive (AR) model. The Holt-Winters model allows forecasts to be obtained in additive and multiplicative variants and allows variables with seasonal variations to be forecast in terms of complete time series. The forecasting process is defined by the following formulas (Szumksta-Zawadzka & Zawadzki, 2014):

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Additive variance:

$$m_t = \alpha(Y_t - C_{t-m}) + (1-\alpha)m_{t-1}, \tag{1}$$

$$S_t = \beta(m_t - m_{t-1}) + (1-\beta)S_{t-1}, \tag{2}$$

$$C_t = \gamma(Y_t - m_t) + (1-\gamma)C_{t-p}. \tag{3}$$

Multiplicative variant:

$$m_t = \frac{\alpha Y_t}{C_{t-m}} + (1-\alpha)(m_{t-1} + S_{t-1}), \tag{4}$$

$$S_t = \beta(m_t - m_{t-1}) + (1-\beta)S_{t-1}, \tag{5}$$

$$C_t = \frac{\gamma Y_t}{m_t} + (1-\gamma)C_{t-m}. \tag{6}$$

where:

m_t – average value assessment,
S_t – trend directional parameter,
C_t – seasonality assessment,
p – the length of the periodic fluctuation period,
α, β, γ – fluctuation and trend smoothing constants – value in the range [0,1].

The predictor in the additive model is expressed by the formula:

$$Y_t = m_{t_0} + S_{t_0}h + C_{t_{0-m+h}}. \tag{7}$$

In terms of the multiplicative model:

$$Y_t = (m_{t_0} + S_{t_0}h)C_{t_{0-m+h}}. \tag{8}$$

The initial forecast values are calculated as follows:

$$m_1 = \frac{1}{r}\sum_{i=1}^{r} y_i, \tag{9}$$

$$S_1 = \frac{1}{r}\sum_{i=r}^{2r} y_i - \frac{1}{r}\sum_{i=1}^{r} y_i. \tag{10}$$

In the case of the additive model:

$$C_m = y_m - \bar{y}. \tag{11}$$

And for the multiplicative model:

$$C_m = \frac{y_m}{\bar{y}}. \tag{12}$$

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For the second model, the autoregressive (AR) model, which is the tool used to model and predict ex post variables in time series analysis, the equation is as follows (Autoregressive models, 2021):

$$X_n = \alpha_0 + \alpha_1 X_{n-1} + \alpha_2 X_{n-2} + \cdots + \alpha_k X_{n-k} + \varepsilon, \quad (13)$$

where:
X_n – the value of the time series,
$\alpha_0, \alpha_1, \ldots, \alpha_k$ – ratios,
ε – white noise,
k – row of autoregression.

The root mean square error (RMSE) was used to estimate the statistical error of the prediction results, which tends to better reveal differences in the model performance (Chai & Draxler, 2014, p. 1249):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}, \quad (14)$$

where:
n – number of samples,
e – model errors.

The European Commission is introducing a number of directives aimed at achieving climate neutrality set for 2050. In terms of achieving the set headline target, there is a need to adopt and implement several smaller targets, such as the already realised share of at least 20% of energy from RES in the gross final energy consumption of EU member states by 2020. In the 2018 directive, the European Commission set a target of 32% RES share in gross final energy production for the entire EU community to be met by 2030. (Directive (EU) 2018/2001). In the case of offshore wind energy, the European Commission has published a specific strategy which aims to increase offshore electricity production from 12 GW in 2020 to min. 60 GW by 2030 and 300 GW by 2050 on an EU-wide basis (European Commission (EU) COM(2020)/741 final). The adopted strategies were the object of interest of the authors of the study, who, based on up-to-date statistical data, attempted to check whether the defined targets are feasible to achieve for all the countries of the European Union Community. The following research hypotheses were therefore adopted:

H1: The share of RES in electricity production for 2030 will be at least 50% for most EU countries.

H2: The majority of EU countries will fulfil their commitments to the defined targets for the share of RES in electricity production by 2030.

Results of the research

Table 2 shows the prediction values for the all European Union countries for the years 2022-2030 using two forecasting models: Holt-Winters and AR. In the case of Malta, the values are only for the first 4 years, which results from the small amount of statistical data made available by the "Our World in Data" database since 2012.

Table 2. Forecast values of RES share in electricity production for 2022-2030 (with a step of 2 years), according to the Holt-Winters model (H-W) and the autoregression model (AR) [data in %]

COUNTRY	YEAR										RMSE	
	2022		2024		2026		2028		2030			
	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR
Austria	78.95	73.83	80.45	71.00	77.92	71.60	75.10	70.89	79.87	70.00	5.65	3.18
Belgium	25.51	23.46	27.31	24.66	29.00	30.13	30.82	33.90	32.31	35.21	1.88	1.60
Bulgaria	19.62	18.36	20.80	21.91	20.45	23.97	22.75	25.65	23.29	27.94	2.07	1.97
Croatia	77.29	69.61	76.19	66.34	68.99	68.43	78.77	68.09	77.89	67.83	8.05	6.55
Cyprus	10.19	17.50	11.69	20.71	13.44	22.05	15.99	25.00	21.55	30.51	2.71	0.74
Czech Republic	13.25	12.59	14.14	13.06	13.35	13.53	13.99	13.99	14.73	14.44	0.80	0.67
Denmark	82.31	88.58	89.78	95.44	98.31	108.10	106.51	121.05	108.85	133.93	5.25	3.73
Estonia	49.95	43.49	57.65	69.99	65.43	74.87	73.13	122.75	81.04	197.85	5.39	2.05
Finland	50.86	52.34	52.73	55.86	56.58	59.33	59.20	62.97	63.86	66.99	5.23	3.61
France	25.48	23.42	29.22	24.47	27.03	25.57	27.74	26.79	29.23	28.16	3.46	1.54
Germany	44.92	47.62	49.23	51.08	52.92	54.79	57.50	62.62	61.55	77.29	1.62	0.83
Greece	44.69	41.04	47.55	48.60	47.53	56.94	54.54	66.71	60.25	78.47	3.05	2.62
Hungary	21.18	22.47	25.26	29.79	29.41	37.21	33.40	44.55	37.39	53.28	1.05	0.76
Ireland	41.80	42.43	47.13	50.96	50.17	58.21	53.45	68.04	54.50	78.98	2.68	2.29
Italy	43.18	40.22	42.45	41.09	38.92	41.72	43.64	42.38	44.92	43.02	3.22	2.69
Latvia	63.02	59.36	56.56	55.17	68.34	59.92	58.97	55.95	69.73	59.66	9.62	5.07
Lithuania	50.01	55.41	51.62	57.57	54.23	60.87	55.93	63.88	61.10	66.90	6.38	5.21
Luxembourg	51.35	50.75	57.20	56.83	61.90	62.78	70.07	62.70	78.76	58.93	3.77	2.53
Malta	12.34	16.97	15.11	20.20	N/A	N/A	N/A	N/A	N/A	N/A	6.50	7.71
Netherlands	39.64	38.37	55.11	51.61	70.47	56.67	84.75	52.70	99.91	49.61	1.43	1.08
Poland	17.51	17.47	18.81	18.77	19.93	19.45	21.43	20.37	22.82	21.37	0.96	0.77

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COUNTRY	YEAR										RMSE	
	2022		2024		2026		2028		2030			
	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR
Portugal	70.05	60.42	81.70	59.60	71.26	57.96	78.21	59.40	81.25	61.02	16.05	8.29
Romania	42.00	43.10	45.11	42.88	47.77	43.12	56.27	43.31	55.48	43.36	7.40	3.77
Slovakia	20.77	23.40	17.29	22.89	16.57	22.37	16.25	22.37	17.41	22.31	4.16	1.88
Slovenia	32.06	32.36	31.12	32.66	32.42	33.67	36.94	33.56	36.35	34.39	3.22	2.66
Spain	48.06	45.27	51.63	49.32	49.43	52.65	54.18	55.60	59.14	59.03	6.44	4.09
Sweden	62.34	66.02	68.72	63.47	70.95	68.61	72.73	70.39	75.53	70.97	6.27	4.22
UE – 27	38.86	39.20	41.85	43.15	42.27	47.49	45.80	52.34	48.25	57.90	1.62	1.10

Source: authors' work based on "Our World in Data" data.

An interesting example turns out to be Denmark, where models have shown that by 2026/2028 all electricity could come from RES. Wind power, whose energy transition has a very long history dating back to the mid-1970s, may prove to be the key to achieving such an outcome (Ruszel, 2016). The construction of a power hub in the North Sea, which is estimated to be able to cover the consumption of 10 million European households (Danish Ministry of Climate, Energy and Utilities, 2021), may prove to be the key to achieving self-sufficient electricity production from RES. It should be emphasized, that already on 7 July 2015, wind power was able to generate 140% of the daily electricity demand for the country (The Guardian, 2015), where the excess production was exported to neighbouring countries. The projected self-sufficiency of electricity from RES was also shown in the case of Estonia, where the AR model for 2028 showed a result of more than 122%, but compared to the Holt-Winters model (whose projection exceeds only 73%), it can be concluded that it is significantly overestimated. Similar results were obtained in the case of the Netherlands, where the initial values deviate slightly, while each subsequent year of prediction determines a larger distance, particularly evident in the case of 2030. The development of RES in the case of the Netherlands should be attributed to technological developments, where only in recent years the capacity of offshore wind turbines has been increased, allowing a capacity increase over 2019-2020 from 4500 MW to 6600 MW (Trade, 2021). For Romania, the AR forecast showed a stable share of RES in electricity production, whereas a similar forecast was presented by another team of researchers (Mehadintu et al., 2021) only in terms of the share of RES in final energy consumption. The largest forecast error was obtained in the case of Portugal, where the Holt-Winters model identified forecast deviations from the data in the range of more than 16 pp, and in the case of the autore-

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gressive model, this value takes on more than 8 pp. This statistical error is due to the fitting of the model to the input data, which are characterised by particular fluctuations in the range of successive closely consecutive years. Irregular decreases and increases determine the troublesome fit of the model to further forecasts, where from 1985 to 2005 a significant downward trend was visible, while from 2006 onwards there was a rebound compounding the increase in the RES share in electricity production (Figure 3).

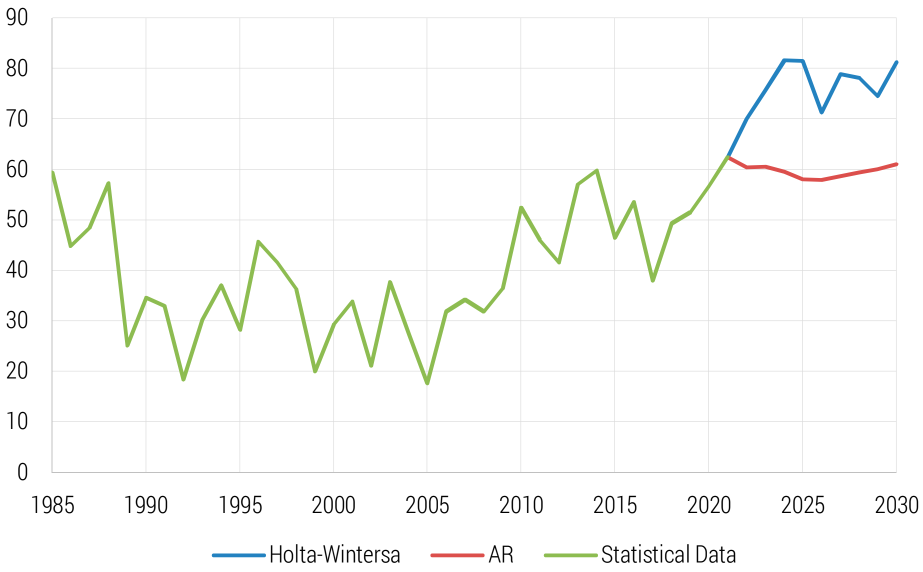

Figure 3. Current (Statistical Data) and projected values (Holt-Winters, AR) of the share of RES in electricity production [%] for Portugal

Source: authors' work based on "Our World in Data" data.

In the case of Poland (Figure 4), very similar results were obtained for both models, where the prediction value was about 17.47% for 2022 and increased to 21.37% in terms of the autoregression model or 22.82% in terms of the Holt-Winters model for 2030. This means, therefore, that the projected dynamics of change will develop at an average annual rate of about 0.5% which makes the obtained value of change too small to ensure that the projections for the share of RES in electricity production, where it was projected to increase to about 27% in terms of 2030, are met. (Ministry of Energy, 2019, p. 21), and was later raised to 32% (Ministry of State Assets, 2019, p. 31). Similar findings for Poland regarding the share of RES in electricity generation have been identified by the International Renewable Energy Agency (IRENA), which predicts a share of 19.2% in 2030 (IRENA, 2015, p.15), but noting that the final consumption of energy from renewable

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sources will increase significantly. This may be confirmed by the increase in the contracted capacity under corporate green energy purchase agreements, which increased in Europe by about 60% for 2020 compared to 2019 (CIRE. PL, 2022). According to the development plan of the Polish Power Grid, in 2030 half of the energy in Poland will come from renewable energy (PSE, 2022), but such optimistic forecasts will probably not be metThe document focuses on the potential of building wind farms, and the current legal status regarding, among others to the construction of wind farms (the so-called wind farm act) strictly defines the distances of wind farms to residential development – the 10H rule, which inhibits the development of wind energy (Dawid, 2017; Talarek et al., 2022). It should also be emphasised that the depicted prediction results in Figure 4 show a very characteristic alignment over time, and the standard statistical error obtained for both models did not exceed a value of 1, which may suggest very accurate prediction values. The high dynamics of RES participation in Poland, which has been evident since around 2007, could have been achieved thanks to the introduction of the so-called green certificates (Pająk & Mazurkiewicz, 2014). Unfortunately, the development of RES in Poland faces some difficulties, including those resulting from geographical conditions, which translate into the efficiency of photovoltaic panels resulting from the degree of insolation (Buriak, 2014).

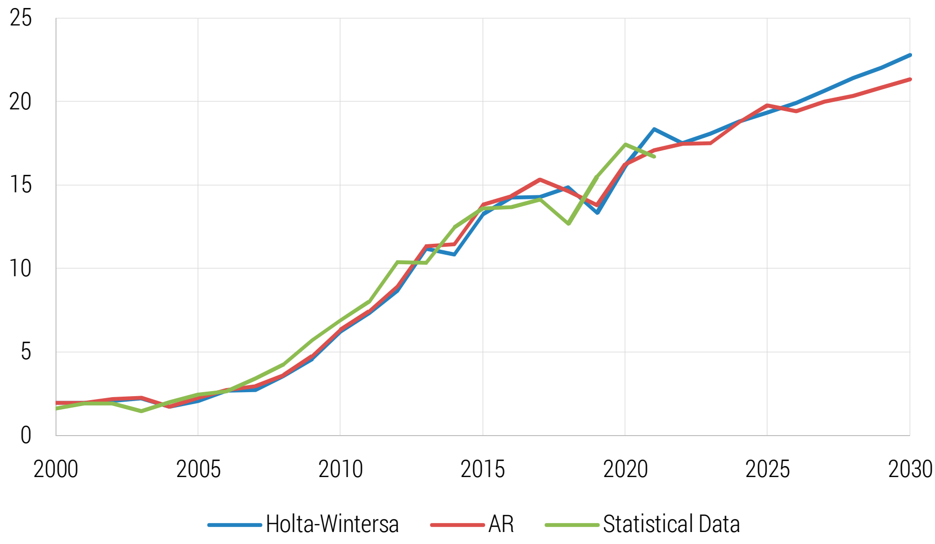

Figure 4. Current (Statistical Data) and projected values (Holt-Winters, AR) of RES share in electricity production [%] for Poland

Source: own study based on "Our World in Data" data.

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In the case of Romania, very similar research results were obtained by another team of researchers, who made a forecast of the RES share within the framework of sustainable development of the EU and Romania. In their study, they showed that the average values of the EU share for 2030 oscillate between 48.33% and 52.10% which is in line with the results of the study for the Holt-Winters model in particular (Mehedintu et al., 2021, p. 18). Similarly, for Romania, where the forecast values are more divergent, with estimates ranging from 40.43% to 64.24%. The dynamic growth of the RES share in the case of the Holt-Winters model may be covered by future investments by the Italian energy group Enel, which envisages the construction of more than a dozen wind and photovoltaic farms cooperating with energy storage in the country (300economy, 2022). Romania expects the share of RES in the electricity segment to increase to 43.6% in 2025. (Romania-Insider, 2018), which would have coverage, especially in the AR prediction model of this study.

Referring therefore to the research hypothesis set, where the prediction values allow us to estimate that 15 Community countries will obtain min. 50% of their electricity from RES, which is expected to represent about 55% of all the EU member states, the authors of the study are therefore inclined to confirm the truth of the hypothesis (H1). It should be taken into account that energy efficiency can improve the pursuit of zero-energy economic growth, which aims at the security of energy supply, or the sustainable development of the entire European Community (Miciuła, 2015, p. 63).

In order to verify hypothesis 2 (H2), a summary statement setting out the national energy and climate plans up to 2030 was used as a framework for climate target and policy (Windeurope, 2022). A comparison of the results of the study with the development of EU Member State plans is presented in Table 3.

Table 3. Comparison of projection results of RES share in electricity production against adopted plans for EU member states

COUNTRY	DECLARATION [%]	FORECAST [%]		ACHIEVING THE GOAL		
		H-W	AR	H-W	AR	$\bar{x}$
Austria	100.00	79.87	70.00	no	no	no
Belgium	40.40	32.31	35.21	no	no	no
Bulgaria	30.33	23.29	27.94	no	no	no
Croatia	63.80	77.89	67.83	yes	yes	yes
Cyprus	40.00	21.55	30.51	no	no	no
Czech Republic	16.90	14.73	14.44	no	no	no
Denmark	100.00	108.85	133.93	yes	yes	yes

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COUNTRY	DECLARATION [%]	FORECAST [%]		ACHIEVING THE GOAL		
		H-W	AR	H-W	AR	$\bar{x}$
Estonia	40.00	81.04	197.85	yes	yes	yes
Finland	53.00	63.86	66.99	yes	yes	yes
France	40.00	29.23	28.16	no	no	no
Germany	65.00	61.55	77.29	no	yes	yes
Greece	61.00	60.25	78.47	no	yes	yes
Hungary	21.30	37.39	53.28	yes	yes	yes
Ireland	70.00	54.50	78.98	no	yes	no
Italy	55.00	44.92	43.02	no	no	no
Latvia	60.00	69.73	59.66	yes	no	yes
Lithuania	45.00	61.10	66.90	yes	yes	yes
Luxembourg	33.60	78.76	58.93	yes	yes	yes
Malta	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands	70.00	99.91	49.61	yes	no	yes
Poland	32.00	22.82	21.37	no	no	no
Portugal	80.00	81.25	61.02	yes	no	no
Romania	49.40	55.48	43.36	yes	no	yes
Slovakia	27.30	17.41	22.31	no	no	no
Slovenia	43.00	36.35	34.39	no	no	no
Spain	74.00	59.14	59.03	no	no	no
Sweden	82.60	75.53	70.97	no	no	no
Total goal fulfillment				42%	38%	44%

Source: authors' work based on "Our World in Data" data and "Windeurope.pl".

The summary of Table 3 shows that, in the case of the Holt-Winters forecast, 11 EU countries will meet their commitments to the adopted targets, while for the autoregressive model the result is lower and concerns 10 countries. When considering the forecast results in terms of both models, where the prediction values for both models were averaged (, it was found that fulfilment applies to 12 countries. The situation of Malta also remains specific, where no comparison is defined, due to the lack of a target (only a final target is available) as well as the lack of prediction results for 2030. Therefore, the results for this country are not included in the final table summary. Accepting a summary of the fulfilment of the adopted targets from a general point of view, the Holt-Winters model indicated that 42% of the EU community countries would meet the targets; for the autoregressive model it would be 38%, and for the two-method alternative 44%. Relating the results obtained to hypothesis 2 (H2), the authors of the study found it to be disproved by determining that the majority of the EU countries will not meet the set targets for the share of RES in electricity production. Although the two-model alternative meets the assumptions made in hypothesis 2, the results of a single model and their arithmetic mean do not allow this to be concluded. The authors encourage further verification of the hypothesis by using other research methods in this regard.

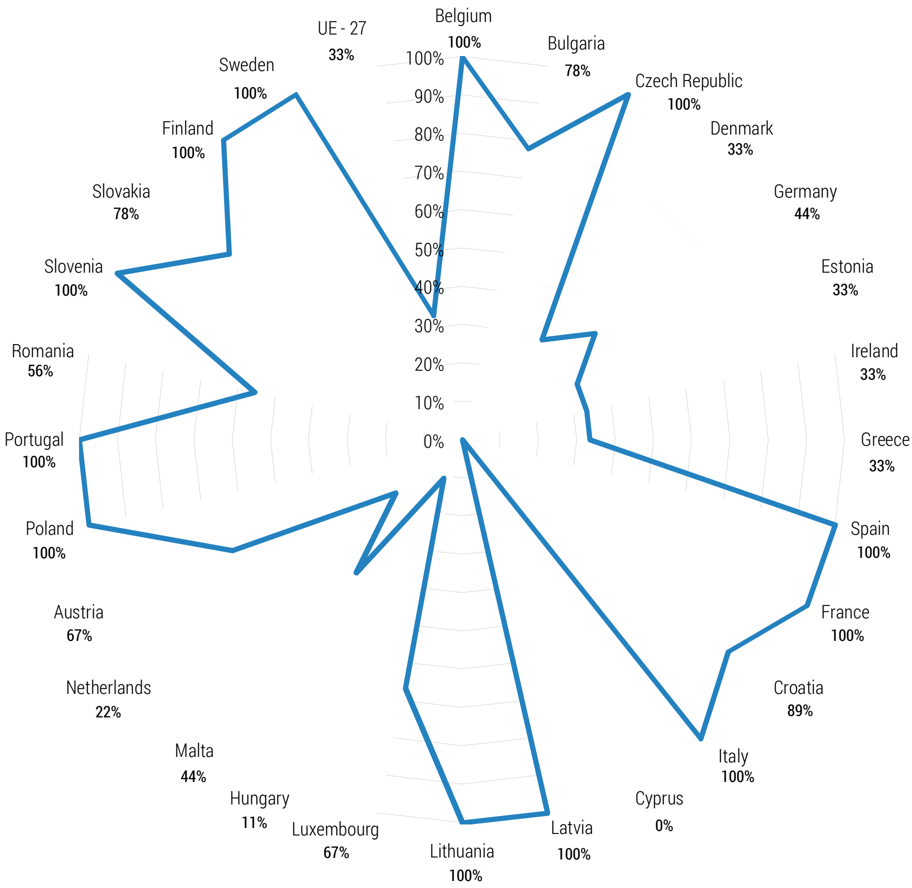

Figure 5. The results of prediction coverage for 2022-2030, where the values of one model fall within the prediction of the other

Figure 5 illustrates the results of the overlap between the prediction values for 2022-2030 for the two models with the resulting forecast error. The figure takes the aggregated values for the specified time interval. When detailed, it is 70% of the predicted values overlap (within the error), while the missing 30% diverges in terms of the specific forecast year. The most similar model predictions are for the next few years (up to 2025), with each subsequent year having a higher error. In the comparison, Cyprus stands out significantly, with a coverage value of 0%, which may be due to the specifics of the input data, which were available from 2004 onwards, and the models' estimates of initial values differed significantly from each other. It should also be noted that in the case of Malta, the values apply to only 4 projections – up to 2025. An overall summary of the prediction coverage allowed us to conclude that, for a given statistical period, it is the forecasts for 13 countries are almost 100% and concern countries such as Belgium, Bulgaria, Spain, France, Italy, Lithuania, Latvia, Malta, Poland, Portugal, Slovenia, Finland and Sweden.

Conclusions

The European Union, faced with limited resources of conventional energy sources and their destructive impact on the well-being of the natural environment, as well as threats to energy security, is forced to seek alternative solutions. An attempt to respond to the challenges of meeting the energy needs of Community member states is to implement renewable energy sources, which are an integral part of the energy policy pursued in the European Union. The different operating conditions of individual EU economies imply a different level of utilisation of renewable sources for electricity production, as well as different national obligations in this aspect in the 2030 perspective.

The research presented in this study fills the research gap in the dimension of forecasting the development of electricity production from renewable sources by 2030 and authorises the construction of the following research conclusions:

1. In the case of Poland, it is projected that there is a high probability of not meeting the commitment for the percentage of electricity generated from renewable sources in 2030.
2. Most EU member states (Austria, Croatia, Denmark, Estonia, Finland, Germany, Greece, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Spain, and Sweden) are projected to generate more than 50% of their electricity from renewable energy sources in 2030.
3. The projection of the chances of meeting the commitments outlined in the National Energy and Climate Plans for the share of renewable energy sources in electricity generation in EU member states in 2030 indicates that they will not be met in most EU economies. The commitments are projected to be met only in: Croatia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, and Romania.

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4. The projection of both electricity production of more than 50% from renewable energy sources and meeting national commitments for the share of renewable energy sources in electricity production in 2030 is successful for 10 countries (Croatia, Denmark, Estonia, Finland, Germany, Greece, Latvia, Lithuania, Luxembourg, Netherlands). For these countries, this will have a particularly significant impact on the reduction of harmful gas emissions due to the reduction of fossil fuel combustion, as well as increasing the degree of energy security through partial or total independence from the supply of conventional energy sources from outside the European Union.
5. The wide variation in the projected increase in the share of renewable energy sources in electricity production in EU countries may be due to various reasons. For example, geographical location favourable to the development of renewable energy sources (e.g. Denmark) or technological development (e.g. the Netherlands).
6. In the conditions of disturbed energy security and unfavourable energy prices, EU Member States should strengthen actions to implement the declarations contained in the national plans for energy and climate. The unfavourable geopolitical situation requires not only the fulfilment of these declarations but also their verification in the direction of even greater expectations regarding the use of renewable sources for electricity production.

Like all studies, this one also has some limitations. Firstly, the study used two different forecasting models, which implied different results. Secondly, in the case of Malta, the availability of statistical data was limited.

The future of renewable energy sources is an extremely valuable and cognitively interesting topic and may prompt further studies that may address, for example, the determinants of its use for electricity generation.

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The contribution of the authors

Conceptualization, K.A.F.; methodology, K.A.F. and M.S.; obtaining data, M.S.; literature review, K.A.F.; estimation of models, M.S.; analysis and interpretation of data, M.S.; writing – original draft preparation, K.A.F. and M.S.; project administration, K.A.F.; funding acquisition, K.A.F. and M.S. All authors have read and agreed to the published version of the manuscript.

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