

THE USAGE OF RENEWABLE ENERGY SOURCES BY COUNTRIES IN THE VISEGRÁD GROUP. DIAGNOSIS AND ENVIRONMENTAL EFFECTS

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Purpose: The goal of this article is evaluation and comparative analysis of the usage of renewable energy sources in the countries of the Visegrád Group in the years 2000-2020, in context of the current environmental situation in the European Union, concerning the reduction of CO₂ emissions.

Design/methodology/approach: The data regarding the creation of renewable energy used in this article is divided into: solar energy, wind energy, biomass and hydroenergy the division, in order to evaluate their usage in the energy mix of the Visegrád Group nations. Furthermore, in the research, the data on CO₂ emissions in those countries has been used to measure the effects of the European Union's environment policy. This analysis used: average annual rate of change, trend function, as well as dependency analysis using the Pearson correlation coefficient.

Findings: The results of the study suggest, that all of the countries belonging to the Visegrád Group take systemic measures to increase the share of renewable sources in the energy mix (most intensively in Poland). Nonetheless, the countries that reduce CO₂ emissions the fastest are the Czech Republic and Slovakia. A smaller amount of success in this area is noted by Hungary. The CO₂ emission rate per capita in Poland is maintained on a constant level, which shows ineffectiveness of the actions taken as part of the environmental policy.

Research limitations/implications: The main limitation of the study is the usage of simple analytical methods of evaluation, that result from poor quality of available data and the restriction of the environmental effect assessment, which only identifies the correlation of linear relationships between CO₂ emissions and the involvement of renewable sources in the energy mix of the studied countries.

Practical implications: The results represent a foundation for recommendations to address the energetic policies of the studied countries. They may also serve as an example of the energy mix transformation in growing economies.

Social implications: The results point to a low usage of renewable energy in the Visegrád Group and also partly (Poland, Hungary) a small range of the reduction of CO₂ emissions per capita, which suggests the need to intensify actions for more efficient energy mix transformations, as well as sustainable development in the studied countries.

Originality/value: The authenticity of the study results stems from a comparative analysis of the Visegrád Group's countries energy resource mix. Another advantage of this analysis is its embedding in the context of CO₂ emission results.

Keywords: renewable energy sources; energy policy; resource economics; energy mix analysis.

Category of the paper: research article.

1. Introduction

In the current conditions of growing economies, great importance is attached to environmental protection, as well as sustainable growth, which guarantees maintenance and/or improvement of the quality of life for current and future generations. These priorities are of great importance, particularly for the European Union, which has been realizing its deeply regulated environmental policy, focused on minimizing the usage of non-renewable energy sources, along with reducing CO₂ emissions. This finds confirmation in a few key, systematically implemented documents, that regulate the functioning of energetic policy in all of the states making up the European community. Currently it is stated, that by 2030 (<https://www.europarl.europa.eu/factsheets/pl/sheet/68/polityka-energetyczna-zasady-ogolne>):

- at least 40% of greenhouse gas emissions will be reduced in comparison to the levels from 1990,
- there will be an increase up to 32% of the share of renewable energy in all sources of energy,
- the energetic efficiency will improve by 32,5%,
- at least 15% of EU electrical power systems will be interconnected.

In context of such ambitious intentions, it is very important to monitor the environmental effects of energy strategies adopted by various European Union countries, especially those encountering problems in the process of executing European climate policy.

Having in mind the circumstances stated above, the goal of this article is evaluation and comparative analysis of the usage of renewable energy sources in the countries of the Visegrád Group in the years 2000-2020, in context of the current environmental situation in the European Union, concerning the reduction of CO₂ emissions. Additionally, the article attempts to answer the following research problems:

- What is and how does the usage of renewable energy sources change throughout time in the energy mix of Visegrád Group countries since the intensification of EU's environmental policy incorporated in the years 2000-2020?

- Which renewable energy sources are used by countries belonging to the Visegrád Group?
- How does the CO₂ emission rate per capita change in the Visegrád Group countries in reference to the scope of renewable sources used in order to satisfy energetic needs?

During the research process, the data from *BP Statistical Review of World Energy* and *Eurostat* were used. Several techniques used to conduct research were: literature studies, dynamic and structural analysis, trend analysis and the identification of dependence, that was realized with the help of the Pearson correlation coefficient.

2. Literature overview

As mentioned above, the key goal of the European Union's environmental policy is the reduction of CO₂ emissions, which is related directly with the energy industry, responsible for about 2/3 of emissions. With regard to the Union's concept, such a goal should be realized primarily by expanding the scope of renewable energy source usage in the energy mix of the Union's Member States. The existing results, stemming from executed analyses, experiments and studies, show that the achievement of this goal is complicated and often ineffective, due to a few factors.

The first factor being the need of deep and often prolonged overhaul of energetic infrastructure. This, in turn, requires a substantial amount of capital, as well as well-planned, effective energetic policies, realized in a consistent manner (Zhang and Wang, 2022; Várez et al., 2022).

The second factor deals with the cost of renewable energy. Existing studies and experiments show, that renewable energy sources are in need of subsidizing (Al-Refaie and Lepkova, 2022; Dolores et al., 2022; Lee and Xydis, 2022), which, in turn, is related to additional costs for local and national budgets.

The third factor is linked to political circumstances. Political terms do not favor consistent execution of given energetic policies. Oftentimes, once defined directions of development of renewable energy sources are negated and changed, this, on one hand, prevents grounding the effects of the taken actions and, on the other, creates uncertainty and reluctance to take initiatives in the future.

The fourth factor is akin to the environmental awareness of households and corporations in a given country (Janik et al., 2021; Ober and Karwot, 2022). The lesser it is, the worse are the effects of energetic transformation, in which all participants of socio-economic life must comply. In this case, another barrier is the income, which often limits environmental actions, despite higher ecological awareness of citizens.

As a result, the achievement of environmental policy goals set by the EU is most effective in well-developed Western European countries, backed by free market and democratic traditions. According to current study results, the countries, which are handling ecological challenges best, are the Scandinavian countries, Germany, Great Britain and France (Trotta, 2020; Goh and Ang, 2018; Saidi and Omri, 2020; Li et al., 2016). The economies of Central and Eastern Europe encounter many barriers, that deeply complicate and slow down energetic transformation. As a result, this group of countries shows poor environmental effects in the form of insignificant CO₂ emission reduction (Grosse, 2011; Ptak, 2009, 2014; Mašloch, 2009). The only countries, which are efficient in lowering greenhouse gas emissions in this region are the Czech Republic and Slovenia. The rest of the countries in this group are known to be less effective in taking on the EU's environmental policies.

This is known to be a typical case for emerging and developing economies, which is confirmed in studies conducted worldwide. Regions such as Asia, Africa and Central America deal with similar problems (Dokas et al., 2022; Esquivias et al., 2022; Lee and Yoo, 2016). This primarily results from those countries' heavy usage of cheaper and easier to access non-renewable materials, as well as problems in maintaining consistence in working to reach ecological goals. It is important to note that these regions do not display common ground in environmental policies, which impose radical changes in the energy mix. The absence of formal regulations and financial restrictions connected to CO₂ emissions – as shown in current studies – does not support effective prevention of degradation of the natural environment (Wolde-Rufael and Weldemeskel, 2020; Guo and Wang, 2022; Beal and King, 2022).

3. Research method

The data regarding the creation of renewable energy used in this article is divided into: solar energy, wind energy, biomass and hydroenergy the division, in order to evaluate their usage in the energy mix of the Visegrád Group nations. Furthermore, in the research, the data on CO₂ emissions in those countries has been used to measure the effects of the European Union's environment policy. This analysis used: average annual rate of change, trend function, as well as dependency analysis using the Pearson correlation coefficient.

The methods stated above were used to solve the following problems:

- What is and how does the usage of renewable energy sources change throughout time in the energy mix of Visegrád Group countries since the intensification of EU's environmental policy incorporated in the years 2000-2020?

- Which renewable energy sources are used by countries belonging to the Visegrád Group?
- How does the CO₂ emission rate per capita change in the Visegrád Group countries in reference to the scope of renewable sources used in order to satisfy energetic needs?

The studies and description of results have been divided into two stages. During the first stage, the usage of renewable energy sources in energy mixes, as well as their structure were analyzed. The second stage concentrated on the environmental effects of climate policy in the form of CO₂ emission reduction in the studied countries.

4. Research results

4.1. The analysis of the share of renewable sources in energy mixes

The first step was the analysis of the change in the share of renewable sources in the energy mixes of the studied countries, as well as pointing to their development tendencies. The sum of used solar, hydro- and biomass energy was considered. The results are shown in Figures 1-2.

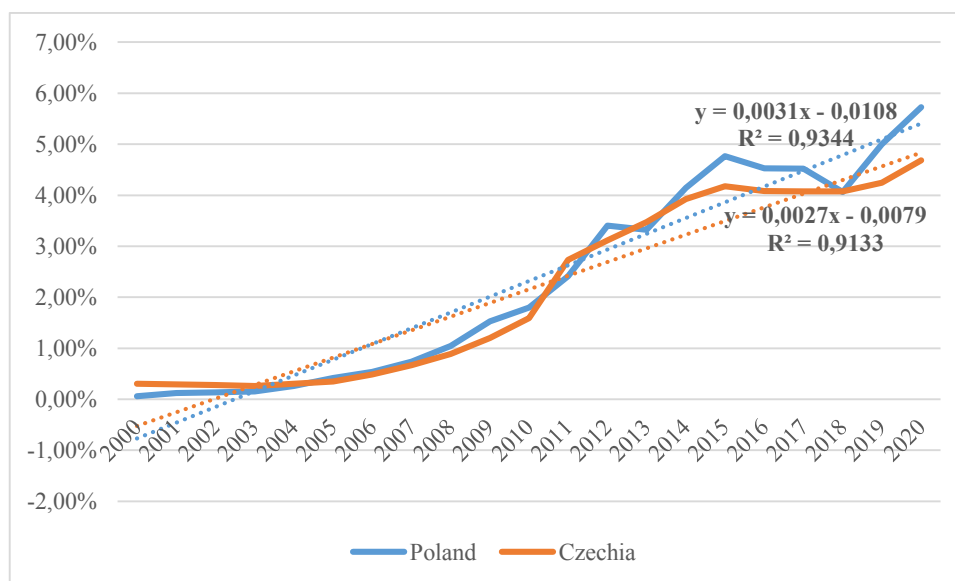


Figure 1. The share of non-renewable sources in the energy mixes of Poland and Czech Republic in the years 2000-2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

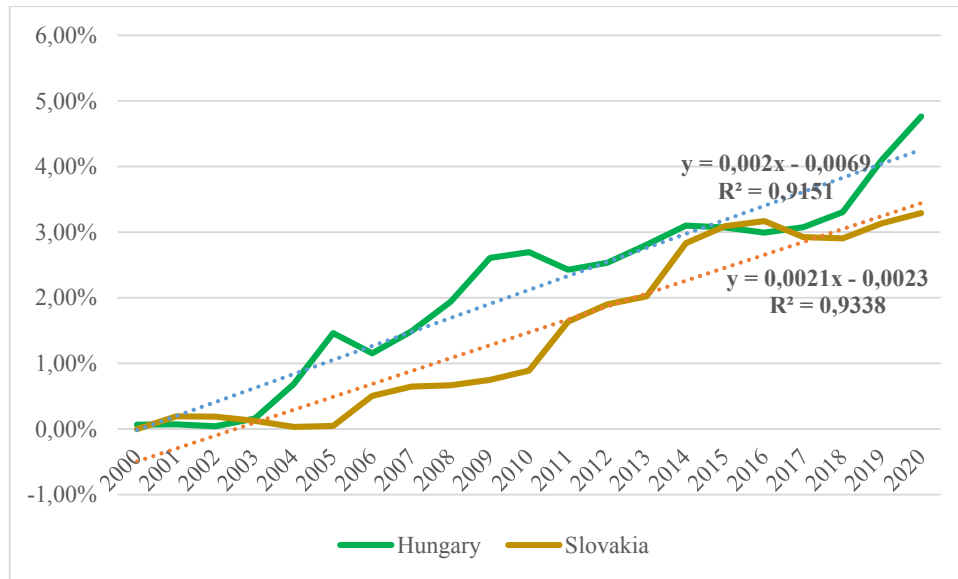


Figure 2. The share of non-renewable sources in the energy mixes of Hungary and Slovakia in the years 2000-2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

And yes, the total share of renewable sources in energy mixes in the studied countries has passed 6% only in Poland. In the Czech Republic and Hungary, the share came close to 5%, however the lowest level was noted in Slovakia (not much higher than 3%). All of the studied countries note upward trends, which shows that countries are putting a great effort into trying to achieve the goals set by the EU's environmental policy and they systematically increase the usage of solar, hydro- and biomass energy. All of these trends are well-suited, which may suggest a high probability of further growth and increase in share of renewable energy sources, in order to satisfy energetic needs in the studied countries. It also confirms their slow, but sure energetic transformation. It is important to note that the interpretation of the coefficient of the trend's linear function leads to the conclusion that the share of non-renewable sources had its quickest growth in the energy mix of Poland (0.31% annually) and the Czech Republic (0.27% annually). Smaller, but similar growth could be observed in Hungary (0.2% annually) and Slovakia (0.21%). In the last three years of analysis, the growth rate increased extensively in Poland and Hungary. Initial observations show that Poland and the Czech Republic are the most efficient in achieving the environmental goals of the European Union, Hungary being the country to follow and Slovakia having the slowest growth rate.

The conclusions stated above are confirmed by the statistics of the share of renewable sources in energy mixes of Visegrád Group countries shown in Figure 3. Poland and the Czech Republic were characterized by the greatest average share during the study. The share in these countries also changed most intensively, which was a result of an acceleration in energetic transformation after 2010.

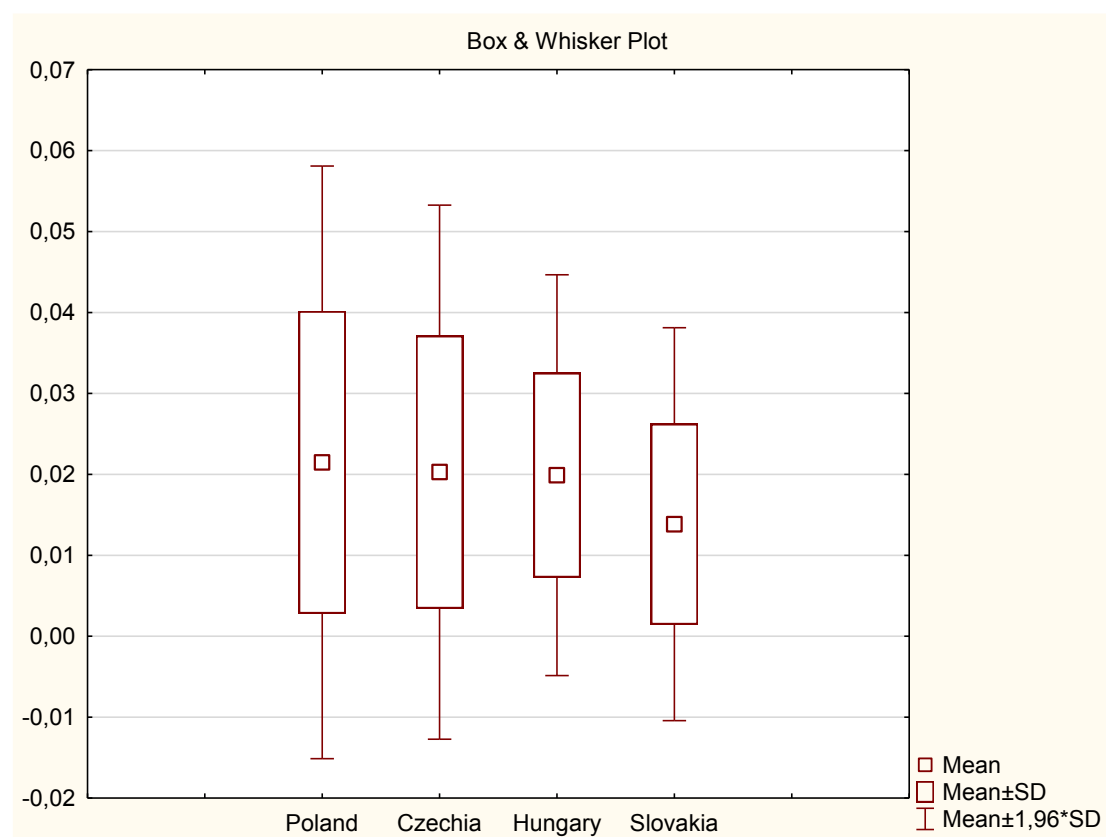


Figure 3. The box plots show the share of renewable sources in the energy mixes of the studied countries in the years 2000-2020. Source: own work.

In line with the previous conclusions, Poland and the Czech Republic are characterized by a similar development path of renewable energy sources in the years 2000-2020. This is also confirmed by Pearson's linear correlation coefficients between the shares of renewable sources in the energy mixes of the analyzed countries presented in Table 1. All values included in the table are statistically significant and indicate that the scale of changes made in the analyzed period in Poland, the Czech Republic and Slovakia were almost identical. On the contrary, the least similarity concerned Hungary, where the identified correlations were the weakest.

Table 1.

Correlation matrix for the share of renewable sources in the energy mixes of the studied countries for years 2020-2021

Country	Correlation coefficients			
	Poland	Czech Republic	Hungary	Slovakia
Poland	1.0000	0.9911*	0.9220*	0.9891*
Czech Republic	0.9911*	1.0000	0.8973*	0.9898*
Hungary	0.9220*	0.8973*	1.000	0.8862*
Slovakia	0.9891*	0.9898*	0.8862*	1.0000

$p < 0.001^*$

Source: own work.

In the next part, an analysis of the structure of the use of individual non-renewable sources was performed on the example of 2020 – the most recent in the studied time series. The results for individual countries are presented in Figures 4-7.

And yes, in Poland (Figure 4) the most popular was wind energy, followed by biomass. Solar energy was used to a small extent, but it should be noted that currently the energy policy of Poland actively supports the acquisition of solar energy, which may lead to an increase in the share of this source in meeting the national energy needs.

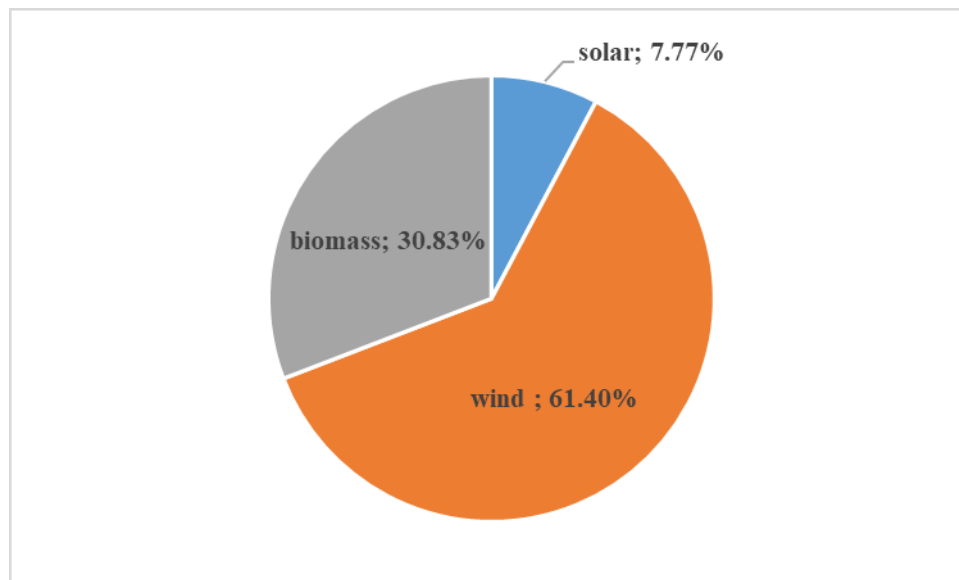


Figure 4. The structure of the use of renewable sources in Poland in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

The Czech Republic (Figure 5), on the other hand, had biomass as the largest share in renewable sources, constituting approx. $2/3$ of the total use of these sources. The second most important source was solar energy. Meanwhile, wind energy was used to a small extent. Thus, despite the similarity in the development tendencies and the level of use of renewable sources, the mixes of these sources for the Czech Republic and Poland differ significantly, which results both from the chosen directions of energy policy development and from climatic and geographical conditions (e.g., the possibility of creating wind farms in Poland near the sea, not available in the Czech Republic).

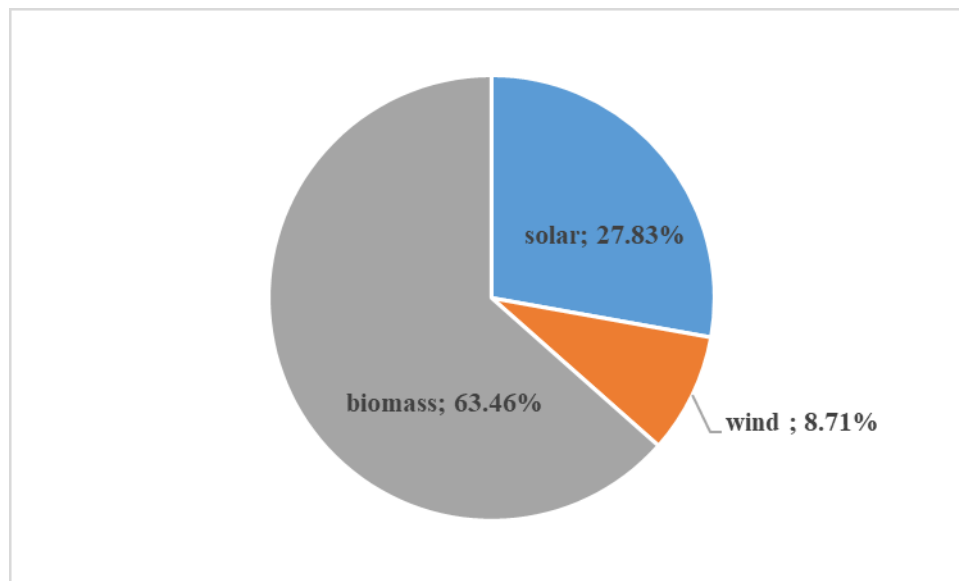


Figure 5. The structure of the use of renewable sources in the Czech Republic in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

Hungary displays a similar mix of renewable sources. It is dominated, similarly, by solar and biomass energy (Figure 6). Wind energy was only a minor supplement to renewable sources.

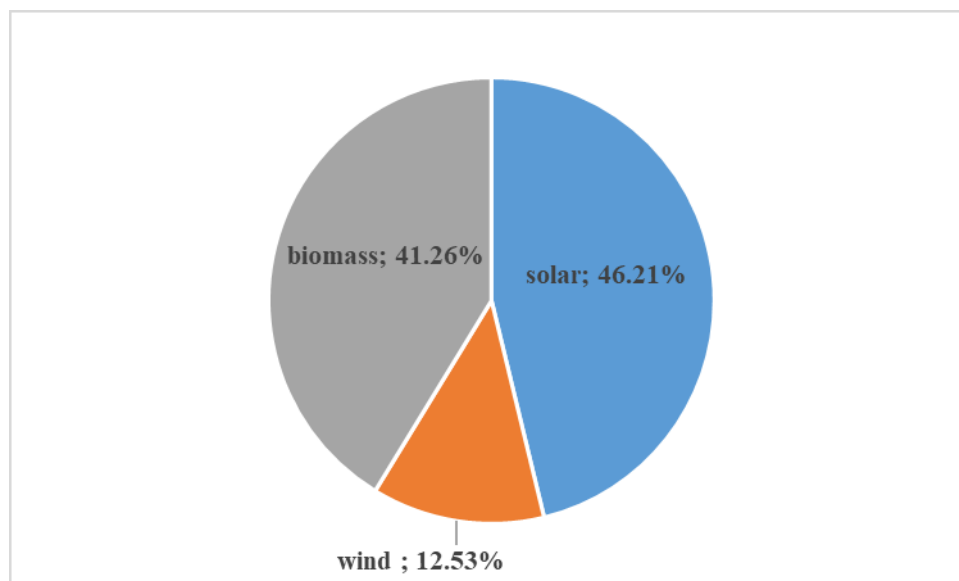


Figure 6. The structure of the use of renewable sources in Hungary in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

In turn, in the Slovak mix, biomass was primarily used, which was supplemented with solar energy. The use of wind energy was marginal. Therefore, despite the geographical proximity of the countries making up the Visegrád Group, each of them used different proportions of renewable energy sources.

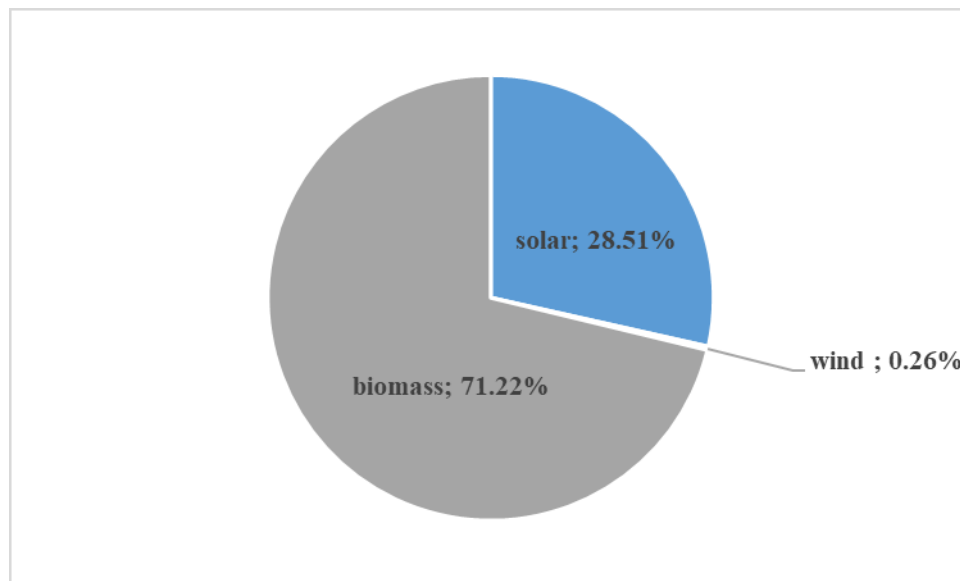


Figure 7. The structure of the use of renewable sources in Slovakia in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

As mentioned in the introduction, hydroenergy is also included among low-emission and renewable energy sources. Its share in the energy mix of the studied countries is shown in Figure 8. The data presented there shows that this source was used to the greatest extent in Slovakia (3-9%). In other countries, the share of hydroenergy in satisfying energy needs did not exceed 2%. It can, therefore, be concluded that Slovakia chose a different direction of energy transformation than the other 3 countries, choosing hydroenergy to a greater extent than classic renewable sources (solar, wind or biomass energy).

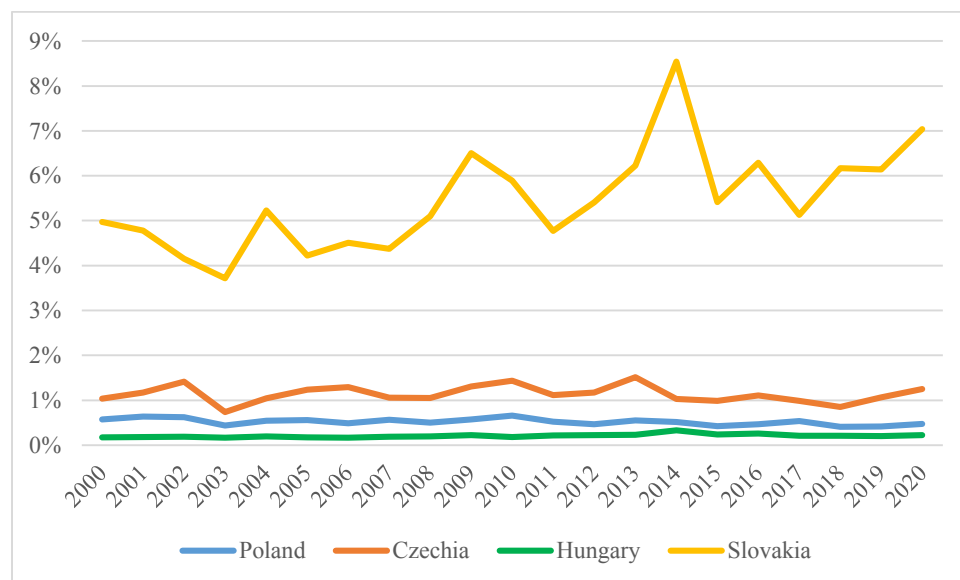


Figure 8. The share of hydroenergy in the energy mix of the studied countries in the years 2000-2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

4.2. Evaluation of effectiveness of changes made to the energy mix in the context of CO₂ emissions

In the second stage of the study, the impact of changes in the share of renewable sources in the energy mix on the reduction of CO₂ emissions was analyzed. The reduction of CO₂ – in terms of the assumptions of the EU energy policy – is to be the main effect of the pro-environmental energy transformation. The degree of reduction achieved by the studied countries of the Visegrád Group in absolute terms is shown in Figure 5.

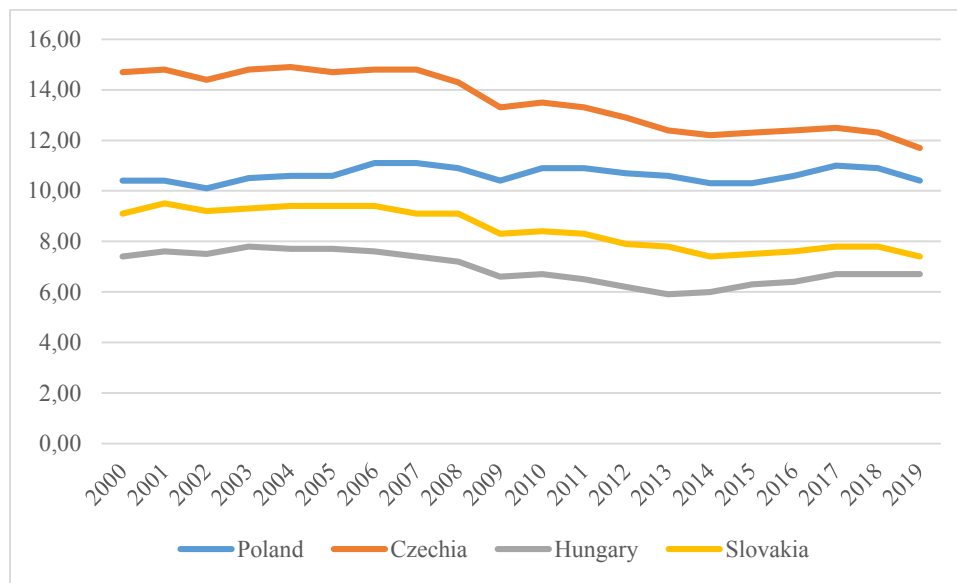


Figure 5. CO₂ emissions per capita in the studied countries in the years 2000-2020 [ton per citizen]. Source: own work.

Starting from 2009, CO₂ emissions in the Czech Republic, Slovakia and Hungary have been systematically decreasing. Poland was not able to maintain the same rate of reduction. The chart clearly shows two periods, in which the emission of CO₂ in Poland increased. Its highest level was characteristic for the Czech Republic and Poland – this situation did not change until the end of the analyzed period.

The lack of effective CO₂ reduction in Poland is confirmed by the correlation coefficient between the share of renewable sources in the energy mix and the level of CO₂ emissions (Table 2). It is the only country in the study, where no statistically significant correlations were found between increasing the share of renewable sources in the energy mix and reducing CO₂ emissions. For instance, there is a strong correlation in the Czech Republic and Slovakia. Hungary displays a weaker one, but still clearly indicative of the mutual negative correlation of the described variables.

The observations above are also confirmed by the average annual rate of change in CO₂ emissions and the level of its reduction in the twenty-one-year research period. In Poland, both the first and the second parameter were 0.00%, while in the leading Czech Republic, CO₂ emissions were reduced annually by approx. 1.19%, which allowed to reduce it by over 1/5 in the years 2000-2020. Slovakia achieved a similar effectiveness in reducing CO₂. Even in

Hungary, which showed significantly worse results, CO₂ emissions decreased annually by 0.52% and, finally, in 2020 it was reduced by 9.46% compared to 2000.

Table 2.

Pearson linear correlation coefficients for the share of renewable sources in energy mixes and CO₂ emissions, as well as the average annual rate of change in CO₂ and the total change in CO₂ emissions in 2000-2020

Country	Statistical parameters		
	Correlation coefficient	Average annual rate of change	Changes throughout 2000-2021
Poland	-0.0016	0.00%	0.00%
Czech Republic	-0.9691*	-1.19%	-20.41%
Hungary	-0.8188*	-0.52%	-9.46%
Slovakia	-0.9475*	-1.08%	-18.68%

p < 0.001*

Source: own work.

5. Discussion

The results of the analyses confirm the observations described in the literature on the subject. Emerging economies struggle to increase the share of renewable sources in their energy mix. In the studied group – as in other described countries with a similar degree of economic development – non-renewable sources are predominantly used to meet energy needs. This is difficult to change, especially in the context of a large economic gap separating the countries of the Visegrád group from the leaders of the EU economy.

As a result, the environmental effects in the form of reducing CO₂ emissions in the studied regions are not impressive. Although it is worth emphasizing the achievements of the Czech Republic, which not only systematically increases the share of renewable energy sources in the mix, but also effectively and quickly reduces CO₂ emissions per capita. The success of the Czech energy sector in this area is also confirmed by previous analyzes, pointing to the country as an example of the effective implementation of environmental goals, also in developing economies. It is worth adding that the Czech Republic has given up hard coal mining and its use in the energy sector, and is systematically using nuclear energy, which certainly also has a positive effect on the scope of greenhouse gas emissions.

In the context of the statements and observations above, the recommendations for the studied economies should primarily include the intensification of actions to increase the share of renewable sources in the energy mix, because, in the light of the research results, the EU intention to increase this share to 35% in 2030 seems unrealistic. According to the guidelines of theory and practice, the following may be helpful in this respect: consistent and unchanging energy policy, subsidizing renewable energy sources and spreading ecological awareness in the society.

6. Summary

The results of the study suggest, that all of the countries belonging to the Visegrád Group take measures to increase the share of renewable sources in the energy mix. Nevertheless, the rate of change and the comparison of the surveyed countries with the leaders of the European energy transformation, such as Germany or the Scandinavian countries, testify to a very slow annual growth and the level of the total share of renewable sources in meeting energy needs in the surveyed regions. In these terms, the leader is Poland, with Slovakia being the weakest in taking these measures.

The energy mixes of renewable sources of the studied Visegrád Group countries differ in the proportions of the use of these sources, which indicates that the paths of energy transformation are individualized, despite their geographical proximity. There are, however, similarities between Slovakia, the Czech Republic and Hungary, which mainly use biomass and solar energy, while Poland focuses on wind and biomass. Common to all mixes is the significant use of biomass. It is also worth noting that Slovakia – apart from solar, wind and biomass energy – also uses hydroenergy to a large extent, which is treated as a low-emission source of energy, enriching its energy mix and diversifying the risk associated with suppliers of energy carriers.

In the conducted analysis, attention was also paid to the result of the adopted energy policies, assessed in the context of reducing CO₂ emissions. In this category, the best results are achieved by the Czech Republic and Slovakia, which show the highest rate and level of overall emission reduction. Hungary is characterized by a lower dynamic of changes, but the overall observed trends also prove the effectiveness of the implementation of environmental objectives, although they are implemented to a lesser extent. For Poland, both the rate of change and the level of CO₂ reduction equals 0.00%, which proves the ineffectiveness of the pro-environmental energy policy.

The main limitation of these analyses is the usage of simple statistical methods of evaluation, that result from poor quality of available data and the restriction of the environmental effect assessment, which only identifies the correlation of linear relationships between CO₂ emissions and the involvement of renewable sources in the energy mix of the studied countries.

Therefore, further research should be focused on an in-depth analysis of the initially identified relationships between the use of renewable sources in the studied countries and the effects of the implementation of the EU climate policy. It would also be worth identifying the reasons for the low effectiveness of actions taken for the benefit of sustainable energy.

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