Annals of "Dunarea de Jos" University of Galati
Fascicle I. Economics and Applied Informatics
Years XXVIII – nº3/2022
ISSN-L 1584-0409 ISSN-Online 2344-441X
www.eia.feaa.ugal.ro

DOI https://doi.org/10.35219/eai15840409287

Analysis of the Energy Status in Romania from the Sustainable Development Perspective in the Current Geopolitical Context

Costinela FORTEA★, Monica-Laura ZLATI★★, Valentin-Marian ANTOHI★★★, Romeo-Victor IONESCU★★★★, Dragos-Sebastian CRISTEA★★★★★

ARTICLE INFO

Article history:
Accepted December 2022
Available online December 2022
JEL Classification
Q41, Q56

Keywords:
Energy, crisis, econometric model, sustainable development, Romania

ABSTRACT

The current geopolitical context has brought an unprecedented energy crisis to the European energy market. The European Union has been forced to restrict its energy consumption and diversify its sources of supply due to its dependence on energy imports from Russia. We aim to analyze the dynamics of the main energy indicators in Romania from a sustainable perspective and to highlight through econometric modeling the vulnerabilities induced by the current geopolitical context and the energy price crisis in Romania. The used methods include literature review, analysis of energy consumption and allocation dynamics in the period 2010-2020 according to Eurostat reports as well as modelling techniques of consumption trends in order to identify a valid econometric model adapted to the sustainable development targets assumed by Romania. The results of the study are useful for national decision-makers in setting sustainable energy development policies for the period 2022-2030.

1. Introduction

According to the Romanian Energy Strategy, the main objective of the development and modernization of the energy system is the development and increase of economic competitiveness in correlation with the increase of the quality of life and care for the environment. In terms of this ambitious goal, the authorities have proposed several strategic targets for 2030 in line with European guidelines on reducing greenhouse gas emissions, increasing energy efficiency and making more efficient use of renewable energy sources. Thus, from a quantitative point of view, Romania has committed to a 2% reduction in greenhouse gas emissions in the transport, agriculture and construction sectors, an increase of more than 30% in renewable energy by 2030 and a 40% reduction in final energy consumption for the same forecast period (Ministerul Energiei, 2022).

The main objectives of the Romanian Energy Strategy are: access to electricity for all, energy efficiency and clean energy, increasing institutional and regulatory capacity in the energy sector, reducing energy poverty, achieving a good level of energy competitiveness, qualification of human resources working in the energy sector, harnessing primary resources to increase Romania's energy contribution to the European Union market (Ministerul Energiei, 2022).

Currently Romania uses nuclear, wind, hydro, hydro-based, solid fuels, solar energy capture and biomass for electricity generation. The production dynamics of these resources are shown in Figure 1.

In addition to the National Energy Strategy and in line with the National Energy and Climate Change Plan (PNIESC), Romania proposes to adopt several additional measures to support the objectives it has set itself, namely the construction of two more nuclear reactors (U3 and U4); the development of new low-carbon energy capacity (high-efficiency cogeneration plants and low-carbon power plants); the development of new low-carbon energy capacity (high-efficiency cogeneration plants and low-carbon power plants); and the development of new low-carbon energy technologies and natural gas-fired combined cycle)(Comisia Europeana, 2020). All these aspects argue the necessity and timeliness of the scientific approach.

★, ★★, ★★★★, ★★★★★ Dunarea de Jos University of Galati, Romania; ★★★ Transilvania University of Brasov, Romania. Email addressess: costinela.fortea@yahoo.com (C. Fortea), monica.zlati@ugal.ro (M. L. Zlati), valentin.antohi@yahoo.com (V. M. Antohi), ionescu_v_romeo@yahoo.com (V. R. Ionescu), dragoscristea@yahoo.com (D. S. Cristea).

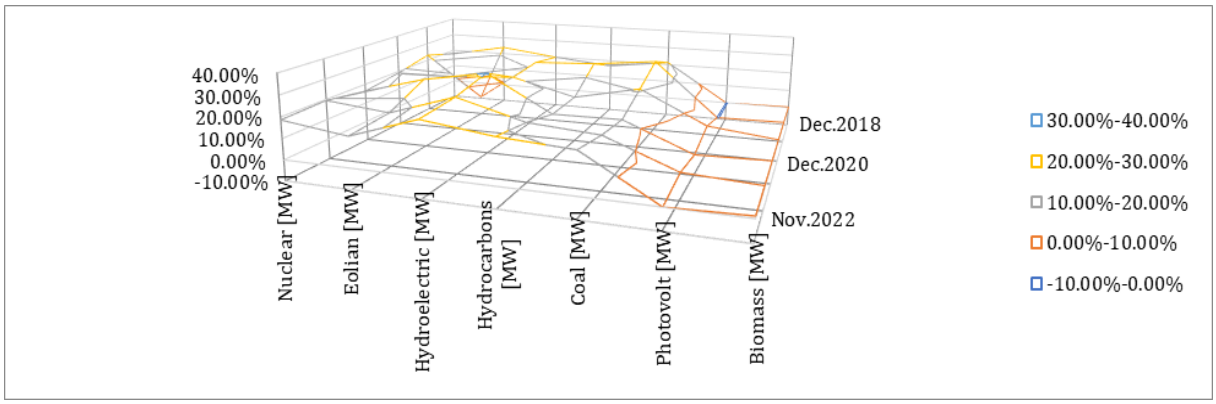

Figure no. 1. Dynamics and structure of Romanian energy production

Source: Elaborated by the authors after https://www.sistemulenergetic.ro/statistics/show_graph/2020/12/21/0/0/2022/12/23/23/59

We propose to study the impact that Romania could generate through the implementation of sustainable development measures in the energy sector and we will study the analysis of electricity allocation and consumption dynamics in the period 2010-2020 to identify a sustainable energy model that would improve and rebalance the sustainable energy balance affected during the crisis as follows (Figure 2).

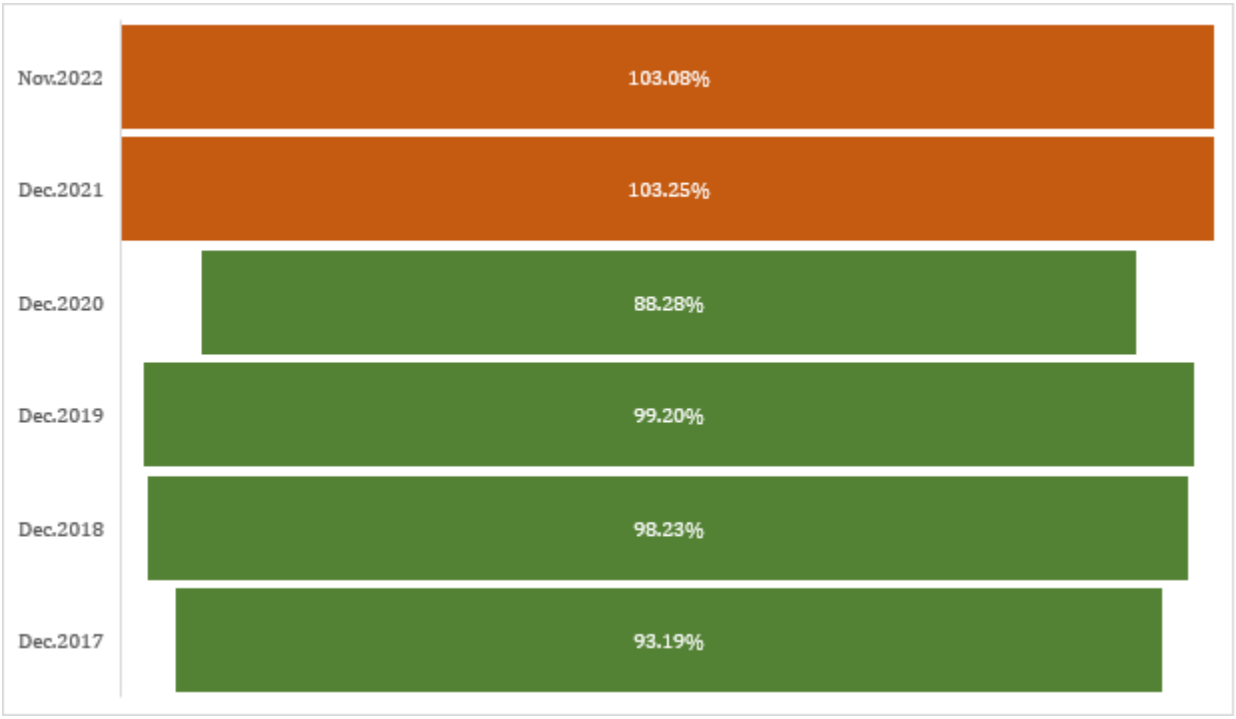

Figure no. 2. Balance of energy consumption in relation to energy production in Romania

Source: Elaborated by the author after https://www.sistemulenergetic.ro/statistics/show_graph/2020/12/21/0/0/2022/12/23/23/59

The objectives of the study are:
O1. Literature review;
O2. Conceptualization of the model
O3. Model testing
O4. Dissemination of the results.

The expected results will highlight the following main issues: dynamics of the energy consumption structure, econometric modeling and conceptualization of the sustainable development model of the energy sector in Romania, solutions for improving the energy consumption balance in Romania.

2. Literature review

According to a study conducted by the authors on the Web of Science platform, interest in energy research is growing in European academia, especially after the outbreak of the geopolitical conflict that resulted in a significant European economic and energy crisis. Thus, out of 36,600 articles included in the Core Collection Web of Science for the topic European energy, more than a third were written in the period 2012-2022, in the last two years 2021 and 2022 being published 5730 articles whose results were

disseminated in 15,800 researches without including the authors' self-citations, obtaining according to the analysis a citation rate of 3.7 citations per article and a Hirsch index of 41 points.

The most significant areas of research, which attracted more than 70 citations per item, were the analysis of carbon neutrality projections, the impact of energy on climate change, the impact of renewable energy consumption on sustainable economic growth and spatio-temporal patterns of analysis at the level of European countries, investments in the energy sector, determination of energy poverty rates and the circular economy aspect (Figure 3).

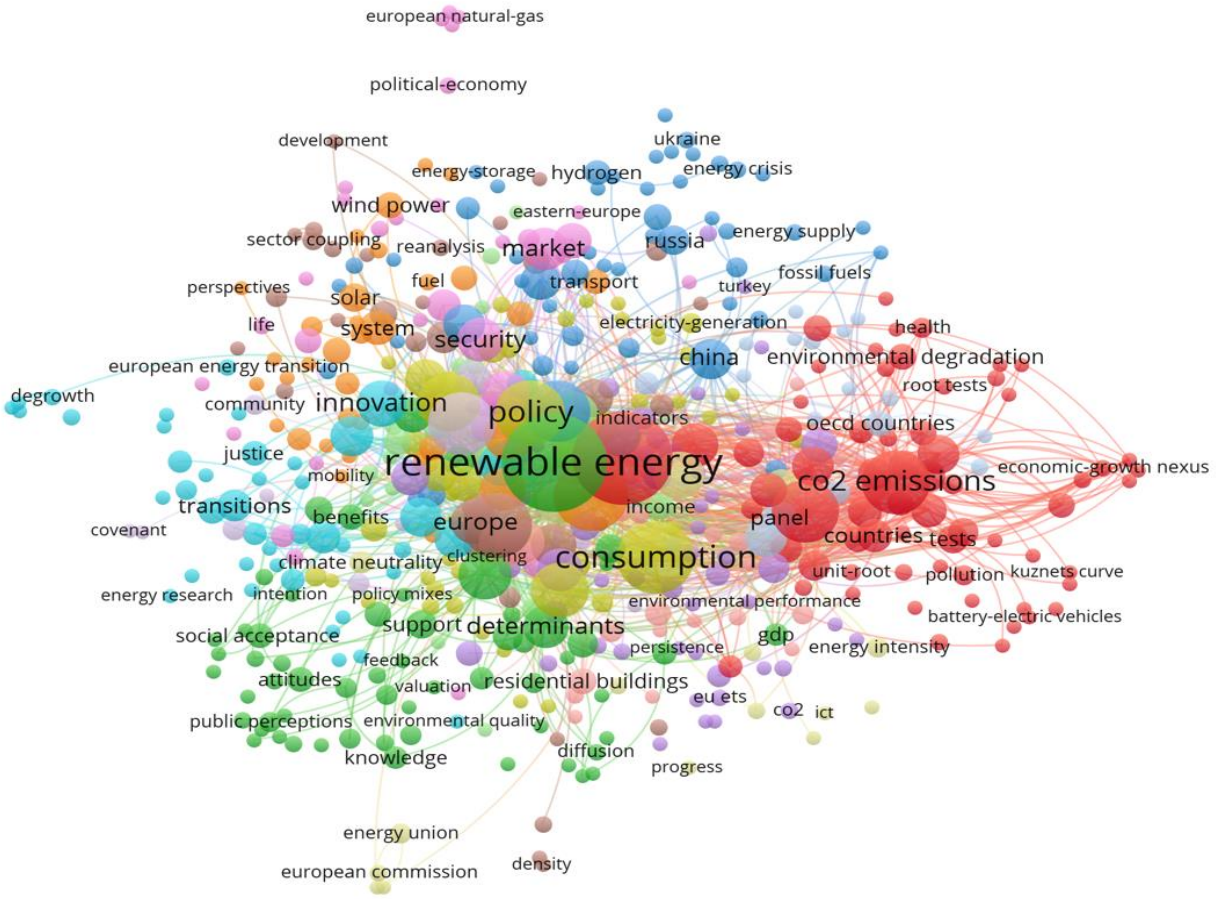

Figure no. 3. Study of the impact of energy policies on sustainable development at European level through bibliometric analysis of the literature

Source: Developed by the author using VOSviewer software

Figure 1 shows that the concerns of energy researchers can be grouped into 14 clusters according to keyword co-occurrence rates of which the first cluster is related to pollution in relation to energy consumption at European level, financial development of the European community and modelling of welfare parameters using statistical methods such as Kuznets curves, life cycle analysis of energy products, nexus techniques, panel data analysis, quartile regressions, statistical tests to determine the impact of energy sector development at European level. Cluster two groups scientific concerns about the effects of energy policy development including climate change, eco-innovation, socio-economic surveillance at European level, development of alternative energy sources including nuclear and renewable energy, energy responsibility and the theory of planned energy consumer behaviour. Cluster three examines concerns about decarbonisation, energy dependence, energy regulatory frameworks, European energy policies, regional distribution of energy consumption and production, energy dependence on Russia and energy security strategies. Cluster four focuses on energy efficiency analysis and energy optimisation, carbon footprint calculation, energy generation efficiency, energy strategies, energy management and sustainable development. Cluster five looks at competitiveness from the perspective of achieving clean energy, reducing carbon emissions, limiting energy poverty. On the same note of diversity of research concerns in the field, the other clusters look at innovation, energy transition, energy consumption, European regulatory policies, energy governance, energy communities, etc.

In the literature, energy development at European level is reflected in studies on energy and environmental impacts, but also in energy efficiency analyses. In the context of the transition to clean energy, a study (Koltsaklis et al., 2020) shows that electricity demand in Romania has a seasonal character being

maximized in the cold period of the year, the structure of power generation capacities being favorable to fossil fuels and Fossil Gas. The authors also show that there is a favourable development in the period 2016-2019 in terms of the use of water and wind sources, with the potential to improve energy performance from solar energy capture by 2040. The study concludes that Romania is following a transition program from the use of solid fuels to the use of renewable sources, a process that will improve the energy capacity and decarbonize this sector, aiming for an 87% decrease of carbon emissions in the sector by 2040 compared to the base year 2020.

Another study (Mehedintu et al., 2021) analyses the evolution and forecast of energy consumption from renewable sources in the context of sustainable development at national (Romania) and European level. The analysis highlights that in the long term the balance between energy consumption from renewable sources and consumption from traditional sources will be achieved against the background of European regulations. The authors point out that both at national and European level, the targets set in the 2030 sustainable development directives can be achieved if effective energy policies are adopted, renewable energy consumption is stimulated, especially in the transport, agriculture and construction sectors.

Another study (Girleanu et al., 2021) carried out at the level of the Black Sea basin on the Romanian coast shows that the wind energy potential in this area is significant and can be exploited throughout the year with applications for the port localities of Constanta and Mangalia in order to improve processes and port operations.

Several authors (Carfora et al., 2022; Chen et al., 2022; He et al., 2022; Potrč et al., 2021; Swain & Karimu, 2020) analyse sustainable development through the lens of Goal 7 Affordable Clean Energy. It shows that achieving the targets set by the Paris Agreement 2050 horizon is a priority target that involves moving to net carbon neutrality through integrated development programmes, which can be oriented towards energy production from biomass and waste (Potrč et al., 2021), renewable generation (Carfora et al., 2022) and increasing energy efficiency (Atalla & Bean, 2017; Chen et al., 2022) and reducing carbon emissions (Manta et al., 2020).

Other authors (Costantini et al., 2020) analyse the evolution of energy system efficiency for the residential sectors of European countries. The authors show that there are intra-EU differences in national policy mixes and technology development trajectories so that energy efficiency can be achieved through structural process changes.

Another study on the implications of reducing the use of fossil fuels in the energy sector (Apostu et al., 2022) shows that in the context of the new regulations for rebalancing the energy mix, Romania must reorient itself towards diversification of energy sources with a focus on clean technologies. The analysis of the scenarios made by the authors allowed the identification of some energy policy statuses for the continuation of sustainable development and environmental protection, namely the replacement of coal with renewable energy sources, with the reduction of carbon emissions to zero, there is a probability that these sources cannot be 100% exploited due to economic aspects and the pace of investment, in which case the authors identified alternative sources such as the use of oil, liquefied gas or nuclear energy, in which case emissions will be significantly reduced but not neutralized. The authors' proposals are based on a significant financing need that requires even large investments and a transition period to maintain energy security in Romania.

3. Methodology

The main objective of the analysis carried out by the authors is to determine the level of Energy Security based on a sustainability model derived from the study of the following indicators, in dynamics in the period 2010-2020 (Eurostat, 2020) :

- Final energy consumption (Million tonnes of oil equivalent)
- Primary energy consumption (Million tonnes of oil equivalent)
- Final energy consumption in households per capita (Kilogram of oil equivalent (KGOE)
- Renewable energy sources in electricity
- Energy import dependency by products
- Energy import dependency by products (Oil and petroleum products (excluding biofuel portion))
- Energy import dependency by products (Natural gas)
- Exports of oil and petroleum products
- Exports of electricity and derived heat (Gigawatt-hour)
- Energy dependence %
- Electricity prices by type of user (Electrical energy- Euro-Kilowatt-hour)
- The implementation of the model allowed the following working hypotheses to be followed and validated:
- H1- there is an average correlation in Romania between primary energy consumption and final energy consumption, the Pearson coefficient of the correlation of the two dimensions of consumption being 0.516.

- H2- there is a strong correlation of final energy consumption with import dependence in the sector in Romania (Pearson correlation coefficient 0.925), which is more strongly related to oil consumption (Pearson correlation coefficient 0.747) than to gas consumption (Pearson coefficient 0.563);
- H3- consumption of renewable resources is mainly influenced by dependence on oil imports (Pearson coefficient 0.712) and shows an inverse correlation with dependence on gas imports (Pearson coefficient -0.508).

A regression function was applied based on the following table of energy consumption dynamics (Table 1):

Table no. 1. Dynamics of energy consumption in Romania between 2010-2020

Year	FinalEn Consumption	PrimaryEn Consumption	RenewEn Source	EnImport Dependency	EnImport DependencyOil	EnImport DependencyGas	EnImport Dependency Petroleum	EnImport Dependency Other
2010	22.50	33.00	30.38	21.39	52.62	16.83	443.92	5,316.00
2011	22.70	33.50	31.13	21.14	47.39	22.19	445.58	3,650.00
2012	22.80	33.30	33.57	22.46	52.17	21.32	447.25	4,753.00
2013	21.80	30.40	37.52	18.32	47.65	11.84	431.00	9,937.00
2014	21.70	30.10	41.68	16.66	54.95	4.98	432.00	11,220.00
2015	21.90	30.80	43.16	16.69	54.24	1.80	399.00	9,194.00
2016	22.20	30.70	42.71	21.90	57.33	13.03	531.00	7,735.38
2017	23.30	32.50	41.97	23.30	61.29	9.70	482.00	6,241.03
2018	23.60	32.60	41.79	24.29	63.13	12.03	487.00	3,974.61
2019	23.90	32.10	42.62	30.28	65.37	23.18	515.00	5,459.33
2020	23.50	30.90	43.37	28.20	64.70	16.63	361.00	6,827.09

Source: Own contribution according to Eurostat data (Eurostat, 2020)

Table 1 shows that final energy consumption is increasing over the period 2017-2020, a period that overlapped with the digitisation component of the global economy combined with the onset of the pandemic that accelerated this phenomenon. From the final energy consumption point of view, it can be observed that under the impact of the transition measures to green energy it has a decreasing trend in the 2020s, while historically energy consumption in households reaches a maximum in 2020 for the reference period, which is the result of the conflict in Ukraine, the present energy crisis in Europe and Romania. Note that for 2021 Eurostat data are not available for the analysis of energy consumption trends.

The regression function of the model is defined as follows:

$$\begin{aligned}\text{FinalEnConsumption} &= 0{,}335 * \text{PrimaryEnConsumption} + 0{,}042 * \text{RenewEnSource} + 0{,}163 \\ &* \text{EnImportDependency} - 0{,}007 * \text{EnImportDependencyOil} - 0{,}028 \\ &* \text{EnImportDependencyGas} - 0{,}001 * \text{EnImportDependencyPetroleum} - 9{,}34 * 10^{-6} \\ &* \text{EnImportDependencyOther} + 8{,}187\end{aligned}$$

According to the regression function, the correlation between primary consumption and final consumption is 33%, which means that at the level of the Romanian economy the dynamics of energy consumption influences at least one third of the dynamics of final energy consumption. Also from the regression equation it can be seen that energy consumption from renewable sources has a low dependence on final energy consumption, in this situation there is also a dependence on energy imports from oil or gas and oil products. Another significant component in the final energy consumption equation is the dependence on energy imports which has an impact of 16% on final energy consumption, so we can say that in an economic crisis the energy dependence on imports has a marginal impact of maximum 16% of the impact of the variation of energy production on final energy consumption.

4. Results of the study

The model results are described in the Model Summary Table and show a statistical significance of 97.9%, with a high level of homogeneity of the regression function determined in relation to the significance threshold of the error distribution $\alpha = 0.05$ (Table 2).

Table no. 2. Model Summary

Model [b]	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
					R Square Change	F Change
1	0.989[a]	0.979	0.930	0.2055	0.979	19.859

Model	Change Statistics		
	df1	df2	Sig. F Change
1	7	3	0.016

a. Predictors: (Constant), EnImportDependencyOther, EnImportDependencyOil, EnImportDependencyPetroleum, EnImportDependencyGas, RenewEnSource, PrimaryEnConsumption, EnImportDependency

b. Dependent Variable: FinalEnConsumption

Source: Authors' calculations using SPSS v 25

Table 3 shows the distribution of the Anova test results on the regression value and the residual value of the regression showing that the residual value is strictly smaller than the regression value which gives a high level of homogeneity to the regression function with a correlation distribution of 70% in favour of the regression function and 30% in favour of the non-homogeneous residual component (Figure 4).

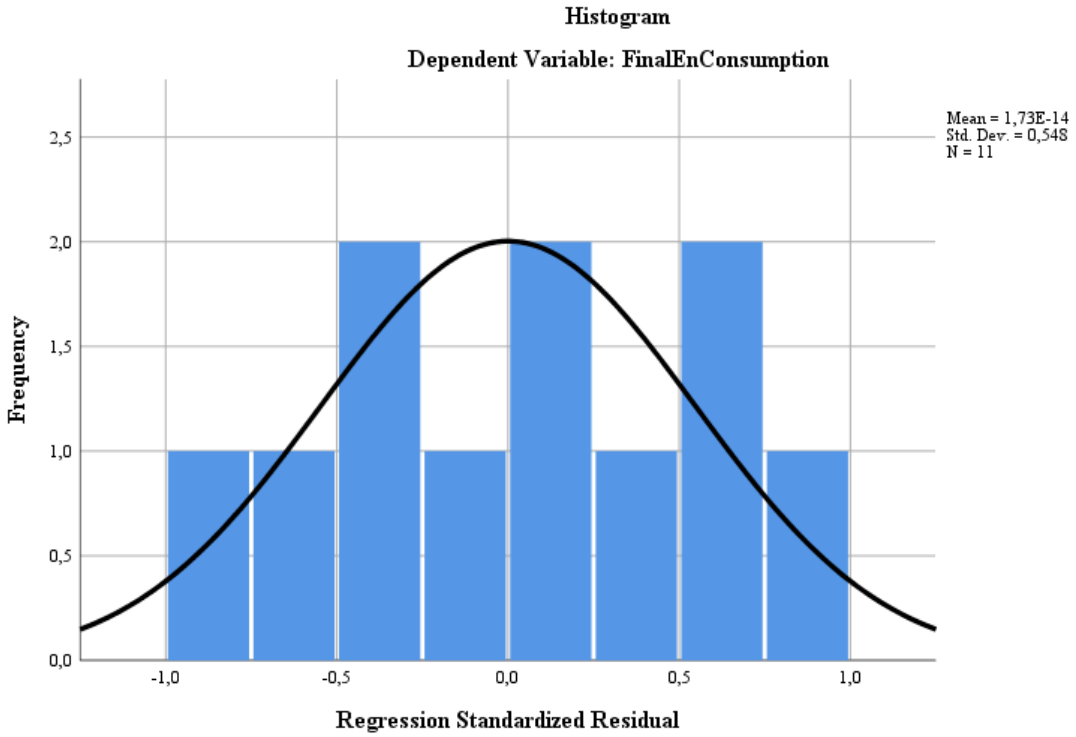

Figure no. 4 . Distribution histogram of the dependent variable final energy consumption

Source: Authors' calculations using SPSS v.25

The Sig coefficient of the F function validates the alternative hypothesis by the value obtained lower than the chosen significance threshold, thus rejecting the null hypothesis and demonstrating the validity of the model.

Table no. 3 –Anova Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5,870	7	,839	19,859	,016[b]
	Residual	,127	3	,042		
	Total	5,996	10			

a. Dependent Variable: FinalEnConsumption

b. Predictors: (Constant), EnImportDependencyOther, EnImportDependencyOil, EnImportDependencyPetroleum, EnImportDependencyGas, RenewEnSource, PrimaryEnConsumption, EnImportDependency

Source: Authors' calculations using SPSS v 25

The modelling of energy sustainability from a security perspective in Romania shows that there is a coherent energy policy, the change in primary consumption influencing 33% of the change in final energy consumption. Consumption of renewables still has a residual contribution to the balance of energy consumption so a one unit increase in consumption of renewables changes final consumption by 5%.

A significant indicator of the energy equation is the reduction of energy import dependency, which contributes 16% of the increase in final energy consumption.

Based on Table 1 we have made Pareto diagrams of the evolution of primary and final energy consumption showing the distribution of consumption options by year as shown in Figure 5.

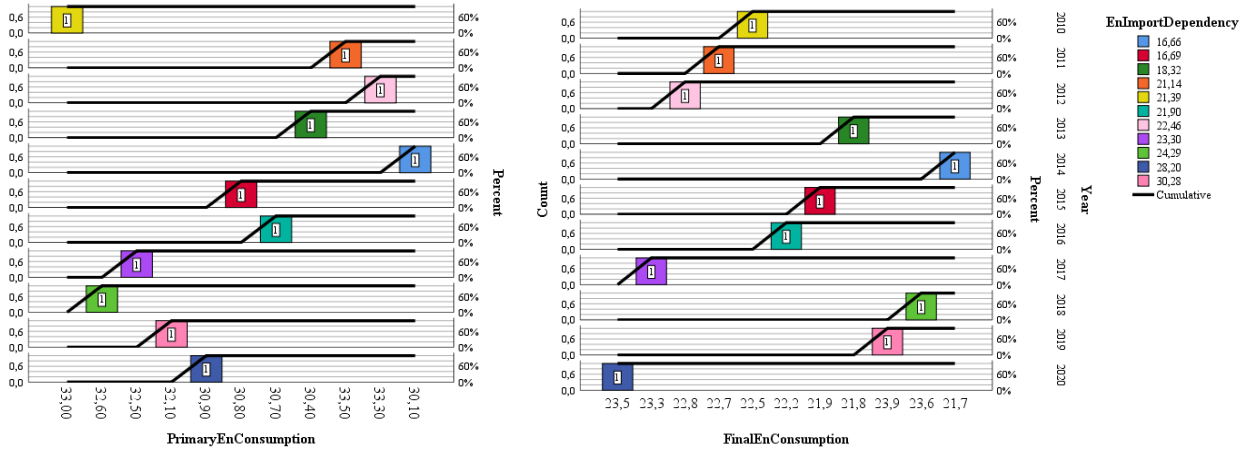

Figure no. 5. Pareto diagrams of primary and final energy

Source: Authors' calculations using SPSS v 25

It is observed that energy security reaches an optimal level in the years of economic stability 2014 (primary consumption index 30.1% and final consumption index 21.7%), 2018 (primary consumption index 32.5% and final consumption index 23.6%) and 2019 (primary consumption index 32.1% and final consumption index 23.9%). The statistical representativeness of the proposed model is 93%, the null hypothesis being rejected by the value of the sig. coefficient of the correlation function F which is lower than the chosen representativeness threshold of 0.05 which confirms the homogeneity of the model.

5. Conclusions

The research aimed to achieve the objectives of the literature review, which meant the consistent study of the literature published in the recent past, with a focus on the cross-cutting linkage of research on energy consumption dynamics in relation to sustainable growth, the transition to green energy and responsible consumption promoted through regulatory approaches by EU authorities, this concludes that there is an intense scientific concern for the sustainable development of the energy sector in the light of several cumulative global challenges since the pandemic period, including the ecological, social, economic and material dimensions that ultimately led to the current energy crisis. As far as the applied research is concerned, we focused on the conceptualization of an energy consumption model, which proved its validity and homogeneity for the analyzed period 2010-2020, with the mention that on Eurostat the data for the year 2021 are not yet valid or definitive at the date of the research. The working hypotheses underlying the modelling were validated by the one-sided critical probability test showing that there is a medium correlation at the Romanian level between primary energy consumption and final energy consumption (hypothesis H1); that there is a strong correlation of final energy consumption with import dependence in the branch at the Romanian level (hypothesis H2). It was also shown that the consumption of renewable resources is mainly influenced by the dependence on oil imports, which proves hypothesis H3.

We set out to assess the energy sustainability of Romania, which according to the results of the study is based on a coherent energy policy that aims in particular to reduce energy consumption and strengthen the green branch based on sustainable consumption of renewable energy. It can be seen that in terms of consumption it had an oscillating evolution with increases in the periods of economic advance with differentiated evolution curves at the level of final consumption and primary energy consumption, thus final consumption and consumption in households had during the pandemic positive changes while primary consumption changed by about 3% (negative growth). From the the model point of view, it was statistically representative and homogeneous, confirming the sustainable development of the energy sector with slight impacts on the green branch amidst European disparities in the implementation of renewable technologies. Romania plays a significant role in the energy equation due to its untapped Black Sea resources and significant energy infrastructure.

The results of the study are useful for policy makers to improve the energy deficit through sustainable practices.

References

1. *Apostu, I.-M., Lazar, M., & Faur, F. (2022). Implications of coal disappearance from the energy mix in Romania. MATEC Web of Conferences, 354(January), 00057. https://doi.org/10.1051/matecconf/202235400057*
2. *Atalla, T., & Bean, P. (2017). Determinants of energy productivity in 39 countries: An empirical investigation. Energy Economics, 62, 217–229. https://doi.org/https://doi.org/10.1016/j.eneco.2016.12.003*
3. *Carfora, A., Pansini, R. V., & Scandurra, G. (2022). Energy dependence, renewable energy generation and import demand: Are EU countries resilient? Renewable Energy, 195, 1262–1274. https://doi.org/10.1016/j.renene.2022.06.098*
4. *Chen, H., Gangopadhyay, P., Singh, B., & Shankar, S. (2022). Measuring preferences for energy efficiency in ACI and EU nations and uncovering their impacts on energy conservation. Renewable and Sustainable Energy Reviews, 156(November 2021), 111944. https://doi.org/10.1016/j.rser.2021.111944*
5. *Comisia Europeana. (2020). Planul Național Integrat în domeniul Energiei și Schimbărilor Climatice 2021-2030. https://energy.ec.europa.eu/system/files/2020-04/ro_final_necp_main_ro_0.pdf*
6. *Costantini, V., Crespi, F., Paglialunga, E., & Sforna, G. (2020). System transition and structural change processes in the energy efficiency of residential sector: Evidence from EU countries. Structural Change and Economic Dynamics, 53, 309–329. https://doi.org/10.1016/j.strueco.2019.05.001*
7. *Eurostat. (2020). Affordable and clean energy. Europa.Eu. https://ec.europa.eu/eurostat/web/sdi/affordable-and-clean-energy*
8. *Girleanu, A., Onea, F., & Rusu, E. (2021). Assessment of the Wind Energy Potential along the Romanian Coastal Zone. In Inventions (Vol. 6, Issue 2). https://doi.org/10.3390/inventions6020041*
9. *He, J., Yang, Y., Liao, Z., Xu, A., & Fang, K. (2022). Linking SDG 7 to assess the renewable energy footprint of nations by 2030. Applied Energy, 317, 119167. https://doi.org/https://doi.org/10.1016/j.apenergy.2022.119167*
10. *Koltsaklis, N. E., Dagoumas, A. S., Seritan, G., & Porumb, R. (2020). Energy transition in the South East Europe: The case of the Romanian power system. Energy Reports, 6, 2376–2393. https://doi.org/10.1016/j.egyr.2020.07.032*
11. *Manta, A. G., Florea, N. M., Bădîrcea, R. M., Popescu, J., Cîrciumaru, D., & Doran, M. D. (2020). The Nexus between Carbon Emissions, Energy Use, Economic Growth and Financial Development: Evidence from Central and Eastern European Countries. In Sustainability (Vol. 12, Issue 18). https://doi.org/10.3390/su12187747*
12. *Mehedintu, A., Soava, G., Sterpu, M., & Grecu, E. (2021). Evolution and forecasting of the renewable energy consumption in the frame of sustainable development: EU vs. Romania. Sustainability (Switzerland), 13(18). https://doi.org/10.3390/su131810327*
13. *Ministerul Energiei. (2022). Strategia energetică a României 2022-2030, cu perspectiva anului 2050. https://energie.gov.ro/wp-content/uploads/2022/08/Strategia-2030_DGJRI_AM_12.08.2022_MU_Clean_25.08.2022-1.pdf*
14. *Potrč, S., Čuček, L., Martin, M., & Kravanja, Z. (2021). Sustainable renewable energy supply networks optimization – The gradual transition to a renewable energy system within the European Union by 2050. Renewable and Sustainable Energy Reviews, 146. https://doi.org/10.1016/j.rser.2021.111186*
15. *Swain, R. B., & Karimu, A. (2020). Renewable electricity and sustainable development goals in the EU. World Development, 125, 104693. https://doi.org/10.1016/j.worlddev.2019.104693*