



Hierarchical Structure Analysis of Electricity Consumption Based on Alternative Energy Sources: A Comparative Assessment of 66 Countries

Nevfel Yunus COSKUN^{1*}, Ersin KANTAR²

¹Yozgat Bozok University, Sorgun Vocational School, Department of Motor Vehicles and Transport Technologies, 66700, Yozgat, Türkiye

²Yozgat Bozok University, Sorgun Vocational School, Medical Services and Techniques Department, 66700, Yozgat, Türkiye

*Correspondence: nevfelyunus.coskun@bozok.edu.tr

Received: 21/04/2025

Accepted: 14/05/2025

Final Version: 26.05.2025

Abstract

Energy is of strategic importance in terms of economic growth, sustainable development, and environmental balance. The continuous increase in global energy demand necessitates the development of new policies for the use of energy resources. Traditional fossil fuel-based energy production does not offer a sustainable solution in the long term due to its environmental impacts and limited reserves. This situation is driving countries toward the more widespread use of renewable energy sources. Alternative energy sources such as solar, wind, hydroelectric, and geothermal energy support environmental sustainability by reducing carbon emissions and ensuring energy supply security. However, there are significant differences among countries in terms of their rates of alternative energy use, levels of economic development, energy policies, and infrastructure capabilities. This study aims to analyze the consumption of electricity generated from alternative energy sources using hierarchical structure methods. In the study, topological analysis was performed using minimal spanning tree (MST) and hierarchical tree (HT) methods, based on data on electricity consumption from alternative energy sources in 66 countries worldwide between 1990 and 2023. The reliability of the obtained networks was tested using the Bootstrap method. The findings indicate that developed countries lead in renewable energy use, while developing countries are increasingly investing in this area. Additionally, a strong correlation was found between countries' energy consumption patterns and their levels of economic development. In this context, the role of renewable energy sources in economic growth and environmental sustainability was emphasized, and it was concluded that energy policies must be effectively managed.

Keywords: Energy, Renewable Energy, Econophysics, Hierarchical Structure Methods, Electricity consumption

1. INTRODUCTION

Energy is one of the basic building blocks of the economic, social and environmental development of countries and has a strategic importance worldwide. Many areas such as economic growth, industrial production, transport and daily life depend on the efficient use of energy resources. While traditional energy sources such as fossil fuels have an important place in energy supply, the limited availability of these resources and their environmental impacts encourage the use of renewable energy sources (Kim, 2015; Wang, 2022). At the global level, energy security is at the center of countries' foreign policies and international relations, while interruptions in energy supply can threaten economic stability. Moreover, in line with climate change and sustainability goals, the adoption of low carbon emission policies and increasing investments in energy transition are becoming increasingly important worldwide. Therefore, energy is not only an economic resource, but also a factor that determines environmental and political balances (Başol, 2021; Bilgiç, 2019; Cabreira et al., 2024; Dudzevičiūtė, 2013).

The production and consumption of electrical energy is directly related to the sustainability objectives of countries' energy policies. The environmental impacts and limited reserves of energy production based on traditional fossil fuels force countries to turn to alternative energy sources. Countries that utilize renewable energy sources such as solar, wind, hydroelectricity and geothermal at higher rates

generally achieve significant gains in both environmental and economic terms. While increasing energy supply security, these countries also reduce carbon emissions and comply with international climate policies. Renewable energy investments not only reduce energy costs in the long run but also contribute to social development through their employment-generating effects (Gostkowski et al., 2021; Hu et al., 2018; Kasperowicz, 2014). Countries with high rates of renewable energy use, such as Northern European countries, reflect the positive effects of this transformation concretely with their strong economies, high living standards and environmentally friendly policies. This shows that the use of renewable energy sources plays a critical role not only in terms of environmental sustainability but also economic stability and social welfare (Eyyüboğlu et al., 2022; Zhou et al., 2017; Balzannikov, 2017; Cicea et al., 2021).

Table 1. Summary of literature studies

Authors	Term	Country/ Region	Methodology	Independent Variables	Common Themes/Findings
Kantar and Keskin (2013)	1971 - 2008	30 Asian countries	Hierarchical structure analysis with (Minimal Spanning Tree) MST and HT methods	Electricity consumption, Gross domestic product (GDP)	A strong relationship was found between electricity consumption and economic growth, and different clustering structures were identified according to income groups.
Kantar et al. (2016)	1971 - 2008	64 world countries	MST and HT methods, Bootstrap techniques	Electricity consumption, GDP	The statistical reliability of the linkages was tested with the Bootstrap method. Electricity consumption patterns are categorized in detail on the basis of three different income groups (low, medium, high).
Yao et al. (2015)	2005 - 2013	South China	Electricity consumption-correlation analysis with MST and Bootstrap techniques	Industrial electricity consumption	Electricity consumption correlations are analyzed before and after the crisis and conclusions are drawn for the optimization of industrial organization.
Mendonça et al. (2020)	1990 - 2015	50 major economies	Hierarchical regression model	GDP, population, renewable energy production, Carbon dioxide (CO ₂) emissions	It is observed that renewable energy production is effective in reducing CO ₂ emissions, while GDP and population growth increase emissions.
Bekareva et al. (2017)	2000 - 2014	United States of America (USA)	Panel data analysis, cluster analysis	Renewable energy consumption, economic growth	The contribution of renewable energy to economic growth has been analyzed
Gitana Dudzevičiūtė (2013)	1990 - 2010	13 countries	Correlation analysis, panel data methods	Energy consumption, economic growth, sectors	While there is a strong relationship between economic growth and energy consumption in countries with high energy consumption, this relationship is weak in countries with low consumption.

In the literature, studies on the conversion of alternative energy sources into electricity emphasize the effects of renewable energy sources on economic growth and environmental sustainability. These studies have been conducted with methods such as hierarchical structure analysis, panel data analysis and regression models and it has been revealed that the use of renewable energy is effective in reducing CO₂ emissions and contributing to economic growth. In this study, it is aimed to evaluate the data of 66 countries of the world for the period 1990-2023 on the analysis of the relationship between energy consumption and economic growth by using the Kruskal algorithm-based hierarchical structure methods of MST and HT with a systematic approach. In addition, the statistical reliability of the obtained trees was tested by applying the Bootstrap method.

2. MATERIAL AND METHODS

In this study, the data on electricity generated from alternative energy sources for the period 1990-2023 for 66 countries of the world given in Table 2 are taken from the Organization for Economic Co-operation and Development (OECD, 2024). The connection networks of the countries were created based on alternative energy source electrical energy data.

The correlation coefficients were transformed into the corresponding distance matrices and the networks of electrical energy consumed from alternative energy were constructed for these countries. It is possible to create correlations between a combination of electrical energy consumption data with a specific time window. The time window 1990-2023 is used in the study. $P_i(t)$, S_i The data on the electrical energy used from alternative energy sources in the world countries in year t and its logarithmic change in time $[t, t + \tau]$ can be written as follows:

$$R_i(t) = \ln P_i(t + \tau) - \ln P_i(t) \tag{1}$$

where $R_i(t)$ is the daily, weekly or monthly rate of change, depending on the system to be analyzed and the scope of the study. $P_i(t)$ is the value of the i 'th asset at time t and τ is the time series used. Using the assets obtained from Equation (1), the correlation coefficient between asset pairs is calculated (Mantegna, 1999; Kantar, 2015).

In probability theory and statistics, correlation refers to the direction and strength of the linear relationship between two random variables. In general statistical usage, correlation indicates how far one moves away from independence. In addition, the correlation coefficient gives information about the direction of the variables and how they interact. It can be observed whether there is an interaction between the variables, if there is, whether the interaction is very high or strong, and whether the observation values of one of the observation groups increase while the other decreases or whether the values change in the same direction. If there is only one independent variable in the correlation analysis, this type of analysis is called simple correlation analysis, and if there is more than one independent variable, it is called multiple correlation. In scientific research, simple correlation analysis is most commonly used. Different correlation coefficients have been developed for different situations. The best known of these is the Pearson correlation coefficient and

$$C_{ij} = \frac{\langle R_i R_j \rangle - \langle R_i \rangle \langle R_j \rangle}{\sqrt{(\langle R_i^2 \rangle - \langle R_i \rangle^2)(\langle R_j^2 \rangle - \langle R_j \rangle^2)}} \tag{2}$$

is defined as. Here, the notations $\langle R_i \rangle \langle R_j \rangle$ and $\langle R_i R_j \rangle$ stand for statistical averages over time. The correlation coefficient C_{ij} has values between $-1 \leq C_{ij} \leq +1$ and $C_{ij} = -1$, and when stands for completely opposite-correlated entities, and when $C_{ij} = +1$ stands for completely correlated entities. If $C_{ij} = 0$, there is no relationship between assets i and j (Mantegna, 1999; Kantar, 2015).

$$d_{ij} = \sqrt{2(1 - C_{ij})} \tag{3}$$

It's here,

i) It becomes $d_{ij} = 0$ only when $i=j$,

ii) $d_{ij} = d_{ji}$

iii) $d_{ij} \leq d_{ik} + d_{kj}$

d_{ij} The metric distance has values between $0 \leq d_{ij} \leq 2$. The relationship between d_{ij} and C_{ij} is given in equation 2. Using Equation 3, MST can be constructed for N entities using the $N \times N$ matrix obtained from d_{ij} s (Mantegna, 1999; Kantar, 2015).

In running the analysis, the low-income group is colored in green, the lower-upper middle income group in yellow and the high income group in red according to the classification of GDP of the countries for 2023 (World Bank List of Economies, 2025) given in Figure 3 in the MSTs, which are arranged according to the electrical energy data of the countries obtained from alternative energy sources.

Finally, an important method used in the analysis of hierarchical structures is known as the Bootstrap method. With this method, the reliability of the links in hierarchical networks can be analyzed. Bootstrap method was developed by Efron (Efron, 1979) and was first named as Bootstrap method in 1979.

Financial assets are selected for system analysis, and the date range to be analyzed is determined. This date range is divided into sub-date ranges. For each sub-date range, MST and HT are created for the number of sub-ranges. All these trees are compared to determine the number of similar links connecting financial asset pairs. A higher number of similar links between financial asset pairs increases the reliability of these links. Conversely, a decrease in the number of similar links indicates a weakening of the reliability between financial asset pairs.

The electric energy consumption data from alternative energy sources in countries between 1990 and 2023 were obtained from the Energy Institute (EI, 2025). The electric energy consumption of countries from these sources during this period is presented in Figure 1. Analyzing the consumption trends of electric energy produced from alternative sources, it is observed that the curve remained relatively stable until 2000 but started to increase rapidly thereafter, driven by rising renewable energy investments, countries' shift toward sustainable energy, and transformations in global energy policies (EI, 2025).

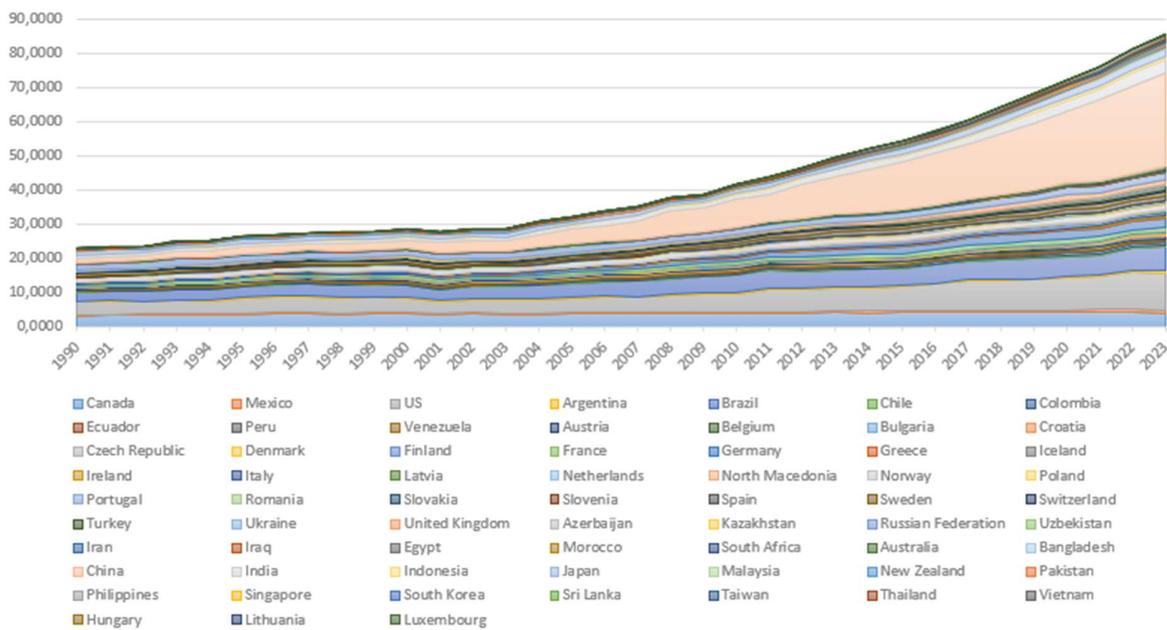


Figure 1. Electric energy consumption of countries from alternative energy sources for the period 1990-2023 (EI, 2025)

Electricity consumption of countries from alternative energy sources for the period 1990-2023 is given in Figure 2. In countries with developed economies, policies that encourage the use of renewable energy by moving away from fossil fuels have led to a transformation in electricity generation. In developing countries, despite economic and technical difficulties, investments in renewable energy infrastructure are gradually increasing. (EIA, 2024; Zarghami, 2025; Nicolli and Vona, 2019).

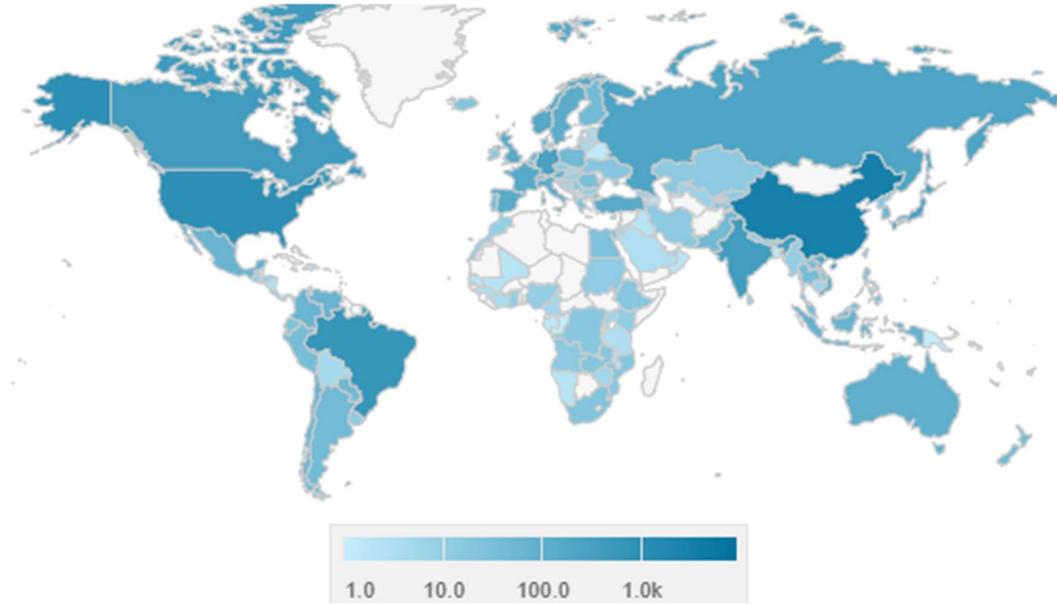


Figure 2. Electric energy consumption of countries from alternative energy sources for the period 1990-2023 (EİA, 2024)

The World Bank analyses global economic differences by dividing countries into four main groups according to their per capita gross national income levels: high income, upper-middle income, lower-middle income and low-income countries. Figure 3 shows that according to the 2023 classification, high-income countries are mainly concentrated in North America, Western Europe, Australia and some Asia-Pacific regions, while upper-middle-income countries are found in Latin America, Eastern Europe and certain parts of Asia. Lower-middle-income countries are common in the northern and eastern parts of Africa and South Asia, while low-income countries are generally concentrated in Sub-Saharan Africa and some South Asian countries (World Banks, 2025).

■ High Income
 ■ Upper-middle Income
 ■ Lower-middle Income
 ■ Low Income
 ■ Not Classified

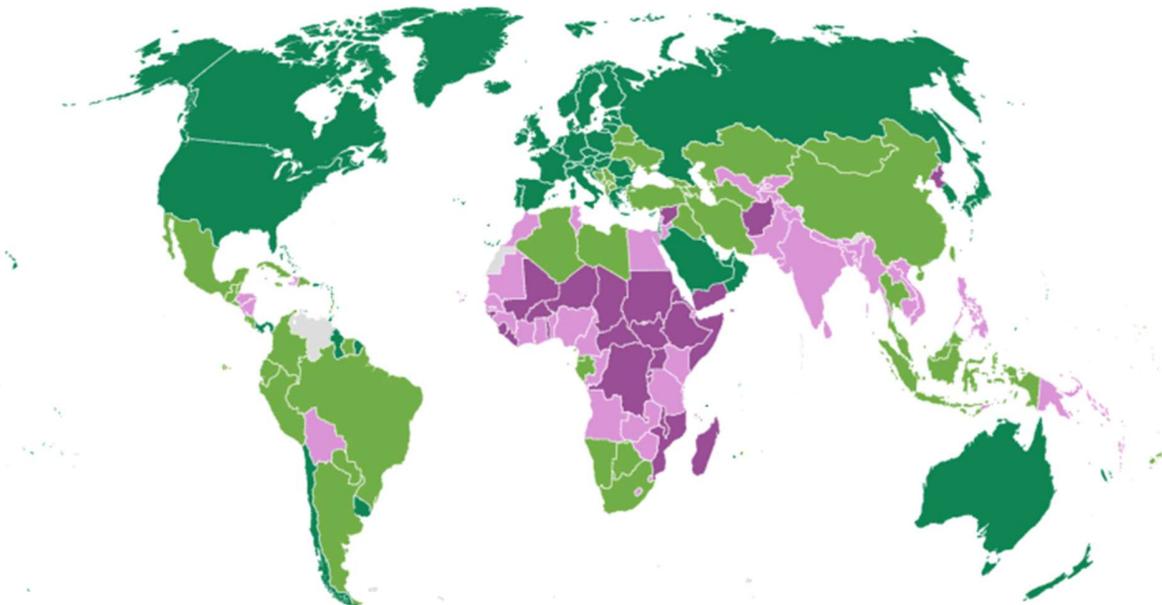


Figure 3. World Bank Group country classification by income level (World Banks, 2025)

3. RESULTS AND DISCUSSION

An MST was created for 66 selected countries around the world for which the HT method will be applied, using correlation matrices for electricity consumption data from alternative energy sources for the years 1990-2023. For the period 1990–2023, MSTs were created using Kruskal's algorithm (West, 2001; Kruskal, 1956; Cormen et al., 2022). Finally, average connection clustering analysis was applied to observe different cluster structures for HA more clearly. The coloring of the obtained MST and HT was based on the World Bank Group country classification according to income level. Accordingly, in these trees, red represents the high-income group, yellow represents the upper-middle-income group, and green represents the lower-middle-income and low-income groups.

Table 2. Names, abbreviations and flags of world countries

Country	Abbreviation	Flag	Country	Abbreviation	Flag	Country	Abbreviation	Flag
USA	USA		India	IND		Egypt	EGY	
Germany	DEU		Netherlands	NLD		Norway	NOR	
Argentina	ARG		Croatia	HRV		Uzbekistan	UZ	
Australia	AUS		Iraq	IRQ		Pakistan	PAK	
Austria	AUT		Iran	IRN		Peru	PER	
Azerbaijan	AZE		Ireland	IRL		Poland	POL	
Bangladesh	BGD		Spain	ESP		Portugal	PRT	
Belgium	BEL		Sweden	SWE		Romania	ROU	
United Kingdom	GBR		Switzerland	CHE		Russian Federation	RUS	
Brazil	BRA		Italy	ITA		Singapore	SGP	
Bulgaria	BGR		Iceland	ISL		Slovakia	SVK	
Czech Republic	CZE		Japan	JPN		Slovenia	SVN	
China	CHN		Canada	CAN		Sri Lanka	LKA	
Denmark	DNK		Kazakhstan	KAZ		Chile	CHL	
Ecuador	ECU		Colombia	COL		Thailand	THA	
Indonesia	IDN		North Macedonia	MKD		Taiwan	TWN	
Morocco	MAR		Latvia	LVA		Turkey	TUR	
Philippines	PHL		Lithuania	LTU		Ukraine	UKR	
Finland	FIN		Luxembourg	LUX		Venezuela	VEN	
France	FRA		Hungary	HUN		Vietnam	VNM	
South Africa	ZAF		Malaysia	MYS		New Zealand	NZ	
South Korea	KOR		Mexico	MEX		Greece	GRC	

The time window 1990-2023 is used in the study. $P_i(t)$, S_i are the data on the electricity consumed from alternative energy sources in country t and its logarithmic change at time $[t, t + \tau]$ can be written as follows:

$$R_i(t) = \ln P_i(t + \tau) - \ln P_i(t) \tag{4}$$

is of the form Here $R_i(t)$ is defined as the logarithmic rate of change (Mantegna, 1999). Correlation coefficients between country pairs are calculated using Equation 4.

The correlation matrix for $N=66$ countries given in Table 1 is constructed from $66(66-1)/2$ country pairs. The distance matrix can also be obtained using the correlation matrix (Mantegna, 1999 and equation (5) below is used to obtain the distance matrix.

$$d_{ij} = \sqrt{2(1 - C_{ij})} \tag{5}$$

The data used in this equation and given in Table 1 for the 66 countries between January 1, 1990 and December 31, 2023 are taken from the International Institute for Electricity Consumption and Energy (EIA, 2025; EI, 2025). Here, d_{ij} is a metric distance and MST for 66 assets was obtained using a 66×66 matrix obtained from d_{ij} s. Connectivity networks of countries based on alternative energy source electricity data were created.

According to the classification of the countries' gross national product (GDP) for 2023 (World Bank List of Economies, 2025), which is arranged according to the countries' electricity energy data from alternative energy sources and given in MST Figure 4, the low-income group is colored in green, the lower-upper middle-income group in yellow and the high-income group in red.

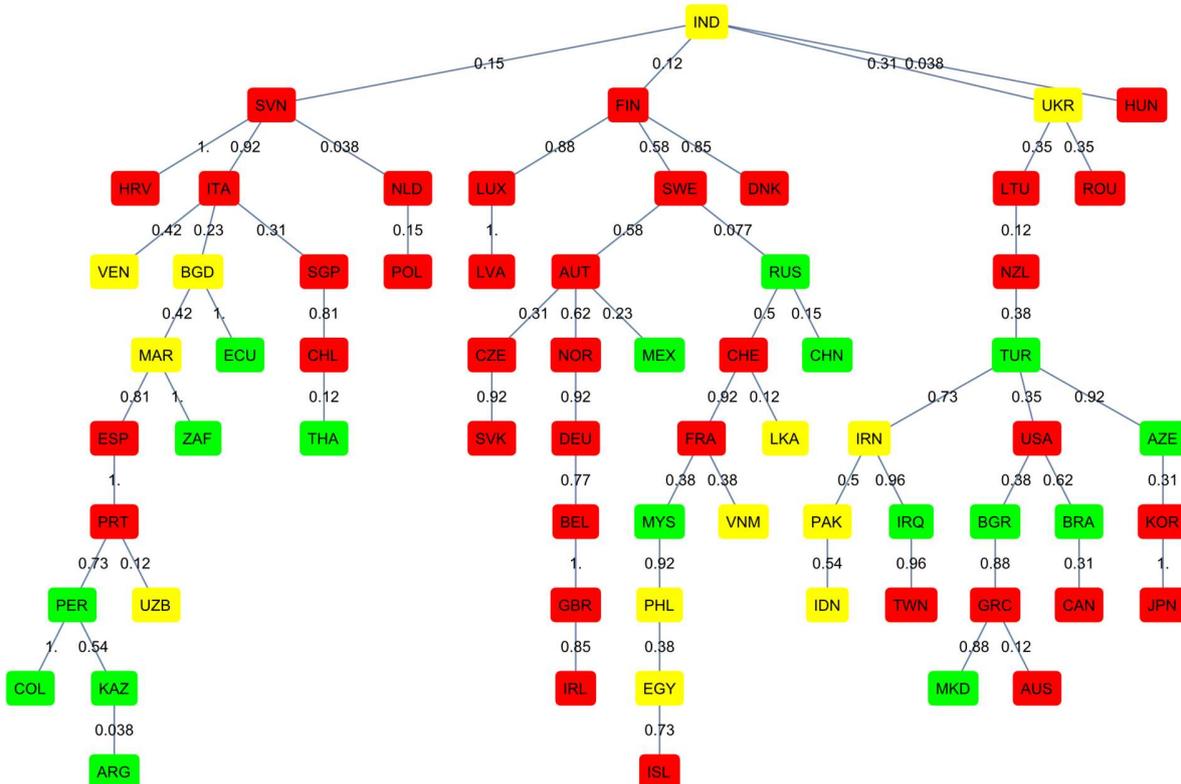


Figure 4. Electricity consumption of countries from alternative energy sources for the years 1990-2023 MST

According to the classification of the countries' gross national product (GDP) for 2023 (World Bank List of Economies, 2025), which is arranged according to the countries' electricity energy data from alternative energy sources and given in MST Figure 4, the low-income group is colored in green, the lower-upper middle-income group in yellow and the high-income group in red.

According to Figure 4, there are 66 countries in total and 65 links between these countries. Each link between countries has confidence coefficient. This coefficient was obtained by Bootstrap method. According to this method, values close to 1 indicate a strong connection between countries and values close to 0 indicate a weak connection. USA, Canada (CAN) and Brazil (BRA) have formed a group of

countries due to the strong economic integration between these countries (NAFTA) as well as their geographical neighborhood. A similar situation was observed between JPN-KOR, PRT-ESP, TUR-IRN- IRQ-PAK-IDN, ARG-PER-COL, RUS-CHN as a dyadic group.

4. CONCLUSION

This study analyses the consumption of electrical energy generated from alternative energy sources using hierarchical structure methods and reveals the relationship between energy consumption patterns and the level of economic development. The findings show that renewable energy consumption is more prevalent in developed economies and that these countries minimise environmental impacts by adopting sustainable energy policies. Developing countries, on the other hand, tend to invest in renewable energy with increasing energy demand, but progress at different speeds in this transformation process due to economic and technical constraints.

The shift away from fossil fuels in energy production towards renewable energy sources plays an important role in reducing carbon emissions as well as ensuring energy supply security. The results obtained in this study are in line with the findings in the literature and show that investments in renewable energy are critical for environmental sustainability. In the literature, it has been reported that there is a strong relationship between renewable energy consumption and economic growth (Mendonça et al., 2020; Kim, 2015). Similarly, this study shows that high-income countries consume more renewable energy and prioritize sustainability in their energy policies.

Within the scope of the study, electricity consumption patterns of countries based on alternative energy sources were classified by using hierarchical structure analyses. It is observed that the correlation between energy consumption and economic growth is more pronounced, especially in developed economies. However, it is observed that developing countries have increased their renewable energy investments but have not fully realized sustainable transformation due to infrastructure deficiencies and financial constraints. This result is in line with previous studies and reveals that energy policies are directly linked to the economic structures of countries (Eyyüboğlu et al., 2022; Cicea et al., 2021).

In line with the results obtained within the scope of the study, the following recommendations were developed:

1. **Policy Development and Incentives:** Increasing state-supported incentive mechanisms for renewable energy sources will accelerate the energy transition, especially in developing countries.
2. **International Cooperation:** In order to ensure sustainability in energy production, cooperation between countries should be increased and joint energy projects should be encouraged.
3. **Technological Investments:** Increasing investments in renewable energy technologies will strengthen the energy supply security of countries and reduce energy costs in the long term.
4. **Data Analytics and Modelling:** More widespread use of advanced modelling techniques such as hierarchical structure analyses in the formulation of energy policies will contribute to the development of more efficient energy management processes.
5. **Financial Support Mechanisms:** Expanding low-interest loans and funding mechanisms for renewable energy investments will help developing countries transform their energy infrastructure faster.

This study sheds light on the energy policies of countries by making a topological analysis of energy consumption patterns. In future research, it is suggested that energy relations between countries should be examined in more detail and analyzed with different methodologies using more comprehensive data sets.

ACKNOWLEDGMENT

This study was supported by the Scientific Research Project coded FGA-2025-1636. The authors would like to express their gratitude to the Scientific Research Projects Coordination Unit of Yozgat Bozok University for their financial and academic support.

AUTHOR'S CONTRIBUTIONS

Author 1: Conceptualisation, methodology, software, validation, formal analysis, research, sources, writing - original draft. Author 2: Method, software, validation, research, sources, writing - revising and editing.

CONFLICTS OF INTEREST

There is no conflict of interest between the authors.

RESEARCH AND PUBLICATION ETHICS

The author declares that this study complies with Research and Publication Ethics.

REFERENCES

- Başol, F. (2021). Advantages, risks and dangers of renewable energy sources (Master's Thesis). Çankaya University Institute of Science and Technology, Ankara, Türkiye.
- Balzannikov, M. (2017). Technical and economic viability of electric power plants on the basis of renewable energy resources regarding hierarchical structure. In MATEC Web of Conferences (Vol. 106, p. 06010). EDP Sciences. Doi: 10.1051/mateconf/201710606010.
- Bekareva, S. V., Meltenisova, E. N., & Gsysa, J. A. (2017). Evaluation of the role of renewables consumption on economic growth of the US regions. *International Journal of Energy Economics and Policy*, 7(2), 160-171.
- Bilgiç, S. (2019). Evaluation of renewable energy resources for energy sustainability with BWM method (Master's Thesis). Konya Technical University, Konya, Türkiye.
- Cabreira, M. M. L., Silva, F. L. C., Cordeiro, J. S., Hernández, R. M. S., Rodrigues, P. C., & López-Gonzales, J. L. (2024). A hybrid approach for hierarchical forecasting of industrial electricity consumption in Brazil. *Energies*, 17(3200), 1-15. Doi: 10.3390/en17133200.
- Cicea, C., Ciocoiu, C. N., & Marinescu, C. (2021). Exploring the Research Regarding Energy-Economic Growth Relationship. *Energies*, 14(9), 2661. Doi: 10.3390/en14092661
- Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. (2022). Introduction to algorithms. MIT press.
- Dudzevičiūtė, G. (2013). The research of the economic structural changes: Energy consumption aspect. *Journal of Security and Sustainability Issues*, 2(4), 13-23.
- EIA, International, Electricity Consumption, <https://www.eia.gov/international/data/world>. [Access Date: 07-May-2025].
- Energy institute (EI), Resources and data, <https://www.energyinst.org/statistical-review/resources-and-data-downloads>. [Access Date: 07-May-2025].
- Eyyüboğlu, K., Akdağ, S., Yildirim, H., & Alola, A. A. (2022). The causal trend of energy intensity and urbanization in emerging countries. *Letters in Spatial and Resource Sciences*, 15(3), 653-663. Doi: 10.1007/s12076-022-00317-5.
- Gostkowski, M., Rokicki, T., Ochnio, L., Koszela, G., Wojtczuk, K., Ratajczak, M., ... & Beldycka-Bórawska, A. (2021). Clustering analysis of energy consumption in the countries of the visegrad group. *Energies*, 14(18), 5612. Doi: 10.3390/en14185612.
- Hu, Y., Peng, L., Li, X., Yao, X., Lin, H., & Chi, T. (2018). A novel evolution tree for analyzing the global energy consumption structure. *Energy*, 147, 1177-1187. Doi: 10.1016/j.energy.2018.01.093.
- Kantar, E., Aslan, A., Deviren, B., & Keskin, M. (2016). Hierarchical structure of the countries based on electricity consumption and economic growth. *Physica A: Statistical Mechanics and its Applications*, 454, 1-10. Doi: 10.1016/j.physa.2016.01.075.

- Kantar, E., & Keskin, M. (2013). The relationships between electricity consumption and GDP in Asian countries, using hierarchical structure methods. *Physica A: Statistical Mechanics and its Applications*, 392(22), 5678-5684. Doi: 10.1016/j.physa.2013.07.029.
- Kantar, E. (2015). Topological Analysis of Important Turkish Companies and Sectors with Export and Import Including Hierarchical Structure Methods (Doctoral Dissertation). Erciyes University Institute of Science and Technology, Kayseri, Türkiye.
- Kasperowicz, R. (2014). Electricity consumption and economic growth: Evidence from Poland. *Journal of International Studies*, 7(1), 46-57. Doi: 10.14254/20718330.2014/71/4.
- Kim, Y. S. (2015). Electricity consumption and economic development: are countries converging to a common trend?. *Energy Economics*, 49, 192-202. Doi: 10.1016/j.eneco.2015.02.001.
- Kruskal, J.B. (1956) On the Shortest Spanning Subtree of a Graph and the Traveling Salesman Problem. *Proceedings of the American Mathematical Society*, 7, 48-50. Doi: 10.1090/S0002-9939-1956-0078686-7.
- Mendonça, A. K. S., Barni, G. A. C., Moro, M. F., Bornia, A. C., & Kupek, E. (2020). Hierarchical modeling of the 50 largest economies to verify the impact of GDP, population, and renewable energy generation on CO₂ emissions. *Sustainable Production and Consumption*, 22, 58-67. Doi: 10.1016/j.spc.2020.02.001.
- Nicolli, F., & Vona, F. (2019). Energy market liberalization and renewable energy policies in OECD countries. *Energy Policy*, 128, 853-867. Doi: 10.1016/j.enpol.2019.01.018.
- Yao, C. Z., Lin, J. N., & Liu, X. F. (2016). A study of hierarchical structure on South China industrial electricity-consumption correlation. *Physica A*, 444, 129-145. Doi: 10.1016/j.physa.2016.06.072.
- Zarghami, S. A. (2025). The role of economic policies in achieving sustainable development goal 7: Insights from OECD and European countries. *Applied Energy*, 377, 124558. Doi: 10.1016/j.apenergy.2024.124558.
- Zhou, Y., Wu, Q., & Yan, T. (2017). A hierarchical system for energy consumption monitoring and information management. In 2017 12th IEEE Conference on Industrial Electronics and Applications (ICIEA) (pp. 449-454). IEEE. Doi: 10.1109/ICIEA.2017.8282887.
- Wang, S. (2022). Differences between energy consumption and regional economic growth under the energy environment. *Energy Reports*, 8, 10017-10024. Doi: 10.1016/j.egyr.2022.07.065.
- West, D. B. (2001). Introduction to graph theory (Vol. 2). Upper Saddle River: Prentice hall.
- World Banks Blog, <https://blogs.worldbank.org/en/opendata/world-bank-country-classifications-by-income-level-for-2024-2025>. [Access Date: 07-May-2025]
- World Bank List of Economies, https://training.iarc.who.int/wp-content/uploads/2022/11/2023_World-Bank-Country_Classification_until-July-2023.xl. [Access Date: 07-May-2025]