sciendo
Proceedings of the 5th International Conference on Economics and Social Sciences (2022), ISSN 2704-6524, pp. 77-86

The 5th International Conference on Economics and Social Sciences
Fostering recovery through metaverse business modelling
June 16-17, 2022
Bucharest University of Economic Studies, Romania

The New Frontier of EU Energy: "Green Pass" for Nuclear Energy and Natural Gas. Political Approaches and State Dynamics

Cristian-Gabriel IANC[1], Gabriela DRĂGAN[2],
Bogdan-Florin MATEI[3*], Giani Ionel GRĂDINARU[4]

DOI: 10.24789788367405072-008

Abstract

The European Union's effort to reach the targets set by the Green Deal has met with a concrete barrier to potential energy crises fuelled by the scarcity of green energy resources. The introduction of nuclear energy along with natural gas thus becomes a controversial desideratum. This paper aims to analyse the issue of integrating the two new resources into the green energy catalogue. The analysis is divided into two sections. The first will focus on a qualitative approach by analysing the gaps and issues of labelling these resources in the 'green' sphere of the European Union by highlighting production disparities, pro-nuclear lobbying and differentiated political views. The second approach will use quantitative methods to capture possible adjustments of the ranking of the EU countries in terms of sustainability, fulfilment of the objectives assumed through the Green Deal, and energy production. Both sections of the analysis will help us to outline the change generated by the new European directive on the labelling of nuclear energy and natural gas as green energy, forming a future perspective for the European energy gear.

Keywords: green energy, nuclear energy, natural gas, sustainability, energy efficiency.

JEL Classification: O13, P28, P48, Q4.

[1] Bucharest University of Economic Studies, Bucharest, Romania, ianccristian.g@gmail.com.
[2] Bucharest University of Economic Studies, Bucharest, Romania, gabriela.dragan@rei.ase.ro.
[3] Bucharest University of Economic Studies, Bucharest, Romania, florinmatei01@gmail.com.
[4] Bucharest University of Economic Studies, Bucharest, Romania; Institute of National Economy - Romanian Academy, Bucharest, Romania, giani.gradinaru@csie.ase.ro.
* Corresponding author.

1. Introduction

The emerging energy crisis in the European Union needs to be addressed early, and the Member States' machinery needs to start interacting productively and building a future of European energy independence as quickly as possible. This European independence has a political and security dimension, and its foundations lie in the production of clean, non-polluting energy that complies with the European Agenda 2030 and the Green Deal agreement.

In the current context, there are several factors pushing this much needed change. Decades of reliance on fossil fuel energy and the high cost of fossil fuel energy are encouraging the rapid adoption of renewable energy (Papiez et al., 2018).

In addition to the cost factor of using expensive fuels to produce energy, there are the carbon dioxide emissions and pollution that fuel the global environmental crisis (Marques & Fuinhas, 2011).

At this delicate juncture with environmental, political, and security implications, the European Union's Kyoto commitment to reduce nuclear capacity had to be reconsidered, and the commitment to phase out nuclear energy production capacity was nullified. The commitment at that time could not foresee the fragility that the energy grid would acquire. This fragility began to be addressed by the European Commission and nuclear power and gas received the green label.

Taking all these factors into account, our paper will focus on two systems: an analysis of the current energy situation that will highlight the current fragility of the system, examine potential barriers and limitations and present the relevance of using nuclear and natural gas energy potential on the one hand, then we will focus on a comprehensive-quantitative analysis in the second part of the paper that will present data and test two functional hypotheses centred on the creation of European nuclear energy hubs and the concept of energy self-sufficiency.

2. Problem Statement

The European green energy context and the clear objectives set by the European Union in 2019 face adaptive and functional difficulties due to the deteriorating international context caused by the Russian-Ukrainian conflict. In this context, the targets set to reduce resource consumption in relation to economic growth and eliminate CO_2 emissions (European Commission, 2019a) undergo adaptations and aids. The most recent adjustment being the labelling of nuclear energy and natural gas on the list of green energy sources.

The systemic fragility of European energy production is amply presented in a study by Kuik (2003), which highlights the energy dependence that the European Union has in terms of imports; thus, in 2019 Europe imports according to data provided by the European Commission represented 61% of the total energy resources needed (European Commission, 2019b). At the time of the study, the EU's dependence on imports stood at 42%, and according to Kuik's predictions, this pre-recession dependence will reach 70% in 2030. The most critical issue in the current context is that Russia is the main supplier of oil (27%) and gas (41%)

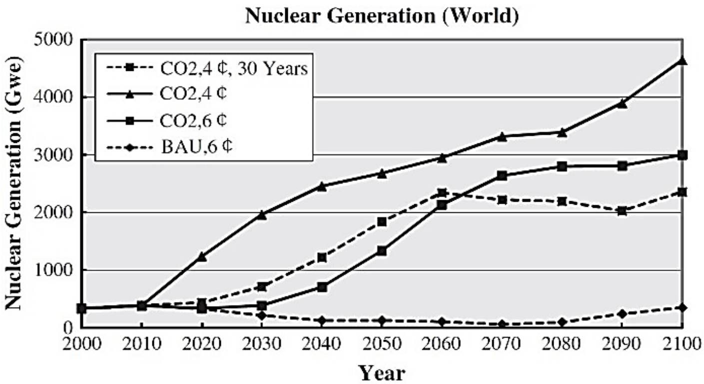
(Eurostat, 2022), and this pressure on the existence of energy dependence must be adjusted by identifying alternative sources of imports while increasing the exploitation of nuclear energy and natural gas as viable and resilient energy sources for the whole European community.

The use of nuclear energy in a safe, gradual and well-regulated environment in terms of national safety and nuclear waste management (which does not yet have a clear structure at European level) will be a first step towards making the stability of the European community permanent. Ristic et al. (2019) rank the yield of energy resources in the following order: nuclear, geothermal, wind with a high production rate, then hydropower, oil and biomass. Based on this classification, we consider that the application of the green label for nuclear energy is an important first step to be taken, the next one being the creation of European nuclear energy production centres or an increase of the production potential in each country.

In order to better substantiate the need to expand nuclear energy production to stabilise European energy-economic security and limit dependencies, it is very important to observe global trends, which, according to data presented by the World Nuclear Association, nuclear energy production is on an upward trend “the nuclear capacity growth will be around 25 % in difference of only 25 years (2015 to 2040)” (World Nuclear Association, 2022a). An example of good practice among European countries is France, which uses nuclear energy to cover 70% of the country's energy needs and is currently building a new nuclear facility. Other countries such as Hungary, Slovenia (together with Croatia), Czech Republic, and Slovakia are planning to expand their nuclear power generators network (World Nuclear Association, 2022b).

This expansion has several limitations that we have considered. Two of these physical limitations are identified by Ujita et al. (2006), namely carbon control and nuclear cost condition. The graph in Figure 1 shows these interactions and how, over a time horizon limited to the year 2100, this production will have the upward (Ujita et al., 2006).

Figure 1. Nuclear Generation power expansion



Source: Ujita et al., 2016.

Another resource that can be used to complement and support the European energy plan toward the goal of stability is natural gas. Many European countries are energy-dependent on this resource. Romania, Poland, Germany, Austria, and Croatia (European Network of Transmission System Operators Transparency platform, 2021) are just a few of them.

The green label has been assigned to this resource because of the low CO_2 emissions that the exploitation of this resource releases and comes as a functional alternative for countries that are still in the process of implementing green energy technologies. The disadvantages of this system are the limited gas reserve of the EU and the limited external access to natural gas supply, the main pipeline being the Russian one and passing through an area whose fragile security can no longer guarantee the integrity of the transmission system, while the rest of the pipeline projects are still under construction. Another vulnerability is the political and economic link that the strategic gas supply structure may have within the European Union (Kuzemko et al., 2019).

The problem of energy security can be addressed by a beneficial mix of eco-friendly energy resources. As we have presented, many authors identify the nuclear solution as viable and resilient, deserving the green label, and in combination with other energy resources, energy imports can be gradually reduced, leading to continental independence, and Europe can become a central player in the production, storage, and energy export.

3. Research Questions / Aims of the Research

Given the European Union's aim of reducing external energy independence and forming a stable and functioning internal grid, the first question to be answered in this study is the following:

Q1: Does nuclear energy have a future in the European Union?

Some of Europe's current nuclear power plants are already ageing, reaching the end of their operating life (The Consultative Forum for the Environment and Sustainable Development, 2000). In this context, new facilities will have to be built, existing ones will have to be modernised, or their lifetime will simply have to be extended, implying in this sector the need for a European and national analysis for each individual country regarding the prolonged use of these plants under a well-defined safety management system.

Q2: To what extent and in what strategic direction should the European Union pursue nuclear energy production?

There are currently 103 nuclear reactors in the European Union with a production capacity of 100 GWe. They operate in 13 of the 27 member states (World Nuclear Association, 2022c). In our research, we will highlight what is the production optimum that needs to be reached to meet the strategic directions for European energy security. Bearing in mind that using nuclear energy, the EU manages to avoid pollution by twelve million tonnes of carbon dioxide emissions every year (European

Commission, 2000), the strategic approach highlighted is the most beneficial in the production-implementation-security ratio.

Q3: Should regions with nuclear potential be developed into supply centres for the whole community in an equal-European contribution format?

The details and answers to this question will be explored by studying and analysing the factors of nuclear production, and then extending them within working hypotheses centred on European production clusters.

Q4: What is the level of resilient energy sufficiency that the European Union needs to achieve, and how does it affect production centres?

Establishing the optimal parameters that European nuclear power production centres will have to achieve and the burden that will be placed on them will give us a practical dimension in the implementation framework.

4. Research Methods

The study highlights the potential of nuclear energy and natural gas to ensure energy efficiency within the European Union and reduce its dependence on imports. As a result, several factors were considered relevant for quantitative analysis, according to previous studies by researchers in the field:

- Gross and net production of electricity and derived heat based on nuclear power;
- Production of nuclear fuel elements;
- Number of operable reactors;
- Gross and net production of electricity and derived heat based on natural gas;
- Primary energy consumption;
- Final energy consumption;
- Energy imports dependency.

The chosen period was 2020 for all indicators presented, and the data source is Eurostat. The observations are represented by the 27 countries of the European Union. Data cleaning and calculation methods have been applied in the Statistical Analysis System (SAS). The standardisation of the values was done using z scores, the power of a factor was determined using the principal component analysis, while the weight within the cluster with the help of relevant equations. The final aggregation led to the creation of a score for each country, necessary to establish their importance in achieving energy independence of the European Union, helped by nuclear power and natural gas.

In a more detailed approach, the z scores standardisation method was considered to ensure the comparability of data by converting them into standard units. The formula for a population is the following:

$$z_{ij} = \left(X_{ij} - \mu\right)/\sigma \tag{1}$$

where X_{ij} stands for the initial value of the *i*th factor and the *j*th country, while μ and σ are the population mean and standard deviation respectively.

The principal component analysis was used to determine which variables explain more of the variation in the analysed phenomenon. As a result, a correlation matrix was created from the correlation coefficients calculated for each pair of indicators

(Khatun, 2007; Sharma, 2008; James et al., 2017). For the 6 clusters considered for the analysis, we have determined the same number of 7x7 matrixes.

The weights have been further calculated using the correlation coefficient for each factor combination divided by the root square of the sum of all coefficients in the correlation matrix, as stated by the formula below (Sharma, 2008):

$$w_1 = \sum r_{xiy1} / \sqrt{\sum r_{x.y.}} \quad (2)$$

A total of 7 weights were determined for the score calculation.

The last step was to aggregate the resulted values after weights have been applied to show the final score of the nuclear and natural gas efficiency, necessary for assessing the energy self-sufficiency of a country.

5. Findings

The summary of the factors included in the analysis is presented in Table 1. For the year 2020 there were no missing values, while the data has been normalized to prevent biased output. The gross production of nuclear electricity and the number of nuclear reactors showed high values for France and null for 15 of the 27 member states of the EU. Nuclear fuel element production, on the other hand, is available in only five EU states. Germany, France, and Italy used energy the most, while the smaller states such as Luxembourg, Cyprus, and Malta used 70 times less energy for households and industry than the first ones. The latter three were the most dependent on imports in 2020, while Estonia, Romania, and Sweden were the least dependent.

Table 1. Descriptive analysis of the factors

Variable	Mean	Std Dev	Minimum	Maximum	N
Nuclear_El_Prod	24743.26	68496.30	0	353832.87	27
Nuclear_F_Prod	72.8888889	180.0803952	0	705.0000000	27
Primary_En_Cons	45.7962963	64.2214975	0.7400000	262.4900000	27
Final_En_Cons	2259.11	1007.49	1062.50	6006.80	27
Imp_Indep	41.9851111	21.1282739	2.4400000	89.4980000	27
No_Reactors	3.8518519	10.7083853	0	56.0000000	27
Gas_El_Prod	10160.93	15470.90	0	55891.04	27

Source: Authors' calculation.

The first hypothesis is defined as the first step in our quantitative approach, as it specifies the objective of focusing on the countries with the greatest potential to host European energy hubs based on nuclear and natural gas resources.

The classification of the European countries will follow the six system development regions presented in Figure 2, as stated by the European Association for the Cooperation of Transmission System Operators in the Regional Investment Plans for 2021, namely the Baltic Sea, North Sea, Continental Central East, Continental South West, Continental South East, and Continental Central South (ENTSO-E, 2020).

Figure 2. System development regions

Source: ENTSO-E, 2020.

The first step in our approach is to clearly separate the countries within the clusters set a priori by measuring the power of each member in the cluster. The countries that are part of more than one cluster and need only a specific one are represented by Germany (member of 4 groups), France and Slovenia with 3 groups, Denmark, Croatia, Italy, Hungary, Austria, Poland, and Romania in 2 clusters each.

Table 2 highlights the calculated weights for each variable. Therefore, we can determine the factors that have the greatest impact in each group. Specifically, nuclear energy production influences most regions, including the Baltic Sea and the Central East. Natural gas is highly demanded in the same areas, with more potential in the Central East region.

Table 2. Calculated weights per variable and region

Variable	BS	NS	CE	SW	SE	CS
Nuclear_El_Prod	0.954637	0.949615	0.955263	0.898489	0.669172	0.975738
Nuclear_F_Prod	0.731636	0.973069	0.718726	0.983741	0.449743	0.991639
Primary_En_Cons	0.621009	0.822367	0.819522	0.990265	0.536299	0.66949
Final_En_Cons	0.553317	-0.36542	0.224034	0.943469	0.302745	-0.26589
Imp_Indep	0.083441	0.577131	-0.07836	-0.75753	0.741442	0.464344
No_Reactors	0.86895	0.905485	0.469935	0.88057	0.668632	0.941803
Gas_El_Prod	0.59371	0.456875	0.905898	0.41397	0.334748	0.065502

Source: Authors' calculation.

The results of PCA and the weighting calculation are presented in Table 3. The resulting scores have pointed out that Austria, Germany, and Poland will join the Central East region, the North Sea region will incorporate Denmark and France, while in the South East we will preserve the rest of the countries included initially in more than one cluster. The Central South region will be excluded from the analysis due to the lack of allocated members.

Table 3. Calculated scores per cluster

Baltic Sea	Score	North Sea	Score	Central East	Score	South West	Score	South East	Score
Sweden	4.37	**France**	8.34	**Germany**	8.30	**Spain**	-1.28	**Romania**	2.93
Finland	1.84	Netherlands	-0.82	Czechia	0.89	Portugal	-4.63	Hungary	2.46
Estonia	-2.25	Denmark	-1.59	Slovakia	-1.40			Bulgaria	1.62
Latvia	-2.44	Belgium	-1.61	Austria	-1.43			Italy	0.99
Lithuania	-2.63	Ireland	-2.04	Poland	-1.75			Slovenia	0.53
		Luxembourg	-4.24					Croatia	-1.25
								Greece	-1.78
								Cyprus	-2.38
								Malta	-3.10

Source: Authors' calculation.

The Principal Component Analysis was used to determine the factors that would have a higher impact on the decision to locate the energy hub and assign weights in a way that maximizes the sum of correlation squares. Therefore, Sweden was chosen as the nuclear and natural gas energetic hub for the Baltic Sea, France for the North Sea, Germany for the Central East, Spain for the South West, while Romania would host the hub for the South East.

The second hypothesis acts as the second step in our analysis and will help us determine the level of self-sufficiency for each European country and, implicitly, the European Union. The analysis will continue with the calculation of the required level of nuclear energy production to cover the gap that prevents the reach of the targets. The delta between primary production and final consumption of energy from all sources was the example that has revealed for 2020 three main exporters, Bulgaria, Estonia, and Sweden. Using the regional classification, the Baltic Sea is the least dependent on energy imports, followed by the South West, while the Central East seems to have the largest dependence.

Table 4 presents the amount necessary in Gwh to reach the sufficiency level for each group, based on data for 2020 for primary production and final consumption of energy.

Table 4. Energy amounts to reach self-sufficiency

Cluster	Amount to be produced yearly (Gwh)
BS	47113.06
NS	604138.90
CE	1437702.20
SW	527074.06
SE	1013181.40

Source: Authors' calculation.

As a result, the European Union had to reach in 2020 an energy sufficiency level of 10301441 Gwh, while the actual gap was situated around 3629210 Gwh. Following the results of the previous step, the European Union should invest in

Sweden, France, Germany, Spain, and Romania the equivalent of 3629210 Gwh in nuclear and natural gas infrastructure.

6. Conclusions

The study reveals several answers to the questions that arise from the potential risks of energy shortcomings in the European Union.

Our research scope has challenged different topics in the natural gas and nuclear energy sectors, by presenting the current status and potential development, as well as the hypothesis of creating energy hubs across Europe to reach a total production capacity at least equal to the household and industrial consumption in 2020.

Starting from the decision to include the energy produced from nuclear power and natural gas, an important step would be to decide whether the approach of having nuclear energy production hubs may be a faster way to reach an empirical self-sufficiency threshold at a European level. Our analysis has proven that five out of six existing clusters would be an optimal solution, with France, Germany, Romania, Spain, and Sweden as nuclear energy hubs, due to their existing infrastructure and regional potential to reach efficiency goals. Furthermore, based on 2020 data, the European Union will need to invest the equivalent of 3629210 Gwh in nuclear and natural gas infrastructure in these countries to reach the level of self-sufficiency.

The limitations of the study were mainly caused by the lack of studies on the hypotheses analysed, as well as a small number of data sets available for the quantitative approach.

The topic can be further improved with comparative analysis of different natural resources, as well as with cost and opportunity calculus.

References

[1] ENTSO-E (2020). Regional Investment Plan 2020. Available online: https://eepublic downloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2020/Foropinion/RegIP2020_CSE.pdf (accessed on 12 April 2022).

[2] European Commission (2000). Towards a European Strategy for Energy Supply Security - Green Paper. COM (2000) 769 final, 29 November 2000 [EU Commission - COM Document].

[3] European Commission (2019a). Communication from the Commission to the European Parliament – The European Green Deal; European Commission: Brussels, Belgium, 2019; Available online: https://ec.europa.eu/info/sites/info/files/european-green-deal communication_en.pdf (accessed on 12 April 2022).

[4] European Commission (2019b). From where do we import energy?, available at: https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-2c.html, accessed on 12 April 2022.

[5] Eurostat (2022). Energy imports dependency, available at: https://ec.europa.eu/eurostat/databrowser/bookmark/f1ab4519-82df-4a89-a329-1b8d0a5925f7?lang=en&lang=en, (accessed on 13 April 2022).

[6] European Network of Transmission System Operators Transparency platform (2021). Available at https://transparency.entsoe.eu (Accessed 14 April 2022).

[7] James, G., Witten, D., Hastie, T. & amp; Tibshirani, R. (2017). An introduction to statistical learning: With applications in R. Springer.

[8] Khatun, T. (2007). Measuring environmental degradation by using principal component analysis. Environment, *Development and Sustainability*, 11(2), pp. 439-457, https://doi.org/10.1007/s10668-007-9123-2.

[9] Kuik, O. (2003), "Climate change policies, energy security and carbon dependency trade-offs for the European union in the longer term", International Environmental Agreements: Politics, *Law and Economics*, 3(3).

[10] Kuzemko, C., Lawrence, A., Watson, M. (2019). New directions in the international political economy of energy. Rev. Int. Polit. Econ., 26(1), pp. 1-24, https://doi.org/10.1080/09692290.2018.1553796.

[11] Marques, A.C., Fuinhas, J.A. (2011). Drivers promoting renewable energy: a dynamic panel approach, Renew. Sustain. Energy Rev. DOI: https://doi.org/10.1016/j.rser.2010.11.048.

[12] Papiez, M., Smiech, S., Frodyma, K. (2018). Determinants of renewable energy development in the EU countries. A 20-year perspective, Renew. Sustain. Energy Rev. DOI: https://doi.org/10.1016/j.rser.2018.04.075.

[13] Ristic, B., Mahlooji, M., Gaudard, L., Madani, K. (2019). The relative aggregate footprint of electricity generation technologies in the European Union (EU): A system of systems approach. Resource Conserv Recycl, 143, pp. 282-90.

[14] Sharma, S. (2008). Principal Component Analysis (PCA) to rank countries on their readiness for e-tail. *Journal of Retail & amp*; Leisure Property, 7(2), pp. 87-94, https://doi.org/10.1057/rlp.2008.1.

[15] The Consultative Forum for the Environment and Sustainable Development (2000). "Nuclear Reactor Safety in the European Union". 15 February 2000.

[16] Ujita, H. et al. (2006). Survey on future energy system structure under carbon dioxide constraints and generation cost. In: 29th IAEE International Conference.

[17] World Nuclear Association (2022a). Plans For New Reactors Worldwide, available at: https://world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx, accessed on 14 April 2022.

[18] World Nuclear Association (2022b). Country Profiles, available at: https://world-nuclear.org/information-library/country-profiles.aspx , accessed on 14 April 2022.

[19] World Nuclear Association (2022c). Nuclear Power in the European Union available at: https://world-nuclear.org/information-library/country-profiles/others/european-union.aspx, accessed on 14 April 2022.