RENEWABLE ENERGY SOURCES IN THE EU – CURRENT STATE OF USAGE AND IMPORT DEPENDENCY

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Abstract

European Union countries consumed in 2020 more energy than they produced themselves. Only its part was obtained from renewable sources (14.4%). Because of this, the Community focuses its activities largely on energy, where it is produced and the level of its consumption. To this purpose, through tools such as EU directives, it obliges Member States to reduce the energy they consume, as well as to increase the share of renewable sources in energy production. The paper analyses the energy and climate targets for the European Union, particularly those for renewables and energy efficiency, for the oncoming years. In addition, the consumption and production of energy from renewable sources of each country was summarized. Only Sweden and Latvia have been shown to consume more than 50% of their energy from renewable sources. On the other hand, about 58% of the EU's consumed renewable energy in 2020 comes from biofuels and renewable waste. The countries' dependence on energy imports is also apparent, but that from renewable sources usually does not account for a large share. It has also been shown that sixteen of the twenty-seven countries import more than 50% of their energy needs.

Keywords: energy consumption, energy production, energy policy

1. Introduction

27 European countries (EU27) contribute to 10% of the total final energy consumption of the world (*EU energy in figures*, 2022) with less than 6% of the global population. Therefore, for many years, the activities of the European Union (EU) have been related to energy, its production and consumption. In its work, the Community has placed great emphasis on reducing energy consumption and

DOI: 10.5604/01.3001.0053.8566

Received: 26.06.2023 Revised: 24.07.2023 Accepted: 28.07.2023

greenhouse gas (GHG) emissions and increasing energy efficiency (*EU Reference Scenario 2020. Energy, transport and GHG emissions - Trends to 2050*, 2021). As a result, plans and strategies have been developed, including the 3 × 20 Energy and climate package ("DIRECTIVE 2009/29/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL," 2009), the Energy Security Strategy ("The European energy security strategy," 2014), the European Green Deal ("The European Green Deal," 2019), Fit for 55 Plan ("Fit for 55 – The EU's plan for a green transition – Consilium," n.d.) and the Renovation Wave Strategy ("A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives," 2020). They introduce directions and proposals for action, and one of the goals is to achieve climate naturality by 2050. The EU is causing an increase in clean energy production in EU27 through subsidies for renewable energy sources (RES) projects.

It is worth noting that the undertaken actions influence the CO_2 emission costs in the European Trading System (ETS). At the end of 2019 the price prediction of tonne of CO_2 equivalent (tCO_2eq) has been made (*EU Reference Scenario 2020. Energy, transport and GHG emissions - Trends to 2050*, 2021). The values are presented in Figure 1 as grey columns. The price was predicted to rise up to 150 EUR/tCO_2eq in 2050 (the year in which the EU wants to become climate-neutral). However, due to the EU plan of reducing net GHG emission by at least 55% by 2030, a rapid change has occurred. The change is shown by pink columns that indicate the actual prices (*REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the Functioning of the European carbon market in 2021 pursuant to Articles 10(5) and 21(2) of Directive 2003/87/EC (as amended by Directive 2009/29/EC and Directive (EU) 2018/410)*, 2022). The 2020 price was 25 EUR/tCO_2eq, which was both the planned and the actual price. In this year the EU Commission has launched a public consultation concerning 2030 goals. In 2021 when EU Commission has adopted various legislative proposals the price achieved 30 EUR/tCO_2eq (that price was predicted to be in 2030). Furthermore, in the 2022 the price (85 EUR/tCO_2eq) exceeded the level of predictions for 2040 (80 EUR/tCO_2eq). Policymakers and the customers must be aware of unstable CO_2 emission market and the prices that are very likely to rise in the nearest future. Therefore, a broad view on current state of RES usage in EU27 is needed as it can significantly decrease the amount of CO_2eq emitted.

Scientists individually assess energy-consuming sectors: agriculture (Li et al., 2016; Paris et al., 2022; Rokicki et al., 2021), residential (Aydin and Brounen, 2019; Lopes et al., 2015; Tzeiranaki et al., 2019), industrial (Brodny and Tutak, 2022; Korczak et al., 2022). The importance of RES in all sectors was underscored after 2009 when the EU decided to reduce GHG emissions by 20% in 2020 (Cansino et al., 2011; Capros et al., 2011; Tolón-Becerra et al., 2011). Later on, when the new policy has been introduced (climate neutral EU by 2050), the RES were once again evaluated and they still remain the main tool to meet the assumed EU energy goals (Potrč et al., 2021; Tutak and Brodny, 2022). Furthermore, a positive correlation between energy consumption and economic growth has been proven (Streimikiene

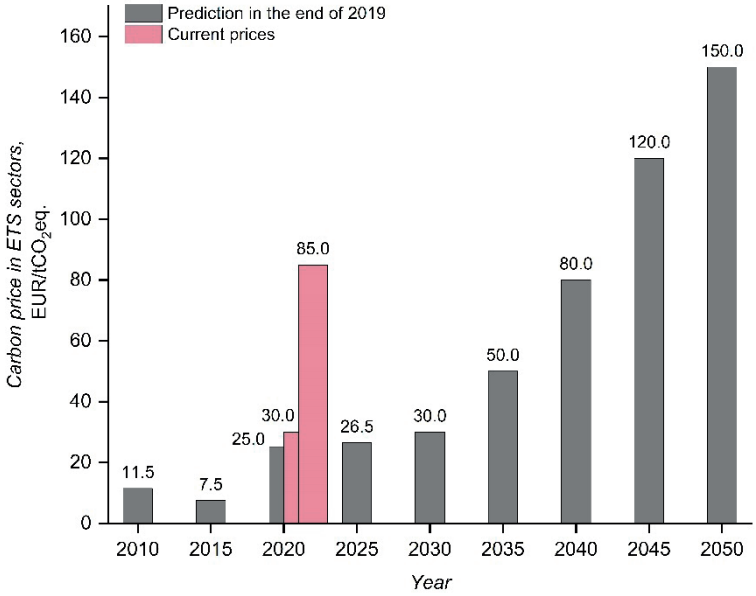

Figure 1. Carbon price in ETS for 2010–2050, predictions (grey) and actual prices (pink) (EU Reference Scenario 2020. Energy, transport and GHG emissions - Trends to 2050, 2021)

and Kasperowicz, 2016). Considering further economic development in the EU27 combined with stable population numbers (*EU Reference Scenario 2020. Energy, transport and GHG emissions – Trends to 2050*, 2021), the increase in energy consumption is possible. Concurrently, economic growth is encouraging increased use of RES (Bilan et al., 2019). This observation is promising in terms of achieving climate neutrality by 2050 in the EU27.

European countries differ in terms of geology, topography, climate and economic development. Therefore, the extent and potential of using renewable sources of a given type also differs. Sources of geothermal energy are limited by their occurrence in only a few places (Kabir et al., 2018). Some areas, such as the Scandinavian countries, have great potential for generating energy from wind and water (Ruokonen et al., 2008). On the other hand, solar energy has the greatest global potential, and its production depends, among others, on latitude, and in the tropical areas the profits may prove to be the highest (Kabir et al., 2018). It should also be emphasized that due to the prevailing climatic conditions in Europe, the needs related to the use of energy to maintain comfort conditions in rooms, in residential and industrial buildings, as well as in various types of works performed in agriculture or the industrial sector, are diverse. The development of energy production from RES is related not only to the climate potential, but also to the cost of generated energy. For example, in the Scandinavian countries, places enabling the installation of the most effective wind farms have already been used up, and the cost of producing more energy is becoming more expensive (Ruokonen et al., 2008).

Basic framework of the paper

In this paper, we present the current state of RES usage in the European Union. The EU27 countries were presented individually in each analysis. Additionally, recent policy packages are analysed in terms of the importance of RES in achieving the climate goals. The data from 2020 have been analysed as the most recent and complete in terms of compared values. The geographical interpretation of the production and consumption of energy from RES was presented. The most popular types of RES were identified, and the unit production costs trends in the last decade (2010–2021) were compared. Also, the energy forms of RES import and export was depicted. Finally, the import dependency was combined against the RES usage in the EU27. There is a deficit of research in the field of current state of RES energy in the EU as well as their popularity and unit costs. Therefore, the paper represents a broad view on the topic along with the considerations on the extent to which countries rely on energy from outside the EU27 area. Moreover, the aim of the article is to identify how policy regulations influence the CO_2 emission costs and what is the current trend in costs of renewable energy production.

2. Regulations

The research and analysis carried out in this work are based on studies from the European Union Publications Office and the International Energy Agency. They refer to energy, transport, GHG, and socio-economic and environmental indicators, among others.

The data they contain were taken from Eurostat and other European Commission's services, the European Environment Agency, the International Energy Agency. The data analysed in this work concern information on the types of energy used in all sectors of the economy. In particular, the study includes an analysis of RES, taking into account both its production and consumption in each EU country. Analyses were carried out for 2020.

The energy economies of EU27 and their development depend on the availability of raw materials and on EU regulations. The Community implements energy and climate policy by forming targets, i.e. for RES and energy efficiency. However, it is up to each member state to decide how to achieve these targets (Baborska-Narożny et al., 2020). To systematize and facilitate RES-related measures, the EU introduced the Directive on the Promotion of Energy from Renewable Sources and the *Fit for 55* package ("Fit for 55 - The EU's plan for a green transition," n.d.). According to the above Directive, by 2030 the share of energy from RES in gross final energy consumption should be 32%. On the other hand, the share of RES and waste heat for heating and cooling generation is to increase by a minimum of 1.3 p.p. each year (y/y), and if only from RES then by 1.1. p.p. ("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 (recast) (Text with EEA relevance)," n.d.).

The set of proposals is comprised by Fit for 55 ("Fit for 55 - The EU's plan for a green transition," n.d.) developed to revise and update legislation to ensure that the climate goals would be achieved. Many items in the package are directly connected to RES. Opportunities to improve the implementation of RES were divided into direct and indirect ones, as shown in **Figure *2***.

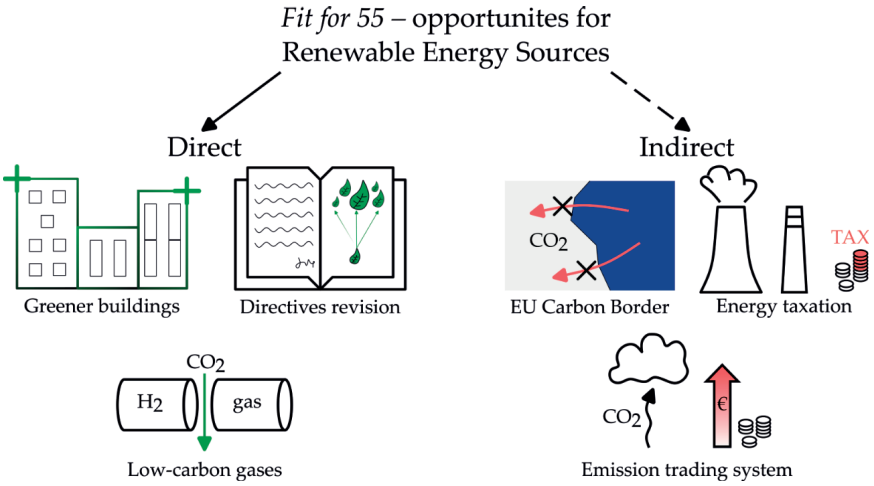

Figure 2. Opportunities to improve the implementation of RES described in the Fit for 55 package

The main direct action is to revise the existing directives on renewable energy and update them to align new EU energy targets (55% of GHG emission reduction by 2030). The aim is to boost the share of RES among EU27. It is strictly connected to the approach to green buildings. Not only the performance of a building is to be increased but also RES should be used to supply and recover the building energy. The last direct package is connected with the change in the energy sector. Switching from fossil fuels to RES by hydrogen and decarbonised gas market will influence the carbon footprint and reduce the import dependency of EU.

The indirect actions are connected to increased costs of non-renewable energy production and restrictions on emissions outside of the EU. Firstly, the CO_2 emissions costs will be increased in the near future (*EU Reference Scenario 2020. Energy, transport and GHG emissions - Trends to 2050*, 2021). Therefore, production costs of energy from sources with high carbon footprint would be raised as well. Furthermore, processes with high CO_2 emissions will not be able to move outside the EU. The Carbon Border Adjustment System (CBAS) is included in the package so that the carbon leakage by production shift outside the EU would be stopped. Finally, the high-emission energy sources will be taxed with revised taxes.

3. Results and Discussion

3.1. Analysis data of consumed and produced energy

EU27 in 2020 produced 565 Mtoe representing ca. 4% of global production of energy. In the same year, they consumed 963 Mtoe out of 9573 Mtoe of global energy. Data sources indicate that this is ca. 6% less than 20 years earlier. In contrast, the target by 2030 is 846 Mtoe, indicating the need to continue the strategy or take further steps intended to reduce energy intensity. It is worth noting that in 2020 the most energy-intensive sectors were transport and housing (*EU energy in figures*, 2022).

The share of renewable energy production for EU increased by almost 6% between 2012 and 2021 ("Database - Eurostat," n.d.). Some countries have significantly increased the share of energy production from RES during this period. For Sweden, it was as high as more than 13%, while Hungary reduced production by ca. 1.5%. **Figure *3*** shows the percentage of energy consumption from renewable

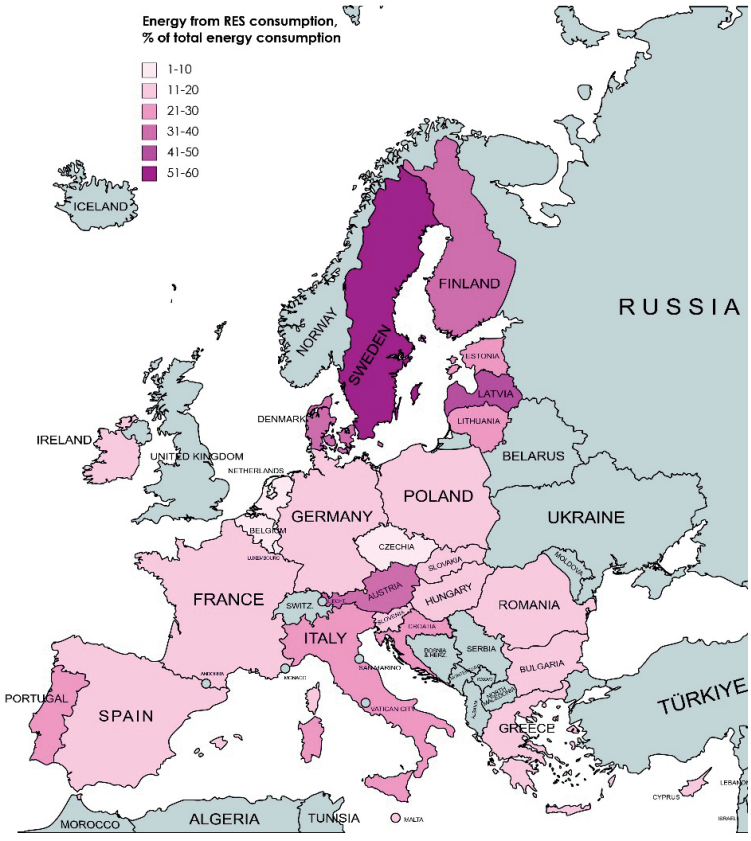

Figure 3. Map of the percentage of renewable energy consumption from RES in the EU27 in total energy consumption in 2020 (own study, created with mapchart.net (EU energy in figures, 2022))

sources in relation to total energy consumption. In most countries, the energy consumed comes between 11–20% from RES. The EU consumes the most energy from RES, which should be related to its production (**Figure *4***). Sweden, located in this area, is the country with the highest percentage of energy consumption from RES, at 51.3%. Latvia consumes slightly less, 40.% of its energy from renewable sources. On the other hand, in the Czech Republic only 6.4% of the energy consumed comes from RES.

In most EU countries, the share of energy production from RES in relation to total energy production oscillates between 21 and 40%, as seen in **Figure *4***. It can be noticed that the northern and southern parts of Europe produce more energy from RES than the centre of Europe. Luxembourg, Estonia, Cyprus and Latvia are countries whose energy production from RES accounts for 100% of the energy produced. On the other hand, Poland has the lowest share of energy production from RES, as low as 21.6%. The only country that does not produce energy from the EU27 included in the analysis is Malta.

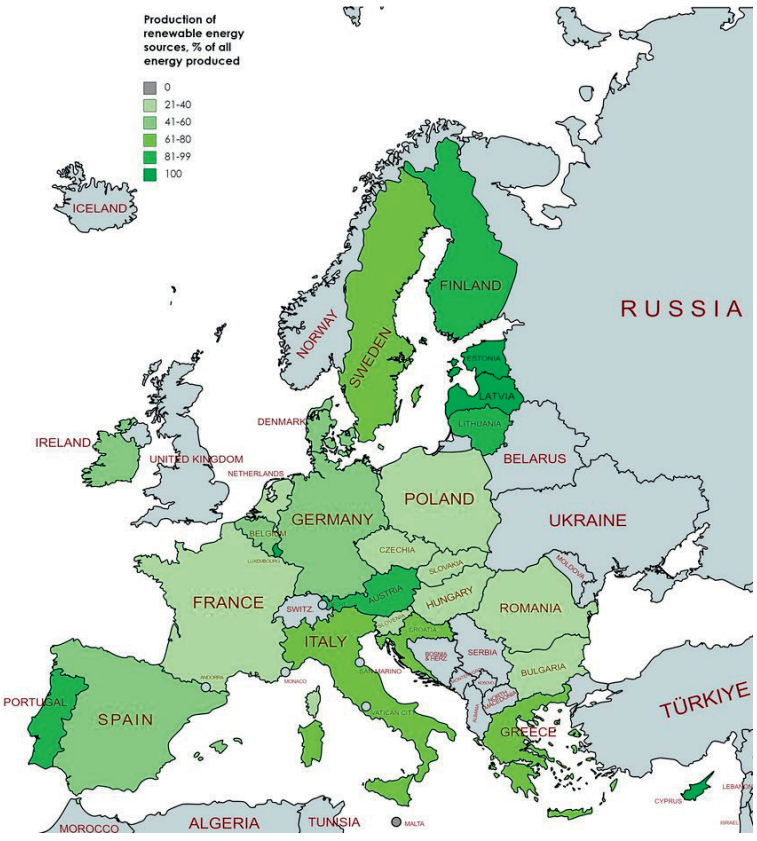

Figure 4. Map of the percentage of renewable energy production from RES in the EU27 in total energy production in 2020 (own study, created with mapchart.net (EU energy in figures, 2022))

In order to present a full view on the RES and biofuels used in EU27 countries, the energy sources have been compiled. They include in particular the following energy sources:

- Hydropower,
- Wind power,
- Geothermal energy,
- Solar thermal energy,
- Solar photovoltaic energy,
- Ambient heat (heat pumps),
- Biofuels and renewable wastes.

The analysis shows that energy from biofuels and renewable waste has the greatest value of gross inland consumption in all countries besides Ireland (where wind is the most popular RES). Overall, 58% of European renewable energy consumption is provided by biofuels and renewable waste (*EU energy in figures*, 2022). This is the result of the waste-to-energy approach, which increases the use of waste as a renewable and sustainable energy source (Malinauskaite et al., 2017; Scarlat et al.,

Figure 5. The second RES (by energy produced) in global inland consumption in 2020 (own study, created with mapchart.net (EU energy in figures, 2022))

2019; Zheng, 2010). The potential of energy obtained from waste is satisfying and increasing in the EU27 countries (Halkos and Petrou, 2019), also in terms of energy security (Yamaka et al., 2022). Additionally, it provides a possibility to reduce CO_2 emissions, which is a crucial point considering costs of CO_2 emissions as stated earlier (Ali et al., 2021; Bayar et al., 2021). Biofuels are also widely implemented in the EU (Bórawski et al., 2019). Not only in the transport sector (Simionescu et al., 2017), but also in industry (Achinas et al., 2019). Nevertheless, further research has been done, and the second most popular source is shown in (**Figure 5**). The map shows that wind and hydro RES are mostly used.

3.2. Opportunities and limitations

The RES types popularity is strictly connected to the cost of production, as some of them are already competitive in terms of the economy (Edenhofer et al., 2011). Data from the IRENA database (IRENA, 2022) prove that the main types of RES already have a low price or their price has been decreasing in the last decade as compared with fossil fuels energy. Figure 6 presents the trends from the last decade in energy prices against 2021 prices of energy from fossil fuels and waste. With fossil fuels cost range as a point of reference (0.05–0.17 USD/kWh) the energy produced from waste proves to be competitive (less than 0.1 USD/kWh depending on waste type). What is more, bioenergy costs (Figure 5, second the most popular RES) are lower, especially hydropower and onshore wind, 0.048 and 0.033 USD/kWh

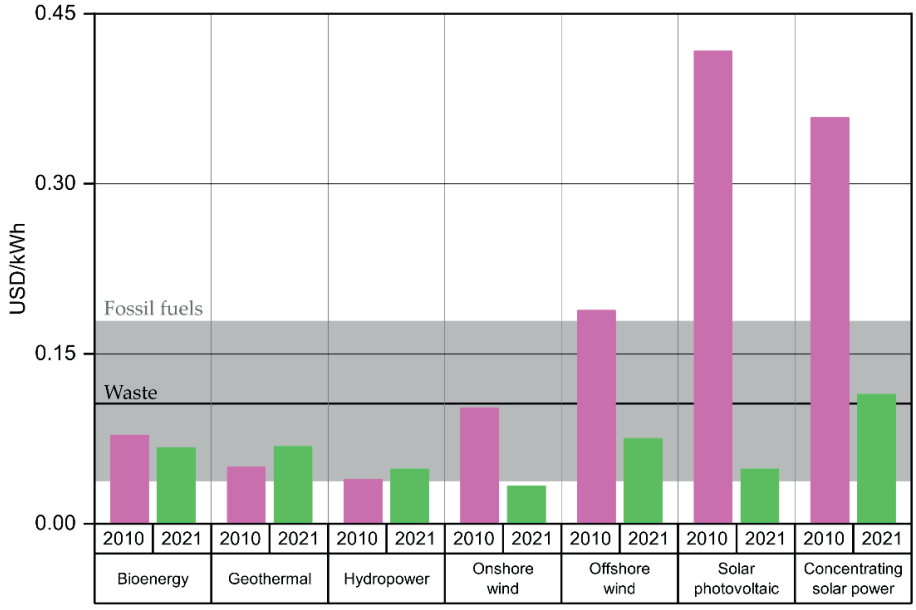

Figure 6. Chosen RES prices with cost of energy form waste and fossil fuels for 2010 and 2021 (IRENA, 2022)

respectively. Only offshore wind energy is in the range of fossil fuels energy production costs (0.075 USD/kWh). Still there is a significant drop in solar and wind energy costs, which are promising for the future in terms of economic aspect.

Many times countries, due to various conditions, including lack of funds for new investments, renovations, or limitations related to climate potential, are unable to produce the RES energy necessary for the country's operation on its own. In this case, energy is imported. **Table *1*** presents the Gross Inland Consumption of EU27 for RES and total energy. In order to present full view on the current situation in EU, percentage values of Import share (*IS*, %) and Import dependency (*ID*, %) were shown. *IS* is defined as a ratio of renewables and biofuels net import (*NIR*, Mtoe) to the gross inland consumption of renewables (*GICR*, Mtoe):

$$IS = \frac{NI_R}{GIC_R} \cdot 100\%$$

ID describes to what extent a country relies on energy from import that is needed to meet energy needs. It its defined as a ratio of total energy net import (*NITE*, Mtoe) divided by gross inland consumption of total energy (*GICTE*, Mtoe) and international maritime bunkers (*IMT*, Mtoe):

$$ID = \frac{NI_{TE}}{GIC_{TE} + IM_T} \cdot 100\%$$

Table 1. The Gross Inland Consumption of EU27 for RES and total energy in 2020 (compiled using data from (EU energy in figures, 2022))

Country	Renewable Energy Sources		Total energy	
	Gross Inland Consumption, *Mtoe*	Import share	Gross Inland Consumption, *Mtoe*	Import dependency
BE	4.9	18%	51.4	87%
BG	2.6	0%	17.8	38%
CZ	5.2	0%	40.2	39%
DK	6.2	31%	15.9	45%
DE	46.9	1%	284.7	64%
EE	1.3	-38%	4.5	11%
IE	1.8	11%	13.7	71%
EL	3.3	3%	20.5	81%
ES	18.9	-4%	111.8	68%
FR	28.7	2%	223.7	44%
HR	2.2	-5%	8.3	54%
IT	29.5	7%	141.6	74%

Country	Renewable Energy Sources		Total energy	
	Gross Inland Consumption, *Mtoe*	Import share	Gross Inland Consumption, *Mtoe*	Import dependency
CY	0.3	33%	2.3	93%
LV	1.9	-42%	4.4	46%
LT	1.6	-6%	7.6	75%
LU	0.4	25%	4.0	92%
HU	3.0	-3%	26.2	57%
MT	0.0	-	0.8	98%
NL	6.9	-3%	71.9	68%
AT	10.5	0%	32.2	58%
PL	12.9	3%	103.0	43%
PT	6.4	-5%	21.4	65%
RO	6.0	3%	32.2	28%
SI	1.2	8%	6.3	46%
SK	2.2	0%	16.5	56%
FI	12.1	2%	32.1	43%
SE	23.3	6%	45.2	32%

Despite the growing popularity of cheap RES, they have not become yet a significant part of the energy system in many countries; neither the production nor the import of RES is popular. Half of the EU27 countries do not import any energy from RES or export it. The highest percentage of RES import is 31% for Denmark, while Latvia has the lowest and negative value of –42%, which means export of energy from RES. At the same time import dependency (*ID*) in almost every country is very high. Only Estonia (EE) reaches 11%, which is the lowest value, and the next one is Romania (RO) with *ID* of 28%. More than half of the energy needed in the country is imported in sixteen EU countries. Overall, the production of energy in Europe is decreasing and it becomes less harmful to the environment. However, the import dependency is very high (with an average of 58%), so the energy is produced outside the EU and then imported. Therefore, a further analysis of import energy types and emissions connected is needed.

4. Conclusions

The paper summarizes the results of the actual state of renewable energy analysis in the EU. Research concerning RES has recently become an important topic regarding the actual policy updates. The paper presents a broad overview of the recent policy and its influence on CO_2 emission prices, consumption and production of RES and

their prices trends. The research adds value to the actual state of knowledge and is important in terms of further development of RES policies and use in the EU.

The policymakers not only regulate the RES market and provide encouragements to shift the energy sector into climate neutral, but also influence the EU ETS indirectly. The comparison of predicted and actual CO_2 emission price in the EU clearly presents that implemented regulations can change the emission market rapidly. Therefore climate neutral energy becomes not only important in environmental and social sector but also in the economic one. In the future countries that do not support RES development may face the problem of covering the emission costs.

Despite the fact that in 2022 CO_2 emission costs exceed the predicted price for 2040 there is a possibility to deal with the economic problem. Along with the development of technology, energy produced from RES is now at a similar level as that from fossil fuels. Taking into account ongoing investments in RES technology, further reduction in RES energy price may be expected. A switch towards sustainable energy production can therefore become available for low income countries.

The research reveals also the problem of import dependency of EU27. The ID of sixteen countries is above 50%, which implies that more than a half of energy consumed in the country is imported. This is partially due to the low cost energy production outside the EU. However, in those cases the emissions are not controlled by EU regulations. In order to prevent emission leakage outside the EU, new regulations of Carbon Border Adjustment Mechanism have been presented in Fit for 55 regulation. One must be aware that those actions will affect for example ETS.

Another aspect that can significantly influence the energy market is the global political situation and conflicts. The Russian invasion of Ukraine and other energy conflicts prove the importance of energy independency nowadays. Fossil fuels availability is strictly defined by geographical location and is used as a political and economic power. However, different RES are available at diverse geographical locations and offer a a possibility of reducing the import dependency and therefore reduce the influence of superpowers. In the current situation the EU had to immediately seek energy sources outside the countries involved in conflict. What is more, the nuclear power plants are no longer perceived as they had been, mainly because of the fact that in case of conflict they may become a threat and a weapon.

In the past 20 years the energy consumption in EU has only decreased by 6%. This shows that the reduction policies fail to satisfy the needs of 2030 targets. Solution may be found in decreasing prices of different RES types, which with regard to emission cost are becoming a competitive market. Another, solution already adopted is the use of biofuels and renewable wastes. As stated in the text 26 countries in EU27 has this RES as the most used of all RES. Still there are many social barriers to overcome in this area.

Funding

This research received no external funding.

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ODNAWIALNE ŹRÓDŁA ENERGII W UE – OBECNY STAN WYKORZYSTANIA I ZALEŻNOŚĆ OD IMPORTU

Abstrakt

Kraje Unii Europejskiej w 2020 r. zużyły więcej energii niż same wyprodukowały. Natomiast tylko jej część pochodziła ze źródeł odnawialnych (14.4%). W związku z tym Wspólnota swoje działania w dużej mierze koncentruje na energii, miejscach jej wytwarzania i ilości zużycia. W tym celu za pośrednictwem narzędzi, jakimi są m.in. dyrektywy UE zobowiązuje kraje do redukcji zużywanej energii, a także do wzrostu udziału źródeł odnawialnych w jej produkcji. W artykule przeanalizowano cele energetyczno-klimatyczne, w szczególności dotyczące OZE i efektywności energetycznej dla krajów Unii Europejskiej na najbliższe lata. Ponadto zestawiono zużycie oraz produkcję energii pochodzącej ze źródeł odnawialnych poszczególnych krajów. Wykazano, że jedynie Szwecja i Łotwa konsumują więcej niż 50% energii pochodzącej z OZE. Natomiast około 58% skonsumowanej w 2020 r. energii odnawialnej w EU pochodzi z biopaliw i odpadów odnawialnych. Widoczne jest także uzależnienie krajów wchodzących w skład UE od importu energii, lecz ta pochodząca ze źródeł odnawialnych zwykle nie stanowi dużego udziału w energii importowanej. Wykazano również, że 16 z 27 krajów EU importuje ponad 50% swojego zapotrzebowania na energię.

Słowa kluczowe: zużycie energii, produkcja energii, polityka energetyczna