

THE IMPACT OF ENERGY IMPORT DEPENDENCY ON AFFORDABLE AND RELIABLE ENERGY ACCESS IN EUROPE

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Abstract:

This paper examines the relationship between external energy dependence in the energy sector and the development of cleaner domestic energy sources in the 27 European Union Member States. Using Eurostat data for 2024, the study focuses on two indicators: energy import dependence and the share of renewable energy in total final energy consumption. The empirical approach combines descriptive statistics, scatterplot analysis, Pearson correlation, simple linear regression and the construction of a composite vulnerability indicator based on min-max normalization. The results reveal significant heterogeneity across EU Member States in terms of both external energy dependence and progress in the transition to cleaner energy sources. The Pearson correlation coefficient indicates a statistically significant negative relationship between energy import dependence and the share of renewable energy, while the regression results confirm that higher external energy dependence is associated with a lower share of renewable energy. The composite indicator highlights significant differences between countries, with Malta, Luxembourg, Ireland, Belgium and Cyprus showing the highest levels of dependency, while Sweden, Estonia, Finland, Latvia and Denmark have more favourable scores. The findings suggest that reducing structural exposure requires not only limiting reliance on external supplies, but also accelerating the development of domestic clean energy capacities, improving infrastructure and strengthening the conditions for a more resilient transition.

Key words. Security of supply; external exposure; green transition; structural risk; resilience.

JEL classification: Q42; Q43; Q48; O13

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1. INTRODUCTION

Energy security is one of the greatest challenges of the 21st century, affecting both the global and individual levels of countries, regardless of their level of economic development. In the European context, this issue has become particularly urgent after the energy crisis between 2021 and 2023, which showed the susceptibility of national energy systems to attacks originating from external sources, price fluctuations and risks arising from an excessive reliance on imported energy resources. Therefore, energy security is no longer confined to the technical aspects of energy production, transport and distribution of energy, but must be seen as a complex concept involving several aspects, such as the economy, politics, society, the environment and national strategies.

From the perspective of the International Energy Agency, a secure energy system must guarantee both the sustained availability of energy and its affordability for the population. This notion emphasizes both the short-term part, which has to do with managing supply disruptions, and the long-term part, which refers to investment, diversifying energy sources and reducing the structural vulnerability of energy systems. In the specialized literature, dependence on energy imports is seen as one of the key indicators showing how vulnerable an economy is to external risks, because it shows how much domestic energy consumption depends on external markets, the stability of energy companies and political movements in energy-producing regions (Chalvatzis & Ioannidis, 2017).

The European Union remains one of the most important examples for studying energy vulnerability, as it continues to depend on importing a large amount of energy, even though continuous efforts are being made to diversify sources and move towards a more sustainable economy. Dependence on imported energy has ceased to be just a topic of debate and has become a genuine strength for Europe. Against the backdrop of expanding supplies from Russia and the Ukrainian crisis, countries are confronted with the realities of soaring prices, budget deficits, and the risk of citizens falling into poverty due to exorbitant electricity and heating bills. Energy

independence is now more than just a political slogan; it is the foundation upon which the economic survival and strategic independence of European states are built.

According to official Eurostat data for 2024, the European Union still relies heavily on energy imports. Almost 57% of the energy the European Union needs is taken from imports, but this average value hides large differences between member countries. At one end are countries like Malta, Luxembourg and Cyprus, which have a very high dependence on imports, and at the other end are countries like Estonia, Sweden and Latvia, which have a much lower energy dependence. These differences show that countries have different energy structures, domestic resources that are not distributed equally, different levels of electricity interconnection and policies for energy change that have been implemented with different speeds and forces.

The degree of dependence on imported energy does not, by itself, determine the resilience of a member state's energy sector. Vulnerability may persist even where imports are relatively limited, particularly when domestic renewable generation is inadequate or when the energy system does not possess sufficient adaptability to incorporate these resources. At the same time, renewable energy is not only part of policies to combat climate change, but also a way to reduce dependence on other countries, by developing domestic energy production capacities and diversifying the types of energy used. Research on the energy security of the European Union shows that diversifying energy sources, reducing import dependence and promoting renewable energy must be studied together, because all of these affect the resilience of the energy systems of the Member States at the same time (Carfora et al., 2022; De Rosa et al., 2022).

This view is also supported by research on eco-efficiency and sustainable development, according to which long-term economic performance must be linked to better use of resources and reduced environmental impact. In this context, Lupan and Cozorici highlight the role of eco-efficiency in supporting sustainable economic development. This perspective is equally relevant to the energy transition, as expanding renewable energy capacity and reducing reliance on external resources may strengthen energy security, improve competitiveness, and contribute to long-term sustainability (Lupan & Cozorici, 2015).

Taking into account the above, the article intends to examine how energy import dependency is linked to the development of renewable energy in European Union countries and to analyze how these two aspects influence an overall indicator that measures energy vulnerability. The analysis focuses on 2024 and is based on two key indicators: the level of energy import dependence and the proportion of renewable energy in gross final energy consumption. Based on these indicators, the study aims to show the differences between European Union countries, to examine whether there is a link between import dependency and the development of renewable sources and to create a score that shows how vulnerable each country is in terms of energy.

This material is distinguished by the fact that it unites the two dimensions in a single analytical tool. The first stage of the study provides an updated comparative assessment of the 27 EU member states, focusing on their reliance on external energy supplies and the progress achieved in expanding renewable energy.

On the other hand, an overall score is proposed measuring the level of energy vulnerability, which takes into account both the risk linked to a high dependence on imports and the risk due to a low proportion of renewable energy. Instead, Member States are divided into different categories according to their level of vulnerability, providing a model for the differentiated interpretation of energy risks and for the development of energy policy recommendations suitable for each group of countries.

2. LITERATURE REVIEW

The literature on energy security has advanced significantly in recent years, moving from an approach that primarily aimed at physical availability of energy resources to a more comprehensive picture that takes into account import dependence, source diversification, affordability, sustainability, infrastructure resilience, and the ability to adapt to external challenges. Based on a comprehensive

analysis of the concepts, dimensions, and indices used to evaluate energy security, Ang et al. emphasize the absence of a universally accepted measurement approach. Instead, indicator selection reflects the distinct economic structure, geographical position, and political environment of individual states (Ang et al., 2015). This conclusion is important for the present study, as it justifies the need to use a composite approach in the analysis of energy vulnerability.

An important conceptual contribution is offered by Cherp and Jewell, who propose the interpretation of energy security through the point of view of the vulnerability of vital energy systems (Cherp & Jewell, 2014). In this context, energy security is not just about the existence of energy sources, but also how a system can avoid, bear or overcome risks that can influence the functioning of the economy and society. The authors mention that vulnerability should be studied by combining the dangers to which it is exposed with the capacity to resist and recover. This approach is important for the present article, because dependence on energy imports shows a form of vulnerability to the outside, while the development of renewable energy can be seen as part of the internal power to reduce this vulnerability.

In the same sense, Sovacool states that energy security must be assessed through a set of indicators, not through a single variable (Sovacool, 2013). Its analysis model takes into account aspects such as availability, accessibility, efficiency, sustainability and governance, which proves that energy security is a complex issue. This perspective supports the use of composite scores in energy vulnerability research, since a single indicator, such as import dependence, can only partially capture a country's energy position. Therefore, integrating external dependence with the level of renewable energy development allows for a more balanced assessment of energy vulnerability. Complementing this perspective, energy efficiency is treated in the economic literature as a relevant dimension both for organizational performance and for reducing vulnerabilities associated with energy consumption that influence corporate performance by reducing costs, optimizing consumption and increasing the capacity of organizations to respond to economic and environmental pressures (Frecautan & Nastase, 2022).

Research on the European Union frequently evaluates energy security by considering the extent to which Member States rely on external energy supplies. Chalvatzis and Ioannidis approach this issue by analysing the relationship between supply security, the composition of primary energy sources, and import dependence (Chalvatzis & Ioannidis, 2017). Their results suggest that developing renewable energy and diversifying the energy portfolio can enhance domestic supply capacity while lowering dependence on foreign sources. Thus, renewable energy is not only a component of climate policies, but also a factor in strengthening energy security by reducing external exposure.

A similar analysis is carried out by Matsumoto et al., who assess the historical performance of energy security in EU states. The relationship between energy security and renewable energy development is analyzed in detail in another research, which investigates whether the expansion of renewable sources contributes to the strengthening of energy security in the European Union (Matsumoto et al., 2018). The authors show that this relationship is not always linear and depends on how energy security is conceptualized. While renewable energy can reduce import dependence and support energy diversification, its effect on energy security depends on the capacity of the energy system to integrate these sources, on infrastructure, on public policies and on the specific conditions of each state.

In the context of renewable energy, the scholarly literature on sustainability-oriented business innovation shows that the development of the sector does not depend exclusively on the availability of natural resources, but also on the economy's capacity to capitalize on technological, investment and entrepreneurial opportunities (Lucaci et al., 2021). This vision is relevant for energy vulnerability analysis, because the share of renewable energy shows not only where public policy is directed, but also how confident the innovation system is and what level of development the infrastructure has that helps the transition to more sustainable energy.

The contribution of De Rosa et al. approaches EU energy supply through three interrelated dimensions: diversification, concentration, and the role of renewable sources (De Rosa et al., 2022). Their analysis combines indicators of external dependence, market structure, and renewable energy

development, thereby supporting a multidimensional approach to the evaluation of energy security. This approach is very close to the logic of the current article, which combines import dependence and the renewable energy measure into an overall energy vulnerability score.

In a related study, Carfora et al. (2022) investigate EU countries by considering three interconnected dimensions: dependence on external energy supplies, renewable energy production, and demand for imported energy. The authors highlight the differential role of both renewable and non-renewable energy resources in shaping import demand, showing that the development of renewable energy can contribute to reducing external exposure, but the impact depends on the economic and energy structure of each country. This perspective supports the hypothesis that energy vulnerability is determined by the interaction between import dependence and domestic capacity to produce energy from renewable sources.

More recently, another study analyses energy vulnerability and resilience in the European Union, highlighting that the position of Member States towards energy shocks is determined by a broad set of indicators, including import dependence, supplier concentration, share of energy-intensive industries, technological capacities in the field of green energy and public policies oriented towards resilience (Guarascio, Reljic, et al., 2025). The authors insist on the heterogeneous nature of energy vulnerability in the EU and on the need for comparative mapping of Member States. This direction is convergent with the present study, but the present article focuses more specifically on the relationship between import dependence and renewable energy development, based on which a composite vulnerability score is constructed.

In terms of sustainable development, (Lupan & Cozorici, 2015) it analyzes eco-efficiency and sustainable economic growth, highlighting the importance of rational use of resources, reducing energy intensity and increasing the share of alternative energy sources. Although the study does not focus on energy vulnerability, its contribution is important for today's research, because it puts renewable energy and the way resources are used in the broader context of sustainable economic change. Thus, reducing energy vulnerability can be seen not only as a reaction to risks related to the geographical position of countries, but also as an effect of a profound change in the way the economy operates, more efficient, less dependent on resources from outside the country and more environmentally oriented.

In the regional literature, the green transition is studied not only through energy policies, but also through how it links to infrastructure, innovation, circular economy and sustainable development. Research shows that SDG 9 has an important role in promoting economic growth and environmental protection, highlighting the need for infrastructure, innovation and technologies to support sustainable change (Gheorghita et al., 2024). This perspective is important for understanding the weaknesses in the energy sector, because the growth of renewable energy depends not only on the presence of natural resources, but also on how well economies are prepared to invest in the right infrastructure, technologies and institutional systems.

In another direction, another research explores how well circular economy strategies are understood and adopted in public and private institutions in the Republic of Moldova, showing that the transition to sustainable models is affected by the lack of financial resources, technologies and information (Turcan et al., 2025). These observations may be related to the energy transition, as increasing the use of renewable energy and decreasing import dependence requires not only public policy measures, but also organizational, investment and technological capacity.

Also, research conducted by Stratila et al. emphasizes that the sustainable development of economic sectors is conditioned by their ability to respond to climate risks, attract investments and capitalize on modernization opportunities (Stratila et al., 2024), thus, the problem of energy vulnerability became evident, as economic resilience is based on the ability to adapt to external risks and the integration of modern technologies. In the same context, other research from the region addresses the European circular economy as a model for sustainable development, highlighting the importance of reducing the impact on resources and shifting towards more efficient economic systems that are less dependent on linear resource consumption (Ganea & Birca, 2020). This paper contributes to the debate on energy security at the global and national levels. Sustainable development requires

a comprehensive approach, including structural transformation, innovation, and adherence to sustainability principles. As the literature demonstrates, energy security is a multidimensional and difficult-to-define concept. While numerous studies have examined energy import dependence or the transition to alternative energy sources, a comprehensive analysis of the current energy situation in the EU-27 countries has been lacking. This study aims to fill this gap in the scientific literature. In this regard, this article makes a contribution by developing a score that measures energy vulnerability, based on two key dimensions: energy import dependence and the share of renewable energy in gross final consumption. This method allows not only to rank Member States, but also to group them into separate groups according to vulnerability, providing a useful analytical tool for discussing the differences between their structures and the consequences for energy policy.

3. MATERIALS AND METHODS

The analysis draws upon quantitative, comparative and cross-sectional research, aiming to assess the composite energy vulnerability of the Member States of the European Union. The analysis applies to all 27 Member States of the European Union and uses the year 2024 as a reference point. The choice of the current year provides a current picture of how the energy systems in our countries are functioning, after the problems caused by the energy crisis of 2021-2023.

The data used come from the Eurostat database and cover two main indicators: the dependency on energy imports, corresponding to indicator SDG_07_50, and the share of renewable energy in gross final energy consumption, corresponding to indicator SDG_07_30. The first indicator shows how much an economy needs sources from elsewhere to cover its energy needs, and the second shows how developed renewable sources are in terms of final energy consumption. These indicators ensure that data can be compared between countries in the European Union and allow a joint assessment of external exposure and the possibilities for switching to a cleaner energy source.

To describe the energy profile of the Member States, several descriptive statistics were calculated, such as the mean, median, standard deviation, minimum and maximum value, skewness and kurtosis. These results showed how the structure of the EU-27 states differs in terms of their dependence on foreign energy and the progress made in the field of renewable energy. The median values were used as the cut-off points in the graphical analysis on quadrants, as they are less influenced by extreme values than the arithmetic mean.

The relationship between energy import dependence and the share of renewable energy was studied using Pearson analysis and a simple linear regression model. In this model, the share of renewable energy in gross final consumption was taken as the dependent variable, and import dependence was considered as the independent variable. This method allows to analyze the meaning, strength and statistical significance of the link between the two indicators, without considering the results as evidence that one causes the other. In order to bring the two dimensions into a single analysis framework, a combined score measuring energy vulnerability was created. The two indicators were standardized using the min-max method on a common scale ranging from 0 to 100. High import dependence was seen as a risk factor, and a decrease in the share of renewable energy became a risk indicator by inverting the initial values. The composite score was calculated as the arithmetic mean of the two normalized components: the risk related to import dependence and the risk related to a low share of renewable energy. Higher scores indicate greater energy vulnerability.

The participating countries were divided into four categories based on their vulnerability scores: countries with low, medium, high, and extremely high vulnerability. This division helps transition from an initial ranking to a more complex typology analysis of the sample countries. To identify differences between the four groups, an analysis of the score distribution was carried out using boxplots. In addition, the k-means clustering method was used to separate the four clusters.

The computations and visualizations were performed in RStudio. The results of the calculations are presented in the form of a table with descriptive statistics, scatter plots, calculations of correlations and regression analysis, and graphs of the distribution of scores for the four categories mentioned above.

The current analysis has several limitations, the first of which is related to the nature of the data used. Since the study used data that characterizes the situation at one point in time, it does not allow for analyzing trends. In addition, the model used only two indicators, while other factors affect energy vulnerability, including the level of household income, access to energy, the structure of industry, energy storage infrastructure, grid flexibility, and the country's energy strategy. Despite the limitations, the approach offered allows for analyzing energy vulnerability in EU-27 countries relatively simply and efficiently.

4. RESULTS AND DISCUSSION

Empirical evidence suggests that the energy vulnerability of EU countries is determined not so much by the degree of their import dependence as by the potential of national economies to increase electricity generation from renewable sources. In the scientific community, dependence on external supplies is traditionally associated with geopolitical instability and risks to supply security. At the same time, the development of green energy is seen as a key mechanism for reducing the vulnerability of national energy systems (Gawel & Strunz, 2019; Guarascio, Holzner, et al., 2025). In this research, the analysis of the results is focused on three stages. The first stage involves examining conceptual indicators such as: dependence on energy imports and the proportion of renewable energy in total energy consumption. The second stage analyzes the statistical relationship between these indicators using correlation and linear regression methods. The third stage integrates the two dimensions into a composite energy vulnerability score, which allows for the comparison of EU-27 Member States and their classification into distinct risk groups.

In order to highlight the general profile of energy vulnerability in the EU-27 Member States, the empirical analysis starts from the descriptive examination of the two central indicators of the study: energy import dependency and the share of renewable energy in gross final energy consumption. The results presented in Table 1 allow the assessment of the degree of variation across Member States and provide the statistical basis for the subsequent analysis of the relationship between these indicators.

Table no. 1. Descriptive statistics of energy import dependence and renewable energy share in EU-27 member states, 2024

Indicator	Mean	Median	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
Energy imports dependency (%)	56.041	53.501	22.453	4.622	98.388	-0.117	2.492
Share of renewables in gross final energy consumption (%)	28.019	23.229	12.839	14.336	62.846	1.140	3.333

Source: Authors' calculations based on Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio

The descriptive statistical analysis presented in Table 1 highlights a high degree of manifoldness between the EU-27 Member States in terms of the two energy indicators analysed. The dependence on energy imports is on average 56.04%, which shows that Member States are still very dependent on the supply of energy resources from abroad. However, the standard deviation of 22.45 percentage points shows that this exposure is not the same in all countries, but shows that there are large differences between the energy system of one country and another. The amplitude of the variation is very large, going from 4.62% in Estonia to 98.39% in Malta, which clearly shows that there are very different national energy models, even if they all operate within the same European economic and regulatory framework. The median value, of 53.50%, is close to the arithmetic mean, and the negative skewness coefficient, of (-0.117), shows a balanced data distribution, without a strong concentration at one end. Similarly, the kurtosis value of 2.49 shows us a slightly platykurtic

distribution. This means that the data are more dispersed around the mean and highlights that at national level energy profiles are diverse.

A more uncertain distribution can be observed in the share of renewable energy in gross final energy consumption. The average of 28.02% is higher than the median of 23.23%, and the positive asymmetry coefficient (1.140) demonstrates that a good part of the Member States are below this average, while a smaller number of countries with higher performances in the field of renewable energy lead to an increase in the average of the indicator. This configuration is also confirmed by the distance between the lowest value, of 14.34%, and the highest, of 62.85%, which shows that the enhancement of renewable energy is not equally good in all EU-27 countries. If we compare it with the dependence on imports, renewable energy has a more asymmetrical distribution, which shows that the shift towards renewable sources is not taking place at the same level in all Member States. From an analytical point of view, these characteristics explain why the median is more suitable as a cut-off point in the quadrant analysis, as the arithmetic mean can be affected by the high performances of a small number of countries and could give an overly optimistic picture of the overall level of renewable energy development across all EU-27 states.

The descriptive results show that there are large differences between EU-27 Member States, both in terms of energy import dependence and in terms of the level of renewable energy development. To better understand how these two indicators relate in a given country, Figure 1 shows the distribution of Member States by energy dependence and renewable energy share, using median values as thresholds for separating the quadrants.

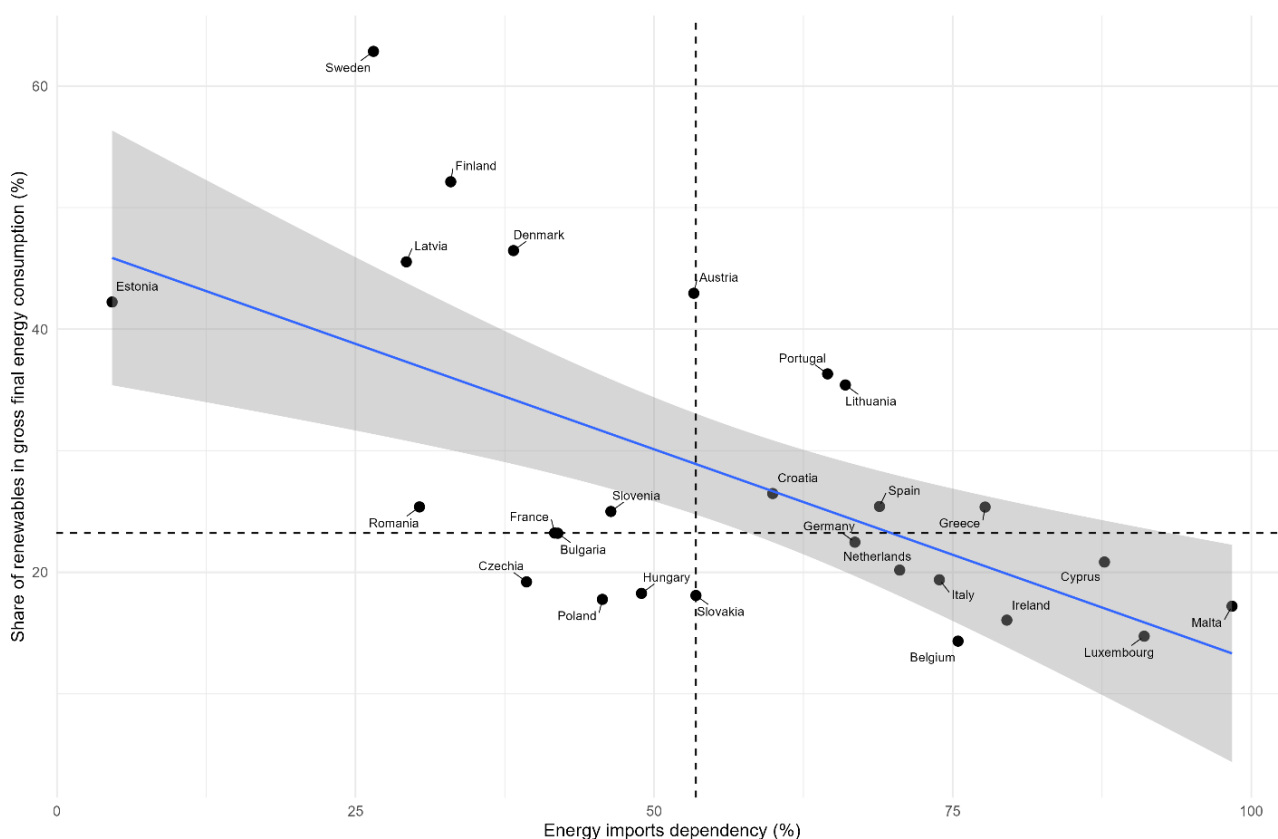


Figure no. 1. Scatter plot of energy import dependence and share of renewables in gross final energy consumption in EU-27 member states, 2024

Source: Authors' elaboration based on Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio

Figure 1 graphically shows how the dependence on energy imports is related to the share of renewable energy in final energy consumption in the EU-27 member countries. The downward-sloping regression line shows that the general trend found in the descriptive analysis is confirmed: countries with a higher level of dependence on imports have a lower share of renewable energy. This

aspect supports the main idea of the research, according to which energy vulnerability should be considered not only in terms of dependence on external energy sources, but also in terms of the capacity of countries to create their own renewable sources. A similar approach is also present in the literature on eco-efficiency and sustainable development, where resource efficiency, reduction of traditional energy consumption and the use of alternative sources are seen as complementary parts of sustainable economic change (Lupan & Cozorici, 2015).

The distribution of countries by quadrant shows that there are different energy profiles within the European Union. Countries that are in the quadrant with low import dependence and a high share of renewable energy, such as Sweden, Finland, Latvia, Denmark and Estonia, have a better energy profile. They are less exposed to external risks and have a greater capacity to use domestic or renewable energy resources. At the opposite end, countries such as Malta, Luxembourg, Ireland, Belgium, Cyprus, Italy and the Netherlands have a high dependence on imports, but use a smaller amount of renewable energy, which shows that they are less prepared to get involved in an energy crisis. The indicated discrepancies show that the joint participation of states in a single economic-regulatory space does not guarantee the synchronization of their energy strategies. This is due to significant differences in the structure of domestic production, availability of investment resources, geographical limitations and pace of implementation of measures to transform the fuel and energy sector.

The key conclusion is that the relationship between the considered parameters is not linear or predetermined. Observations demonstrate that countries such as Austria, Portugal, Lithuania, Croatia, Spain and Greece, despite the high volumes of energy imports, are actively integrating renewable energy sources. Similar examples prove that, although the share of renewable energy is capable of slightly reducing import dependence, it does not allow to completely eliminate this risk. On the other hand, states with minimal or zero dependence on supplies from abroad, but with limited implementation of "green" energy, confirm that the long-term sustainability of the energy system depends not only on the current indicators of imports, but also on the scale, as well as on the speed of the transition to renewable energy sources.

Romania's position is important in this case, as the country is below the median of the 27 European Union countries in terms of import dependence and slightly above the median in the share of renewable energy. This position shows a more balanced profile compared to countries with high dependence and a lower share of renewables, but does not indicate the absence of structural vulnerabilities. The distance compared to the Nordic countries, which combine much higher shares of renewable energy with low or moderate levels of import dependence, shows that the relative advantage of lower import dependence needs to be consolidated by accelerating investments in renewables, energy infrastructure and grid integration capacities. Thus, the scatter plot of energy import dependence and share of renewables not only confirms the negative relationship between the two indicators, but also provides the analytical foundation for constructing the composite energy vulnerability indicator used in the remainder of the study.

The negative trend visually observed in Figure 1 requires further statistical validation to determine whether the association between energy import dependence and the share of renewable energy is significant at the EU-27 level. For this purpose, the Pearson correlation coefficient was applied, the results of which are presented in Table 2.

Table no. 2. Pearson correlation between energy import dependence and renewable energy share in EU-27 member states, 2024

Variable 1	Variable 2	Pearson coefficient r	p-value	Lower 95% CI	Upper 95% CI
Energy imports dependency (%)	Share of renewables in gross final energy consumption (%)	-0.607	0.0008	-0.802	-0.295

Source: Authors' calculations based on Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio

The results presented in Table 2 confirm the existence of a statistically significant negative relationship between energy import dependence and the share of renewable energy in gross final energy consumption in the EU-27 Member States. The Pearson coefficient has the value $r = -0.607$, which indicates a negative association of moderate to high intensity. Consequently, countries with a higher level of import dependence generally have a lower share of renewable energy, while countries that develop renewable sources better are less dependent on foreign sources.

The statistical significance of the result is confirmed by the value of $p = 0.0008$, which indicates that the observed relationship cannot be considered random at the generally accepted threshold values of statistical significance. In addition, the 95% confidence interval, which is in the range from -0.802 to -0.295 , does not include the zero value, which increases the statistical credibility of the revealed negative relationship. This conclusion is related to the topic of the study, as it confirms the idea that the dependence on energy imports and the development of renewable energy should be analyzed together as two complementary aspects of energy vulnerability.

Conceptually, the result is consistent with existing research in the field of energy security and energy balance change, which links import dependence to external risks, and considers increasing the share of renewable energy sources as a way to strengthen energy independence and reduce high systemic risks (Strunz and Gawel, 2019; Guarascio et al., 2025). However, the Pearson correlation should not be interpreted as evidence of a direct causal relationship. It indicates the existence of a relevant statistical association, which justifies further analysis by linear regression and by constructing a composite energy vulnerability score. After confirming the existence of a significant negative association between the two indicators, the analysis was extended by applying a simple linear regression model. This model allows estimating the extent to which the variation in energy import dependence is associated with the variation in the share of renewable energy in gross final energy consumption at the level of the EU-27 Member States.

Table no. 3. Linear regression of renewable energy share on energy import dependence in EU-27 member states, 2024

Parameter	Value	p-value
Model constant, β_0	47.465	0
Coefficient of energy imports dependency, β_1	-0.347	8e-04
R-squared	0.368	

Source: Authors' calculations based on Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio

The results of the simple linear regression presented in Table 3 confirm the direction of the relationship previously identified through the correlation analysis. In the model, the share of renewable energy in gross final energy consumption is the dependent variable, and the dependence on energy imports is the independent variable. The estimated coefficient on import dependence is negative, $\beta_1 = -0.347$, and statistically significant, indicating that a one percentage point increase in energy import dependence is associated, on average, with a reduction of about 0.35 percentage points in the share of renewable energy..

The model constant, $\beta_0 = 47.465$, suggests the estimated level of renewable energy share under zero import dependence, but this value should be interpreted mainly as a technical parameter of the model, not as an empirical situation observable for all Member States. More relevant for the present analysis is the coefficient of determination $R^2 = 0.368$, which shows that approximately 36.8% of the variation in the renewable energy share across the EU-27 can be statistically explained by differences in energy import dependence. The rest of the variation reflects how other factors, not taken into account in the model, can affect the situation. These factors include how the energy mix is composed, the natural resources we have, the capacity to invest money, the way institutions work, the quality of the distribution network and the country's energy transition policies.

This result is important because it demonstrates that import dependence and renewable energy development are not separate factors determining energy security, but rather interrelated phenomena with statistical significance. However, this model should not be interpreted as proof of a direct causal relationship, as simple linear regression does not include all structural variables that may influence renewable energy development. In this sense, the results should be seen as empirical confirmation that the two dimensions can be justifiably integrated into a composite energy vulnerability score. This approach is consistent with the literature on energy transition and security of supply, which emphasizes that reducing energy vulnerability depends on both reducing external exposure and strengthening domestic renewable energy production capacities (Gawel & Strunz, 2019; Guarascio, Holzner, et al., 2025).

The results of the correlation and linear regression confirm that energy import dependency and the share of renewable energy are two interconnected dimensions of energy vulnerability. However, to assess the comparative position of each Member State, the separate analysis of the two indicators is not sufficient. For this reason, the two dimensions have been integrated into a composite energy vulnerability score, presented in Figure 2.

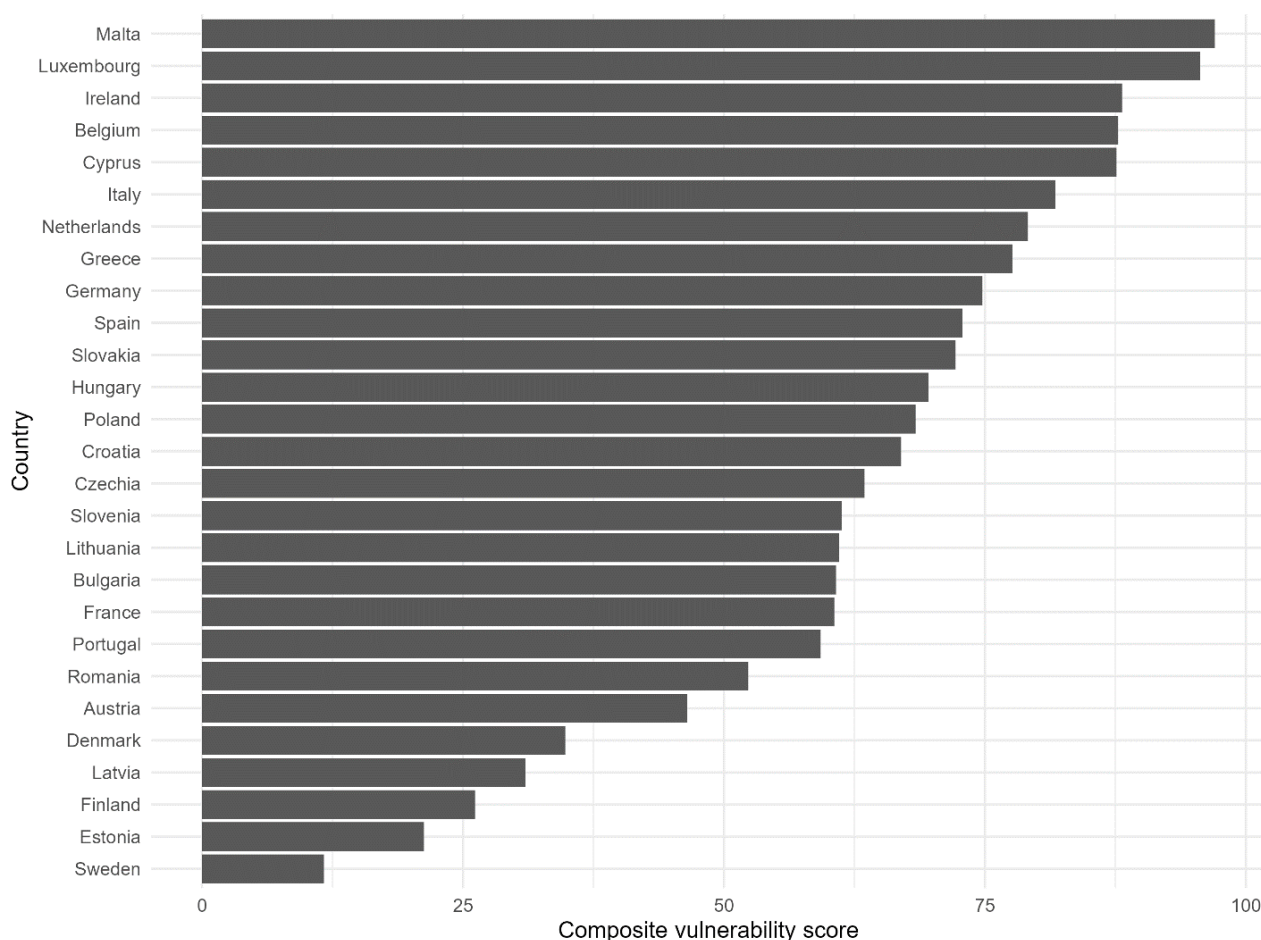


Figure no. 2. Composite energy vulnerability score of EU-27 member states, 2024

Source: Authors' calculations based on Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio

Figure 2 presents the ranking of the EU-27 Member States according to the composite energy vulnerability score. The score was constructed by integrating two dimensions relevant to energy security: the risk associated with high dependence on energy imports and the risk associated with a low share of renewable energy in gross final consumption. Thus, the figure allows for a more comprehensive comparative assessment than the separate analysis of each indicator, as it simultaneously reflects the external exposure of energy systems and the level of development of domestic capacities based on renewable sources.

The results reveal significant differences between Member States. The highest vulnerability scores are recorded by Malta, Luxembourg, Ireland, Belgium and Cyprus, countries characterised by high dependence on energy imports and/or a low share of renewable energy. The high ranking of these countries shows that the lack of renewable energy development amplifies their energy vulnerability, especially when dependence on foreign sources is not sufficiently reduced. This observation is consistent with studies on energy security, where dependence on imports is linked to increased vulnerability to external shocks, price fluctuations and geopolitical risks (Strunz and Gawel, 2019; Guarascio et al., 2025).

On the other hand, Sweden, Estonia, Finland, Latvia and Denmark have the lowest levels of the composite vulnerability score. The countries in question generally have low import dependence or use a high proportion of renewable energy, which makes them more energy resilient. In particular, the case of Sweden is interesting, as the low score reflects a high use of renewable energy and a better capacity to reduce structural vulnerabilities, by using domestic and sustainable energy resources. Romania has a place in the middle of the ranking, with a vulnerability score of 52.34. This positioning shows that the relatively moderate level of import dependence partially reduces the risk of external exposure, but the proportion of renewable energy is still too low for the country to be considered in a group of countries with a low level of vulnerability. Therefore, the case of Romania shows that reducing energy dependence is not only done by reducing imports, but also by accelerating the construction of renewable sources and by improving the capacity of the energy system to use these sources.

The ranking analysis demonstrates that energy vulnerability does not develop in isolation, but rather through a complex interaction between external dependence and the share of renewable energy sources. This approach provides a reliable foundation for further classification of member states by risk level and the development of targeted energy policy strategies.

While the data in Figure 2 clearly illustrates the contrasts between EU-27 countries, a detailed analysis of each indicator separately could complicate the analysis. To summarize the results and identify key energy profiles, countries were classified into four vulnerability categories based on the resulting composite indicator. This structuring simplifies the interpretation of cross-country differences and provides a more practical basis for discussing specific energy policy decisions.

Table no. 4. Classification of EU-27 member states according to the composite energy vulnerability score, 2024

Vulnerability level	Countries	Number of countries
Very high vulnerability	Malta, Luxembourg, Ireland, Belgium, Cyprus, Italy, Netherlands, Greece, Germany, Spain	10
High vulnerability	Slovakia, Hungary, Poland, Croatia, Czechia, Slovenia, Lithuania, Bulgaria, France, Portugal	10
Moderate vulnerability	Romania, Austria, Denmark, Latvia, Finland, Estonia	6
Low vulnerability	Sweden	1

Source: Authors' classification based on the composite vulnerability score calculated from Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio.

Table 4 presents the results of the energy vulnerability assessment, dividing the EU-27 member states into four categories: very high, high, moderate and low. This classification allows for a shift from a strictly numerical analysis to a typological one, highlighting not only the individual situation of each country but also the fact that certain similarities in energy consumption exist within the European Union.

The first category, which includes countries with a very high vulnerability, includes ten countries: Malta, Luxembourg, Ireland, Belgium, Cyprus, Italy, the Netherlands, Greece, Germany and Spain. This group shows how things are in countries where the high level of dependence on imports is often combined with a lower or insufficient participation of renewable energy. The

presence of countries with developed economies in this category shows that energy vulnerability does not only depend on the general level of economic development, but also on how the energy system is structured, how much energy can be produced domestically and how quickly the transition to renewable sources is made.

The high vulnerability category also includes ten countries: Slovakia, Hungary, Poland, Croatia, the Czech Republic, Slovenia, Lithuania, Bulgaria, France and Portugal. These countries are not at the highest risk level, but continue to have major problems between dependence on external energy and the degree of development of renewable energy. In the case of this group, vulnerability can be explained either by a still modest share of renewables, or by a relatively significant dependence on imports, or by a partial combination of these two dimensions.

The moderate vulnerability group includes Romania, Austria, Denmark, Latvia, Finland and Estonia. These countries have a more balanced energy profile compared to the first two categories. In the case of Romania, the positioning in this group suggests that the relatively lower dependence on imports contributes to reducing the overall vulnerability, but the share of renewable energy remains an element that needs to be strengthened. Therefore, Romania is not among the most vulnerable EU-27 countries, but it cannot be considered an example of low energy vulnerability either, as the transition to renewable sources needs to be accelerated to strengthen the resilience of the energy system.

The only country in the low vulnerability category is Sweden. This advantageous position is explained by the favorable combination of a very high share of renewable energy and a relatively manageable level of import dependence. Sweden's example demonstrates that reducing energy vulnerability is possible when renewable energy development is sufficiently advanced to offset a significant portion of the risks associated with external supply.

From an energy vulnerability perspective, the results confirm the need for a multidimensional approach, in which import dependence, energy mix and renewable development capacity are analyzed together, not separately (Elustu, 2021). This finding is consistent with studies showing that dependence on energy imports reduces energy security performance, while expanding renewable energy production contributes to reducing the external exposure of national energy systems (Carfora et al., 2022). Overall, the classification presented in Table 4 confirms the central hypothesis of the research: energy vulnerability in the EU-27 is determined by the interaction between dependence on energy imports and the level of renewable energy development.

After grouping Member States according to the level of composite energy vulnerability, it is necessary to verify the extent to which these categories reflect real differences between the energy profiles of the countries analysed. In this respect, Figure 3 complements the synthetic information in Table 4 by representing the distribution of the composite score within each risk group, allowing the observation of both the separation between groups and the internal variation of the scores.

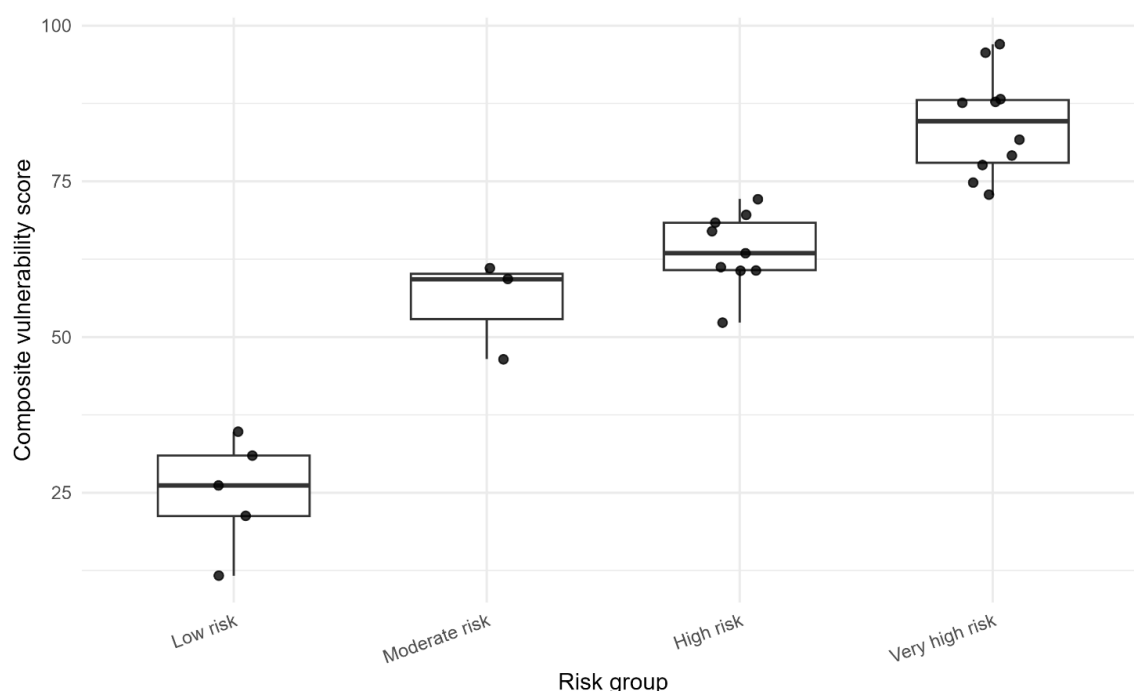


Figure no. 3. Distribution of the composite energy vulnerability score by k-means risk group in EU-27 member states, 2024

Source: Authors' elaboration based on the composite vulnerability score calculated from Eurostat data for SDG_07_50 and SDG_07_30, processed in RStudio

Unlike individual ranking of Member States, this representation allows for the assessment of the internal coherence of the groups and the differences between them. The results demonstrate a visible difference between the four categories, which confirms that the classification used is relevant for the analysis of energy vulnerability at EU-27 level.

The low-risk group is characterized by the lowest composite score values and relatively limited dispersion, indicating that the energy profile is more stable and less affected by issues related to import dependence and the low share of renewable energy. These countries have a better combination of external exposure and renewable development, which allows them to be placed at the bottom of the distribution.

The moderate-risk group occupies an intermediate position, with composite score values around an average level of vulnerability. Compared to the low-risk group, these countries present more pronounced vulnerabilities, but do not reach the high levels observed in the higher categories. This situation indicates some imbalances, which may be linked to a higher dependence on imports, or to the still limited development of renewable energy.

The high-risk and very high-risk groups clearly differ from the first two groups by higher values of the composite score. In particular, the very high-risk group has the highest vulnerability values, which shows that countries falling into this category have a high dependence on imports and a low capacity to compensate for them through renewable sources. The greater dispersion of scores in this group indicates that very high vulnerability can arise from various structural combinations, but which lead to the same general result: a higher energy exposure.

The distributions are relatively clearly separated, indicating that energy vulnerability is not found randomly across countries, but rather shows that there are different structural profiles between them. This observation supports the main idea of the research, according to which dependence on energy imports and progress in renewable energy should be studied together to better understand why some European Union countries are less prepared for energy crises.

5. CONCLUSIONS

The core focus of this research was the connection between EU-27 nations' reliance on energy imports and their utilization of renewable resources. We viewed these factors as interconnected components of a shared energy vulnerability. Interestingly, external dependency alone is not the full picture. A nation's capacity to develop its own renewable energy infrastructure may be even more critical. Without this, any discussion of energy system resilience remains incomplete. Basically, an energy system becomes solid and able to withstand shocks only when these two factors support each other. By combining these two aspects into one analysis approach, the study offers a way to compare the various ways different countries in the European Union are vulnerable when it comes to energy. The analysis showed big differences between the countries in the EU-27. Even though the average amount of energy a country depends on imports is still quite high, there are big differences between countries. These differences show that each nation has its own way of using energy, varies in how much energy it can produce locally, and is at a different stage in moving away from using a lot of energy. At the same time, the way renewable energy is spread out shows that the use of renewables is not the same everywhere in the European Union. Only a few countries have managed to get a much higher amount of renewable energy compared to the total energy they use.

The correlation and regression analysis revealed a significant negative relationship between energy import dependence and the share of renewable energy in a country's energy mix. Basically, the Pearson coefficient confirms something quite intuitive: the more a country relies on imports, the lower the share of renewables tends to be. Linear regression comes to strengthen this relationship and the degree of import dependence explains, at least partially, the differences between the EU-27 states in terms of renewable energy adoption. This is not a causal relationship, of course. But the relationship exists, it is visible, and it is hard to ignore.

After developing a comprehensive energy sector vulnerability index, it became possible to harmonize the two key indicators into a single scale for comparison. This revealed that Malta, Luxembourg, Ireland, Belgium, and Cyprus are among the most vulnerable countries. This is due not so much to high import volumes as to the lack of sufficient renewable energy development to offset external dependence. At the other extreme, Sweden, Estonia, Finland, Latvia, and Denmark demonstrate strong results thanks to a harmonious balance between the degree of external dependence and achievements in green energy.

The study also classifies EU-27 countries into four categories based on their vulnerability level. This grouping demonstrates that the distribution of risks is not random, but follows clear structural patterns. The most vulnerable countries include both small countries critically dependent on external supplies and a number of wealthy economies with high import levels and lagging renewable energy adoption. At the same time, countries with moderate and low levels of vulnerability confirm that reducing import dependence, along with an increase in the share of renewable energy sources, helps reduce structural risks, although the actual resilience of each specific country remains different.

As for Romania, it is somewhere in the middle. Relatively low import dependence helps reduce its exposure to external risks, but the current level of renewable energy is not enough to place it among the least vulnerable countries in the EU. What this result suggests is that Romania's energy future depends not only on keeping imports under control, but also on accelerating the transition to clean energy, integrating these sources more efficiently into the system and, last but not least, strengthening the infrastructure so that it can support an increasing share of renewable energy.

The political aspect is crystal clear: reducing energy vulnerability requires a coherent strategy, not piecemeal actions. Import restrictions without parallel investments in renewable energy, flexible grids, energy storage, energy efficiency, and innovation yield only limited results. Renewable energy reveals its potential where there is reliable infrastructure, stable regulation, and investment attractiveness. A secure energy system simultaneously implies reduced dependence on external supplies and increased domestic production of clean energy.

The study demonstrates that import dependence and the share of renewable energy are not isolated elements of security, but interrelated factors that jointly determine the level of risk. The proposed methodology allows for a clear and reproducible comparison of 27 EU countries, identifying groups with different levels of vulnerability. This will stimulate a more in-depth discussion on energy policy and will help the EU minimize risks and move more consistently toward a transition to renewable energy sources.

REFERENCES

1. Ang, B. W., Choong, W. L., & Ng, T. S. (2015). Energy security: Definitions, dimensions and indexes. *Renewable and Sustainable Energy Reviews*, 42, 1077–1093. <https://doi.org/10.1016/j.rser.2014.10.064>
2. Carfora, A., Pansini, R. V., & Scandurra, G. (2022). Energy dependence, renewable energy generation and import demand: Are EU countries resilient? *Renewable Energy*, 195(C), 1262–1274.
3. Chalvatzis, K. J., & Ioannidis, A. (2017). Energy supply security in the EU: Benchmarking diversity and dependence of primary energy. *Applied Energy, Transformative Innovations for a Sustainable Future – Part II*, 207, 465–476. <https://doi.org/10.1016/j.apenergy.2017.07.010>
4. Cherp, A., & Jewell, J. (2014). The concept of energy security: Beyond the four As. *Energy Policy*, 75, 415–421. <https://doi.org/10.1016/j.enpol.2014.09.005>
5. De Rosa, M., Gainsford, K., Pallonetto, F., & Finn, D. P. (2022). Diversification, concentration and renewability of the energy supply in the European Union. *Energy*, 253, 124097. <https://doi.org/10.1016/j.energy.2022.124097>
6. Elustu, S. (2021). Energy Security of the European Union: The Relationship between Energy Import Dependency and Economic Growth. *Istanbul Journal of Economics-Istanbul İktisat Dergisi*, 71(1), 133–162.
7. Frecautan, I., & Nastase, C. (2022). The Impact Of Energy Efficiency On Corporate Performance: Global Academic Review. *The USV Annals of Economics and Public Administration*, 22(2(36)), 16–31.
8. Ganea, V., & Birca, I. (2020). European Circular Economy – A Real Model For The Sustainable Development Of The Economy Of The Republic Of Moldova. *European Journal of Accounting, Finance & Business*, 14(24), 46–53.
9. Gawel, E., & Strunz, S. (2019). The EU Internal Market and the Transformation of Energy Systems to Sustainability. *Intereconomics*, 54(6), 346–353. <https://doi.org/10.1007/s10272-019-0852-x>
10. Gheorghita, M., Turcan, R., & Stratila, A. (2024). Evaluating the role of SDG 9 in economic growth and environmental sustainability: A quantitative analysis across the European Union. *The USV Annals of Economics and Public Administration*, 24(1 (39)), 163–173.
11. Guarascio, D., Holzner, M., Iacobucci, D., & Meliciani, V. (2025). European competitiveness in the new global context: Structural constraints, strategic dependencies and the role of the new industrial policy. *Journal of Industrial and Business Economics*, 52(3), 525–533. <https://doi.org/10.1007/s40812-025-00368-x>
12. Guarascio, D., Reljic, J., & Zezza, F. (2025). Energy vulnerability and resilience in the EU: Concepts, empirics and policy. *Journal of Industrial and Business Economics*, 52(3), 683–726. <https://doi.org/10.1007/s40812-025-00340-9>
13. Lucaci, A., Nastase, C., & Prelicean, G. (2021). Assessment of Innovative Sustainable Businesses in Europe. A Case Study in the field of Renewable Energy. *Ovidius University Annals, Economic Sciences Series*, XXI(1), 328–335.
14. Lupan, M., & Cozorici, A. N. (2015). Sustainable Economic Growth And Eco-Efficiency. *The USV Annals of Economics and Public Administration*, 15(1(21)), 63–73.

15. Matsumoto, K., Doumpos, M., & Andriosopoulos, K. (2018). Historical energy security performance in EU countries. *Renewable and Sustainable Energy Reviews*, 82, 1737–1748. <https://doi.org/10.1016/j.rser.2017.06.058>
16. Sovacool, B. K. (2013). An international assessment of energy security performance. *Ecological Economics, Transaction Costs and Environmental Policy*, 88, 148–158. <https://doi.org/10.1016/j.ecolecon.2013.01.019>
17. Stratila, A., Litvin, A., & Turcan, R. (2024). Sustainable agricultural progress in the Republic of Moldova: Through economic indicators and growth opportunities. *Romanian Journal of Economics*, 59(2(68)), 258–268.
18. Turcan, I., Bugaian, L., Gheorghita, M., & Turcan, R. (2025). Towards circularity: mapping the level of understanding and adoption of circular economy strategies. *The USV Annals of Economics and Public Administration*, 25(2(42)), 16–29. [https://doi.org/10.4316/aepa.2025.25.2\(42\).16-29](https://doi.org/10.4316/aepa.2025.25.2(42).16-29)