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The Renewable Energy Performances of Black Sea and Balkan Countries: An Application of Grey Principal Component Analysis

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ABSTRACT

Renewable energy, accepted as a solution to global energy needs, is an environmentally benign energy source that contributes to the economic development of countries, protects natural resources, and reduces pollution. Dependency on non-renewable energy sources raises serious concerns such as environmental degradation, energy security problems, and supply shortages. This study aims to evaluate the renewable energy performances of 14 Balkan and Black Sea countries with similar historical, cultural, and structural characteristics. For this purpose, the data on countries' renewable energy indicators in 2020 is used in the grey principal component analysis that integrates grey system theory and principal component analysis. Thanks to the grey principal component analysis, it is possible to measure the countries' existing state in renewable energy and evaluate the performance of countries comparatively. Results indicate that countries such as Russia and Türkiye, which stem from their potential in renewable energy indicators, or European Union member countries such as Greece and Romania, which are expected to fulfill certain obligations on renewable energy, rank first in the reference year. On the other hand, countries such as Bosnia–Herzegovina and Serbia, which have critical shortcomings in renewable energy applications, are in last place in the performance evaluation.

Keywords: Renewable Energy, Performance, Ranking, Black Sea and Balkan Countries, Grey Principal Component Analysis.

JEL Classification Codes: Q4, Q42, C60

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INTRODUCTION

Today, increasing environmental concerns, greenhouse gas emissions, and depletion of fossil fuel reserves as the dominant energy source necessitate transformation and draw attention to renewable energy sources. According to the Energy Transformation 2050 report published by the International Renewable Energy Agency (IRENA), while the share of renewable energy in global energy consumption was 10.5% in 2010, this ratio will be foreseen as 28% in 2030 and 66% in 2050 according to the planned energy scenario (IRENA, 2020: 23). Therefore, increasing the use of renewable energy sources no doubt contributes to developing a safe, sustainable, and competitive energy system. It brings with it the expectations of economic development, social inclusion, and environmental sustainability, especially for developing countries (Cantatero, 2020: 1). As a matter of fact, renewable energy sources are essential for these countries as a way of economic development, ensuring energy security, reducing dependency on energy imports and protecting the environment (Lanshina et al., 2018: 600).

Increasing energy consumption and greenhouse gas emissions with rapid industrialization and urbanization in countries cause climate change and warming problems. Countries are accelerating their transition to renewable energy sources to reduce greenhouse gas emissions, which cause damage to the environment, and to combat climate change and increasing warming threats (Shafiei and Salim, 2014: 547). Overcoming these destructive problems, which are global, is possible with the conclusion of international agreements and the implementation of global actions (Bhat and Mishra, 2018: 152). One of the first crucial international steps to reduce greenhouse gas emissions is the Kyoto Protocol adopted in 1997 within the scope of the United Nations Framework Convention on Climate Change (UNFCCC). Adherence to the protocol sets binding targets for countries in reducing greenhouse gas emissions, which require the use of renewable energy sources and the application of environmentally friendly technologies (UNFCCC, 2008: 39). Sustainable Development Goals (SDGs), adopted by the United Nations General Assembly (UNGA) in 2015, provide a transformative framework that guides

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development in economic, social and environmental fields to achieve a sustainable future (Allen et al., 2016: 199). Sustainable energy is at the center of the agenda described as "Transforming Our World: The 2030 Agenda for Sustainable Development". Because while the related target emphasizes the use of clean and sustainable energy sources to meet energy needs, this use reduces greenhouse gas emissions and thus contributes to the fight against climate change (Gielen et al., 2019: 38). At the same time, reasons such as the supply chain difficulties due to the pandemic, the Russia-Ukraine conflict and the rising energy prices caused by the conflict have added urgency for countries to accelerate their transition to renewable energy today (International Energy Agency (IEA), 2022: 16). In particular, the European Commission has determined the 2030 target for renewable energy sources as 45% to reduce the dependence on fossil fuels imported from Russia (REPowerEU, 2022). Similarly, the IEA Sustainable Development Scenario mandates a 40% reduction in the proportion of fossil fuels in the energy mix by 2030 to achieve the SDGs related to energy (IEA, 2020: 89, 105). In this context, considering the central role of renewable energy in the transition to a sustainable future energy system, determining the current situation of the countries constitutes the originality of this study.

This study uses grey principal components analysis to determine each country's performance in terms of renewable energy. Grey principal component analysis, introduced to the literature by Tung and Lee (2009), is an analysis that integrates grey system theory and principal component analysis and measures the closeness of the relationship between the data according to the similarities of the geometric curves. In this analysis, which does not require any statistical distribution of the data, a matrix is constructed using the grey absolute correlation degree. This matrix is considered a correlation matrix in principal component analysis, and a performance evaluation model is defined. The study aims to measure the renewable energy performance of the selected Black Sea and Balkan countries based on this defined model. For this purpose, the study determines the country performance of 14 countries in the Black Sea and Balkan geography by using 15 renewable energy indicators in 2020.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature on renewable energy. The grey absolute relationship degree and the theoretical structure of the grey principal component analysis are defined in Section 3. Section 4 gives the experimental results, country performance scores, and rankings. Finally, the study ends with the presentation of the findings and recommendations for the comparative evaluation of the renewable energy performances of the countries.

LITERATURE REVIEW

The economic potential of renewable energy sources has started to attract the attention of policymakers, academics, industry workers, and other stakeholders in recent years. In this context, the following studies on the economic potential, environmental effectiveness, and effects on sustainable development of renewable energy are presented.

Đurašković et al. (2021) analyzed the current trends and policies in the renewable energies of the Western Balkan countries (Albania, Bosnia–Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia). They showed that if the countries adopt a transparent, predictable, planned, and active approach to their renewable energy policies, they can create sustainable and flexible energy systems that support their economic development. Karakosta et al. (2012) examined the economic, political, and institutional development processes of renewable energy resources in Serbia and Bosnia–Herzegovina. They discovered that to increase the share of renewable energy in the energy mix of countries, initiatives towards renewable energy sources should be supported and environmental action plans based on energy efficiency should be implemented.

Bhattacharya et al. (2016) examined the effects of renewable energy consumption on the economic growth of 38 countries, including Bulgaria, Romania, Slovenia, Türkiye, Ukraine, and Greece, between 1991 and 2012 using panel data analysis. Consumption of renewable energy is a significant economic growth driver for nations like Bulgaria, Greece, and Romania; it has no positive or negative impact on economic growth in Türkiye; and it has a negative impact on economic growth in Ukraine. Koçak and Şarkgüneşi (2017) evaluated whether renewable energy consumption has an impact on economic growth in 9 Black Sea and Balkan countries for the period 1990-2012 within the framework of the traditional production function. The results demonstrate that using renewable energy has a long-term beneficial impact on economic growth.

Gökgöz and Güvercin (2018) evaluated renewable energy efficiency and productivity performance for European Union (EU) countries between 2004 and 2014 using data envelopment analysis. They found that countries such as Sweden, Germany, Spain, Belgium, and Romania are among the leading countries in renewable energy efficiency. Carfora et al. (2022) examined the role of renewable and non-renewable energy sources in shaping energy import demand in EU countries. The analysis made using Input-Output tables showed that in the case of import substitution with domestic renewable energy sources, there will be positive contributions to energy dependence, energy security, and sustainable development.

Li and Leung (2021) tried to reveal the renewable energy economic growth relationship in 7 European countries (Germany, Italy, Netherlands, Poland, Spain, Türkiye, and the United Kingdom) with econometric modeling techniques from 1985 to 2018. Empirical findings show that economic growth and fossil fuel prices are essential starting points in the transition to renewable energy. Woo et al. (2015) examined the environmental efficiency of renewable energy in OECD countries from static and dynamic perspectives. Geographical disparities in the environmental efficiency of renewable energy across the OECD were revealed by the implementation results for 2004–2011.

Wang et al. (2022) examined the factors affecting the renewable energy consumption of E7 (Brazil, China, Indonesia, India, Mexico, Russia, Türkiye) countries for the period 1990-2021. Using various panel data approaches, they found that renewable energy consumption contributes more to economic growth and carbon emissions reduction than conventional fuels. Meng et al. (2022) examined the effect of trade diversification, green innovation, and renewable energy on carbon emissions of BRICS-T (Brazil, Russia, India, China, South Africa, and Türkiye) countries for the period 1995-2020. As a result of the analysis with panel data approaches, it has been shown that countries have transformed their production technologies into green technologies and encouraged their renewable energy consumption to reduce carbon emissions.

Recently, many ecological studies have been carried out to meet sustainable development goals by taking renewable energy sources, greenhouse gas emissions, and energy inequality as an indicator of environmental sustainability. Bianco et al. (2021) evaluated the countries in the Eurasian Economic Union within the scope of SDG-7 "Ensure access to affordable, reliable, sustainable and modern energy for all" target. As a result of the analysis for the period 2000-2017, they found that GDP growth and energy intensity are the main factors that determine energy consumption. Wang et al. (2022) evaluated the relationship between different renewable energy sources and economic growth in selected Asian countries within the scope of the SDG 7 target. It has been concluded that the use of renewable energy resources has a positive and significant effect on Asian economies. Adebayo et al. (2023), within the scope of SDG-13 "Take urgent action to combat climate change and its impacts" target, examined the effect of renewable energy use and natural resources in BRICS countries on the limitation of greenhouse gas emissions with the CS-ARDL technique. They have shown that investments in technological innovation, renewable energy consumption, and natural resources increase environmental sustainability by limiting greenhouse gas emissions.

The literature presented above shows that the economic potential of renewable energy sources and energy efficiency have provided many studies in the related literature. However, this study differs from the studies in the literature in terms of comparing the renewable energy performances of the Black Sea and Balkan countries.

RESEARCH METHODOLOGY

Grey Absolute Degree of Incidence

Grey system theory, introduced to the literature by Deng Julong in 1982, is widely used for relationship analysis, forecasting, decision-making, programming, and control in systems with little data and limited information (Huang, Tsai, and Subeq, 2020: 8099). The absolute grey relationship degree, a part of the grey system theory, measures the degree of relationship between the series according to the similarity of the geometric curves obtained from the series. The more similar the curves, the higher the degree of relationship between the series (Liu and Lin, 2006: 86). The steps of the absolute grey relationship degree as follows:

Provided that there are n ($k=1,2,...,n$) alternatives and m ($i=1,2,…,m$) evaluation indicators, the behavioral series $Z_i=(z_i(1),z_i(2),…,z_i(n)),\forall i$ is created. For the comparability of these series with different qualities and units, the normalized series $X_i=(x_i\ (1),x_i\ (2)\ ,…\ ,\ x_i\ (n)),\forall i$ is needed. While performing the normalization process, the following equations are applied, respectively, according to the desired target being benefit, cost, and optimum value (Tung and Lee, 2009: 5917):

$$x_i(k) = \frac{z_i(k) - \min_k z_i(k)}{\max_k z_i(k) - \min_k z_i(k)}, \forall i, k \quad (1)$$

$$x_i(k) = \frac{\max_k z_i(k) - z_i(k)}{\max_k z_i(k) - \min_k z_i(k)}, \forall i, k \quad (2)$$

$$x_i(k) = 1 - \frac{|z_i(k) - OV|}{\max\left(\max_k z_i(k) - OV, OV - \min_k z_i(k)\right)}, \forall i, k \quad (3)$$

where OV is the optimum value.

The absolute grey degree of relationship emphasizes the similarity between the geometric curves obtained from the series, not the relative positions of the series. Therefore, it is necessary to obtain zero initial points images of all series curves, namely $x_i^0(k) = x_i(k) - x_i(1), k = 1, 2, \ldots, n$ Let $X_i^0(k) = \left(x_i^0(1), x_i^0(2), \ldots, x_i^0(n)\right)$ be images with zero initial points, the equations s_i and s_i-s_j are defined as in equations (4) and (5), respectively (Tung and Lee, 2009: 5917):

$$s_i = \int_1^n X_i^0 dt \quad (4)$$

$$s_i - s_j = \int_1^n X_i^0 - X_j^0 dt \quad (5)$$

Where s_i and s_i-s_j satisfy equations (6) and (7) respectively:

$$|s_i| = \left|\sum_{k=2}^{n-1} x_i^0(k) + \frac{1}{2} x_i^0(n)\right| \quad (6)$$

$$|s_i - s_j| = \left|\sum_{k=2}^{n-1} \left(x_i^0(k) - x_j^0(k)\right) + \frac{1}{2}\left(x_i^0(k) - x_j^0(k)\right)\right| \quad (7)$$

Let X_i and X_j be two series with the same length, the absolute grey relationship degree between these two series is calculated using equation (8) (Tung and Lee, 2009: 5918).

$$r_{ij} = \frac{1 + |s_i| + |s_j|}{1 + |s_i| + |s_j| + d(s_i, s_j)} \quad (8)$$

Where $d(s_i, s_j) = \sum_{k=2}^{n} \left|x_i^0(k) - x_j^0(k)\right|$.

The grey correlation matrix R from the elements r_{ij}, which expresses the absolute grey relationship degree between the X_i and X_j series, is formed as in equation (9). The r_{ij} elements here provide the properties $r_{ii} = 1, 0 < r_{ij} \leq 1$ and $r_{ij} = r_{ji}$. Since R is a symmetric matrix, it is accepted as a correlation matrix (Tung and Lee, 2009: 5918).

$$\boldsymbol{R} = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1m} \\ r_{21} & 1 & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & 1 \end{bmatrix} \quad (9)$$

Grey Principal Component Analysis

The grey principal component analysis is based on the R matrix. Let $X' = [X_1, X_2, \ldots, X_m]$ be a matrix. Using the linear transform $Y_i = \mathbf{y}_i^t \mathbf{X}$ with $\mathbf{y}_i^t = [y_{i1}, y_{i2}, \ldots, y_{im}]$, grey covariance of Y_i and Y_j series is expressed as $GC(Y_i, Y_j) = \mathbf{y}_i^t \boldsymbol{R} \boldsymbol{y}_j$, grey variance of Y_i series as $GV(Y_i) = \mathbf{y}_i^t \boldsymbol{R} \boldsymbol{y}_i$. Therefore, the principal component problem expresses the maximization of $GV(Y_i) = \mathbf{y}_i^t \boldsymbol{R} \boldsymbol{y}_i$ under the constraint $\mathbf{y}_i^t \boldsymbol{y}_i = 1$. According to the Kaiser rule, $Y_i, i = 1, 2, \ldots, l$ related principal components with eigenvalues greater than one are selected (Tung and Lee, 2009: 5918).

Let it be $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_l$ and $l \leq m$. If $(\lambda_1, e_1), (\lambda_2, e_2), \ldots, (\lambda_l, e_l)$ are the eigenvalue-eigenvector pairs of the R matrix, the principal component is defined as in equation (10) (Tung and Lee, 2009: 5918):

$$Y_i = \mathbf{e}_i^t \mathbf{X} = e_{11} X_1 + e_{12} X_2 + \cdots + e_{1m} X_m, 1 \leq i \leq l \quad (10)$$

where $\mathbf{e}_i^t = [e_{i1}, e_{i2}, \ldots, e_{im}]$. When eigenvectors are used as weights, the score of principal component of alternative is calculated using equation (11):

$$pc_i(j) = \sum_{k=1}^{m} e_{ik} x_k(j), \forall i, j \quad (11)$$

Using each principal component and its corresponding eigenvalue as weight, the total score of the alternatives is calculated using equation (12). The performance ranking of the alternatives is made according to the total score (Tung and Lee, 2009: 5919).

$$PC_i(j) = \sum_{i=1}^{t} \frac{\lambda_i}{\sum_{i=1}^{t} \lambda_i} pc_i(j) \quad (12)$$

DATA AND EXPERIMENTAL RESULTS

This study aims to evaluate the renewable energy performances of selected Black Sea and Balkan countries, taking into account the central role of renewable energy in the transition to a future sustainable energy system. For this purpose, the sample of the study consists of 14 countries (Albania, Bosnia–Herzegovina, Bulgaria, Croatia, Georgia, Greece, Montenegro, North Macedonia, Romania, Russia, Serbia, Slovenia, Türkiye, and Ukraine) located in the Black Sea and Balkan geography. The indicators used in the evaluation of the renewable energy performance of the countries that are the subject of the

Table 1: Indicators used in Renewable Energy Performance Evaluation

Code	Indicator	Source
X_1	CO_2 emissions (kt)	WDI
X_2	Adjusted savings: carbon dioxide damage (% of GNI)	WDI
X_3	Total renewable energy capacity (MW)	IRENA
X_4	Renewable electricity generation (GWh)	IRENA
X_5	Renewable energy imports (Terajoules)	UNSD
X_6	Renewable energy supply (Terajoules)	UNSD
X_7	Renewable energy consumption (Mtoe)	UNSD
X_8	Development of environment-related technologies (% all technologies)	OECD Green Growth
X_9	Environmentally related government R&D budget (% total government R&D)	OECD Green Growth
X_{10}	Kyoto Protocol ratification year	UNFCCC
X_{11}	Regulatory quality (value)	WDI
X_{12}	GDP per capita (constant 2015 US$)	WDI
X_{13}	Population (total)	WDI
X_{14}	Population growth (annual %)	WDI
X_{15}	Labor force (total)	WDI

Table 2: GADI matrix

1.00	0.54	0.95	0.98	0.83	0.94	0.91	0.86	0.85	0.54	0.76	0.84	0.97	0.80	0.97
0.54	1.00	0.57	0.56	0.59	0.57	0.56	0.58	0.55	0.83	0.62	0.60	0.54	0.63	0.49
0.95	0.57	1.00	0.97	0.84	0.98	0.91	0.85	0.84	0.58	0.77	0.86	0.97	0.84	0.96
0.98	0.56	0.97	1.00	0.83	0.96	0.91	0.85	0.85	0.56	0.76	0.86	0.99	0.82	0.98
0.83	0.59	0.84	0.83	1.00	0.84	0.88	0.85	0.89	0.59	0.86	0.88	0.82	0.84	0.80
0.94	0.57	0.98	0.96	0.84	1.00	0.91	0.85	0.84	0.58	0.77	0.86	0.96	0.85	0.94
0.91	0.56	0.91	0.91	0.88	0.91	1.00	0.86	0.90	0.72	0.81	0.89	0.90	0.83	0.89
0.86	0.58	0.85	0.85	0.85	0.85	0.86	1.00	0.81	0.58	0.81	0.83	0.85	0.82	0.82
0.85	0.55	0.84	0.85	0.89	0.84	0.90	0.81	1.00	0.55	0.81	0.89	0.83	0.81	0.81
0.54	0.83	0.58	0.56	0.59	0.58	0.72	0.58	0.55	1.00	0.63	0.60	0.55	0.64	0.49
0.76	0.62	0.77	0.76	0.86	0.77	0.81	0.81	0.81	0.63	1.00	0.87	0.75	0.89	0.71
0.84	0.60	0.86	0.86	0.88	0.86	0.89	0.83	0.89	0.60	0.87	1.00	0.84	0.89	0.81
0.97	0.54	0.97	0.99	0.82	0.96	0.90	0.85	0.83	0.55	0.75	0.84	1.00	0.82	0.99
0.80	0.63	0.84	0.82	0.84	0.85	0.83	0.82	0.81	0.64	0.89	0.89	0.82	1.00	0.77
0.97	0.49	0.96	0.98	0.80	0.94	0.89	0.82	0.81	0.49	0.71	0.81	0.99	0.77	1.00

study were decided as a result of the examination of the renewable energy reports of the international energy agencies together with the studies of Marques et al. (2010), Aguirre and Ibikunle (2014), and these indicators, together with their codes and units, are presented in Table 1[1]. While evaluating the performances of 14 selected countries, 2020 data for 15 indicators of countries were compiled from World Development Indicators (WDI), IRENA, United Nations Statistics Divisions (UNSD), OECD Green Growth, and UNFCCC.

Grey principal component analysis, which allows size reduction and gives appropriate weights to the variables, was used to evaluate the renewable energy performance of the countries. First, the countries' values for the 15 variables presented in Table 1 were normalized. Second, the absolute grey correlation degree was calculated by

[1] In indicators CO_2 emissions and development of environment-related technologies, the data of the previous year were used, since the data of the countries for the year 2020 are not available.

Table 3: Eigenvalue, Accumulative Explanatory Variance Proportion, Eigenvectors

Eigenvalue	Accumulation	Eigenvector 1	Eigenvector 2
12.22	81.44	0.27	0.19
1.12	89.93	0.19	-0.61
0.56		0.27	0.15
0.27		0.27	0.18
0.21		0.26	-0.03
0.19		0.27	0.14
0.11		0.27	0.00
0.10		0.26	0.02
0.08		0.26	0.04
0.06		0.20	-0.61
0.03		0.25	-0.17
0.02		0.27	-0.03
0.02		0.27	0.20
0.01		0.26	-0.11

Table 4: Grey Principal Component Scores and Rank of Countries

	2020 Score	2020 Rank
Albania	0.62	10
Bosnia–Herzegovina	0.42	13
Bulgaria	0.73	6
Croatia	0.67	8
Georgia	0.70	7
Greece	1.42	3
Montenegro	0.47	12
North Macedonia	0.57	11
Romania	1.31	4
Russia	1.90	1
Serbia	0.41	14
Slovenia	1.26	5
Türkiye	1.61	2
Ukraine	0.64	9

using equation (8) and then the grey correlation matrix was created by using the absolute grey relation degree elements and equation (9). Table 2 presents the grey correlation matrix calculated for the year 2020.

According to the grey correlation matrix, eigenvalue, eigenvector, and accumulative explanatory variance ratio proportion were calculated. As a result of the selection of the principal components with eigenvalues greater than one, Table 3 was created for 2020.

As a result of using the eigenvalues and eigenvectors presented in Table 3 in equations (11) and (12), the grey principal components total score was calculated for the countries. Table 4 presents the grey principal component scores and rankings calculated for the renewable energy performances of 14 Black Sea and Balkan countries for the relevant year.

As can be seen from Table 4 and Figure 1, it can be seen that Russia, Türkiye, Greece, Romania, and Slovenia have a value greater than one in the renewable energy performance ranking and are in the top five in the ranking.

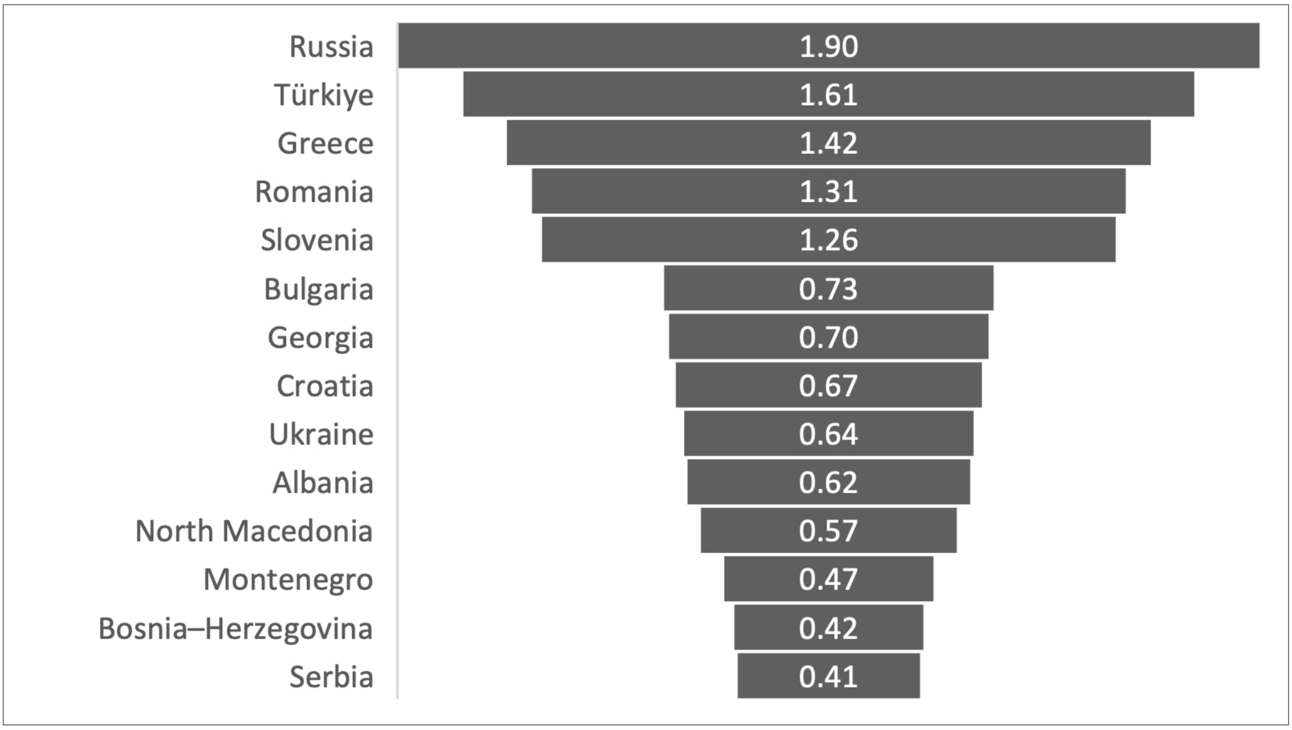

Figure 1. Grey Principal Component Scores of Countries

Russia is thought to play a significant role in the world's energy markets. The country's abundance of natural gas, coal, and oil reserves makes it difficult to develop its renewable energy sources (Proskuryakova and Ermolenko, 2019: 1671). However, several changes to laws and regulations have been implemented to advance the nation's renewable energy industry. For instance, the Ministry of Energy of the Russian Federation published a report titled Energy Strategy of Russia - For the Period Up to 2030 in which it mentioned the importance of renewable energy sources in raising energy efficiency and set various goals for producing electricity from renewable sources (Ministry of Energy of the Russian Federation, 2009). At the same time, the country, which has a renewable energy area of 17 million km2, is considered a market with high potential for technologies such as wind turbines, biomass/biogas-burning power generators, and geothermal power plants (Lombardi et al., 2016: 532; Agyekum et al., 2021: 4502). According to the Renewable Capacity Statistics 2022 report published by IRENA, Russia's total renewable energy capacity is 55219.00 MW in 2020, which is the highest value among the countries included in the analysis (IRENA, 2022: 3). Considering the variables in the study, the fact that the country has the highest value in terms of variables such as renewable energy capacity (MW), renewable electricity production (GWh), renewable energy consumption (Mtoe), population and workforce makes it inevitable to rank first in the relevant year.

Türkiye has increased its renewable energy consumption from hydraulic, wind, and solar, especially in the last ten years, and has achieved impressive growth by tripling its renewable electricity production (IEA, 2021a: 11, 73). Thanks to its total renewable energy capacity of 49165.00 MW in 2020, Türkiye stands out as the country with the second highest value after Russia (IRENA, 2020: 3). Besides, the share of renewable energy sources in electricity generation is 42% in 2020. The goal of increasing the use of renewable energy resources, stated in the National Energy Policy adopted by the country in 2017, can be considered among the policies that help the country achieve its high ranking. At the same time, while the country's growing population and growing economy increase energy demand, problems such as limited reserves of fossil fuels, dependence on energy imports, and environmental difficulties can be counted among the factors that push the country to use renewable energy sources more (Tükenmez and Demireli, 2012: 1).

Greece ranked third in the assessment of renewable energy performance with a total renewable energy capacity of 10921.00 MW in 2020. While having a total renewable energy capacity of 11121.00 MW, Romania came in fourth place in the corresponding years. Greece and Romania are seen to have increased their use of renewable energy in 2020, particularly wind and solar energy. In addition, national targets such as renewable electricity consumption, renewable heating and cooling, and renewable transportation determined by countries within the scope of the EU Renewable Energy Directive for 2020 can be considered as policies that contribute to the country's inclusion in the relevant rankings within the scope of this analysis (Păcesilă, 2013; IEA, 2017: 101).

Slovenia ranks fifth in the renewable energy performance ranking with a score of 1.26. With the National Energy Program adopted in 2004, Slovenia aimed to increase energy use from renewable sources and realized it to a certain extent. Bulgaria ranks sixth in the performance ranking with a score of 0.73. Concerning renewable energy capacity, Bulgaria, the EU's poorest member state is in a superior position to those of the Western Balkan nations. However, the country must address the flaws in the procedure and governance that support the regulatory framework once it is to effectively expand this capacity and ensure the sustainability of the switch to renewable energy (Andreas et al., 2018: 44). Georgia is followed by Bulgaria with a score of 0.70 and Croatia with a score of 0.67. Although it has potential in renewable energy sources, the military intervention of Russia, which started with the annexation of Crimea in 2014, disrupted the renewable energy sector of Ukraine (Kurbatova and Khlyap, 2015: 223). As a result, it is expected that the country will come in ninth place with a score of 0.64.

In the renewable energy performance evaluation for 2020, the Western Balkan nations of Albania, North Macedonia, Montenegro, Bosnia–Herzegovina, and Serbia are at the bottom of the list, as shown in Table 4. Among these countries, Bosnia–Herzegovina adopted the Energy Framework Strategy in 2018 to increase energy efficiency for sustainable energy use and reduce greenhouse gas emissions (Directorate – General for Neighborhood and Enlargement Negotiations, 2022: 3). Although it has implemented several reforms and plans of action, it still lags behind other nations in the use of renewable energy sources. One of the crucial factors in front of renewable energy positioning in Serbia is seen as regulatory quality. The difficulties experienced in formulating and implementing sound policies and regulations in the country greatly hinder energy efficiency and the production of renewable energy resources (Karakosta et al., 2012: 5174). In conclusion, as a result of the increasing energy demand of the other countries within the scope of the analysis and their ambitious policies and reforms aimed at increasing the share of renewable energy resources in meeting this demand, it is expected that these three countries, which are relatively behind, lag in the performance rankings.

CONCLUSION

The World Energy Outlook 2021 report published by the IEA links energy, air pollution, climate change, global warming, and health (IEA, 2021b: 15-22). The increasing concentration of carbon dioxide from the global energy industry is causing noticeable changes in weather and climate, and people are vulnerable to health risks associated with these changes. All these negativities increase the concerns of environmental deterioration. As these details aim to demonstrate, nations seek sustainable, safe, and effective energy production to avoid depleting fossil fuel reserves, prevent weather and climate extremes, and stop global warming. Renewable energy sources are essential for achieving the carbon-neutral target and expediting the transition of all nations to a green economy, both of which are necessary for sustainable development. This study aims to examine the renewable energy performances of 14 Black Sea and Balkan countries in 2020. Grey principal component analysis, a novel algorithm created by fusing grey system theory with principal component analysis, was utilized for this purpose, which involved using the data from 15 renewable energy variables across countries. Grey principal component analysis provides a reliable performance evaluation analysis by measuring the closeness of the relationship between the data according to the similarities of the geometric curves.

As a result of the analysis made using the grey principal component analysis, Russia and Türkiye took the top positions. The position of these countries in the relevant year is due to their potential in renewable energy variables and their implementation of various policies and actions in the renewable energy sectors. Serbia, Bosnia-Herzegovina, and Montenegro came in last in the evaluation of the performance of renewable energy sources. These findings offer conclusions on renewable energy at the local level based on historical, cultural, and structural similarities. According to the performance analysis, countries can raise their standings and help safeguard the environment by utilizing renewable energy sources more frequently and reaping their economic and energy-saving benefits greater extent. The growth in demand for sustainable, secure, and efficient energy technologies will ensure the progress and development of the relevant sector, even though the world's economic, technological, and social factors are constantly changing and have varying effects on the development of the renewable energy sectors of the countries.

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