Assessing the EU Energy (In)Dependency on Conventional Resources in Times of War

Andrei-Teofil Postolachi
Stefan-Catalin Topliceanu
"Alexandru Ioan Cuza" University of Iasi,
Faculty of Economics and Business Administration, Romania
andrei_postolachi@yahoo.com
stefan.topliceanu@uaic.ro

Abstract

International economic and geopolitical changes caused by the war between Russia and Ukraine have intensified the EU member countries' concerns about the supply of energy resources and its energy security. The aim of the paper is to highlight the differences between EU countries in terms of energy dependence on conventional resources, mainly natural gas, petroleum products and fossil fuels. The research methodology implies a composite index applied for the period 2014-2022. The results show that there are three dimensions of energy dependence for EU countries, such as internal consumption and external supply (D1), self-sustaining capacity with natural gas (D2), and self-sustaining capacity with fossil fuels (D3). Germany, Italy and France have a high degree of energy dependence, while countries such as Poland, Romania and the Netherlands have a low level. These differences between EU countries show that the EU's energy security objectives should focus on renewable energy sources.

Key words: the Ukrainian war, oil dependency, Russian energetic resources, EU energetic imports
J.E.L. classification: Q37, Q43, O52

1. Introduction

Energy has been an important and priority issue for the Member States of the European Union since the 1970s, more precisely because of the first oil crisis between 1973 and 1974. Since then, the EU has made great efforts and progress, while the EU single market has succeeded in providing access to energy to all producers and customers. In addition, the EU has an interest in the sustainable use of energy, while energy supply has remained one of the most pressing challenges, especially in times of war and uncertainty, such as the war in Ukraine.

Against the backdrop of Russia's invasion of Ukraine, there is a growing need for many member states in Europe to end their dependence on Russian energy resources. The EU's energy needs are estimated at about half of Russia's coal production, a quarter of its oil production and about 40% of its natural gas (Rudakov, 2022). According to Roupas *et al.* (2009), the EU's vulnerability to oil increased between 1995 and 2007, while projections for 2030 indicate two scenarios, depending on oil prices. While a high oil price will lead to an increase in European vulnerability, a low price will lead to a decrease in EU oil vulnerability to the same level as in 2005. Acevedo and Lorca-Susino (2021) suggest that the European Union is still dependent on supplies from Russia, despite European efforts to promote bioenergy and alternative forms of energy. Braun *et al.* (2023) confirm that European countries are dependent on Russian energy resources, while the conflict between Russia and Ukraine causes smaller economic consequences for post-Soviet countries, even though these economies have the largest exposure to Russia. For Cappelli and Carnazza (2023), the EU's major problem is its dependence on oil, which has led to geopolitical dependence, more pronounced recently in the context of the war in Ukraine.

Considering these aspects, the aim of this paper is to highlight the differences between the European Union countries in terms of energy dependence on conventional resources. This has achieved by grouping EU countries according to their energy dependence through a composite instrument applied for the period 2014-2022. Using such a tool facilitates the process of understanding the changes taking place in energy security and energy dependence at EU level. Moreover, this research can help to see the links between different dimensions of energy dependence and the degree to which certain components of energy dependence influence others. Furthermore, the paper has the merit of synthesizing an enormous amount of information in a format that facilitates quick comparisons between the EU Member States.

2. Literature review

The literature is rich in studies on the EU's energy dependence. However, most studies focus on theoretical approaches and only a small number of studies provide the necessary statistical tools to quantify this dependence. Most of these studies use a composite index as a measure of vulnerability or energy dependence (Table 1).

Table no. 1. The literature for measuring the EU's energy dependence

Author	Statistical tools	Limitations
Gupta (2008)	Composite index using Principal Component Analysis (PCA)	Refers only to oil vulnerability; the analysis is static (for 2004); must consider more factors and to incorporate the geopolitical risks.
Gnansounou (2008)	Composite index using Euclidian distance	Limited compensation between scores; subjective weighting of index; the analysis is static (for 2003)
Roupas et al. (2011)	Composite index using PCA	The analysis is static (for 2006); need a more dynamic environment and more variables
Cirovic et al. (2015)	Failure Mode and Effect Analysis (FMEA)	Does not consider Croatia,; the methodology does not precisely indicate the link between components
Gatto and Busato (2020)	Composite index using PCA	Equal weights for index, making the weighting rationale subjective.
Cappeli and Carnazza (2023)	Composite index using PCA	Focused only on oil dependency without implying oil vulnerability; they consider only five variables.

Source: (own processing)

Gupta (2008) is interested in oil vulnerability for 26 net oil-importing countries, including 16 EU member states, with Greece and the Czech Republic being the most vulnerable countries at the European level. Although his results are important for this topic, there are some limitations in terms of number of factors, static analysis and lack of geopolitical risks. Using the same methodology, Roupas *et al.* (2011) provide a comparative analysis of oil and natural gas supply, but their analysis is static (for 2006) and needs more variables. Gatto and Busato (2020) indicate that GDP is not a main driver of energy vulnerability. They use a composite indicator through PCA analysis for 265 OECD and non-OECD countries, including European ones, taking into account four dimensions of vulnerability (economic, governance, environmental and social). However, their methodology uses equal weights, which makes the weighting reasoning subjective.

On the other hand, Acevedo and Lorca-Susino (2021) provide a systematic analysis and descriptive approach to the EU's oil dependence as a threat to economic growth and diplomatic freedom. Cappelli and Carnazza (2023) measure oil dependence for EU-28 countries, combining four dimensions of oil dependence, including economic, energy, international and geopolitical dependence. The authors suggest that the notion of energy dependence is a less explored topic, while the literature focuses on oil vulnerability. However, their analysis focuses only on oil dependence, considering it the most used energy resource by EU member states.

Taking into account existing methodological limitations, Percebois (2007) suggests that the scientific literature needs statistical tools to measure both vulnerability and energy dependence, which include quantitative and qualitative variables. On the other hand, Cappelli and Carnazza (2023) indicate that the notion of energy dependence is a less explored topic, while the literature focuses on vulnerability to oil. They also point out that the scientific literature still needs a lot of research to understand the drivers of reducing the multidimensional dependency of EU member countries.

Considering the existing results in the literature, the main contribution made by this paper aims to analyze the current energy crisis at the European level by grouping the EU countries according to the level of energy dependence through a composite tool applied for the period 2014-2022. The index has the merit of capturing the energy security performance of EU countries in the context of the Russia-Ukraine conflict, taking into account the lack of comparative studies between EU countries on energy dependence across a wide range of determinants of energy dependence. Moreover, given the major changes in the world economy because of the war in Ukraine, such a comparative study is particularly important. The proposed analysis is therefore a contribution to the literature.

3. Research methodology

Methodology implies a composite index on energy dependence using Principal Component Analysis (PCA) for period 2014-2022, designed to cover the outbreak of the conflict between Russia and Ukraine in the context of the annexation of the Crimean Peninsula (2014) and culminating in the declared war between the two in early 2022. The construction of the composite index is based on 23 indicators from major statistical databases, including the World Bank and the European Commission (Eurostat). The detail and description of the indicators used to construct the composite index are reflected in Table 2.

Table no. 2 Variables used

No.	Variable	Unit of measurement	Source
1.	Indigenous production of oil and petroleum products	Millions of tones	Ineligible
2.	Exports of oil and petroleum products	Millions of tones	Second pillar
3	Imports of oil and petroleum products	Millions of tones	First pillar
4	External balance on oil and petroleum products	Millions of tones	First pillar
5	Final consumption of oil and petroleum products	Millions of tones	First pillar
6	Indigenous production of solid fossil fuels	Millions of tones	Third pillar
7	Exports of solid fossil fuels	Millions of tones	Third pillar
8	Imports of solid fossil fuels	Millions of tones	First pillar
9	External balance on solid fossil fuels	Millions of tones	First pillar
10	Final consumption of solid fossil fuels	Millions of tones	Third pillar
11	Indigenous production of natural gas	Thousands of terajoules	Second pillar
12	Exports of natural gas	Thousands of terajoules	Second pillar
13	Imports of natural gas	Thousands of terajoules	First pillar
14	External balance on natural gas	Thousands of terajoules	First pillar
15	Final consumption of natural gas	Thousands of terajoules	First pillar
16	Imports from Russia (oil and petroleum products)	Millions of tones	First pillar
17	Imports from Russia (solid fossil fuels)	Millions of tones	Ineligible
18	Imports from Russia (natural gas)	Thousands of terajoules	First pillar
19	Coal rents*	% of GDP	Third pillar
20	Natural gas rents*	% of GDP	Second pillar
21	Oil rents*	% of GDP	Ineligible
22	Total natural resources rents*	% of GDP	Ineligible
23	GDP per capita at market prices	Thousands of euro	Ineligible

Source: Eurostat (2024); (*) The World Bank (2024).

The sample included 27 EU member countries, while the construction of the composite index considered the PCA, whose methodology is widely used in the literature. As presented in Table 1, many authors have used PCA composite indices to measure the energy independence of the EU. At the same time, this analysis is also used for other purposes, such as measuring quality of life (Dalton-Greyling and Tregenna, 2014), quantifying economic welfare (Dopke *et al.*, 2017), assessing economic resilience (Pintilescu and Viorica, 2019) or sustainable development at the European level (Barska *et al.,* 2020), the business environment (Topliceanu & Sorcaru, 2022) or the investment attractiveness (Sorcaru *et al.*, 2023). Nevertheless, this paper considers the methodology developed by Nardo *et al.* (2008, pp. 89-91) and the following statistical characteristics:

- Varimax rotation method;
- Fulfillment of three criteria in the selection of factor axes:
    - Kaiser's criterion, which requires eigenvalues to be greater than 1;
    - The individual contribution of each axis to explaining the total variance is greater than 10%;
    - The cumulative contribution of the axes considered to explain the total variance is greater than 60%.
- Selection of eligible variables with factor values greater than 0.7.

By constructing the composite index, it was possible to see which of the 23 indicators are the most significant in highlighting the energy dependence of the countries analyzed for the period 2014-2022. These indicators are grouped into main components (factorial axes), and the selection of these axes is made according to the three criteria listed above.

4. Findings

Applying PCA resulted in three eligible factor axes, whose values are presented in Table 3. The eigenvalues of these axes are greater than 3, the individual contribution of each axis exceeds 17%, and the cumulative contribution reaches about 78%. Therefore, the three criteria are met.

Table no. 3 Eligible factorial axes

Axis	Eigenvalues	Individual contribution	Cumulative contribution
1	11.409	43.123	43.123
2	3.848	18.163	61.286
3	3.008	17.070	78.356

Source: own processing.

Eligible indicators with factor loadings greater than 0.7 were selected at the level of each factor axis. Of the initial 23 indicators for which PCA was performed, only 18 were considered eligible, selected and normalized, about half of them being grouped in the first axis and four in each of the other two axes (Table 2). The three dimensions reflect the most important aspects of energy dependence for EU countries in the period 2014-2022. In other words, 18 indicators were statistically eligible, grouped in 3 pillars:

- Internal consumption and external supply (10 indicators);
- Self-supply capacity with natural gas (4 indicators);
- Self-supply capacity with solid fuels (4 indicators).

Considering the nature of the eligible variables and the number of factor axes, the three resulting dimensions have a different contribution to the composition of the aggregate index and to the grouping of EU countries according to energy dependence. The resulting positive values for the first dimension indicate a higher degree of energy dependence of the countries analyzed, while for the other two dimensions, the lower or negative values indicate higher energy dependence.

Table 4 shows the index scores for comparing EU countries for each dimension of energy dependence, but also for covering all three dimensions analyzed over the period 2014-2022.

Table no. 4 The EU countries ranked by energy dependence

EU country	First pillar	Second pillar	Third pillar	The energy (in)dependency index
Germany	1.168	0.507	0.244	0.472
Italy	0.462	0.148	-0.142	0.251
France	0.305	0.043	-0.236	0.209
Spain	0.079	0.028	-0.060	0.050
Slovakia	-0.101	-0.276	-0.133	0.037
Finland	-0.096	-0.249	-0.125	0.032
Belgium	-0.011	0.048	-0.176	0.021
Austria	-0.128	-0.244	-0.151	0.019
Latvia	-0.172	-0.322	-0.129	0.008
Hungary	-0.055	-0.125	-0.040	0.007
Luxembourg	-0.178	-0.328	-0.131	0.007
Lithuania	-0.148	-0.246	-0.142	0.006
Portugal	-0.156	-0.276	-0.126	0.005
Estonia	-0.177	-0.313	-0.127	0.003
Cyprus	-0.188	-0.328	-0.128	0.000
Sweden	-0.139	-0.185	-0.154	0.000
Malta	-0.191	-0.325	-0.126	-0.002
Ireland	-0.158	-0.198	-0.151	-0.008
Slovenia	-0.176	-0.308	-0.016	-0.022
Denmark	-0.105	0.049	-0.129	-0.041
Greece	-0.124	-0.149	0.058	-0.046
Croatia	-0.157	-0.020	-0.135	-0.052
Czech Rep.	-0.032	-0.289	0.576	-0.076
Bulgaria	-0.131	-0.277	0.442	-0.104
Poland	0.313	-0.030	1.390	-0.124
Romania	-0.093	0.511	-0.026	-0.164
The Netherlands	0.391	3.154	-0.127	-0.488

Source: own processing.

Ranking the index values by quartiles, the EU countries have been grouped into four dependency categories. A high level of energy dependence is for countries with index values between 0.472 and 0.021, specific to countries such as Germany, Italy, France, Spain, Slovakia, Finland and Belgium. Thus, according to Table 4 and Figure 1, Germany is the most energy-dependent country, with an index value almost twice as high as the second most energy-dependent country, Italy.

Figure no. 1. The energy (in)dependency index

Source: own representation

At the same time, there is a secondary group of countries, including Austria, Hungary, Luxembourg, the Baltic countries and Portugal, whose index values range between 0.003 and 0.019 and are characterized by a moderate to high degree of energy dependence. A third group consists of island EU countries such as Cyprus, Malta and Ireland, together with Sweden, Slovakia and Denmark, whose values fluctuate between 0 and -0.041, indicating a moderate to low degree of energy dependence.

Last but not least, the best performing EU countries in terms of energy independence are Greece, Croatia, the Czech Republic, Bulgaria, Poland, Romania and the Netherlands, with index values ranging from -0.046 to -0.488. It is noteworthy that the score for the Netherlands is about three times lower than that of Romania, indicating a very low energy dependence for the Dutch economy.

5. Conclusions

The issue of energy supply has become an increasingly stressful priority for EU Member States, especially in times of war and uncertainty, such as the conflict in Ukraine.

The results of the analysis of the level of energy dependence of EU countries in the context of the war between Russia and Ukraine show that there are three dimensions of energy dependence for these countries, such as internal consumption and external supply, self-supply capacity with natural gas, and self-supply capacity with fossil fuels. Among the countries with a high degree of energy dependence, Germany, Italy and France have the highest values. Next follows the group of EU countries with a moderate to high level of energy dependency, the best performer being Austria. A group of six EU countries have a moderate to low energy dependency, with Greece, Croatia, the Czech Republic, Bulgaria, Poland, Romania and the Netherlands having a low energy dependency, with the Netherlands being the best performer at EU level in this respect.

A particular case is Germany, which despite having low values on the second dimension, in the end the energy dependency index shows it as the most energy dependent country among the EU countries. This result arises due to its high score on the first component. The explanation comes from the fact that the second dimension emphasizes own production and exports of natural gas, where Germany performed well in the period 2014-2022, while the first dimension encompasses domestic consumption and supply of energy resources through imports, especially from Russia, where the values were relatively high. Another explanation may stem from the fact that some of Germany's natural gas imports were no longer destined for domestic consumption but for export to other destinations within the EU. Even so, Germany remains one of the most energy-dependent economies in the EU. At the opposite pole, the relatively low index score of the Netherlands is largely due to its high natural gas self-sufficiency.

The differences in energy dependency between EU countries show that the EU's energy security objective should focus on renewable energy sources. From this perspective, measures in the field of nuclear energy or natural gas are necessary to avoid possible future energy crises at European level.

6. References

- Acevedo, R., and Lorca-Susino, M., 2021. The European Union oil dependency: a threat to economic growth and diplomatic freedom. *International Journal of Energy Sector Management,* 15(5), pp. 987-1006. https://doi.org/10.1108/IJESM-10-2020-0010
- Barska, A., Jedrzejczak-Gas, J., Wyrwa, J. and Kononowics, K., 2020. Multidimensional assessment of the social development of EU countries in the context of implementing the concept of sustainable development. *Sustainability*, 12(18), 7821. https://doi.org/10.3390/su12187821
- Braun, E., Braun E., Gyimesi, A., Iloskics, Z., and Sebestyen, T., 2023. Exposure to trade disruptions in case of the Russia-Ukraine conflict: A product network approach. *The World Economy,* 46(10), pp. 2950-2982. https://doi.org/10.1111/twec.13417
- Cappelli, F. and Carnazza, G., 2023. The multi-dimensional oil dependency index (MODI) for the European Union. *Resources Policy,* 82, 103480. https://doi.org/10.1016/j.resourpol.2023.103480
- Cirovic, M., Makajic-Nikolic, D., Petrovic, N., Vujosevic, M. and Kuzmanovic, M., 2015. European Union oil import dependency risk analysis. *Polish Journal of Environmental Studies,* 24(1), pp. 75-81. https://doi.org/10.15244/pjoes/26105

- Dalton-Greyling, T. and Tregenna, F., 2014. *Construction and analysis of a composite quality of life for a region of South Africa*. Economic Research Southern Africa Working Paper 481.
- Dopke, J., Knabe, A., Lang, C. and Maschke, P., 2017. Multidimensional well-being and regional disparities in Europe. *Journal of Common Market Studies*, 55(5), pp. 1026-1044. https://doi.org/10.1111/jcms.12551
- Eurostat. 2024. *Energy statistics,* [online]. Available at: https://ec.europa.eu/eurostat/web/energy/database. [Accessed at 3 March 2024]
- Gatto, A. and Busato, F., 2020. Energy vulnerability around the world: The global energy vulnerability index (GEVI). *Journal of Cleaner Production,* 253, 118691. https://doi.org/10.1016/j.jclepro.2019.118691
- Gnansounou, E., 2008. Assessing the energy vulnerability: Case of industrialised countries. *Energy Policy,* 36(10), pp. 3734-3744. https://doi.org/10.1016/j.enpol.2008.07.004
- Gupta, E., 2008. Oil vulnerability index of oil-importing countries. *Energy Policy*, 36(3), pp. 1195-1211. https://doi.org/10.1016/j.enpol.2007.11.011
- Nardo, M., Saisana M., Saltelli, A., Tarantola, S., Hoffman, A., and Giovannini, E., 2008. *Handbook on constructing composite indicators. Methodology and user guide.* Paris: OECD Publishing.
- Percebois, J., 2007. Energy vulnerability and its management. *International Journal of Energy Sector Management,* 1(1), pp. 51-62. https://doi.org/10.1108/17506220710738597
- Pintilescu, C., and Viorica, D., 2019. Current methodological approaches in economic resilience analysis. Empirical findings in the EaP Countries. In G. Rouet and G. C. Pascariu, eds. 2019. *Resilience and the Eu's Eastern Neighbourhood Countries: From theoretical concepts to a normative agenda.* Cham: Palgrave Macmillan. pp. 321–348. https://doi.org/10.1007/978-3-030-25606-7_11
- Roupas, C., Flamos, A. and Psarras, J., 2009. Measurement of EU27 oil vulnerability. *International Journal of Energy Sector Management,* 3(2), pp. 203-218. https://doi.org/10.1108/17506220910970597
- Roupas, C., Flamos, A., and Psarras, J., 2011. Comparative analysis of EU member countries vulnerability in oil and gas. *Energy Sources,* Part B, 6(4), pp. 348-356. https://doi.org/10.1080/15567240802706742
- Rudakov, A., 2022. The EU can simultaneously end dependence on Russia and meet climate goals. *Nature, 604* (7904), pp. 7-8. https://doi.org/10.1038/d41586-022-00920-y
- Sorcaru, S. L., Nuta, F. M., Topliceanu, S.C. and Ambrozie, A. M., 2023. Measuring the FDI attractiveness in the EaP countries from an institutional perspective. *Journal of Business Economics and Management*, 24(6), pp. 1019-1041. https://doi.org/10.3846/jbem.2023.20652
- The World Bank. 2024. *World development indicators,* [online]. Available at: https://databank.worldbank.org/source/world-development-indicators# [Accessed at 21 February 2024]
- Topliceanu, S.C. and Sorcaru, S.L., 2022. The BEI index: an approach for measuring the business environment in Africa. *Journal of Business Economics and Management*, 23(4), pp. 895-914. https://doi.org/10.3846/jbem.2022.16644