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Renewable energy transition in Europe in the last two decades

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Abstract

Aim: The article aims to explore the evolution of the share of renewable energy in selected European countries over the period from 2005 to 2022 by examining countries with varying levels of renewable energy penetration and highlight regional disparities in renewable energy growth.

Methods: This study uses quantitative analysis of Eurostat's energy data to examine the share of renewable energy in total final consumption across European countries in 2005, 2012, and 2022. Descriptive statistics, comparisons, and trend analysis are supported by visualizations, including maps, bar, and line charts, to illustrate changes over time.

Results: The results reveal substantial progress in renewable energy adoption across Europe between 2005 and 2022, with notable variability in growth rates between countries, underscoring both the successes and the challenges faced in achieving energy transition.

Implications and recommendations: The findings highlight the need for targeted policies and support mechanisms to assist countries with slower renewable energy adoption, particularly in addressing economic constraints and structural barriers that hinder progress.

Originality/value: This study provides a comprehensive analysis of renewable energy growth across Europe from 2005 to 2022, offering unique insights into regional disparities and the factors contributing to the varying pace of renewable energy adoption.

Keywords: sustainable development, renewable energy sources, share of renewable energy

1. Introduction

The Europe 2030 climate and energy framework highlights the importance of improving energy efficiency and transitioning to renewable energy production, which are essential priorities for the EU, particularly in the context of addressing climate change (European Commission/Eurostat, 2019). Renewable energy sources are thought as important in the strategies aimed at achieving sustainable development, particularly in Europe. The shift towards renewable energy is not only a means of reducing carbon emissions but also a critical factor in enhancing energy security and creating new employment opportunities in the green energy sector. The integration of renewable energy into national energy mixes has become a key policy goal, driven by both environmental imperatives and economic benefits.

One of the most important metrics used to track progress in this area is the share of energy from renewable sources, which indicates the proportion of a country's total energy consumption derived from renewable sources. The European Union (EU) has been at the forefront of the renewable energy transition, setting ambitious targets under the European Green Deal and Renewable Energy Directive. These initiatives aim to make Europe climate-neutral by 2050 by significantly increasing the share of renewable energy in total energy consumption.

This article aims to explore the evolution of the share of renewable energy in selected European countries over the period from 2005 to 2022. The paper analyses the trends in the share of renewable energy in the final energy consumption of selected European countries over the last two decades. Specifically, it aims to compare countries with high renewable energy adoption and those with lower levels by examining countries with varying levels of renewable energy penetration and highlight regional disparities in renewable energy growth.

2. Literature review

2.1. The pillars and goals of sustainable development

The multitude of dimensions of sustainable development discussed in the subject literature (Megyesiova & Lieskovska, 2018) proves its importance and topicality. It is analysed in both the context of enterprises, cities, regions and at the international level and with different temporal focuses (ex-ante, concurrent, ex-post) (Dizdaroglu, 2019; Joseph et al., 2019; Lazaretti et al., 2019). Moreover, sustainable development is also analysed in various aspects (Herrmann, 2014; Pilewicz et al., 2018; Robert et al., 2005) whenever it refers to three main pillars, namely economic, social and environmental (World Bank, 2012). These pillars are a foundational element for all researchers and occur across all sectors of the economy (Fischer et al., 2013). The climate change and environmental degradation are an existential threat. To fight them, countries worldwide face significant challenges in achieving sustainable growth. It is worth mentioning that sustainable development is reflected by three main domains: economy (services, household needs, agricultural growth, industrial growth, efficient use of labour), social

(equity, participation, social mobility, cultural preservation, empowerment), and environment (biodiversity, natural resources, ecosystem integrity, carrying capacity, clean air and water), and results in complex interactions. One of the sustainable development goals (SDG) is according to the 2030 Agenda for Sustainable Development affordable, reliable, sustainable and modern energy for all (SDG 7) and combating climate changes (SDG 13) (Manolis & Manoli, 2021).

2.2. Energy security as a component of sustainable development

In particular, EU countries are legally bound to meet the goals of the European Climate Law (Regulation (EU) 2021/1119…), which stems from the European Green Deal (Communication from the Commission…). This law sets a clear target for Europe to become climate-neutral by 2050, meaning that by then, net greenhouse gas emissions must be reduced to zero. To reach this goal, countries must focus on reducing emissions, investing in renewable technologies, and protecting the environment. The law also sets an important milestone for 2030, where EU countries must cut their emissions by at least 55% compared to 1990 levels. The aim is for all sectors – energy, transport, industry, and agriculture to contribute to this effort and for EU policies to align with these climate goals. Atici (2009) examined the impact of various factors such as gross domestic product (GDP) *per capita*, energy use *per capita* and trade openness on carbon dioxide emission *per capita* in the Central and Eastern European countries. He found out that this region needs environmentally cleaner technologies in energy production to achieve sustainable development.

The objective of the European Climate Law documents is to establish a long-term strategy for achieving climate neutrality by 2050 through all policies, ensuring that the process is socially fair and cost-effective. It also aims to set a more ambitious EU target for 2030, positioning Europe on a responsible path to becoming climate-neutral by mid-century. Furthermore, the document seeks to develop a system for monitoring progress and taking necessary actions when required. Additionally, it aims to provide stability and predictability for investors and other economic actors while ensuring that the transition to climate neutrality becomes irreversible (Regulation (EU) 2021/1119…).

Energy supply security is one of the most important components of sustainable development, as it is closely linked to the safety and functioning of entire societies as well as individual entities (Rusak, 2009). Renewable energy sources have become a key component of sustainable development strategies all over the world. As countries aim to reduce carbon emissions, increase energy security, and promote economic development, the role of renewable energy has grown significantly. In Europe, the transition to renewable energy is critical to meeting the European Union's environmental and energy goals. The EU's Renewable Energy Directive sets binding targets for the share of energy from renewable sources in total energy consumption, driving member states to make significant investments in green energy. How have European countries managed the implementation of renewable energy sources between 2005 and 2022, and what differences in achieving the share of renewable source of energy can be observed among them? This research question prompts an analysis of the disparities that have arisen from the different approaches European countries have taken toward implementing renewable energy sources.

3. Methodology

This study is based on a quantitative analysis of secondary data obtained from Eurostat's energy statistics. The primary metric used is the share of energy from renewable sources in total final energy consumption. Data for 2005, 2012 and 2022 are analysed using simple descriptive statistics, comparisons, and trend analysis. Graphical visualizations, such as maps, bar and line charts, are used to show the changes in renewable energy shares over time. In this study, to follow changes in share of

energy from renewable sources in European countries (see Table 1), a comparative visual analysis of European countries in 2005, 2012 and 2022 took place. To this end our own maps were implemented.

Table 1. Share of energy from renewable sources in European countries (2005, 2012, 2022) in %

Year / Country	2005	2012	2022
Belgium	2.325	7.086	13.759
Bulgaria	9.173	15.837	19.095
Czechia	7.113	12.814	18.195
Denmark	15.955	25.465	41.602
Germany	7.167	13.549	20.796
Estonia	17.478	25.586	38.472
Ireland	2.822	7.029	13.107
Greece	7.277	13.741	22.678
Spain	8.444	14.239	22.116
France	9.272	13.239	20.259
Croatia	23.691	26.757	27.924
Italy	7.549	15.441	19.131
Cyprus	3.131	7.111	19.429
Latvia	32.264	35.709	43.316
Lithuania	16.768	21.437	29.599
Luxembourg	1.402	3.112	14.356
Hungary	6.931	15.53	15.190
Malta	0.123	2.862	13.404
Netherlands	2.478	4.659	14.972
Austria	24.353	32.734	33.758
Poland	6.867	10.955	16.879
Portugal	19.523	24.574	34.677
Romania	17.571	22.825	24.140
Slovenia	19.809	21.551	25.002
Slovakia	6.36	10.453	17.501
Finland	28.814	34.222	47.886
Sweden	39.982	49.403	66.002
Iceland	60.27	73.727	79.475
Norway	60.069	64.932	75.820

Source: own elaboration based on (Eurostat, n.d.).

4. Results

4.1 Regional disparities and challenges

To summarize and describe the key features of the dataset the descriptive statistics were implemented (see Table 2).

Table 2. The descriptive statistics for 2005 and 2022

Descriptive statistics	2005	2022
Mean	16.03382759	29.26
Standard error	2.926266544	3.376479942
Median	9.173	22.116
Standard deviation	15.75842761	18.18290096
Variation	248.3280407	330.6178871
Curtosis	2.616915617	2.114309277
Skewness	1.669430343	1.647881274
Range	60.147	66.368
Min	0.123	13.107
Max	60.27	79.475
Sum	464.981	848.54
Confidence level (95.0%)	5.994185288	6.916405627

Source: own elaboration.

The average share of renewable energy in European countries increased significantly from 16.03% in 2005 to 29.26% in 2022. This indicates substantial growth in renewable energy adoption across Europe over these 17 years. The standard error, which measures how much individual countries differ from the mean, increased slightly in 2022. This suggests greater variability in renewable energy shares among European countries in 2022 than in 2005. Some countries achieved very high renewable energy shares, while others lagged behind. The standard error, which measures how much individual countries differ from the mean, increased slightly in 2022. This suggests greater variability in renewable energy shares among European countries in 2022 than in 2005. Some countries achieved very high renewable energy shares, while others lagged behind. The standard deviation also increased, indicating greater differences between countries in renewable energy shares. Countries are more varied in their adoption of renewable energy in 2022 than in 2005. Kurtosis slightly decreased. This suggests that the distribution of renewable energy shares across countries in 2022 is slightly flatter, with fewer extreme values compared to 2005. Figure 1 shows the trend in renewable energy shares in selected European countries between 2005 and 2022.

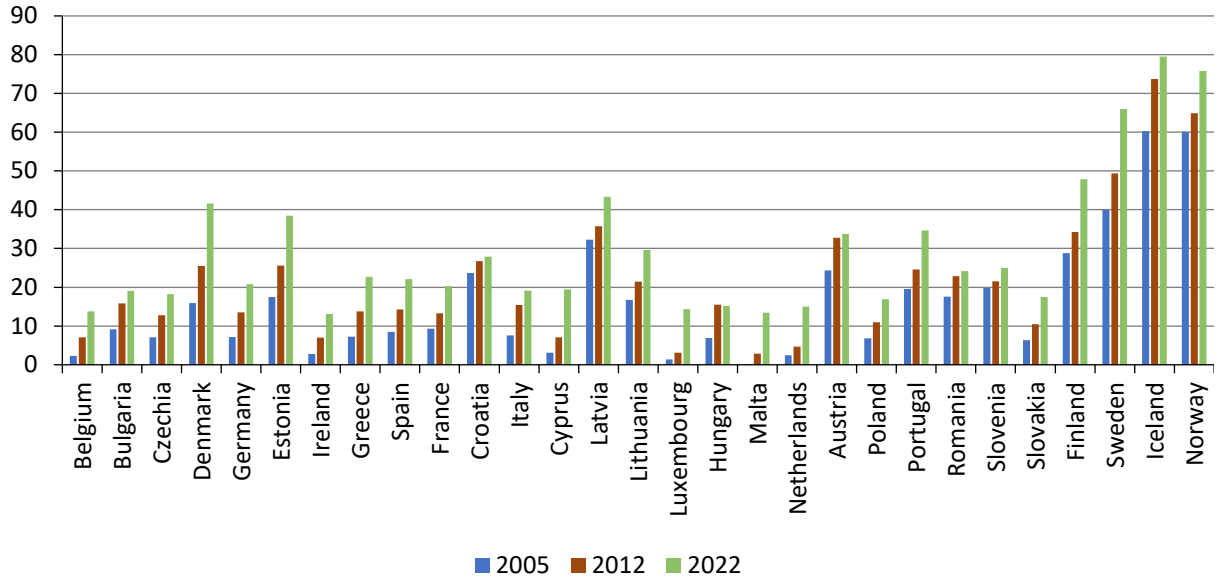

Fig. 1. Share of energy from renewable sources in European countries in % (2005, 2012, 2022)

Source: own elaboration.

From 2005 to 2022, the share of renewable energy in total final energy consumption increased steadily across Europe. However, the pace of adoption varied significantly between countries. Leading nations such as Sweden and Denmark achieved over 50% of their energy consumption from renewable sources by 2022, while other countries, particularly in Central and Eastern Europe, fall behind. For instance, Poland and Hungary struggled to reach the 20% mark by the end of the decade.

The analysis of descriptive statistics highlights significant progress in the adoption of renewable energy across European countries between 2005 and 2022. The average renewable energy share increased from 16.03% in 2005 to 29.26% in 2022, reflecting a substantial shift towards cleaner energy sources over this period. However, the growing standard deviation and range between countries suggest increasing variability in renewable energy adoption. While some countries have made exceptional progress, others have lagged behind, contributing to the widening gap in renewable energy shares. Notably, the country with the lowest share in 2022 still exhibited significant improvement compared to 2005, yet the countries with the highest shares saw even more remarkable growth, driving the disparity further. This trend indicates that while overall renewable energy usage is on the rise, disparities between leading and lagging countries persist, underscoring the need for targeted support and policies to help slower-adopting nations catch up.

The maps presented in Figure 2, which visually depict the share of energy from renewable sources in European countries for the years 2012 and 2022, were prepared to provide a clear geographic comparison of the progress made in renewable energy adoption. These visualizations allow for an immediate understanding of regional disparities and highlight which countries have made significant advancements in increasing their share of renewable energy. By presenting the data in a spatial format, the maps help to illustrate the differences in national efforts and the pace of renewable energy development across Europe. They also enable the identification of patterns and trends over time, contributing to a more comprehensive analysis of the factors influencing the transition to renewable energy.

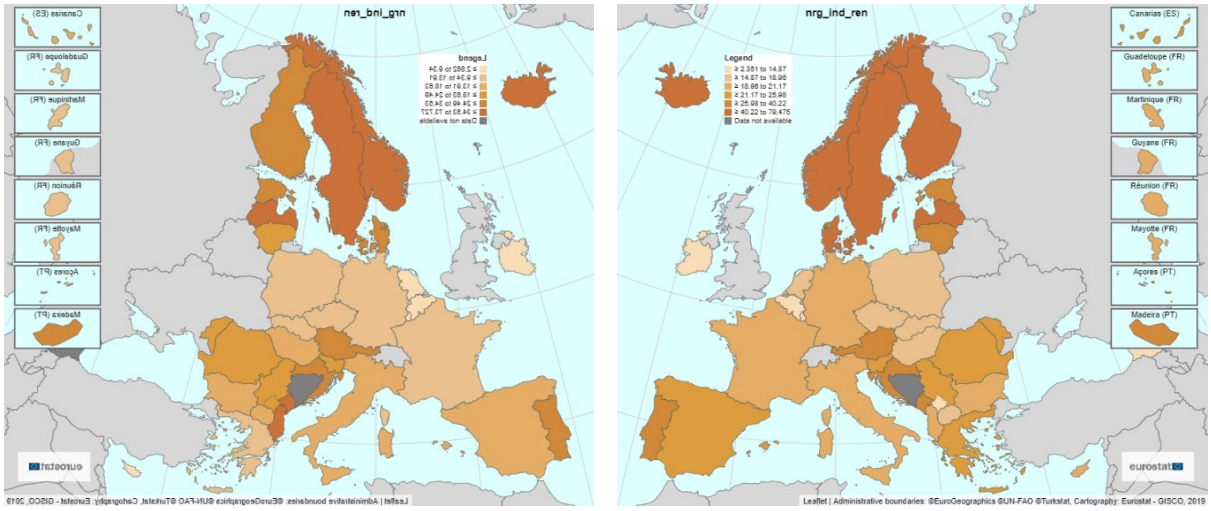

Fig. 2. Visual share of energy from renewable sources in European countries 2012, 2022

Source: own elaboration based od Eurostat data.

In order to capture the differences in the use of renewable energy across various countries, the simple growth rate was calculated for each country and presented in Table 3.

Table 3. Renewable energy growth rates in % (2022 vs 2005 and 2022 vs 2012)

Year / Country	2022 vs 2005	2022 vs 2012
Belgium	492	94
Bulgaria	108	21
Czechia	156	42
Denmark	161	63
Germany	190	53
Estonia	120	50
Ireland	364	86
Greece	212	65
Spain	162	55
France	118	53
Croatia	18	4
Italy	153	24
Cyprus	521	173
Latvia	34	21
Lithuania	77	38
Luxembourg	924	361
Hungary	119	-2
Malta	10798	368
Netherlands	504	221
Austria	39	3
Poland	146	54

Portugal	78	41
Romania	37	6
Slovenia	26	16
Slovakia	175	67
Finland	66	40
Sweden	65	34
Iceland	32	8
Norway	26	17

Source: own elaboration.

To illustrate the development of renewable energy adoption across European countries, a comparative bar chart was created (see Figure 3.), depicting the growth rates of renewable energy share for 2022 versus 2012. The chart highlights notable differences in progress between countries, with Malta, Luxembourg, and the Netherlands demonstrating significant growth, while others, such as Hungary and Croatia, experienced lower or even negative growth rates. This chart helps see which countries progressed rapidly and which ones had slower or negative growth during this period.

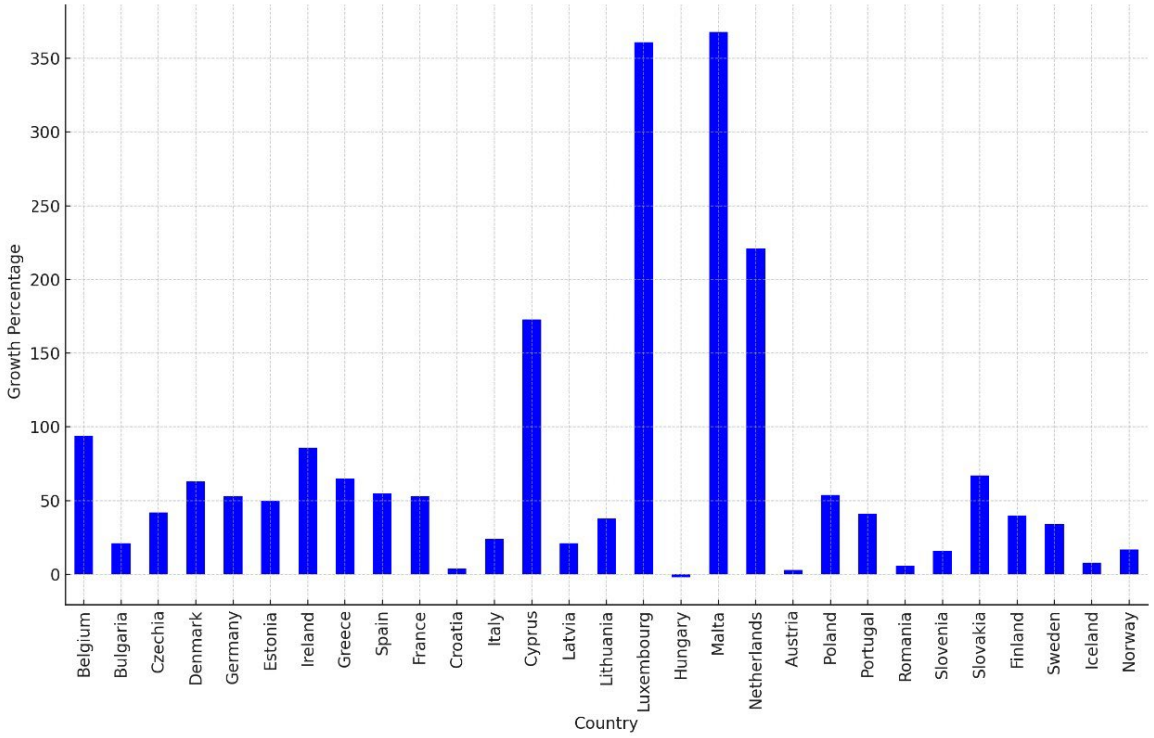

Fig. 3. Growth of renewable energy share by countries (2012 vs 2022)

Source: own elaboration.

The analysis of growth rates in renewable energy share across European countries between 2012 and 2022 reveals significant variations in progress. Countries such as Malta, Luxembourg, and the Netherlands have experienced remarkable growth, with increases of 368, 361, and 221%, respectively. These rapid developments can be attributed to substantial investments in renewable technologies and the implementation of effective energy policies. In contrast, larger economies like Germany, Denmark, and Ireland showed moderate but steady growth rates, ranging from 50 to 86%. This reflects their well--established renewable energy infrastructure, which limits further percentage increases. Over the same period Hungary experienced even a slight decrease of –2%. This stagnation suggests potential barriers to further development, such as economic constraints or political challenges. Overall, the findings show a diverse landscape of renewable energy adoption, with some nations making substantial progress, while others are behind due to structural or economic barriers.

5. Discussion and conclusions

The differences in growth rates across countries suggest that while some nations are making substantial progress, others are facing challenges. Factors such as economic capacity, policy frameworks, infrastructure, and the existing energy mix play significant roles in shaping these growth patterns. As a result, countries showing minimal or negative growth may need additional support or reforms to catch up with their more rapidly developing counterparts.

Several countries during the last 20 years implemented substantial investments in renewable energy, which contributed to impressive growth rates in this sector. Eastern European countries generally experienced moderate growth in their renewable energy share between 2012 and 2022, but the pace of progress varied significantly. An overview of the trends observed in some key Eastern European countries shows that Bulgaria with growth by 21% (2022 vs 2012) showed modest growth in renewable energy adoption, driven mainly by investments in solar and wind energy. Despite this, the growth rate is relatively low compared to western European nations. Romania (6%) had very limited growth in renewable energy share over this period, indicating possible challenges such as economic constraints or reliance on traditional energy sources. Latvia (21%) saw moderate growth in renewable energy, continuing to build on its strong biomass energy sector, though further advancements were somewhat limited. Lithuania (38%) experienced stronger growth in renewable energy, largely due to increasing investments in wind energy and efforts to reduce reliance on imported energy sources. Hungary (–2%) recorded a negative growth rate, indicating a decline in renewable energy share between 2012 and 2022. It could suggest stagnation or possible political challenges that hindered the transition to renewable sources. Slovakia (67%) had one of the strongest growth rates in eastern Europe, driven by increased investments in solar energy and efforts to diversify its energy sources. Poland (54%) made significant progress, reflecting increasing investments in wind power, though it still relies heavily on coal. The growth shows a positive shift towards renewable energy, albeit with ongoing challenges. Austria had a small growth in renewable energy share, mainly because the country already had a high level of renewable energy by 2012. Western European countries have generally led the way in adopting renewable energy, with significant growth across the region. However, the pace and scale of the transition have varied from country to country. Belgium almost doubled its renewable energy share during this period. The country has made significant strides in offshore wind energy, which has become a key component of its renewable energy transition. Germany continues to be a leader in renewable energy, driven by its energy transition policy. The Netherlands (221%) experienced one of the highest growth rates in the region, with a focus on offshore wind farms and solar energy projects. Spain (55%) is one of the leading countries in Europe for solar energy production, with substantial growth in capacity over the past decade. Portugal (41%) and Sweden (34%) were already leaders in renewable energy by 2012 and continue this trend. Norway (17%) remains a global leader in renewable energy, with most of its electricity coming from hydropower. The country's growth rate is modest because it has already had a high renewable energy share in 2012. Despite challenges that may require longer--term solutions, the overall trend across Europe indicates a steady transition towards renewable energy, with varying degrees of progress depending on national policies, economic conditions, and existing energy infrastructures. The analysis reveals significant regional disparities in the adoption of renewable energy. Northern and Western Europe outperformed Southern and Eastern European regions. The reasons for these differences could be attributed to varying political priorities, economic constraints, and availability of renewable resources. It could be the starting point for future research to compare the national policies and geographic conditions in the successful adoption of renewable energy. Countries that have prioritized renewable energy through targeted policies have been able to transition more quickly to sustainable energy systems.

The study of the share of renewable energy from 2005 to 2022 shows significant progress across Europe, but it also highlights the uneven nature of this transition. Leading countries have demonstrated the benefits of robust policy frameworks and natural resource advantages, while other countries face structural challenges. The study highlights that regional disparities in renewable energy adoption

are strongly influenced by structural factors such as economic capacity, political frameworks, and existing energy infrastructure. For instance, the remarkable growth rates observed in countries like Malta and Luxembourg underscore the impact of targeted investments and robust policy support, while the slower progress in Eastern European countries like Hungary reveals the challenges posed by limited financial capacity and over-reliance on traditional energy sources. For countries with lower renewable energy adoption, several challenges hinder the transition, e.g. in countries where coal remains a dominant energy source, making the transition to renewable energy more difficult. In other regions, there is limited financial capacity to invest in large-scale renewable energy projects, particularly in areas requiring significant upfront capital. This is also a problem of differentiation not only at the level of states, but also of different types of regions, for example rural or peripheral (Hlaváček & Skalník, 2021). These findings suggest that addressing such disparities requires tailored approaches, combining targeted investments with policies that encourage innovation and reduce barriers to renewable energy adoption.

However, the regional disparities may suggest a need for more flexible approaches to address the unique challenges faced by countries with lower adoption rates. This regional comparison offers unique insights into the dynamics of energy transitions across Europe, underscoring the importance of aligning national policies with regional capabilities.

Future EU actions could potentially focus on finding solutions for countries that are still economically dependent on fossil fuels, possibly encouraging investment in renewable technologies and infra-structure. Additionally, the increasing importance of renewable energy might indicate a growing potential for cooperation between member states, particularly through initiatives like the European Green Deal which aims to make Europe climate-neutral by 2050. Further studies could investigate factors influencing the share of renewable energy, including the role of technological innovation in speeding up renewable energy adoption, as well as the impact of renewable energy on employment and economic growth.

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Transformacja energetyki odnawialnej w Europie w ciągu ostatnich dwóch dekad

Streszczenie

Cel: Celem artykułu jest zbadanie ewolucji udziału odnawialnych źródeł energii w wybranych krajach europejskich w okresie od 2005 do 2022 r. Analiza obejmuje kraje o różnym poziomie wdrożenia energii odnawialnej i podkreśla regionalne różnice w jej wzroście.

Metoda: W badaniu wykorzystano analizę ilościową danych energetycznych Eurostatu, aby określić udział odnawialnych źródeł energii w całkowitym końcowym zużyciu energii w krajach europejskich w latach 2005, 2012 i 2022. Statystyki opisowe, porównania i analiza trendów są wspierane przez wizualizacje, w tym mapy, wykresy słupkowe i liniowe, aby ukazać zmiany w czasie.

Rezultaty: Wyniki wskazują na znaczny postęp w zakresie wdrażania odnawialnych źródeł energii w Europie w latach 2005-2022, z wyraźnymi różnicami w tempie wzrostu pomiędzy krajami, co podkreśla zarówno sukcesy, jak i wyzwania związane z transformacją energetyczną.

Implikacje i rekomendacje: Wyniki badania podkreślają potrzebę wprowadzenia ukierunkowanych polityk i mechanizmów wsparcia, aby pomóc krajom, które wolniej wdrażają odnawialne źródła energii, szczególnie w zakresie przezwyciężania barier ekonomicznych i strukturalnych, które mogą utrudniać postęp.

Oryginalność/wartość: Badanie dostarcza kompleksowej analizy wzrostu udziału odnawialnych źródeł energii w Europie w latach 2005-2022, oferując unikalne spojrzenie na regionalne różnice i czynniki wpływające na zróżnicowane tempo wdrażania energii odnawialnej.

Słowa kluczowe: rozwój zrównoważony, OZE, udział energii odnawialnej