Theoretical and Applied Economics
Volume XXXI (2024), No. 4(641), Winter, pp. 97-108

Analysis of the global energy resources evolution in the context of the population growth

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Abstract. *The energy resources play a crucial role in national economies, being the engine that drives economic activities and ensures general well-being. Due to their fundamental importance, energy resources must be given priority attention, especially in the current context, where sustainability challenges and climate change are increasingly evident. In this paper, the authors took into account both renewable and traditional energy sources and the evolution of indicators that have a direct influence on national economies and the well-being of the population. At the same time, the increase in energy demand is a phenomenon that humanity is facing and consequently the transition to renewable sources is necessary to ensure long-term sustainability. The analysis of the situation of total energy sources and how they are consumed is essential and some key aspects must be followed in this regard in order to understand how energy resources are managed and used. This approach involves studying the distribution and consumption of energy sources, assessing the efficiency of their use, and identifying current trends and challenges. The global population growth was also considered, which is a complex and unbalanced phenomenon, creating significant challenges related to the need for resources for survival. In this context, the analysis of population dynamics and resource distribution becomes essential for sustainable development.*

Keywords: energy, population growth, consumption, fertility, evolution.

JEL Classification: O13, Q40, Q56.

Introduction

In this paper, the authors turned their attention to renewable and non-renewable energy sources at global, European and national level. Thus, in Romania, non-renewable energy resources, such as oil, natural gas and coal, are limited and exhaustible. These resources lead to considerable expenses with no real prospects for long-term recovery. At the same time, the degree of energy independence in Romania was analyzed, highlighting in this regard the trend that this indicator has, both in terms of total and components.

Internationally, a similar trend of fossil resource depletion is observed, which underlines the need for the transition to renewable energy sources.

At the level of the European Union, the dependence of the member states on energy imports has been highlighted. The European Union places particular emphasis on obtaining renewable energy resources, according to data and indicators provided by Eurostat. EU policies are geared towards broadening the methodologies for exploiting these resources, with the aim of ensuring a gradual and ultimately definitive transition from non-renewable to renewable resources. These efforts are an integral part of the EU's strategies to achieve climate goals and reduce dependence on fossil energy imports.

The growth of the population on the globe, which is somewhat unbalanced, but which needs resources for survival, was also considered. In this regard, the data regarding the countries with the largest populations, global fertility and the prospects for population evolution in the future period were studied and interpreted.

Literature review

This theme related to the evolution of renewable and non-renewable energy sources worldwide has been on the agenda of many researchers. Thus, Adebayo T.S. and others (2021) are concerned with the evolving effects of renewable resource consumption and carbon emissions issues in Sweden, making some statistical-econometric studies in this regard. Ahmad T. and Zhang D. (2020) critically review energy demand and historical global energy consumption. Anghelache C. et al (2023a) carried out a comprehensive study on the current state of non-renewable and renewable energy reserves in the EU and they pointed out that if the current rate of consumption of non-renewable energy resources is maintained, they will soon be depleted, thus it is necessary to use them with caution and even to preserve them and to focus on renewable energy sources. Anghelache C. et al (2023b) conducted an analysis regarding the use of non-renewable resources, as well as the role of research - innovation activity in the discovery, development and implementation of new alternative energy sources in consumption. Blazquez J. et al (2020) are concerned with the energy transition being driven by policy rather than technological improvements, highlighting that the energy transition is disrupting liberalized energy markets and that there is a shift in consumer preferences for cleaner energy. Bouzarovski S. and others (2021) are concerned with energy poverty at the level of the European Union. Driha O. and others (2023) are concerned with the energy produced from renewable sources at the level

of the European Union, approaching in this sense a decomposition analysis of the index together with the logarithmic average division index in the EU27 in the period 2000-2020. Caetano N.S. and others (2017) are concerned with increasing the sustainability of energy production and the efficient use of energy, considering that it is of strategic urgency to use monitoring and control systems and to increase energy production from renewable sources. Chen C. et al. (2021) are concerned with the production of renewable energy and the importance of the involvement of government institutions. Erokhin V. and Tianming G. (2022) were concerned with renewable energy sources in the context of cooperation between China and the Russian Federation. Kufel T. and others (2022) were concerned with the effects of the pandemic (COVID-19) on the business environment considering in this regard energy consumption in some European countries. Rehman A. et al (2021) are concerned with the impact of globalization and energy consumption in Pakistan. Shahzad U. And others (2021) are concerned with environmental policies and whether they facilitate the production and development of renewable energy sources. Sułkowski Ł. and Dobrowolski Z. (2021) consider the issue of implementing the United Nations Sustainable Development Goals (SDGs), which involves sustainable energy, production and consumption, highlighting the fact that energy responsibility is vital. Xu J. et al. (2018) consider decentralized wind energy systems playing an important role in transitioning away from fossil fuel dependence and achieving sustainable economic growth.

Methodology and data, discussions, results

From a methodological point of view, several steps were followed to ensure the rigor and accuracy of the results obtained. Thus, after identifying the problems and research questions related to energy resources and setting the objectives, extensive current research of the specialized literature was carried out.

In the research undertaken, data taken from official sources such as Real Time Worldometers Statistics, Eurostat, the National Institute of Statistics and then processed by the authors through statistical-econometric methods were used to ensure that the comparative study was authentic and accurate.

The methodology used in this research was based on a comprehensive and detailed approach, which involved tabular and graphical representation of data to make the information easier to understand and analyze. In addition, comparative methods were used from one period to another to highlight trends in the evolution of energy resources and the need to expand their use. Dynamic analysis was used to assess the evolution of energy resources and population needs over a longer period of time. This approach was essential to understand long-term trends and changes in the use of energy resources.

This methodology allowed the authors to carry out a rigorous and detailed analysis of Romania's energy resources and their impact on economic macrostability, while providing internationally relevant comparisons.

Results and discussions

If today, the energy resources are represented by a variety of elements, such as oil, coal, gas, hydropower, nuclear energy, wind energy, solar energy and biofuels, a few centuries ago, the humanity focused on one or two energy resources. Thus, for a long time, the predominant source used globally was the combustion of solid fuels, such as: wood, plant waste or coal. In the past, the transition from a certain time of energy resource to another was extremely slow. The explosion in the massive use of coal was generated by the industrial revolution. During the twentieth century, oil, gas and hydropower were used in turn. The nuclear energy was introduced into use relatively late, i.e. after the 1960s. Solar and wind energy, considered modern renewable resources, were included in consumption in the 1980s.

Table no. 1 centralizes data on global primary energy consumption from 1983 to 2023.

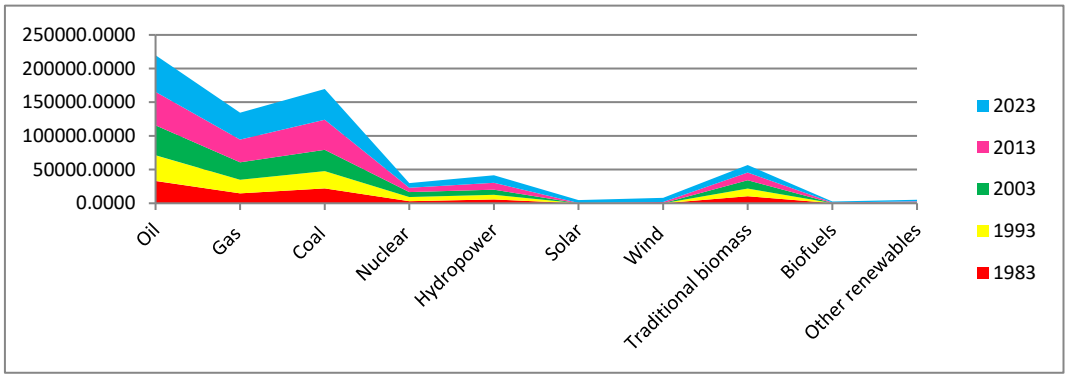
Table no. 1. *Situation of global primary energy consumption, by type of source (TWh, substituted energy)*

	1983	1993	2003	2013	2023
Oil	33099.7580	38024.5700	44580.0500	49654.3630	54564.0000
Gas	14703.8260	20265.4800	25727.7300	33720.7770	40101.7400
Coal	22050.9700	25689.9450	31511.3300	44709.2420	45564.9300
Nuclear	2933.4590	6199.8696	7350.6562	6512.8066	6824.1772
Hydropower	5552.5425	6923.2563	7606.7310	10323.5860	11014.1170
Traditional biomass	10321.0000	11511.0000	12329.0000	11330.0000	11111.0000
Biofuels	49.0192	114.3401	168.9310	820.7763	1317.6246
Solar	0.0089	1.6461	6.5339	377.7912	4264.2610
Wind	0.0970	16.8672	183.5332	1732.0547	6040.3590
Other renewables	211.7706	418.2673	674.7164	1447.8152	2427.8613

Source: https://ourworldindata.org/global-energy-200-years based on the data of Energy Institute - Statistical Review of World Energy, authors' systematization.

For clearer emphasis, the data in the table above have been plotted in Figure 1.

Figure no. 1. *Primary energy consumption worldwide, by type of source*



Source: authors' representation.

Analysing the evolution in dynamics of the indicators presented in table number 1 and graphically sketched in figure number 1, we find a sharp increase in production and energy consumption worldwide. If we analyse these indicators one by one, we find that in 2023, compared to 1983, there is an increase of 64% in terms of oil consumption. Also, significant increases had the production/consumption of natural gas (172%), coal (106%) and nuclear (132%).

What is noteworthy is the development of the renewable energy production system. Thus, if the production / consumption in 1983 of biofuels was of the order of 49.02 TWh, in 2023 it reached 1317.62 TWh. The situation is similar in terms of the energy source based on solar energy, which in 1983 was 0.0089 TWh, and in 2023 it reached 4264.26 TWh and also, wind energy was in the order of 0.097 TWh in 1983 and in 2023 the exploitation reached 62271.74 TWh.

Table number 2 shows the global situation on June 12, 2022 and July 30, 2024 of daily energy consumption and the period of time in which these fossil energy resources will be depleted.

Table no. 2. *Global energy resources as of 12 June 2022 and 30 July 2024*

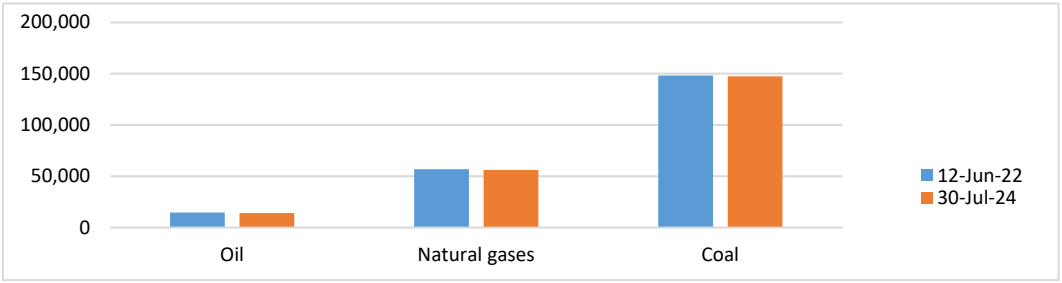
Crt. No.	Source	U.M.	Indicator	Periods	Volumes (June 12, 2022)	Volumes (July 30, 2024)
1	Electricity	Kwh	Consumption	Daily	283,197,500	348,346,000
2	Non-renewable	Kwh	Consumption	Daily	241,332,792	296,576,000
3	Regenerator	Kwh	Consumption	Daily	41,864,708	52,426,000
4	Oil	Barrel	Consumption	Daily	58,312,700	71,676,000
5	Oil	Barrel	Remaining reserves	until exhaustion	1,436,099,720,310	1,361,377,278,000
6	Oil	day	Days until exhaustion	until exhaustion	14,627	14,197
7	Natural gases	Bep	Total Reservations	until exhaustion	1,081,518,350,200	1,066,708,513,000
8	Natural gases	day	Days until exhaustion	until exhaustion	56,922	56,143
9	Coal	Bep	Reservations	until exhaustion	4,294,609,821,700	4,271,991,167,000
10	Coal	day	Days until exhaustion	until exhaustion	148,090	147,310
11	Solar energy that reached the earth	MWh	Extraction	Daily	1,311,454,458,982	2,183,589,452,232

Source: Worldometers accessed June 12, 2022 and July 30, 2024

We note that on July 30, 2024, there was an increase in consumption compared to June 12, 2022 for both electricity and renewable and non-renewable energy with percentages between 22% and 26%. Oil consumption is also up by 22.92% in 2024 compared to the similar period in 2022.

The situation of the reserves of traditional energy sources and the period of time until their depletion is interesting and, in this sense, for an easier visualization and interpretation, the evolution of these variables has been graphically sketched and presented in figures number 2 and 3.

Figure no. 2. *Days left until fossil resources are exhausted*

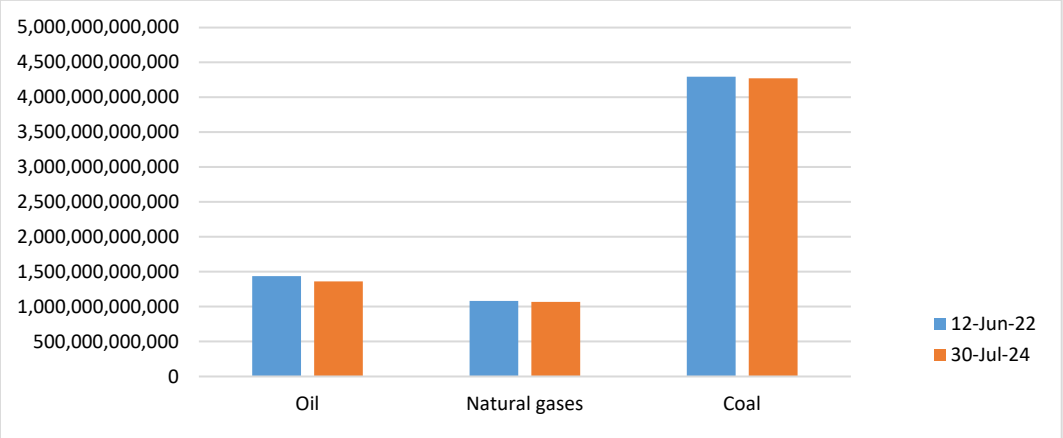


Source: Authors' representation based on Worldometers data.

It can be seen from figure number 2 and the data presented in table number 2 that fossil fuel reserves are decreasing both for oil and for natural gas and coal. The most pronounced

drop is recorded in oil of 5.4% in the last 2 years. The period of time remaining until the exhaustion of these energy sources should not be neglected in the conditions of maintaining this rate of exploitation.

Figure no. 3. *Fossil resource reserves*

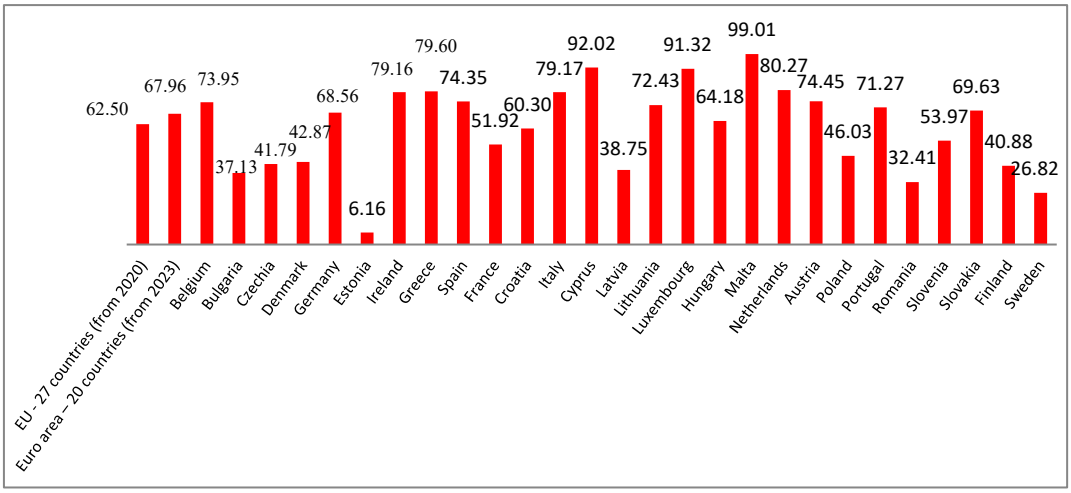


Source: Authors' representation based on Worldometers data.

According to the data presented in the table and represented in figure number 3, we find that as far as oil reserves are concerned, they will be depleted in about 38 years if this pace of exploitation is maintained. As for natural gas reserves, they are sufficient for a period of about 150 years, and coal somewhere around 400 years.

At the level of the European Union, an important indicator is the one that shows how much member states rely on energy imports. In this regard, figure number 4 presents the situation for 2022 in terms of dependence on energy imports at the level of the Member States of the European Union.

Figure no. 4. *Energy imports dependency in the European Union in 2022 (%)*



Source: Authors' representation based on Eurostat data.

There is a strong dependence of many countries, such as Malta (99.01), Luxembourg (91.31) or Cyprus (92.02). Romania occupies a good position, with a share of 32.41% in 2022. It is also relevant to deepen the analysis of energy resources in the context of the growth of the world's population, estimated to reach approximately 10 billion people in 2050. Thus, over time the birth rate on the globe increases, the resources, through exploitation, have diminished. Therefore, it is important to avoid the emergence of crises in the field of energy resources, with instability effects for the future of humanity, and to adopt some measures to limit the impact.

For the analysis of the evolution of the population around the globe, we started by presenting the data on the top ten countries in the world with the largest population, in 2023, making a comparison with the situation they recorded in 1950. The data are contained in Table no. 3.

Table no. 3. *Ranking of countries with the largest population in 2023*

Crt. No.	Country	1950	2023	Relative Exchange 2023/1950
1.	India	346,278,817	1,438,069,597	+315%
2.	China	544,044,354	1,422,584,937	+161%
3.	United States	154,202,683	343,477,332	+123%
4.	Indonesia	68,799,030	281,190,068	+309%
5.	Pakistan	35,849,257	247,504,504	+590%
6.	Nigeria	37,283,018	227,882,949	+511%
7.	Brazil	53,408,551	211,140,731	+295%
8.	Bangladesh	41,206,858	171,466,986	+316%
9.	Russia	103,392,365	145,440,504	+41%
10.	Mexico	27,587,943	129,739,764	+370%

Source: https://ourworldindata.org/population-growth, authors' systematization.

From the analysis of the above data, it can be seen that the predominant number is found in countries on the continents of Asia, North America, Africa, South America. Compared to 1950, some countries have recorded extremely high population growth rates, such as Pakistan (590%), Nigeria (511%) or Mexico (370%).

According to estimates, population growth until 2050 will be extremely unbalanced, and a problem will be the African continent, which will register very high birth rates. In Asia and America (North and South), the birth rate will be relatively acceptable, while Europe will experience a decline in the birth rate.

The main countries with the highest fertility rates are shown in Table no. 4. At the same time, the estimates regarding the number of populations that will be reached as a result of this fertility are also specified.

Table no. 4. *Global fertility in 2023*

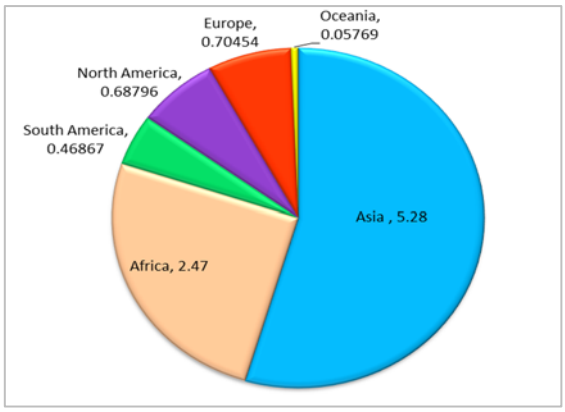
Crt. No.	Country	Number of births 2023	Population 2023 Number of people	Population estimate 2050 Number of persons
1.	Niger	6.06	26,159,862	52,513,880
2.	Angola	5.12	36,749,907	74,295,396
3.	Afghanistan	4.84	41,454,762	76,885,137
4.	Mozambique	4.76	33,635,165	63,530,959
5.	Tanzania	4.61	66,617,607	129,621,093

Source: https://ourworldindata.org/population-growth, authors' systematization.

High fertility is recorded in Somalia (6.13 births), Chad (6.12 births), Democratic Republic of Congo (6.05 births), Mali (5.61 births).

The evolution of the population will cause difficulties in some regions of the planet, especially in Asia and Africa. In fact, the Asian continent will be the most populous, with over 5 billion inhabitants. The population structure by continents in 2050 is highlighted in figure number 5.

Figure no. 5. *Global population in 2050 (billions)*



Source: Authors' representation based on data taken from the https://ourworldindata.org/population-growth

Table number 5 contains data on the countries with the largest population in 2050. So, in almost 25 years, India and China alone will have about 3 billion inhabitants of the planet.

Table no. 5 *Ranking of countries with the largest population in 2050*

Crt. No.	Country	Estimate 2050
1.	India	1,679,589,262
2.	China	1,260,289,087
3.	United States	380,846,899
4.	Pakistan	371,863,799
5.	Nigeria	359,185,557
6.	Indonesia	320,712,943
7.	Ethiopia	225,021,872
8.	Democratic Republic of Congo	218,246,073
9.	Brazil	217,489,299
10.	Bangladesh	214,709,097

Source: https://ourworldindata.org/population-growth, authors' systematization.

We have carried out this detailed analysis of population expansion with the intention of highlighting the need to restructure the energy system, recover materials and prospect for new resources since, at this moment, the future of humanity seems to be influenced by the existing discrepancy between natural population growth and the degree of exploitation of natural resources. In this context, an important role is played by the research, development and innovation activity, in order to focus on other types of resources.

As the expenses for research, prospecting and exploitation are high, there are countries that, although they have resources on their own territory, will not have the financial capacity to

capitalize on this national wealth. Thus, international cooperation becomes essential in the future. At the same time, it would be advisable to succeed in harmonizing the population density of countries/areas of the globe with the resources of those regions.

It is necessary to identify the parallel trend regarding population growth with that of the general resources that humanity will have at its disposal.

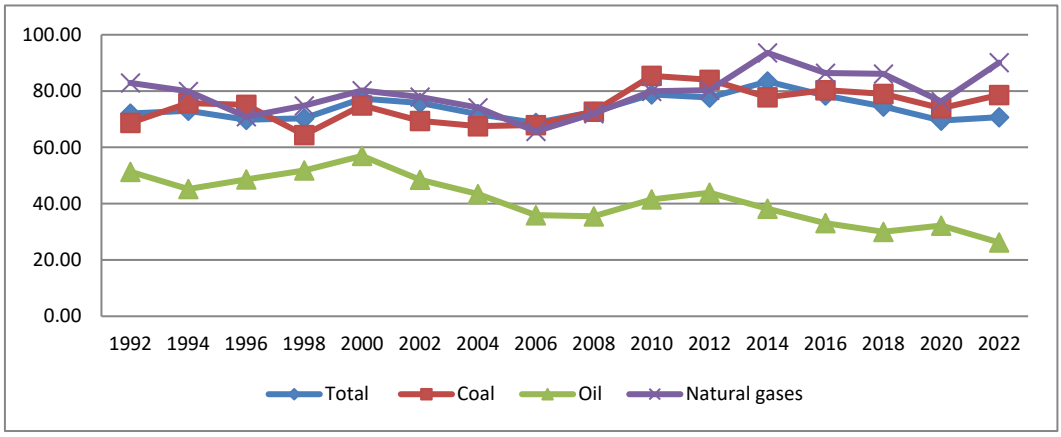
Another indicator that we took into account in this study is the degree of energy independence, which is expressed in percentages and represents the ratio between the production of primary energy and the amount of primary energy available in the reference period. This quantity is calculated by subtracting export and stocks from energy resources at the end of the reference period. Thus, table number 6 and figure number 6 show the evolution of the degree of energy independence in Romania between 1992 and 2022.

Table no. 6. *The degree of energy independence in Romania*

Year	Total	Coal	Oil	Natural gases
1992	72.00	68.70	51.30	82.90
1994	73.00	75.70	45.20	79.90
1996	69.80	75.10	48.60	70.90
1998	70.30	64.40	51.80	74.80
2000	77.30	74.90	57.00	80.20
2002	75.80	69.40	48.50	77.90
2004	71.80	67.50	43.40	74.10
2006	68.70	67.90	35.90	65.70
2008	72.60	72.70	35.50	72.00
2010	78.80	85.40	41.50	79.90
2012	77.70	84.00	43.90	80.30
2014	83.40	77.80	38.20	93.60
2016	78.40	80.30	33.10	86.40
2018	74.50	79.00	30.00	86.10
2020	69.50	73.90	32.20	76.30
2022	70.70	78.60	26.20	90.10

Source: National Institute of Statistics, authors' systematization; Total (including energy products obtained and consumed in households), Coal (including coke), Natural gas (excluding gas oil and ethane from extraction scaffolds that are included in crude oil).

Figure no. 6. *Evolution of the degree of energy independence in Romania during 1992-2022*



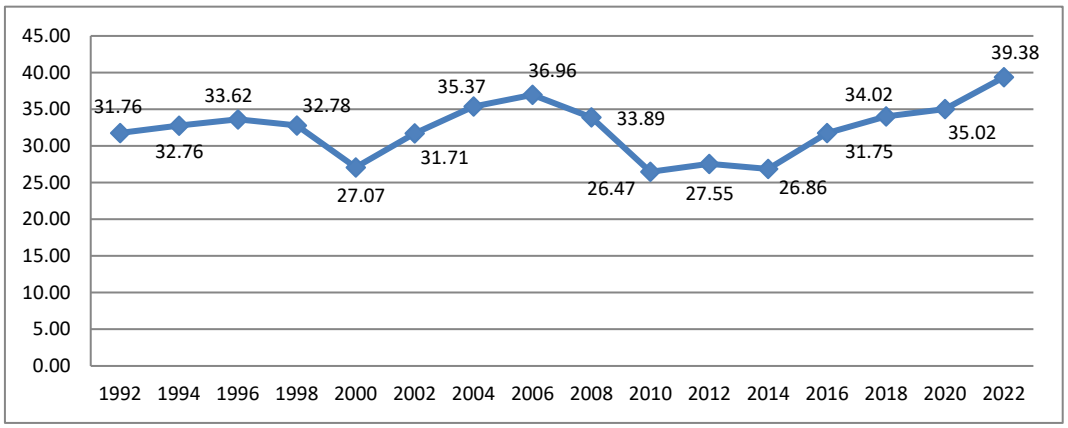
Source: authors' representation based on National Institute of Statistics data.

Analysing the evolution of the degree of energy independence in Romania in the period 1992-2022, we find that both overall and component, the evolution was oscillating, but the trend is linear, with no significant upward or downward evolutions, except in the case of oil, which since 2000 has registered a downward trend with some syncope during the crises (the financial-economic one in the period 2008-2010 and the pandemic one triggered at the end of the year 2019).

However, the degree of dependence on oil in Romania in 2022 is the lowest in the analysed period and it seems that this downward trend is maintained.

Figure number 7 shows the evolution of the share of imports in total primary energy resources in Romania, in the period 1992-2022.

Figure no. 7. *Evolution of the share of imports in total primary energy resources in Romania, during 1992-2022*



Source: authors' representation based on National Institute of Statistics data.

Analysing the data, we find that at the level of Romania, the share of imports in total primary energy resources oscillated from 31.76% in 1992 to 39.38% in 2022. What is interesting is the fact that although there were some downward evolutions related to the periods 1996–2000 and 2006-2010, the crises faced by the world's economies and implicitly Romania had the effect of an increase in the analysed indicator.

Conclusions

From the study done by the authors and presented in this article, a series of conclusions can be drawn. First, given the limitations of non-renewable resources and the urgent need to ensure long-term energy sustainability, it is essential for Romania to invest in the development of renewable resources. National policies must be aligned with European ones, promoting investment in the necessary infrastructure, research and innovation, as well as the creation of an enabling legislative framework. Only through a proactive and sustainable approach can long-term macroeconomic stability and a resilient and competitive national economy be ensured.

Another conclusion is that long-term macroeconomic stability can be maintained through resource sustainability, which involves assessing each country's ability to maintain a balance between energy consumption and production in the long term. Also, a particularly important element is the analysis of the investments needed to develop the energy infrastructure and ensure the transition to renewable sources. By addressing these issues, the research aims to contribute to understanding the complexity and importance of energy resources in the context of economic development and environmental sustainability worldwide.

Another conclusion is that the study found that there are significant possibilities for the development of wind, solar and other renewable energy sources, which can ensure a much more favorable situation for national economies in the future. Within the European Union, analysing the indicators obtained from Eurostat and properly processed, there is a continuous concern for the expansion of methodologies for the exploitation of renewable resources, the objective being to gradually replace, until definitively, non-renewable energy resources in the near future.

Last but not least, the growth of the global population, regionally unbalanced, imposes an urgent need for resources for survival and development, and the efficient management of resources, the promotion of renewable energy sources and the adoption of sustainable development strategies are essential to ensure a stable and sustainable global economy. By implementing these measures, it is possible to respond to the challenges posed by population growth and ensure a better future for future generations.

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