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MANAGEMENT IN THE RENEWABLE ENERGY SECTOR IN THE EUROPEAN UNION COUNTRIES

ABSTRACT Management in the field of the Green Deal in the European Union (EU) has become a pivotal goal in recent years as the region continues to prioritise sustainability and combat climate change. The EU has established ambitious goals to transition towards a greener and more sustainable energy landscape. This transformation needs strategic management practices that encompass various aspects of the sector. The aim of this article is to analyse the correlation between the variables X – the share of renewable energy in final energy consumption and Y – CO_2 emissions. The paper assumes that there is a correlation between the variables studied. The study did not confirm this hypothesis for all EU countries, but only for a selected group. Due to the variables analysed, the countries were grouped using the k-means method, which made it possible to identify the leaders, middle countries and marauders of the Green Transformation.

Keywords: renewable energy, energy sector, management, European Union

INTRODUCTION

Management in the renewable energy sector in the European Union (EU) involves a complex interplay of policies, regulations, technologies, and market dynamics. The EU has been at the forefront of promoting renewable energy sources to mitigate climate change and reduce dependence on fossil fuels.

Available literature on management in the renewable energy segment in the EU provides insights into the current state, challenges, and future directions of this crucial aspect of the EU's energy policy.[1] The newest literature highlights the importance of EU-wide renewable energy targets and the transition from the 20-20-20 targets to the more ambitious 2030 targets.[2] Researchers often emphasise the need for clear, stable, and consistent policy frameworks to attract investments in the sector. On the other hand, Scholars discuss how member states vary in their approaches to achieving renewable energy targets.[3] Some countries have excelled in certain technologies (e.g., wind power in Denmark[4], geothermal energy in Italy[5], or solar sources in Greece[6]), while others lag behind (e.g., in Poland[7] or in Hungary[8]).

1 M. da Graça Carvalho, "EU Energy and Climate Change Strategy," *Energy*, vol. 40, no. 1 (2012), pp. 19-22; A. Mihajlov, "Opportunities and Challenges for a Sustainable Energy Policy in SE Europe: SE European Energy Community Treaty," *Renewable and Sustainable Energy Reviews*, vol. 14, no. 2 (2010), pp. 872-875; E. Papadis, G. Tsatsaronis, "Challenges in the Decarbonization of the Energy Sector," *Energy*, vol. 205 (2020).

2 S. Ćetković, A. Buzogány, "Varieties of Capitalism and Clean Energy Transitions in the European Union: When Renewable Energy Hits Different Economic Logics," *Climate Policy*, vol. 16, no. 5 (2016), pp. 642-657; S. Tagliapietra et al., "The European Union Energy Transition: Key Priorities for the Next Five Years," *Energy Policy*, vol. 132 (2019), pp. 950-954.

3 T. Haas, "Comparing Energy Transitions in Germany and Spain Using a Political Economy Perspective," *Environmental Innovation and Societal Transitions*, vol. 31 (2019), pp. 200-210; K. Hansen, B.V. Mathiesen, I.R. Skov, "Full Energy System Transition Towards 100% Renewable Energy in Germany in 2050," *Renewable and Sustainable Energy Reviews*, vol. 102 (2019), pp. 1-13; B.E. Lebrouhi et al., "Energy Transition in France," *Sustainability*, vol. 14, no. 10 (2022), pp. 1-28; S. Proença, M.S. Aubyn, "Hybrid Modeling to Support Energy-Climate Policy: Effects of Feed-in Tariffs to Promote Renewable Energy in Portugal," *Energy Economics*, vol. 38 (2013), pp. 176-185.

4 F. Mey, M. Diesendorf, "Who Owns an Energy Transition? Strategic Action Fields and Community Wind Energy in Denmark," *Energy research & Social Science*, vol. 35 (2018), pp. 108-117.

5 A. Manzella et al., "Environmental and Social Aspects of Geothermal Energy in Italy," *Geothermics*, vol. 72 (2018), pp. 232-248.

6 E. Bellos, C. Tzivanidis, "Solar Concentrating Systems and Applications in Greece – A Critical Review," *Journal of Cleaner Production*, vol. 272 (2020).

7 P. Bórawski, A. Bełdycka-Bórawska, L. Holden, "Changes in the Polish Coal Sector Economic Situation with the Background of the European Union Energy Security and Eco-Efficiency Policy," *Energies*, vol. 16, no. 2 (2023), pp. 1-17; M. Przybylska-Cząstkiewicz, "The Legal Conditions for the Development of Renewable Energy in Poland after 2015," *Polityka Energetyczna. Energy Policy Journal*, vol. 20, no. 1 (2017), pp. 115-116.

8 M. Antal, "How the Regime Hampered a Transition to Renewable Electricity in Hungary," *Environmental Innovation and Societal Transitions*, vol. 33 (2019), pp. 162-182.

Technological innovation is one of the most interesting areas, which have improved people's ability to manage energy supplies.[9] Scientists explore the technological mix of renewable energy sources across EU member states. Solar[10], wind[11], hydro[12], and biomass[13] are common technologies, but the balance differs significantly. They examine the factors driving these choices and their environmental and economic implications. Also, grid integration and energy storage are recurring topics in the literature.[14] In articles, Scientists investigate the challenges of integrating intermittent renewables into existing energy grids, and the role of energy storage technologies in ensuring a stable energy supply. It should be also underlined, that the articles explore the environmental and social aspects of renewable energy deployment too.[15] These include the impact on land use, biodiversity, and the local communities where renewable projects are located. The balance between environmental sustainability and energy generation is a critical area of research.

The analysis of the available literature on management in the renewable energy sector underscores the multifaceted nature of this field. It provides valuable insights for policymakers, researchers, and industry stakeholders working to advance renewable energy adoption and achieve the EU's clean energy goals. But the available literature lacks specific articles which analyse the reasons of the transition of the energy market. One might ask a question: how does renewable energy production determine the division into leaders, averages or marauders according to the net greenhouse gas emissions?

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9 M. Chen, A. Sinha, K. Hu, M.I. Shah, "Impact of Technological Innovation on Energy Efficiency in Industry 4.0 Era: Moderation of Shadow Economy in Sustainable Development," *Technological Forecasting and Social Change*, vol. 164 (2021); A. Elia, M. Kamidelivand, F. Rogan, B. Ó Gallachóir, "Impacts of Innovation on Renewable Energy Technology Cost Reductions," *Renewable and Sustainable Energy Reviews*, vol. 138 (2021); C. Miao et al., "Driving Effect of Technology Innovation on Energy Utilization Efficiency in Strategic Emerging Industries," *Journal of Cleaner Production*, vol. 170 (2018), pp. 1177-1184.

10 C. Luan, X. Sun, Y. Wang, "Driving Forces of Solar Energy Technology Innovation and Evolution," *Journal of Cleaner Production*, vol. 287 (2021).

11 N. Odam and F.P. De Vries, "Innovation Modelling and Multi-Factor Learning in Wind Energy Technology," *Energy Economics*, vol. 85 (2020).

12 A. Blakers, M. Stocks, B. Lu, C. Cheng, "A Review of Pumped Hydro Energy Storage," *Progress in Energy*, vol. 3, no. 3 (2021), pp. 1-18. Batteries are rapidly falling in price and can compete with pumped hydro for short-term storage (minutes to hours).

13 M. Costa et al., "The 'INNOVARE' Project: Innovative Plants for Distributed Poly-Generation by Residual Biomass," *Energies*, vol. 13, no. 15 (2020).

14 A.N. Abdalla et al., "Integration of Energy Storage System and Renewable Energy Sources Based on Artificial Intelligence: An Overview," *Journal of Energy Storage*, vol. 40 (2021), pp. 1-13; Q. Zeng et al., "Integrated Photorechargeable Energy Storage System: Next-Generation Power Source Driving the Future," *Advanced Energy Materials*, vol. 10, no. 14 (2020).

15 W. Czekała, F. Tarkowski, P. Pochwatka, "Social Aspects of Energy Production from Renewable Sources," *Problemy Ekorozwoju*, vol. 16, no. 1 (2021), pp. 61-66; M. Kumar, "Social, Economic, and Environmental Impacts of Renewable Energy Resources," in K.E. Okedu, A. Tahour, A.G. Aissaou (eds), *Wind Solar Hybrid Renewable Energy System*, London 2020; A.M. Levenda, I. Behrsin, F. Disano, "Renewable Energy for Whom? A Global Systematic Review of the Environmental Justice Implications of Renewable Energy Technologies," *Energy Research & Social Science*, vol. 71 (2021).

The purpose of the article is to group countries according to two categories:
X – Share of renewable energy in gross final energy consumption by sector and
Y – Net greenhouse gas emissions.

The article will be divided into two parts. In the first part, the reasons of the importance of increasing the renewable energy market will be analysed. In the second part, using the k-means algorithm, also known as the centroid algorithm, the input data are grouped into a predetermined number of classes. It allows to determine, which countries belong to leaders, average group or marauders. Dependency between variables allow to show the impact on the achievement of the Green Deal.

REASONS FOR INCREASING THE RENEWABLE ENERGY MARKET

The European Union (EU) implemented the Green Deal as a multifaceted and difficult policy framework for various interrelated reasons, primarily motivated by the requirement to confront important challenges and opportunities concerning the environment, economy, and social welfare.

The European Green Deal outlines a comprehensive set of goals and objectives aimed at making the EU more sustainable, climate-neutral, and environmentally responsible. These goals cover various aspects of the economy, society, and the environment. Some of the primary goals of the European Green Deal include[16]:

1) Increasing the EU's climate ambition for 2030 and 2050;
2) Supplying clean, affordable, secure energy;
3) Mobilising industry for a clean and circular economy;
4) Building and renovating in an energy and resource efficient way;
5) A zero pollution ambition for a toxic-free environment;
6) Preserving and restoring ecosystems and biodiversity;
7) Farm to Fork: a fair, healthy and environmentally friendly food system;
8) Accelerating the shift to sustainable and smart mobility.

These goals are interrelated and interconnected, and they set the direction for EU policy and action over the coming decades. Their emergence in the Green Deal was driven by the considerable needs of the economy, the environment and nature, but most importantly of human beings. It is therefore worth considering what reasons existed for the EU to set such priorities for the next few decades.

The EU's decision to pursue the European Green Deal is driven by the urgent need to combat climate change, preserve the environment, create economic opportunities, enhance energy security, improve public health, and position the EU as a global leader in sustainable and clean technologies. It reflects a recognition that the transition to a more sustainable and green economy is not only a moral imperative but also an economic and strategic necessity for the European Union.

[16] European Commission, *The European Green Deal*, 2019.

The most pressing impetus for the Green Deal has been the exigency to alleviate climate change. The EU's aim is to achieve the distinction of being the first climate--neutral continent in the world by 2050. Why environmental concerns were at the core of the Green Deal's launch and renewable energy objectives? Based on the available literature, one can say that mankind is responsible for the rise in carbon dioxide emissions in the atmosphere. For instant, Melany Banks asked a question: "who is responsible?"[17], and then she divided people's responsibility into collective and individual ones. After the Second World War, energy consumption increased significantly due to the development of civilisation, as it is demonstrated in Figure 1. Fossil fuels, such as coal, oil and natural gas were used to fuel machinery, vehicles and household heating. This policy increased combustion resulted in an unprecedented release of carbon dioxide, a notable greenhouse gas, into the atmosphere.

To attain this environmental objective, the Green Deal stipulates goals to diminish greenhouse gas emissions significantly, as well as foster the employment of renewable sources of energy. By offering leadership in the fight against climate change, the EU can persuade other countries to follow its lead (see Fig. 1).

Figure 1. CO_2 emissions per capita in EU-27

Source: Global Carbon Budget, Per capita CO2 emissions, 2022, https://ourworldindata.org/grapher/co-emissions-per-capita.

Before the industrial revolution, the level of atmospheric carbon dioxide had retained under 2 t per capita. From 1850 until 1939, there was an increase to 4 t CO_2

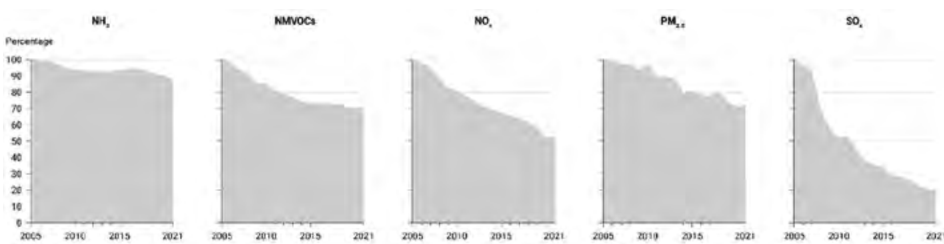
[17] M. Banks, "Individual Responsibility for Climate Change: Individual Responsibility for Climate Change," *The Southern Journal of Philosophy*, vol. 51, no. 1 (2013), p. 42.

by consuming fossil fuels and producing cement, as well as by modifying land use. The sum of these emissions changed rapidly after the WWII, which led to growth pollution of the atmosphere and evoked many other environmental problems too. Figure 1 shows that the European Union has made remarkable progress in reducing CO_2 emissions in recent years. However, this positive trend has been disrupted due to the COVID-19 crisis and the conflict in Ukraine.

Considering environmental issues, it should be emphasised that the EU in the Green Deal recognises that the environmental resources, including air, water, and biodiversity, are under threat. Therefore, the EU would like to preserve and restore the natural environment to protect ecosystems, improve human health, and support the long-term sustainability of the planet.

The factors identified for the destruction of the environment by industrial usage are linked to energy – and therefore should be considerated also from an economical perspective. Burning fossil fuels emits large amounts of greenhouse gases such as carbon dioxide, methane and nitrous oxide, which contribute to global warming and climate change.[18] They can also cause air[19] and water pollution.[20] Burning fossil fuels releases toxic gases such as carbon monoxide, sulphur dioxide and nitrous oxide, which can harm human health and the environment. In addition, the exploration and production of fossil fuels can contaminate groundwater and soil.[21] Mentioned reasons have influenced on the EU decisions that renewable energy sources could be the potential, which provides a reliable and clean energy supply (see Fig. 2).

Figure 2. Percentage emission reductions of main air pollutants in 2021 compared with 2005 levels



Source: EEA, Percentage emission reductions of main air pollutants in 2021 compared with 2005 levels, https://www.eea.europa.eu/data-and-maps/figures/percentage-emission-reductions-of-main-2.

18 M. Tomala, "Monitorowanie jakości powietrza w Polsce w świetle koncepcji smart city," *Środkowoeuropejskie Studia Polityczne*, no. 1 (2023), p. 45.

19 M. Kampa, E. Castanas, "Human Health Effects of Air Pollution," *Environmental Pollution*, vol. 151, no. 2 (2008), pp. 362-367.

20 S. Pandey, "Water Pollution and Health," *Kathmandu University Medical Journal*, vol. 4, no. 1 (2006), pp. 128-134.

21 W. Bojar et al., "A Comprehensive Approach to Assess the Impact of Agricultural Production Factors on Selected Ecosystem Services in Poland," *Resources*, vol. 12, no. 9 (2023), pp. 1-19.

Transitioning away from fossil fuels and reducing emissions leads to improved air quality. This has significant health benefits, as poor air quality is a major public health concern in the EU. It should be noted that the effects of air pollution depend on the type and level of pollutants as well as the duration of exposure. Prolonged exposure to polluted air can lead to respiratory problems, including shortness of breath, cough, bronchitis, asthma[22], and many other diseases such as an increased risk of respiratory infections and a higher risk of cancer.[23] Furthermore, it affects children and pregnant women, who are particularly vulnerable to the effects of pollution.[24]

Transitioning to renewables not only contributes to climate goals but also ensures a stable and sustainable energy future. Reducing dependence on fossil fuels enhances energy security.[25] The EU's Green Deal seeks to diversify its energy sources and reduce reliance on imported fossil fuels, making it more resilient in the face of global energy market fluctuations and security. By using energy more efficiently, the EU can reduce the threat of dependency of the Russian Federation, which attacked the Ukraine in 2021.

Energy security has become a huge challenge for all the EU countries in the wake of Russian aggression and the outbreak of war in Ukraine. First of all, the European Union has been dependent on Russian gas supplies from Gazprom for many years. The conflict in Ukraine has raised concerns about the security of gas supplies, prompting the EU to seek alternative sources of gas supply and diversify energy sources.[26] Uncertainty about gas and oil supplies due to the conflict has contributed to rising energy prices in the EU. High energy prices can affect industry and households, increasing costs and financial burdens.

Moreover, strengthening energy infrastructure, especially in Eastern Europe, is becoming a key challenge. The conflict in Ukraine has introduced political tensions in the region, which may complicate international cooperation and energy negotiations. Ukraine has traditionally been an important transit country for Russian gas moving to the EU. The conflict has affected the security and reliability of gas supplies through Ukraine, leading to the search for alternative delivery routes. In light of the challenges related to supply security and energy source diversification, the EU needs to invest in expanding energy infrastructure, such as pipelines, LNG (liquefied natural gas) terminals[27], and renewable energy sources.

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[22] R. Pawankar, "Allergic Diseases and Asthma: A Global Public Health Concern and a Call to Action," *World Allergy Organization Journal*, vol. 7, no. 12 (2014).

[23] J.A. Bernstein et al., "Health Effects of Air Pollution," *Journal of Allergy and Clinical Immunology*, vol. 114, no. 5 (2004), pp. 1116-1123.

[24] M.J. Neidell, "Air Pollution, Health, and Socio-Economic Status: The Effect of Outdoor Air Quality on Childhood Asthma," *Journal of Health Economics*, vol. 23, no. 6 (2004), pp. 1209-1236.

[25] T. Młynarski, "Unia Europejska w procesie transformacji energetycznej," *Krakowskie Studia Międzynarodowe*, vol. 16, no. 1 (2019), pp. 31-44.

[26] P. Prisecaru, "The War in Ukraine and the Overhaul of EU Energy Security," *Global Economic Observer*, vol. 10, no. 1 (2022), pp. 16-25; M. Ruszel, "Wpływ rosyjsko-ukraińskich kryzysów gazowych na politykę energetyczną UE – ujęcie teoretyczne," *Przegląd Politologiczny*, no. 2 (2015), pp. 49-57.

[27] M. Ruszel, "Znaczenie terminali LNG na wspólnym rynku energii UE," *Polityka i Społeczeństwo*, vol. 12, no. 4 (2014), pp. 49-59.

The most important task for the EU countries is to sustain and strengthen sanctions against Russia. The EU has imposed sanctions against Russia in connection with its involvement in the conflict in Ukraine.[28] These sanctions can affect trade relations between the EU and Russia, which may have an impact on energy supplies. But norms and values such as: human rights and peace should be prioritised to the EU.

It is worth noting that the European Union is taking actions to minimise these threats by diversifying energy sources, developing new technologies, and promoting energy efficiency. However, the situation in the region remains a significant challenge for the energy sector in the EU.

HOW TO MANAGE THE ENERGY MARKET EFFECTIVELY?

This article assumes that renewable energy is a key factor in achieving the EU's greenhouse gas reduction targets. For cluster analysis, the critical issues are sample representativeness and collinearity.

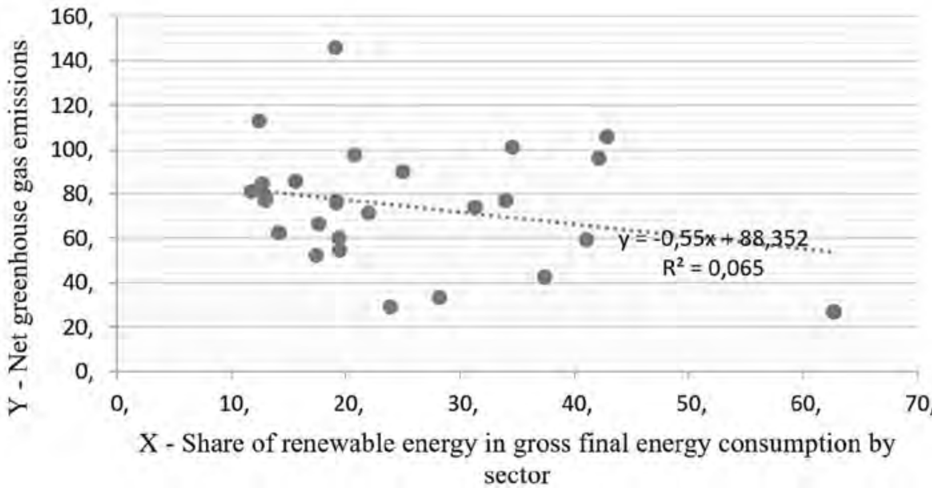
$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - f(x_i))^2}{\sum_{i=1}^{n}(x_i - mean(x))^2}$$

Lack of representativeness can lead to a biased cluster structure. In the present study, all possible units that were classified as European Union countries were included. Therefore, the study was conducted on 27 countries. Collinearity occurs when the independent variables are highly correlated with each other. In this case, the clustering pattern may also be unrealistic, as collinear variables may have a greater impact on similarity (distance) measures. Correlations between variables are presented in Tab. 3.

The value close to zero (-0.2886) indicates a low negative correlation between variables X and Y. This means that there is a certain reversal in the relationship between the values of X and Y: when one variable increases, the other tends to decrease, and vice versa. Nevertheless, the correlation is not strong, suggesting that these variables are not closely linked to each other. In summary, there is a certain negative correlation between X and Y, but it is not too strong. These values seem to be relatively independent, indicating that a change in one variable is not strongly associated with a simultaneous change in the other variable. The assumption of no strong correlation between variables, which was necessary for cluster analysis, has been met. But, on the other hand, the hypothesis about the correlation between X and Y could not be positively confirmed.

[28] M. Bělín, J. Hanousek, "Imposing Sanctions versus Posing in Sanctioners' Clothes: The EU Sanctions against Russia and the Russian Counter-Sanctions," in P.A.G. van Bergeijk (ed.), *Research Handbook on Economic Sanctions*, Massachusetts 2021, pp. 249-263; M. Tomala, M. Prokop, "Zagrożenia militarne i wojenne a bezpieczeństwo gospodarcze państwa. *Case study*: konflikt zbrojny między Ukrainą a Rosją w 2014 roku," *Annales Universitatis Paedagogicae Cracoviensis. Studia de Securitate*, vol. 11, no. 2 (2021), pp. 40-59.

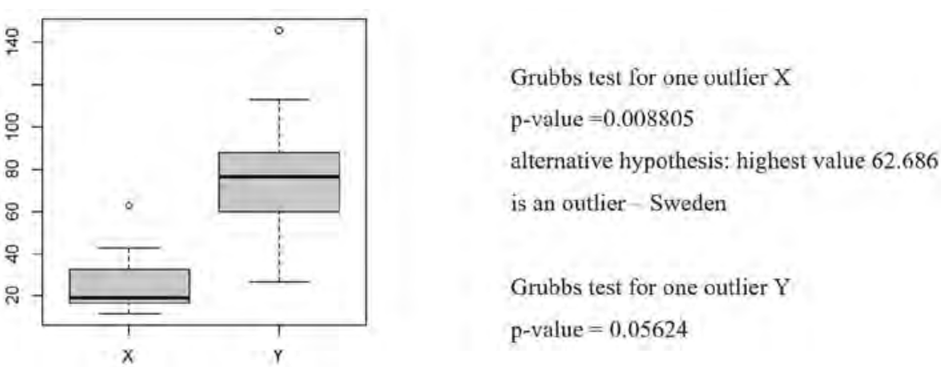
Figure 3. Corellation between X and Y



Source: Eurostat, Share of renewable energy in gross final energy consumption by sector, [online] https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en; Eurostat, Net greenhouse gas emissions, https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en.

Cluster analysis is also sensitive to the presence of outlier points. Box plots were used to detect outlier observations.

Figure 4. Boxplot of variables X and Y



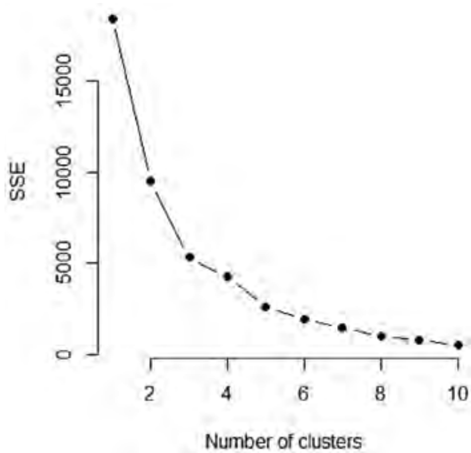
Source: Eurostat, Share of renewable energy in gross final energy consumption by sector, [online] https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en; Eurostat, Net greenhouse gas emissions, https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en.

Outliers in the data are observations that deviate significantly from the rest of the data set. They can provide valuable information about the distribution of the data and potential outliers. For the analysed variables, an outlier can be observed for Sweden. Grubbs test confirms that Sweden significantly exceeds the EU average in terms of the share of renewable energy in final gross energy consumption in various sectors. Sweden implemented an effective and ambitious energy policy, promoting the development and utilisation of renewable energy sources. Sweden has set a goal to achieve climate neutrality by 2045. This means that the country intends to balance greenhouse gas emissions through efforts to reduce emissions and increase the share of renewable energy (26.8). Motivation for a high share of renewable energy could also be driven by the goal of reducing greenhouse gas emissions and air pollution, aligning with sustainable development priorities.

Due to the low correlation between features and simultaneously considering the presence of individual outliers, the variables were subjected to a multivariate analysis to confirm or revise the initial hypotheses.

A chart showing the optimal number of clusters is presented below.

Figure 5. The optimal number of clusters



Source: Eurostat, Share of renewable energy in gross final energy consumption by sector, [online] https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en; Eurostat, Net greenhouse gas emissions, https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en.

This graph shows that the optimal number of clusters is five or six. After this number, the graph flattens out. This confirms the initial assumptions about the feasibility of building four clusters due to the two components. Tables 6 and 7 present the division into 5 and 6 clusters, in line with the mentioned theoretical assumptions.

On the basis of the analysis carried out, it can be concluded that there is a high degree of convergence regarding the groups formed. It should be noted that the leader of the list is Sweden, which achieves the best results in the analysed categories. Homogeneous groups are formed within clusters one, two and three. Cluster four, on the other hand, differs only by the affiliation of Slovenia, which forms part of cluster five when divided into six clusters. In the breakdown of the six clusters, Cyprus is the only country, which indicates unique values regarding the variables studied. On the one hand, it has the highest, among all EU countries, share of greenhouse gas emissions (145.7%) and a rather low share of renewable energy (19.069%). In addition, it should be noted that it is a small island state with a small population. The most numerous is the fourth cluster, which includes countries such as Belgium, Greece, France, Italy, Luxembourg, Malta, the Netherlands and Poland. The group is characterised by a low share of renewable energy in gross final energy consumption and average air pollution results. Group two, which includes Bulgaria, the Czech Republic, Germany, Hungary and Slovakia, performs better. They use more renewable energy, with lower emissions. Cluster five is quite diverse, with countries that use little renewable energy Ireland – 12.376%, as well as Latvia (42.098%) and Finland (42.854%), which have four times the level. All of these countries have high levels of CO_2 emissions. Estonia, Lithuania and Romania, which represent the first cluster, appear to be leaders in both renewable energy consumption and lowest CO_2 emissions. The third cluster with Denmark, Croatia and Portugal performs well. It performs better than cluster one in terms of renewable energy, but worse in terms of emissions.

Figure 6. Five clusters

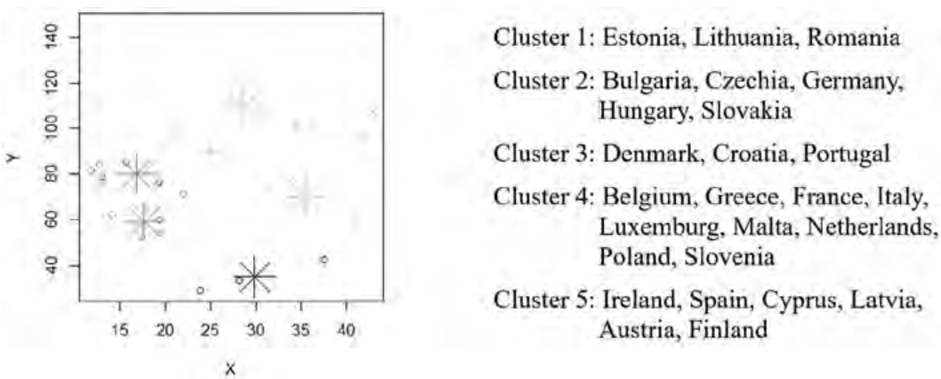
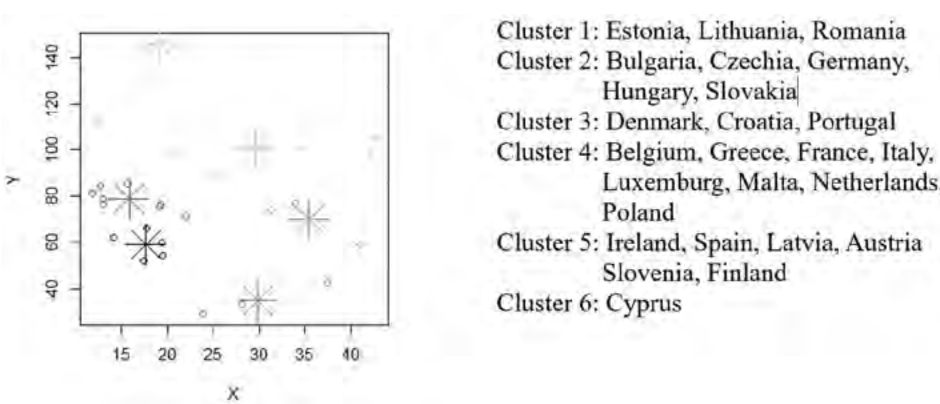


Figure 7. Six clusters



Source: Eurostat, Share of renewable energy in gross final energy consumption by sector, [online] https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en; Eurostat, Net greenhouse gas emissions, https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en.

Furthermore, it can be seen in the graph that countries grouped in cluster one, cluster two and cluster four are more correlated with each other. Indeed, the Pearson correlation in this groups of countries is -0.7275, indicating a strong correlation between the variables. Together, these three clusters cover 16 of the 27 EU countries. The basic statistics for the variables according to clusters for five group are presented below.

Table 1. Basic statistics of variables according to clusters

	Group	n	Mean	Sd	Median	Min	Max	skew	kurtosis
X	First	3	29.83	6.94	28.17	23.87	37.44	0.23	-2.33
	Second	5	17.61	2.16	17.67	14.13	19.45	-0,6	-1.46
	Third	3	35.43	5.02	33.98	31.28	41.01	0.26	-2.33
	Four	9	16.82	4.73	15.61	11.73	25	0.42	-1.52
	Five	6	28.62	12.94	27.65	12.38	42.85	-0.01	-2.07
Y	First	3	34.97	6.95	33.3	29	42.6	0.23	-2.33
	Second	5	59.08	5.77	60.2	52.2	66.3	-0.02	-2
	Third	3	70.07	9.45	73.9	59.3	77	-0.34	-2.33
	Four	9	80.09	5.8	78.9	71.5	90.1	0.26	-1.29
	Five	6	109.85	18.57	103.35	96.2	145.7	1.07	-0.6

Source: Eurostat, Share of renewable energy in gross final energy consumption by sector, [online] https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en; Eurostat, Net greenhouse gas emissions, https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en.

Analysing the data on the X-index of the share of renewables in final energy consumption, cluster three is the best performing cluster, while clusters two and four are the worst performing clusters. The average in cluster three, which includes only three countries, is twice as high as in clusters two and four, which include a total of 15 countries. The average in this respect is achieved by clusters one and five. It is worth noting that within cluster five the standard deviation is the highest, indicating a large variation in the variables. Analysis of the data shows that the best performers are Denmark, Croatia and Portugal, together with Sweden (which is shown as an outlier). The worst performers are the countries in clusters two and four, where the average (around 17%) is below the EU target of a 20% share of renewables in final energy consumption. The worst performers are Luxembourg, Malta, the Netherlands and Ireland (around 12%).

On the other hand, when analysing the Y-index data for CO_2 emissions, the best performing cluster is the first one. The emissions of Lithuania, Latvia and Romania are three times lower than those of cluster five. Cyprus is the worst performing country in terms of emissions. The countries in cluster three, which were leaders according to the X-index, underperform in terms of emissions. Countries in clusters one and two perform better. Cluster four is lagging behind the other countries in terms of emissions. This suggests that there are countries here that can be described as Green Deal plunderers.

CONCLUSIONS

The EU's decision to pursue the European Green Deal is driven by the urgent need to combat climate change, preserve the environment, create economic opportunities, enhance energy security, improve public health, and position the EU as a global leader in sustainable and clean technologies. It reflects a recognition that the transition to a more sustainable and green economy is not only a moral imperative but also an economic and strategic necessity for the European Union.

In summary, management in the renewable energy sector in the European Union is essential for planning, executing, and optimising projects, ensuring regulatory compliance, attracting investments, and contributing to the EU's sustainability and environmental objectives. It plays a central role in advancing the transition to a cleaner and more sustainable energy future in the EU.

For this reason, the weak correlation between the X and Y variables is of great importance. It means that countries are taking insufficient measures to reduce air pollution. However, there is a group of countries within the EU that are taking active measures within the analysed variables. As a result, within this group of countries, the correlation is strong and increasing renewable energy consumption has an impact on reducing CO_2 emissions. On the one hand, representatives of countries in clusters 4 and 3 should improve energy and environmental management. These countries should benefit from the experience and practice of actions that EU leaders are taking, including: Sweden, Denmark, Croatia and Portugal according to production of renewable energy, and Estonia, Lithuania and Romania according to CO_2 emissions.

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