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Article

Reliance on Russian Federation Energy Imports and Renewable Energy in the European Union

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RELIANCE ON RUSSIAN FEDERATION ENERGY IMPORTS AND RENEWABLE ENERGY IN THE EUROPEAN UNION

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Abstract

The paper investigates the importance of renewable energy in the energy mix of EU-27 countries, as well as their dependence on imports of gas, oil and petroleum products from the Russian Federation, considering the long-term energy security of the EU-27, as well as the objectives of the RePowerEU plan. The article divides EU countries into two groups using a clustering algorithm, revealing that Central and Eastern European countries share similar characteristics in terms of their reliance on Russian energy imports and energy mix, while Western European countries show significant variation between group members. Cluster analysis is complemented by an investigation using the Random forests methodology based on machine-learning algorithms, which highlights the importance of variables for grouping countries into clusters. Surprisingly, Eastern European countries have a higher proportion of renewable energy sources in their energy mix than most Western European countries, which could be attributed to their recent efforts to find alternatives to Russian energy imports. At the same time, the lack of interconnected infrastructure between EU member states is a significant contributor to the bloc's reliance on Russian Federation energy imports, as evidenced by cases in Finland, Bulgaria, and Hungary.

Keywords: import dependency, energy mix, renewable energy, cluster analysis, European Union, REPowerEU.

JEL Classification: Q20, Q30, C38, N54.

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Introduction

The beginning of 2022 placed the global economy in a breeze after going through a depressing scenario caused by the COVID-19 pandemic, but the Russian Federation's military aggression against Ukraine in February 2022 brings more critical circumstances compared to recent economic vibrations. The Ukraine conflict has caused a massive shock in the global energy system, resulting in security concerns and economic uncertainty, as well as hyperacute price pressure in Europe. In addition to unsteady trade and investment, financial sanctions imposed by European countries and the United States (such as the removal of the Russian Federation from the SWIFT system) have caused inconsistency in the international financial system. Furthermore, because of the trade and investment links within the global economic system, the spillover effects of the conflict were felt in other major economies. Asia, for example, is still vulnerable to geopolitical tensions, particularly with respect to trade and oil and commodity prices, despite being on the bright side from a macroeconomic point of view (Morgan Stanley, 2022).

The energy interdependence between the European Union (EU) and the Russian Federation (RF) has long been a key element in their trade relations. The decline in fossil energy reserves in the EU, as well as the fight against climate change, have transformed RF into a major energy supplier, which puts Europe in the trap of relying a considerable amount on the natural gas and oil supply of RF. In 2021, two-fifths of the gas burnt by Europeans and more than a quarter of the crude oil imported by the EU came from RF. In the mineral fuel imports of the 27 EU countries, RF represented approximately 62% (98.9 billion EUR) in 2021 (World Economic Forum, 2022).

Natural gas burns cleaner and emits less carbon dioxide than other fossil fuels, leading to increased use in the EU and increased imports from Russia (Solanko and Sutela, 2009). The common action to accelerate the clean energy transition began in the 1990s, when EU countries implemented various environmental taxation schemes, and later in 2005, with the implementation of the greenhouse gas emissions trading scheme (The Official Journal of the European Union, 2003). The EU decided to continue this initiative with the European Green Deal (2019), in which it proposed making Europe the first climate-neutral continent by 2050 and ensuring a transition to a cleaner energy system based on renewable sources (European Commission, 2019). The war in Ukraine demonstrated the imperious need to find a solution to the EU's dependence on RF energy imports, which required significant efforts to build an energy union and implicitly a more resilient energy system. Due to the armed conflict, the EU has taken the first step of phasing out Russian fossil fuel imports. The European Commission's REPowerEU Plan, published in May 2022, supplemented the "Fit for 55" package of solutions by proposing an additional set of actions aimed at transforming the EU's energy system (European Commission, 2023).

Existing literature concludes that supply diversification is the best way to incorporate renewable energy sources into the energy mix (Lau et al., 2018; Saidi and Omri, 2020; Azam et al., 2021; Horobet et al., 2022a) and to reduce RF's dependence on oil and natural gas imports (Keohane and Nye, 1977). However, the war in Ukraine significantly altered the geopolitical context, forcing EU countries to act quickly in order to cover existing energy demand (in the short term), as well as design new energy policies to ensure a robust and diverse energy mix (in the long term). Moving away from energy imports, the long-term impact of sanctions imposed on RF may be less significant for some larger European economies, such as Germany or France, where Russia accounts for between 1% and 2% of

total exports, but other countries, such as those in Central and Eastern Europe, may be much more vulnerable to trade frictions resulting from the conflict (KPMG, 2022).

However, we do not find studies that address in detail the structure of energy systems in EU countries, as well as their level of dependence on Russian fossil fuels. The present study complements the results of the literature, which are limited to the diversification of the supply and the incorporation of renewable energy sources, through the very analysis of the energy structure of the member countries. Furthermore, with the invasion of Ukraine by the Russian Federation, the geopolitical and economic context has changed substantially. Therefore, more research is needed, which considers both the immediate goal of energy supply and the long-term goal of decarbonisation, which will also enable Europe to end its dependence on Russian oil and gas. Therefore, we can ask whether it is more difficult for EU countries to restructure their energy systems due to easy access to cheap fuels from the Russian Federation. Also, what are the similarities and differences between the EU countries in terms of their dependence on Russian oil and gas imports? Finally, rather than having a dramatic impact on the transition trajectory or how the EU will achieve its climate goals, the situation in Ukraine is likely to jump-start renewable energy projects and the shift to more sustainable fuels. This study seeks pertinent answers to all of these questions and attempts to delve into the dependence of EU countries on the Russian Federation on energy and the importance of fossil fuels and renewable energy sources in the energy mix. The research methodology used is based on clustering algorithms to group the EU-27 countries in the period 2015-2020 based on a set of relevant variables, supplemented by an investigation using the Random forests methodology with the aim of identifying the importance of the variables used to group countries into clusters. The findings of this analysis can aid in gaining a more detailed understanding of the structure of the energy system of EU countries and in developing a more resilient energy system. Therefore, the results obtained can be considered in the generation of the suite of strategies and legislative packages that government institutions can take in terms of the recovery and resilience process by developing common European actions and strategies for the security of the energy supply.

The structure of the paper is organized according to the following coordinates: the first section summarizes the most important results from the literature. The second section presents the data and research methodology. The most important results are highlighted and discussed in the third section, while the conclusions outline the policy implications of the findings as well as future research directions.

1. Literature review

Policymakers have long been concerned about the EU's reliance on oil and gas imports from RF, and recent developments have heightened their concern. According to Eurostat data for the third quarter of 2022, energy imports represented 26% of the total import value in the EU, with petroleum oils (56%) and natural gas in the gaseous state (24%) accounting for the majority of the value (Eurostat, 2023). RF remains one of the EU's most important energy providers, despite reduced energy imports. In this framework, the recent literature emphasises two main aspects: the relationship between renewable energy, carbon dioxide emissions, and economic development; and the energy-environmental policy strategies adopted at the EU level.

The vulnerability of the EU's energy supply, the priority given to energy over other capabilities, and the willingness to use energy to achieve foreign policy objectives all shape the EU's energy relationship with the RF. According to Casier (2011), energy is the most influential factor in determining EU-RF relations. Using the EPPA model, Paltsev's (2014) research suggested that natural gas will continue to play a significant role in Russian exports over the next 20 to 40 years.

Despite an increase in liquefied natural gas (LNG) imports, the EU still relies heavily on oil and gas imports from RF. Studies suggested that disrupting them could severely affect some EU countries, particularly those in Eastern Europe, with an estimated general increase in prices by 20% in the first year of the disruption (Egging et al., 2008; Huppmann et al., 2011; Richter and Holz, 2015). Therefore, reducing its dependence on traditional energy sources and fostering energy diversification are crucial for the EU to achieve energy security and meet its carbon reduction targets.

The EU's reliance on fossil fuels from the RF complicates its transition to a low-carbon economy. The European Commission (2020) has identified carbon neutrality as a key priority, with the goal of achieving it by 2050. The introduction of the Renewable Energy Directive (2009/28/EC) in 2009 resulted in a consistent increase in renewable energy deployment, which reached more than 22% by 2020. However, to accelerate the adoption of renewables in the EU, including by expediting permitting processes for their deployment, the proposed revision and the REPowerEU plan were presented in May 2022. Both took into account the ongoing conflict in Ukraine, which caused a significant disruption in Russia's energy exports (European Commission, 2022).

However, achieving carbon neutrality by 2050 will be difficult as long as the EU is dependent on RF energy. To address this issue, the energy sources of the EU must be diversified. The EU already imports oil and gas from other countries, such as Norway and Algeria, according to Söderbergh et al. (2010). Increased supplier diversity and diversification of energy sources could help reduce the EU's dependence on Russian energy. Renewable energy and energy efficiency measures can also help the EU reduce its reliance on Russian oil and gas. Selei et al. (2017) show, using a European Gas Market Model, that implementing policies such as renewable energy, energy efficiency, and gas market interventions could result in cost savings ranging from 32% to 37% for the EU-28 (including the UK, an EU member at the time) by 2030. Furthermore, Dogan and Seker (2016) discovered that reducing the use of non-renewable energy would not have a negative impact on the EU's real income, indicating that policies aimed at reducing non-renewable energy consumption can be implemented without a hurtful impact on GDP.

Horobet et al. (2021) conducted a study on the relationship between energy consumption, energy mix, and economic growth in 24 EU countries from 1995-2018. The authors found that there is a directional relationship between the share of low-carbon energy sources in total energy consumption and CO₂ emissions, as well as between the share of low-carbon energy sources in total energy consumption and GDP per capita. In contrast, Mukhtarov et al. (2023) found that increasing real production can only be achieved by using more energy, which consequently increases CO₂ emissions. They argue that countries with direct access to natural resources prefer to use oil and gas reserves to generate energy because it is more affordable than renewable energy sources. On the contrary, it is crucial to diversify the energy supply to include nuclear and renewable sources, not only to reduce the dependence of EU countries' vulnerability (Keohane and Nye, 1977) to RF imports, but also to address global

environmental degradation (Lau et al. 2018; Saidi and Omri, 2020; Azam et al., 2021; Horobet et al., 2022a; Horobet et al., 2022b). This is in line with the close relationship between CO₂ emissions, total energy consumption and energy mix (Rehman et al., 2022).

The adoption of renewable energy depends on the policy mix, which can be contentious due to conflicting interests among different actors. Some studies have found that decentralization is a more contentious issue than renewables, as it has the potential to disrupt the business of incumbent actors (Markard and Truffer, 2006; Berggren, 2015; Austvik, 2016; Lindberg et al., 2018). The literature on policy mix emphasizes the need for a comprehensive set of policies to achieve net-zero emissions, with these mixes fulfilling critical transition functions. One such function is to decouple greenhouse gas emissions from economic growth by aligning policies that encourage technological advancements. The driving forces behind this approach vary across different phases and issues, with policies being mainly driven by either EU institutions or member states. As climate and energy policies have advanced and energy security is at risk, policy feedback from implementation experiences has emerged as a crucial mechanism for shaping member-state preferences (Skjærseth, 2021).

Based on the prior findings of the literature, our study aims to investigate the importance of dependence on oil and gas imports from RF, the use of renewable energy sources and the energy mix for the EU-27 countries. The research is based on two hypotheses. The first hypothesis considers that it is more difficult for EU countries to restructure their energy systems due to easy access to cheap fuels from the Russian Federation, given that infrastructure, especially gas distribution pipelines, plays a crucial role in achieving energy independence regarding imports from Russia. We also try to find similarities and differences between EU countries in terms of their dependence on Russian oil and gas imports. The second hypothesis assumes that a greater importance of renewable energy sources is associated (but not necessarily in a cause-effect relationship) with increased energy independence from RF imports.

2. Research methodology

Current research analyses the importance of fossil fuels (oil and gas) and renewable energy sources in the energy mix in EU countries, as well as their dependence on RF. All EU-27 countries were included in the analysis, which covers the period 2015-2020. The time span is limited by the available data on the energy dependence of EU countries on the RF. Data was collected from Eurostat with an annual frequency. All variables are presented in Table no. 1.

The research methodology in this paper is based on clustering algorithms, which are widely used in economic and energy studies. Specifically, a tree clustering algorithm is used to group EU countries based on the variables listed above. The tree clustering algorithm is based on the Classification and Regression Trees (C&RT) methodology, proposed by Breiman et al. (1984). This forms the clusters iteratively and arranges the cases (countries in our case) in a heat map that takes into account the variables included in the algorithm. The grouping (clustering) takes into account their similarities and differences in terms of dependence on Russian imports of oil, petroleum products, and natural gas, as well as their energy mix, which is represented by the share of oil and natural gas in final energy consumption, as well as the share of renewables in final energy consumption. The algorithm also includes the overall dependence of EU countries on energy imports, as well as their final energy

consumption and energy productivity, in the list of variables. The final energy consumption measures the total amount of energy consumed by EU countries, while energy productivity measures how efficiently this energy is used to produce goods and services.

Table no. 1. Variables used in the analysis

Variable	Acronym	Definition and measurement	Measure
Import dependence of oil and petroleum products from Russia	OILDR	Percentage of the total supply of oil and petroleum products (production plus imports minus exports)	Percentage (%)
Natural gas import dependency from Russia	GASDR	Percentage of total natural gas supply (production plus imports minus exports)	Percentage (%)
Energy import dependency - all products	ENGDR	Share of total energy needs of a country met by imports from other countries. Calculated as net imports divided by the gross available energy.	Percentage (%)
Final energy consumption	ENGCONS	Sum of the consumption in industry (excluding the energy sector), transport, buildings (residential and services) and agriculture, excluding the fuels used for power generation by autoproducers.	Million tonnes of oil equivalent (Mtoe)
Energy productivity	EP	The amount of economic output produced per unit of gross available energy. Gross available energy represents the quantity of energy products necessary to satisfy all the demands of entities in the geographical area under consideration.	Euro per kilogram of oil equivalent (KGOE)
Share of oil in final energy consumption	OILW	Share of oil and petroleum products (excluding biofuels) in final consumption - energy use	Percentage (%)
Share of natural gas in final energy consumption	GASW	Share of natural gas in final consumption - energy use	Percentage (%)
Share of renewables in final energy consumption	RENEW	Share of renewables and biofuels in final consumption - energy use	Percentage (%)

Note: The definitions in the table are provided by Eurostat.

The variables are introduced into the clustering algorithm using both their mean and trend (the latter denoted by “_T” at the end of the variable notation) from 2015 to 2020, capturing both the level and the changes over time. For each variable, the trend values were calculated as the slope of a time regression. All data were standardized to create clusters; this is a normal adjustment when working with clusters (Milligan and Cooper, 1998; Milligan and Hirtle, 2003). Euclidean distances and the Ward amalgamation method are used to determine the positions of the countries in the clusters. Both are some of the most used parameters used in statistical clustering. The Euclidean distance is calculated as in Equation (1), as the geometric

distance between variables X and Y in a multidimensional space, where i denotes the particular case (countries, in our case) for which the distance is calculated.

$$\text{Distance}(X,Y)=\{\sum_i (X_i-Y_i)^2\}^{1/2} \quad (1)$$

The Ward method generates clusters, so that variance within the cluster is minimized. For each cluster, the means for all variables are calculated. Then, for each object (country, in our case), the squared Euclidean distance to the group means is calculated, and these distances are then summed across all objects. In each clustering step, the two clusters that have the smallest increase in the sum of squares within the cluster distances are combined. Analysis of variance (ANOVA) is used in Ward amalgamation to establish the distance between clusters by minimizing the sum of squares (SS) of any clusters that are generated at each iteration of the algorithm (Murtagh and Legendre, 2014).

The optimal number of clusters for the dataset was determined using both the visual inspection of the resulting clustering dendrogram and the Pseudo F Index (Calinski and Harabasz, 1974). The latter is the ratio of the variance between clusters (calculated as the between-group SS) and the variance within cluster (calculated as the within group SS), as described in Equation (2):

$$\text{Pseudo F} = \frac{\text{GSS}/(k-1)}{\text{WSS}/(n-k)} \quad (2)$$

where n denotes the number of observations in the dataset and k is the number of clusters formed in each step of the algorithm (see also Horobet et al., 2020).

The importance of the variables included in the association algorithm, for the presence of the EU-27 countries in clusters, is highlighted by a Random forests type analysis, based on machine-learning, proposed by Breiman (2001) and recognized in the literature as offering superior results to linear and logistic regression (Biua, 2012; Couronné et al., 2018). The method generates a set of decision trees that show the predictive power of a set of independent variables on a continuous or categorical dependent variable. In our case, the dependent variable is represented by the number of the cluster in which a certain country is found - being a categorical variable -, and the independent variables are those presented in Table no. 1.

3. Results and discussion

Table no. 2 provides a brief statistical summary of the variables used in the study. The EU-27 nations are heavily dependent on energy imports, with Italy being the most susceptible to volatility in energy prices, due to its 85% dependence on imports, followed by Lithuania (84%) and Malta (82%). Despite their high import dependency, these countries rely relatively less on Russian imports compared to Sweden, Finland, and Slovakia. The energy mix varies between EU countries, with Sweden, Latvia, and Finland having more than 25% of their energy mix sourced from renewable energy. On the contrary, the Netherlands has only an average of 3.7% share, with Ireland (4%) and Luxembourg (4.5%) ranking low as well. The trend for energy consumption in the EU is negative, indicating that countries are trying to reduce consumption, while there is a declining trend for fossil fuels in the energy mix.

Figure no. 1 shows the relationship between dependence on RF oil and oil products and the share of renewable energy sources in the energy mix of EU countries, as mean, between 2015

and 2020. At the sample level, the correlation is positive and statistically significant. Therefore, higher levels of dependence on Russian oil and petroleum products have led to concern for the development of renewable energy sources. For some countries, the findings are thought-provoking: Finland, for example, despite having a substantial amount of renewable energy sources similar to Sweden, relies significantly on energy imports from RF. This outlier is explained by considering that Sweden primarily obtains its fossil fuels from Denmark through the Baltic Gas Connector (gas) and Saudi Arabia (oil), whereas Finland was previously disconnected from the EU gas market until the opening of the Balti connector pipeline in 2020. On the other hand, countries like Ireland and Malta assign a minor proportion to renewable energy sources but do not exhibit significant reliance on Russian oil. The rationale behind this is that Malta, with only 0.62 Mtoe, has the lowest energy consumption among EU countries, while Ireland consumes only 11.8 Mtoe. These figures are significantly lower than those of Germany or France, with an average consumption of more than 200 Mtoe.

Table no. 2. Descriptive statistics of variables

	Mean	Median	Minimum	Maximum	Standard deviation
OILDR	36.652	33.530	7.870	82.130	23.436
OILDR_T	-1.353	-0.920	-9.150	2.500	2.065
GASDR	49.903	52.730	0.000	100.000	38.892
GASDR_T	-0.354	0.000	-7.020	8.420	3.213
ENGDR	56.607	56.480	30.010	85.020	17.036
ENGDR_T	0.005	0.460	-14.225	15.558	8.218
ENGCONS	35.849	16.290	0.620	213.340	50.038
ENGCONS_T	-0.243	0.000	-3.100	1.990	0.884
EP	7.259	6.420	2.330	18.190	3.576
EP_T	0.191	0.130	-0.040	1.280	0.238
OILW	39.075	35.750	23.020	62.190	10.386
OILW_T	-0.280	-0.410	-1.800	0.830	0.608
GASW	16.042	16.060	0.000	38.580	10.105
GASW_T	0.037	0.060	-0.620	0.440	0.243
RENEW	12.544	11.480	3.690	25.880	6.291
RENEW_T	0.357	0.280	-0.510	1.360	0.447

When it comes to dependence on natural gas from RF, this is a very different issue from the supply of other fossil energy sources. Gas storage is very expensive, and therefore many countries are forced to depend heavily on Russian natural gas. The graph on the right side of Figure no. 1 shows the relationship between the share of renewable energy sources in the energy mix of EU countries, but with dependence on RF natural gas, as a mean, over the period 2015-2020. Again, the correlation is positively and statistically significant at the sample level, illustrating that dependence on natural gas in the Russian Federation goes hand in hand with the increase in renewable energy sources. However, in most EU countries, the dependence on RF natural gas increased considerably during this period. The exceptions are

Sweden, Portugal and Austria, which have seen above-average shares of renewable energy sources in the energy mix and low values in terms of dependence on natural gas.

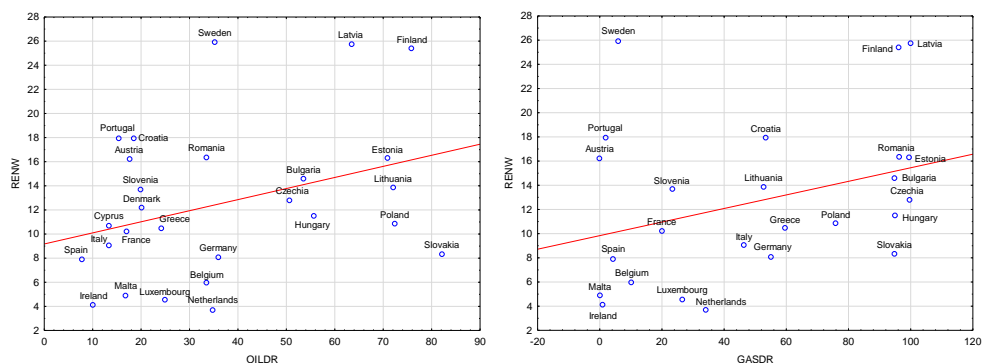


Figure no. 1. Share of renewable sources in the energy mix and dependence on oil and petroleum products (left) and natural gas (right) from the Russian Federation, countries in the EU, means of 2015-2020

Source: Authors' calculations and representation in Statistica 17.0

Figure no. 2 shows the results of applying the iterative clustering algorithm, which includes the averages and evolution trends of the variables presented in Table no. 1 in the period 2015-2020 for all EU-27 countries. In the algorithm used, the countries were grouped into clusters taking into account the Euclidean distances calculated for the variables used, by the Ward method. The dendrogram in the right part of Figure no. 2 and the values of the Pseudo F statistics for 2 versus 3 clusters were examined to determine the number of clusters generated. The inspection of the dendrogram reveals two major clusters, which is confirmed by the Pseudo F statistics: 8.115 for two clusters and 6.16 for three clusters.

The amalgamation schedule (not presented, but available from the authors) shows that Austria and Portugal are the most similar EU countries based on the variables included in our dataset (distance of 1.409), followed by the Belgium-Spain pair (distance of 1.627) and the Czechia-Romania pair (distance of 1.711). On the other hand, the most dissimilar countries are Belgium and Bulgaria (distance of 10.007) and Belgium and Germany (distance of 6.149). Regarding the Austria and Portugal pair, they have a comparable level of dependence on energy imports, at approximately 52%, with minimal reliance on Russian gas (Austria does not import and Portugal has an average dependence of 2% between 2015 and 2020). For Russian oil imports, both countries have a low share below 20%. Although there are variations in energy consumption, its energy mix is quite similar, utilizing renewable energy on average 17%, with the remainder sourced from fossil fuels. On the contrary, Romania and Bulgaria are heavily dependent on Russian energy imports, particularly gas, with imports from the Russian Federation accounting for more than 95% of their gas imports during the evaluated period, although the share of renewable energy is consistent in the energy mix. Furthermore, both countries have a relatively low level of dependence on overall energy imports, with less than 40% of their required energy being imported. The reason behind the two countries' reliance on Russian imports is attributed to the lack of infrastructure. But recently, Hungary, Greece, Bulgaria and Romania signed a Memorandum of Understanding for the development of the Vertical Corridor, which is expected to facilitate the bidirectional flow of gas from the South to the North (Kountantou, 2022).

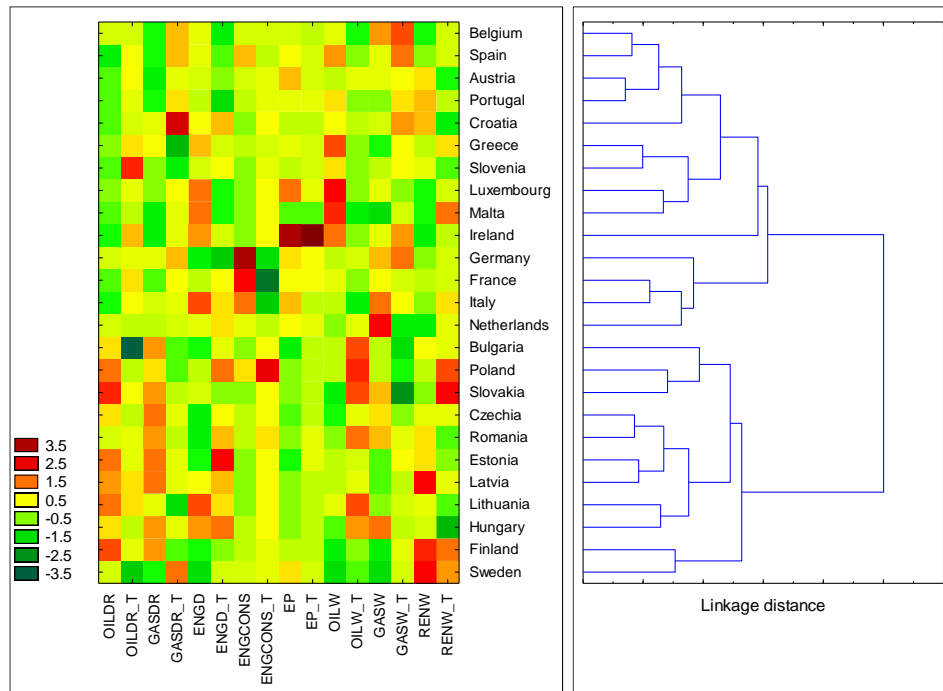


Figure no. 2. Heat map (left) and dendrogram (right) for EU countries, 2015-2020

The two clusters are observed in Figure no. 2 point towards a rather East-West grouping of EU countries. Thus, Cluster 1 (above in Figure no. 2) includes 14 Western EU countries, only Slovenia and Malta representing newer additions to the EU in 2004, and Croatia in 2015. On the other hand, Cluster 2 (below in Figure no. 2) includes mostly Eastern EU countries, with the notable exceptions of Sweden and Finland. Cluster 2 comprises countries with a significant reliance on Russian energy imports, primarily gas, due to the lack of infrastructure development to diversify import sources. Finland is part of this cluster due to its heavy dependence on Russian gas and oil imports, accounting for 95% and 75% respectively, while Sweden's import dependence is relatively low, both sharing similar characteristics to Eastern EU countries. However, all Cluster 2 countries, except Hungary, have notably increased their use of renewable energy between 2015 and 2020. Furthermore, these countries exhibit lower energy efficiency, with an average of 4.3 KGOE, compared to Cluster 1, which demonstrates higher energy efficiency with an output of 9 KGOE.

The characteristics of these clusters are further revealed by the heat map presented in the left part of Figure no. 2. Countries included in Cluster 1 are less dependent than those in Cluster 2 on oil and gas imports from the Russian Federation, on average (20.74% dependency for oil and 24.02% dependency for gas, against 60.52% and 82.84% respectively), but their overall dependence on energy on imports from foreign countries is higher (62.60% versus 49.35% for countries in Cluster 2).

Cluster 2 has relatively low variance between the selected variables. The variables in the energy mix (OILW, GASW, RENW) exhibit low variance, indicating that the proportions of

fossil fuels and renewable energy sources are similar between these countries. In contrast, Cluster 1 shows greater variability in terms of the energy mix between countries. Additionally, we can see a significant variance in energy consumption among Cluster 1 countries, with Malta having the lowest average consumption of 0.62 Mtoe and Germany having the highest consumption of 213.3 Mtoe. This difference can be explained by its social and economic environment. While Malta is a small country with a tourism sector as its main contributor to GDP, Germany's economy is partially driven by the industrial sector, which requires high energy consumption. Furthermore, the variance in energy consumption is also linked to the variability in dependence on Russian imports. For example, Austria has achieved complete independence (its main source of gas is LNG from Norway), and Denmark and Germany have more than 50% dependence on Russian imports.

Regarding the characteristics of clusters related to trends in variables, the low variance between trends in Cluster 2 indicates that changes in energy import dependence among Eastern European countries were relatively similar between countries. However, in Cluster 1, there is considerable variation in the trends in overall dependence on energy imports among western European countries. Germany, for example, exhibits a strong negative trend, with a significant reduction in its dependence on energy imports during the 5-year period, which is associated with a decrease in total energy consumption. However, its use of renewable energy still lags behind the EU-27 average, standing at 8.7% compared to 12.4%. This is also true for most of the other countries in Cluster 1. In contrast, Belgium and Spain show an increase in their imports and a positive trend for both gas and oil dependency on Russian imports.

Figure no. 3 graphically presents the importance of the variables based on which the distribution of countries into clusters was carried out, referring to the most important one (which has a score of 100), using the Random forests methodology. It is important to note that the values presented in Figure no. 3 should not be interpreted as regression coefficients, but as a representation of the hierarchy of independent variables from the perspective of the countries' cluster membership, always in reference to the most important variable, which receives 1 as a value or score. We observe that the most important variables for clustering countries are OILDR (1,000) and GADR (100), indicating that the dependence of the EU-27 countries on Russian fossil fuel is the most important determinant of their clustering. Furthermore, the evolution of the share of oil in the energy mix over time, given by OIL_T, is of high importance (0.837), together with the energy productivity EP and the share of oil in the energy mix OILW, both with a score of 0.809. Overall, mean-type variables have higher mean cumulative importance than trend-type variables (0.616 versus 0.467) for clustering.

To better illustrate the differences between the clusters in terms of the variables used, Figure no. 4 graphically represents the mean values of the variables for each cluster. Due to the different units of measurement, the mean variables are plotted on the left graph, while the trend variables are plotted on the right graph. The graphs show that the countries in the second cluster had, on average, over the period 2015-2020, a much higher dependence on Russia for fossil fuel compared to the countries in the first cluster, despite a lower dependence on energy imports and a lower importance of fossil fuels and slightly higher renewable energy in the energy mix. Regarding the trends of the variables, the positive trend of energy dependence on imports has a higher average value in the second cluster, but the countries in the first cluster had higher trends than those in the second cluster in terms of dependence on Russian

oil (although the trend is negative), but also on gas coming from the same country (this time, however, the average trend is slightly positive for cluster 1, but negative for cluster 2).

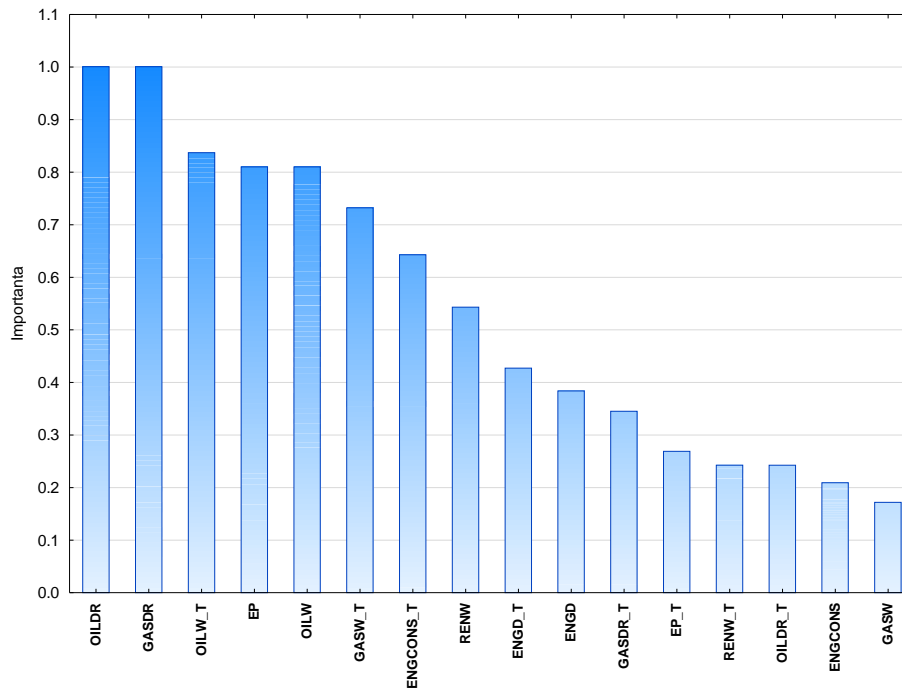


Figure no. 3. Importance of variables for cluster formation

Source: Authors' calculations and representation in Statistica 17.0

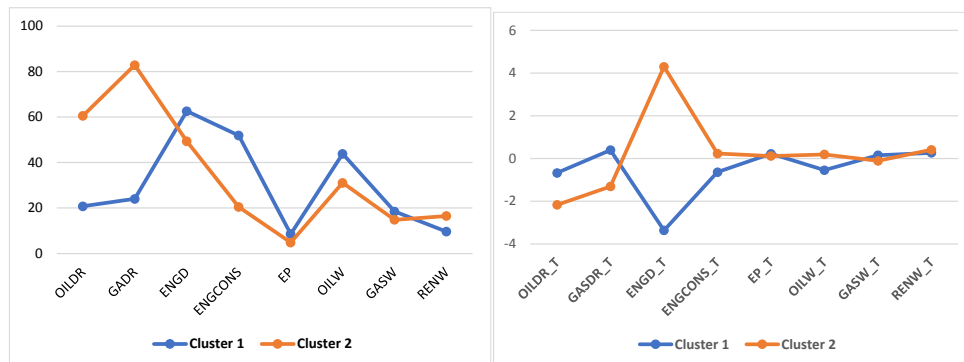


Figure no. 4. Average values of the variables for the clusters

Source: Authors' calculations and representation

In general, the correlation between dependence on oil and oil products in the Russian Federation and the share of renewable sources in the energy mix of EU countries was higher for most EU countries in 2015-2020. As a general trend, most EU economies have seen decreases in dependence on Russian oil, most likely because they had sufficient sources of

oil supply and the availability of this source domestically in the EU. All this is in line with other results in the literature that diversification of energy sources and increased supply sources could contribute to reducing dependence on Russian energy (Selei et al., 2017)).

But when we consider the share of renewable energy sources in the energy mix compared to oil dependence, increases are observed, especially in Sweden, Finland or the Netherlands, which can most likely be due to the favourable climatic conditions in these countries. The elements of surprise are Cyprus and Malta, or Slovakia and Poland. According to the International Trade Administration (ITA), to ensure the green transition of Cyprus through the reforms and investments needed to achieve climate goals, the Government of the Republic of Cyprus has allocated 41% of its \$1.2 billion funds to the Recovery and Resilience Plan (PRP). Cyprus produces 157.5 MW of electricity from wind, 317.8 MW of solar and 14.1 MW of biomass sources. Also, in 2014 the Turkish Cypriot Community adopted the "Renewable Energy Resources Law" through which it set the objective of reducing the use of fossil fuels and increasing the capacity of alternative energy use (ITA, 2022). Malta is following the example of Cyprus, generating 12.15% of its energy needs from renewable sources at the end of 2021. Investments to develop facilities that can provide clean energy are estimated at around €30 million for Malta's energy sector (The Star, 2023). The Slovak market also offers good opportunities for electricity and heat production. In 2019, approximately 54.7% of the total production of 27,149 GWh of electricity in Slovakia was obtained from nuclear power plants. The geothermal potential in Slovakia could be a great addition to the total domestic energy production with around 6,300 GWh per year. In 2019, 21% of the total electricity production in Slovakia came from conventional power plants, 14.4% from hydropower plants, and only 8.9% from renewable sources, but the greatest technical potential is expected to come from biomass, which could account for approximately 40% of Slovakia's total domestic energy production (ITA, 2020).

These evolutions suggest that EU countries have taken the path of increasing the presence of renewable energy sources in the energy mix, and this trend seems to be evident in the Central-Eastern part of the EU as well, even if the levels differ from one country to another. In this way, the results obtained confirm our hypothesis that the allocation of increased importance to renewable energy sources is associated with energy independence regarding the imports from the Russian Federation. Numerous authors have also revealed that renewable energies and energy efficiency measures represent an optimal solution to reduce the EU's dependence on Russian oil and natural gas (Selei et al., 2017; Dogan and Seker, 2016).

When it comes to the trend of dependence on natural gas from RF relative to the trend of the share of renewable sources in the energy mix for EU countries, the scenario unfolds differently. Gas storage is very expensive, with few necessary facilities available and therefore many countries are forced to heavily depend on Russian natural gas. For example, the Baltic countries, which do not have gas storage facilities but only have direct access to the RF pipelines, are highly dependent on gas imports from the Russian Federation. The results of this analysis are therefore consistent with those obtained by Solanko and Sutela (2009) or Mukhatarov et al. (2023). Therefore, we answer our question about the difficulty for EU countries to restructure their energy systems as a result of easy access to cheap fuels from the Russian Federation, taking into account the crucial importance of distribution infrastructure. Moreover, Finland has seen increases in both its dependence on Russian natural gas and the share of renewable energy in the energy mix. Meanwhile, while Finland is highly dependent on Russian imports, its overall dependence on energy imports remained

at an average of 35% during the five-year period. It is one of the most industrialized nations in the EU and beyond, having a very high energy consumption, and therefore, its energy needs are considerable due to the cold climate and high standard of living. The key vector in terms of the electricity generated in the country is nuclear power. Finland has four nuclear reactors that have provided 32.9% (22.7 TWh) of its total energy and will also build small modular reactors (SMR) as potential options to develop clean energy production, both for domestic use in Finland, and for the export of SMR projects globally (International Trade Administration, 2020). At the same time, Finland is one of the leading countries in the world in terms of the use of renewable energy sources, particularly bioenergy. According to ITA, despite a 6% drop in total energy consumption in 2019, which was 1.28 million terajoules (TJ) in 2020, renewable energy production increased, accounting for 44.6% of total final energy consumption (International Trade Administration, 2020).

Conclusions

Although with an unclear outcome yet, the conflict in Ukraine has brought Europe to the point where it must urgently reduce its energy dependence on Russian fossil fuels, taking into account the economic stagnation and the increase in inflation worldwide, but also the objective of combating climate change and the transition to cleaner energy.

The purpose of this study was to analyse the structure of the energy system of the EU-27 and connect it to the extent of their reliance on fossil fuels from RF. To achieve this, a clustering algorithm was used to group EU countries and explore similarities and differences in terms of their dependence on RF imports of oil, petroleum products and natural gas, as well as their energy mix. The study covers the period of 2015 to 2020. Compared to previous studies in the literature (Skjærseth, 2021; Söderbergh et al., 2010) the results of this paper show that although some countries have a high share of renewable energy in the energy mix, there is still a substantial dependence on energy imports from the Russian Federation.

The findings suggest that many Eastern European countries have a greater share of renewable energy sources in their energy mix compared to Western European countries. This may be due to the fact that countries heavily reliant on Russian energy imports have been striving to find alternative solutions in recent years, using renewable resources, including wind, solar, water and geothermal sources. On the contrary, western countries have been slow to develop renewable energy sources. However, most EU countries have been increasing the share of renewable energy sources in their energy mix, including smaller EU countries and emerging economies that used to be heavily dependent on Russian fossil fuels. For example, Cyprus, Malta, Slovakia, and Poland have set goals to reduce their dependence on fossil fuels and increase the use of alternative energy sources. Despite this, EU countries continue to rely heavily on Russian natural gas for economic and infrastructure reasons and because natural gas has a lower carbon dioxide emission rate. However, some countries have managed to increase their production from renewable energy sources, even as imports of Russian fossil fuels have increased significantly.

Thus, the present study has implications both for political decision-makers, energy consumers and economic agents in the energy sector. These findings emphasise the need for policies and strategies aimed at building a resilient energy system and phasing out Russian fossil fuel imports in favour of renewable energy sources, as part of the EU's efforts to establish an energy union that provides clean and affordable energy to its citizens. On the

other hand, it has been shown that the lack of interconnecting infrastructure (pipelines) among EU member states is a significant factor contributing to the EU's reliance on Russian imports. This was evident in the Finnish, Bulgarian, and Hungarian cases. So, there needs to be an awareness that the transition to renewable energy is gradual, and in the short to medium term, energy infrastructure investment for transporting fossil fuel energy still needs to be integrated. Although such developments can be costly and time-consuming, they provide a preferable long-term solution for the energy security of the EU energy market. Furthermore, at the level of energy consumers, the findings of the paper can serve as a starting point in making consumption decisions that may involve a decision to switch to green energy for reducing the costs. Also, at the level of economic agents in the energy market, countries that still have an increased dependence on imports from the Russian Federation can represent a new opportunity for the implementation and development of a sustainable business model through the introduction of renewable energy encouraged by EU policies through incentives economic.

The limitations of the research presented are due to the short timeframe of available data and the methodology. An analysis over a longer period would have revealed more information on the intricacies of the dependence of EU countries on energy imports from Russia and the development of renewable energy. Moving forward, keeping in mind the EU's aim to establish an Energy union to offer clean and cost-effective energy to European citizens, it becomes crucial to investigate the possible threats to competitiveness and growth within this framework. Furthermore, a promising area for future research would be to evaluate the contagion risks arising from the spread of shocks across the joint energy system, based on the clustering model of EU countries.

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