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Population Decline, a Possible Cause for the Reduction of Energy Consumption and thus CO_2 Emissions in Romania

Mihaela-Irma Vlădescu[1], **Mihaela-Georgiana Oprea**[2*]

[1] Center for Demographic Research, National Institute for Economic Research "Costin C. Kirițescu", School of Advanced Studies of the Romanian Academy, Bucharest, Romania
https://orcid.org/0000-0001-8066-4875
e-mail: mihaela.vladescu@ince.ro

[2] Center for Demographic Research, National Institute for Economic Research "Costin C. Kirițescu", School of Advanced Studies of the Romanian Academy, Bucharest, Romania
https://orcid.org/0000-0002-2339-0772
e-mail: oprea@ince.ro

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Abstract: *The transition to a green economy is a complex and necessary process to achieve the goals of sustainable development and climate change mitigation. Population dynamics and sustainable development are closely linked and inseparable. Based on this premise, in this study we try to find out if there is a relationship between demographic decline, energy consumption or population and CO2 emissions at the Romanian level, using the Pearson correlation coefficient. The aim of this study is to analyze the relationship between the transition to the green economy and a number of relevant indicators in Romania in the period 2003-2021. As a result, we will analyze the evolution of the population, the rate of demographic aging, the number of employed people, the level of unemployment, GDP per capita, CO2 and greenhouse gas emissions per capita. Although the results of the analysis indicate that there is a high correlation between both population and per capita energy consumption and between population and CO2 emissions, it is important to note that demographic decline is not the only factor that has led to a decrease in energy consumption and thus a decrease in CO2 emissions. Factors that can produce the same effect include the increase in renewable energy consumption and the strong tendency to use powerful electrical consumers.*

JEL Classification:
Q56; O13; Q40.

Keywords: *Demographic Decline; Population; Energy Consumption; GHG; CO_2 Emissions.*

* Corresponding author

Introduction

The aim of this work is to perform an analysis of the relationship between the population decline and the transition to a green economy, which includes the reduction of energy consumption and CO2 emissions at the Romanian level. In the study, we will try to answer the following question: can population decline contribute to the reduction of energy consumption and CO2 emissions? Therefore, we want to show the interdependencies between these two areas, as well as their impact on social, economic and environmental aspects, in order to enable sustainable development in line with the goals of the 2030 Agenda.

A green economy can be defined as one that aims to "improve human well-being and social equity while significantly reducing environmental risks and ecological scarcity" (UNEP, 2011). It is characterized by low carbon emissions, resource efficiency, and social inclusion.

Population dynamics and sustainable development are closely linked and inseparable, according to Principle 8 of the 1992 Rio Declaration on Environment and Development, "To achieve sustainable development and a better quality of life for all, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate population policies" (UNCED, 1992).

Therefore, it is critical that we pay particular attention to demography, including the changing numbers, characteristics, and distribution of the world's population, when analyzing the challenges and opportunities of sustainable development. Sustainable development must take into account people's impact on the environment and their vulnerability to risks, which vary by age, gender, location, and other socioeconomic characteristics. In general, demographic change is an important factor to consider when it comes to Romania's ability to achieve the 2030 Agenda for Sustainable Development goals (Vădineanu & Celac, 2020).

Demographic analysis is a key factor that allows us to identify the needs and aspirations of the population in order to develop tailored policies and strategies that address the specific needs and challenges of different population groups to achieve sustainable and equitable development. For example, investments in education and health (including reproductive health) can have a significant impact on people's contribution to sustainable development and their ability to adapt to environmental change. Demographic planning can also help anticipate and address the challenges of climate change (Espenshade et al., 1991).

Thus, demography is a key factor in achieving sustainable development and must be integrated into policies and strategies to promote sustainable development. This involves not only understanding demographic characteristics, but also developing appropriate measures and policies that address the specific needs and challenges of different population groups.

Literature Review

Over time, a lot of studies have addressed the key factors that determine carbon emissions. Population growth is often considered the main cause of the increase in CO2 emissions (Guo and Sun, 2017; Chai, 2013; Liddle, 2004). Numerous researchers have studied the relationship between demographic changes, (household) energy consumption, and household CO2 emissions (Maraseni et al., 2015; Li et al., 2016). In addition, researchers have analyzed not only the effects of population size (York et al., 2002), but also possible characteristics due to education, age (Liddle, 2014), gender, occupation, density (Li et al., 2020), and consumption patterns (Kerkhof et al., 2009). In a study, Sørensen (2013) states that there are differences between young and old in energy consumption.

According to some studies in this field, population aging can have a significant impact on CO2 emissions (O'Neil et al., 2012), especially in developing countries (Shi, 2003), and thus on

climate change. In one study, an aging population is found to entail higher government budget expenditures on services specifically for the elderly (Eiras & Niepelt, 2012; Wang et al., 2019), reducing the resources allocated to other sectors. On the other hand, CO2 emissions from transport are decreasing in some countries where the proportion of the population to the total population is increasing (Okada, 2012). An aging population is less active, and as a result, population aging in China (Yu et al., 2018) and South Korea (Kim et al., 2020) has positive effects on carbon emissions. Population aging leads to a decrease in population and, implicitly, a decrease in CO2 emissions due to a decrease in energy consumption (Balezentis, 2020).

Thus, demographic planning can be an essential factor in addressing the challenges posed by climate change and can help anticipate and manage the impacts on human communities and the environment (Espenshade et al., 1991). It is important to note that demographic changes may affect the degree to which the 2030 Agenda goals are achieved (Vădineanu & Celac, 2020).

The increasingly visible effects of climate change require a reduction in evening gas emissions (UNEP, 2022), to which technological innovations can make an important contribution, as they form the fundamental basis for improving energy efficiency and reducing carbon emissions (Li et al., 2020).

Methodology

For the research underlying this paper, a specific methodology was used, which includes the analysis of statistical data series for the period 2003-2021 at the national level, provided by the National Institute of Statistics (INS), Eurostat and Our World In Data. This information is used to identify the structure and evolution of the population, the structure and dynamics of the labor force, the standard of living, as well as an overview of CO2 emissions and greenhouse gasses and energy used. In this sense, since the objective of this study is to find out if the demographic changes affect the energy consumption and consequently the CO2 emissions, we will use the Pearson correlation coefficient to analyze the relationship between the population and the energy consumption per capita or the population and the CO2 emissions in Romania.

The Pearson correlation coefficient indicates a value between -1 and 1 and is interpreted as follows: If the correlation coefficient is -1, it indicates a strong negative relationship. It is a perfect negative relationship between the variables; if the correlation coefficient is 0, it means that there is no relationship; if the correlation coefficient is 1, it means a strong positive relationship. It is a perfect positive relationship between the analyzed variables (Sedgwick, 2012).

Demographic Characteristics and Population Distribution in Romania between 2003 and 2021

Population is one of the most important demographic indicators and has a significant impact on the economy, society, and public policy. Therefore, understanding demographic changes and long-term trends is essential for strategic planning and decision-making in areas such as public health, education, housing, and, last but not least, the labor market

These changes can have a significant impact on the demographic landscape and competitiveness in Europe. According to one study, the magnitude of demographic opportunities is directly proportional to the magnitude of the potential consequences of an aging population (Barsukov, 2019).

In this chapter, we will analyze and interpret data on population trends in Romania in order to draw a comprehensive picture of demographic trends over the last two decades. We will use the available data to trace population trends over the years and identify the factors that have influenced these changes. Special attention will also be given to population structure, which

may be influenced by economic development and environmental conditions (Espenshade et al., 1991).

Between 2003 and 2021, the total population of Romania has changed significantly. For example, Romania's population is projected to increase from 21.6 million inhabitants in 2003 to approximately 19.2 million inhabitants in 2021 (Figure 1). This trend is due to several factors, including a low birth rate, emigration and an aging population.

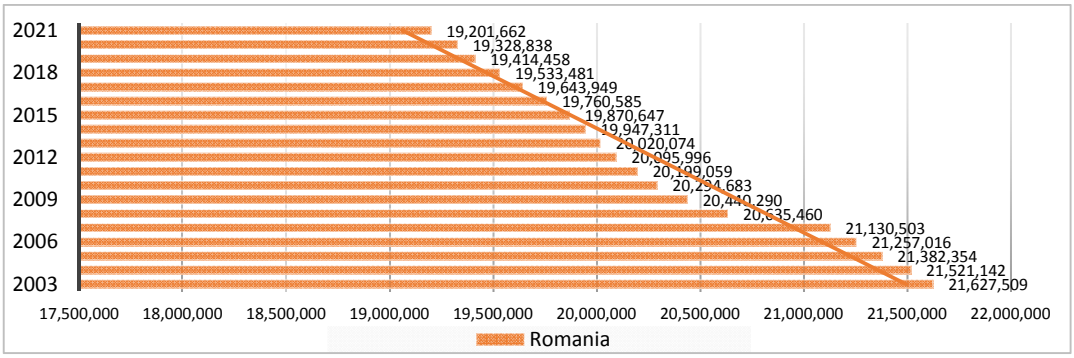

Fig. 1. Population on 1 January

Source: EUROSTAT, demo_pjangroup_page_spreadsheet, accessed on 26.05.2023

In addition to the decline in population, Romania is facing increased demographic aging, characterized by a decline in the proportion of the young population and an increase in the proportion of the elderly population.

As of January 1, 2021, Romania had a resident population of 19,201,662, of which 49% were men and 51% were women. The analysis of the evolution and trends of the stable population shows that in the period 2003-2021, there is a process of demographic decline at the national level, with a negative dynamic of -11.22%, with a higher value at the level of municipalities (-12.64%) and lower in the urban area (-9.95%). Moreover, the downward trend is stronger for the male population (-10.92%) than for the female population (-11.49%). The continuous decrease in the number of inhabitants is part of the national trend of demographic regression. This situation is observed in urban and rural areas, both for the male and female population (Table 1).

Table 1. Evolution of the population at the level of Romania by residence and gender

	2003	**2021**	**population dynamics 2021/2003 %**
Total	21627509	19201662	-11.22
Urban	11434118	10296393	-9.95
Rural	10193391	8905269	-12.64
Male	10538907	9387590	-10.92
Female	11088602	9814072	-11.49

Source: Author's calculations based on data obtained from INS.

Although the population declined by about 2.4 million people between 2003 and 2021, the ratio of males to females fluctuated quite a bit over the years, with the proportion remaining relatively constant. The Romanian population has changed significantly over the past 19 years, particularly due to the decline in the birth rate and the increase in life expectancy. Regarding the distribution of the population by age groups, a different distribution of the population can be observed (Figure 2; Table 2).

Table 2. Population distribution by age groups

	2003 (people)	2012 (people)	2021 (people)	2003 (%)	2012 (%)	2021 (%)
Total	21627509	20095996	19201662			
0-14 years	3804686	3184249	3026943	17.59	15.85	15.76
15-64 years	14769705	13669398	12469723	68,29	68.02	64.94
65+ years	3053118	3242349	3704996	14.12	16.13	19.30

Source: Author's calculations based on data obtained from INS.

The analyzed data show the demographic changes between the years 2003 and 2021, divided into three age groups: under 15 years, between 15-65 years and over 65 years.

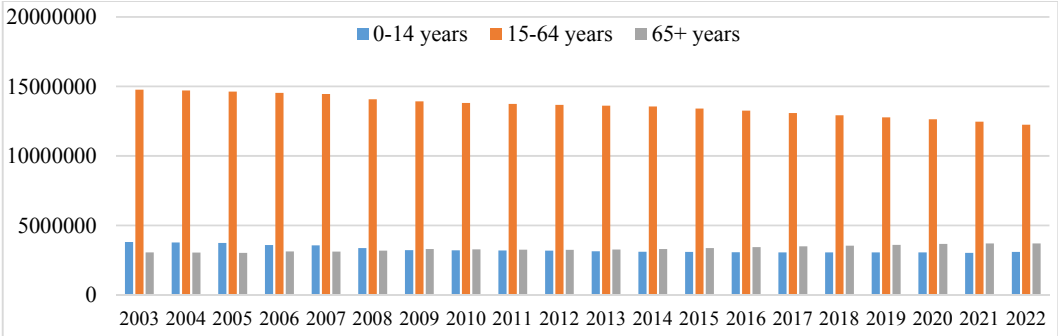

Fig. 2. Romanian usually resident population by age groups 2003 – 2021

Source: INS, TEMPO_POP105A, accessed on 26.05.2023.

As can be seen, the number of people under 15 years old has slightly decreased in the mentioned period, from about 3.8 million in 2003 to about 3 million in 2021, which could indicate a decrease in the birth rate or in the proportion of young people in the population. The 15- to 65-year-old age group has been relatively stable in Romania, with slight fluctuations. The number of people in this category has fluctuated from about 14.7 million in 2003 to about 12.4 million in 2021, which may be influenced by factors such as migration, population aging, and fluctuations in birth and death rates. There has been a significant increase in the over-65 age group in Romania. The number of people in this category has increased from about 3.1 million in 2003 to about 3.7 million in 2021. This could be the result of higher life expectancy and the general aging of the population.

To compare and analyze the age pyramids for Romania in 2003 and 2021, we will examine the main demographic trends and changes in distribution by age group (Figure 3).

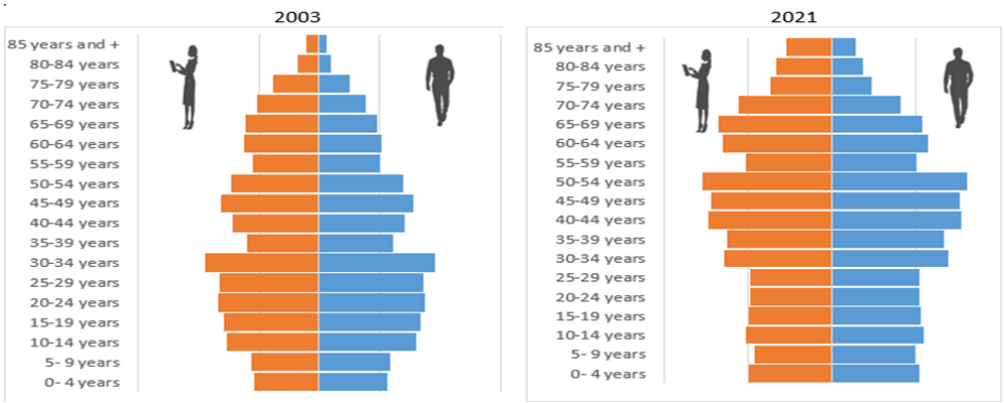

Fig. 3. Romania's population by age groups and sexes (Age Pyramid) on January 2003/2021

Source: INS, TEMPO_POP105A, accessed on 26.05.2023.

In general, an aging trend of the population can be observed in Romania over the years. The young age group (0-4 years) has decreased, while the older age group (60-64 years) has shown a significant increase. This reflects a significant demographic shift that affects the balance between the young and older populations.

Several demographic aspects must be taken into account to explain these developments:

Low birth rate: the decline in the population in the 0-4 age group could indicate a low birth rate. This could be the result of factors such as urbanization, migration, and socioeconomic changes that influence couples' decisions to have children.

Population aging: the 60-64 age group showed a significant increase. This can be attributed to increased life expectancy and improved health care. However, this trend may put additional pressure on the pension system and the health care system, especially with regard to the special needs of the aging population.

Analysis of the age pyramids for Romania in 2003 and 2021 shows a trend toward an aging population, with a decrease in the young population and an increase in the elderly population. These demographic trends may have implications for public policy, health care and pension systems, and the economy and society as a whole.

The population is aging and the labor force is shrinking, raising concerns about future economic growth (Weil, 2006).

Demographic aging leads to an increase in financial transfers from the active portion of the population to the inactive portion represented by the elderly by increasing income taxes and family spending (Mason & Lee, 2011). This aging will lead to an increase in the dependency ratio, which will reduce the disposable income of the working population and lead to a decline in the birth rate (Hock & Weil, 2012).

The demographic aging index is an important indicator of demographic dynamics in a country and reflects changes in the population structure by comparing the proportion of older people with that of young people. In the case of Romania, the evolution of the demographic aging index was influenced by several factors, such as the low birth rate, the increase in life expectancy and the migration of labor. These factors contributed to changing the composition of the population by age group, which led to an increase in the proportion of elderly people and, consequently, to an increase in the demographic aging index in Romania (Figure 4; Figure 5; Figure 6).

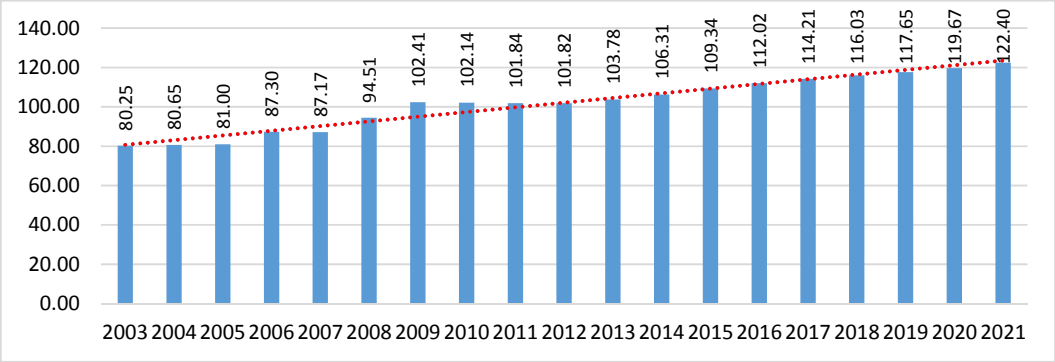

Fig. 4. Demographic aging index in Romania 2003-2021

Source: INS, TEMPO_POP105A, accessed on 26.05.2023.

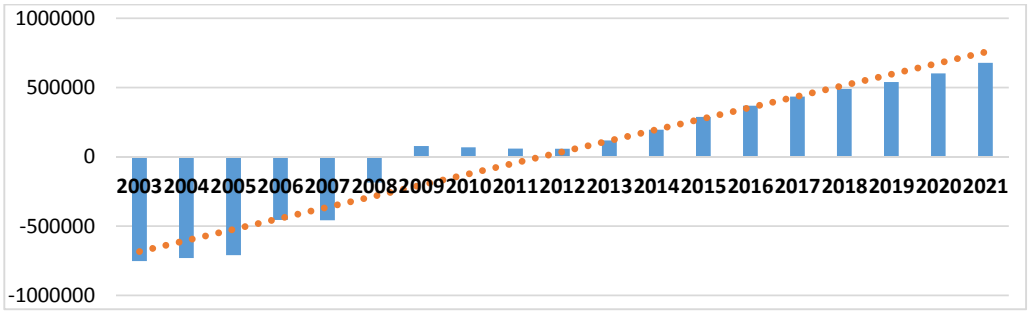

Fig. 5. Demographic gap in Romania 2003-2021

Source: INS, TEMPO_POP105A, accessed on 26.05.2023.

The aging of the population will lead the government to allocate more and more resources to social security programs at the expense of investments in education and infrastructure. This phenomenon will have a negative impact on developing countries as governments' priorities change (Eiras & Niepelt, 2012).

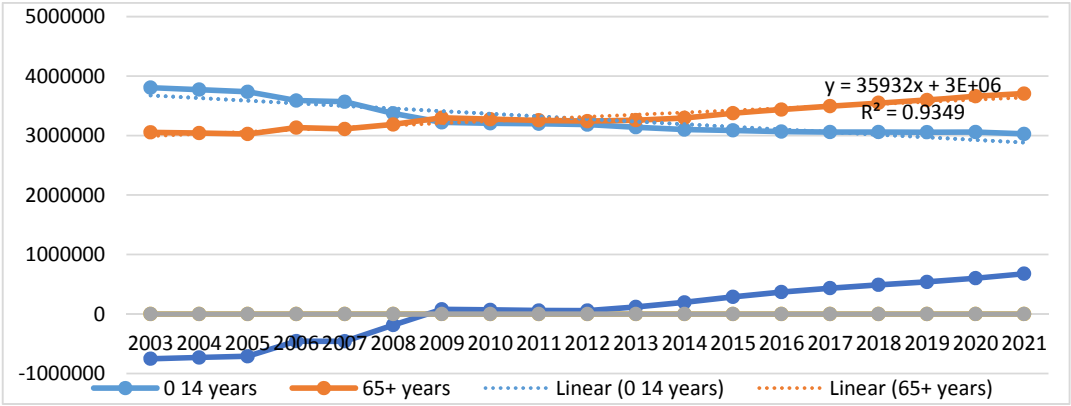

Fig. 6. Evolution of the Demographic Aging Index based on calculations made by the author between 2003 and 2021

Source: INS, TEMPO_POP105A, accessed on 26.05.2023.

The demographic dependency ratio reflects the proportion of the population under 15 years and the population over 65 years compared to the population between 15 and 64 years and shows the impact of aging on economic and social life (Figure 7). The dynamics of this report highlight the extent of demographic imbalances in society (Vasile & Dobre, 2015) and are important for understanding the demographic impact on the economy and the social security system, as well as for identifying future challenges.

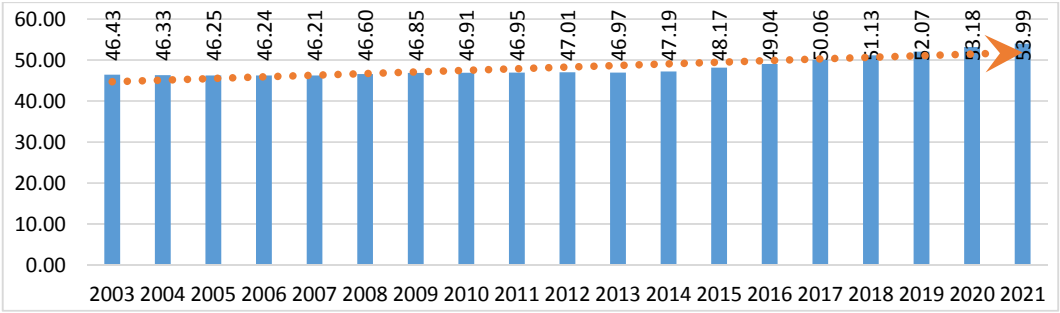

Fig. 7. Demographic dependency ratio based on calculations made by the author (%)

Source: INS, TEMPO_POP105A, accessed on 26.05.2023.

In Romania, the demographic dependency ratio has increased from 46.43% in 2003 to 53.99% in 2021, according to data from INS. This phenomenon can be explained by several causes, including the decline in the birth rate and the increase in life expectancy, as well as the migration of the young population to other countries in search of a better-paid job or a higher standard of living. This trend can have a negative impact on the national economy, as the increasing number of elderly people can lead to higher health and care costs, as well as a decrease in the labor force. To reduce this phenomenon, an integrated approach is needed that includes measures to improve the healthcare system, increase access to education and vocational training for young people, promote investment in research and technology, and, more generally, improve the quality of life in the country. It is important to maintain an intergenerational approach that balances the needs and interests of young, adult and elderly people to ensure a sustainable future for all citizens.

To analyze the evolution of the labor market in Romania in the period 2003-2021, we used data on the employed population and the unemployed from the statistical survey AMIGO (Figure 8; Figure 9).

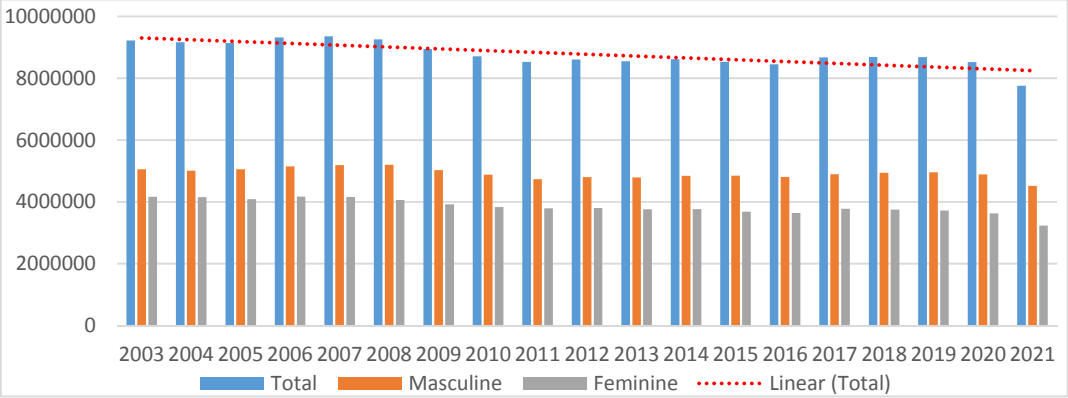

Fig. 8. AMIGO - Employment by sex

Source: INS, TEMPO_AMG110A, accessed on 24.05.2023

In 2003, the number of employed persons in the statistical survey AMIGO was 9,222,508. This number decreased slightly until 2005, then increased again until 2007, reaching a peak of 9,352,472 persons. However, in the following period, the employed population steadily decreased, reaching 7,755,487 people in 2021. This is a worrying trend, indicating a significant decline in the number of employed people in Romania during this period.

The gender distribution shows that in 2003, 5,056,735 men and 4,165,773 women were employed. This distribution remained relatively constant until 2008, after which there was a decline in both categories. In 2021, the number of employed men was 4,519,761 and the number of employed women was 3,235,726.

The interpretation of the data indicates that the employed population in Romania experienced a significant decline in the period 2008-2021. This may be influenced by factors such as economic crises, the health crisis caused by the Covid 19 virus, employment restructuring, and other socioeconomic developments. At the same time, a discrepancy can be observed between the number of employed men and the number of employed women, with the decline being more pronounced for women.

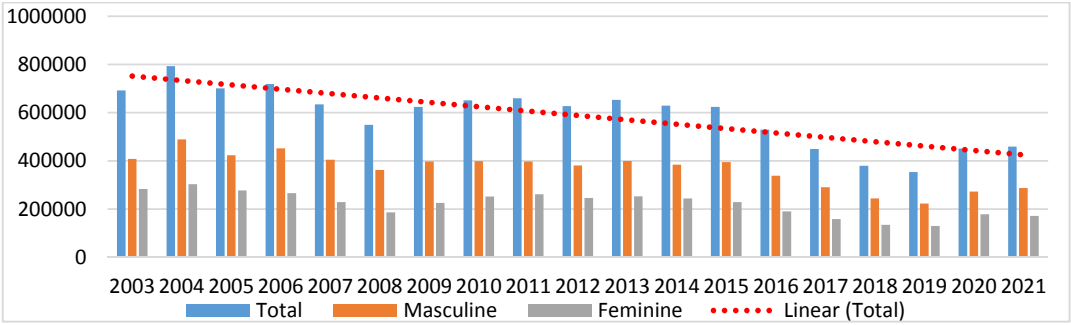

Fig. 9. AMIGO - ILO unemployed by sex

Source: INS, TEMPO_AMG130A, accessed on 27.05.2023.

In 2003, the total number of unemployed was 691,755, while in 2021 this number decreased to 459,195. This indicates a significant decrease in unemployment during this period, although there are significant fluctuations between years. The increasing number of unemployed in 2020 and 2021 could be a result of the Covid 19 pandemic.

The number of unemployed ILOs recorded a significant decrease during the period studied. The gender distribution shows that in 2003 there were 408 006 unemployed ILO men and 283 749 unemployed ILO women. In 2021, the number of unemployed ILO men was 287,296, while the number of unemployed ILO women was 171,899.

Even though the employed population and the number of unemployed ILOs declined during the period under review, the average number of employed persons in Romania increased (Figure 10).

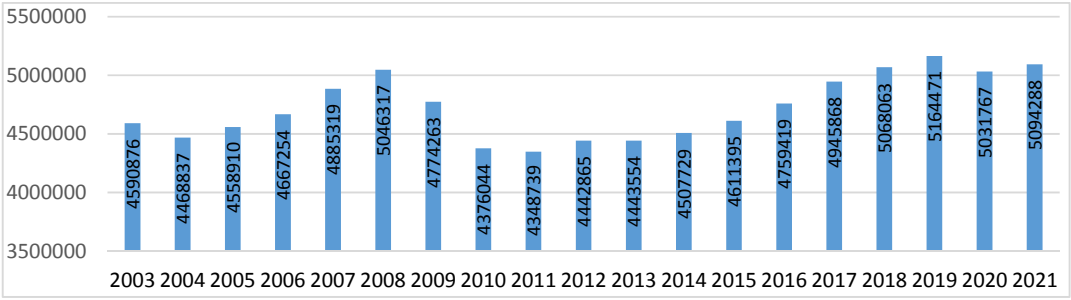

Fig. 10. Evolution of the average number of employees in Romania between 2003 and 2021

Source: INS, tempo_ fom104D, accessed on 26.05.2023

Analyzing the evolution of the average number of employees in Romania between 2003 and 2021, the following trends can be observed:

- General growth: during the period studied, the average number of employees in Romania registered a constant increase. From 4,590,876 employees in 2003, it increased to 5,094,288 in 2021, indicating an expansion of the labor market and an increase in employment in various sectors of the economy.
- Fluctuations over the years: although there is a general upward trend, the average number of employees has also fluctuated over the years. Some fluctuations can be attributed to economic and social factors such as economic crises or changes in labor legislation.
- The impact of the global financial crisis: in particular, during the global financial crisis of 2008-2009, Romania experienced a decrease in the average number of employees. This can be explained by the negative impact of the crisis on the economy and employment.
- Recovery and subsequent growth: after the recession, the Romanian economy gradually recovered, leading to a further increase in the average number of employees. This trend

reflects an improvement in economic conditions and a return of confidence in the labor market.

- Recent trends: In recent years, i.e., prior to the Covid 19 pandemic, the average number of employees has been steadily increasing. However, there was a slight decline in 2020, which can be attributed to the impact of the pandemic on the economy and employment. It is important to note that the data for 2021 may also be affected by the impact of the pandemic.

The trend in the average number of employees in Romania between 2003 and 2021 shows a general increase, with fluctuations over the years due to the impact of the economic crises. The most recent trend indicates an upturn and sustained growth, with the exception of 2020, which was affected by the pandemic. This information can provide insight into the dynamics of the labor market and the economic development of the country during this period.

Although the average number of employees in Romania is decreasing at the county level, the situation differs from county to county in both 2003 and 2021.

In order to analyze the distribution and percentage evolution of the average number of employees in Romania between 2003 and 2021, we calculated the percentage difference between the number of employees in each county in 2021 and the number of employees in the same county in 2003 compared to the number of employees in 2003.

Counties with the highest percentage increase in the number of employees: Ilfov - percentage increase of approximately 175.59% (from 58,113 to 160,167 employees); Cluj - percentage increase of approx. 38.01% (from 175,132 to 241,685 employees); Timiş - percentage increase of approximately 33.01% (from 181,047 to 240,851 employees).

Counties with the largest percentage decrease in the number of employees: Dolj - percentage decrease of about 8.29% (from 133,135 to 122,096 employed); Constanta - percentage decrease of about 6.03% (from 180,383 to 169,267 employees); Braşov - Percentage decrease by approx. 4.84% (from 178,101 to 169,714 employees); Bihor - Percentage decrease by about 4.22% (from 161,258 to 154,451 employees)

As the demographic dynamics have changed, a population forecast is needed to implement appropriate policies and programs to achieve the Sustainable Development Goals (Figure 11).

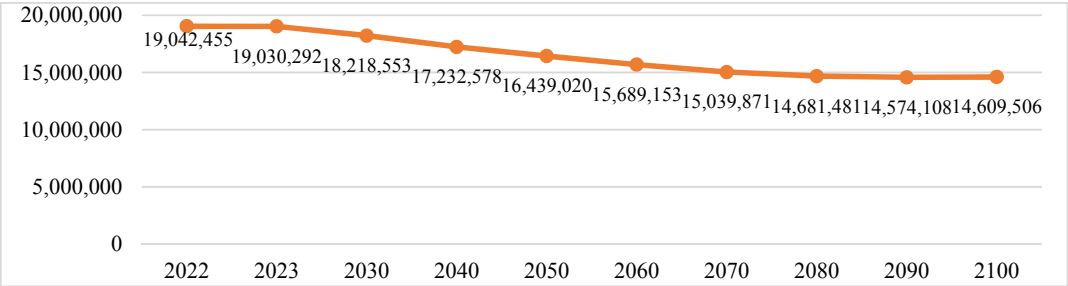

Fig. 11. Population projection until the year 2100 - Romania and the EU

Source: EUROSTAT, tps00002_page_spreadsheet, accessed on 26.05.2023

Population projections show a gradual decline from about 19 million inhabitants in 2022-2023 to about 14.6 million inhabitants in 2100, indicating a long-term demographic downward trend in Romania.

These projections are the result of applying mathematical models and are influenced by a number of factors, including birth, death, and migration rates. Long-term estimates can be uncertain and affected by unforeseen demographic, economic, and social changes.

Analysis of the data shows that Romania is facing demographic challenges, such as an aging population and declining birth rates, which could have economic, social, and political implications that require appropriate policies and measures to respond to demographic challenges.

Energy Consumption and Emissions

Considering that there is a close relationship between demography, environment and the need for a green transition to a sustainable development model, in this chapter we will analyze energy consumption and per capita emissions in Romania.

The green economy can be characterized as one with low carbon emissions, efficient use of resources, and promotion of social inclusion (Loiseau et al., 2016) and is considered a key element of economic development (Mihăilescu et al., 2021).

The development of ecological transition is an important step towards sustainable economic, social and environmental development. The ecological transition refers to the transition from an economic model based on intensive resource consumption and pollution to a sustainable model that promotes the efficient use of resources, the reduction of greenhouse gas emissions, and the protection of the environment (Wang et al., 2023). In this context, Bashir et al. (2023) state that technological progress plays a crucial role in the transition to renewable energy, which is considered an alternative form of energy (Krasovskaya et al., 2023).

Although Romania experienced a decrease in population during this period, it is important to evaluate how this affects energy consumption. A smaller population can have a positive impact on the environment because fewer people mean fewer resources consumed and less waste generated (Rodríguez & Bustamante, 2003). This can lead to lower energy consumption, but this aspect can be offset by other factors such as the level of economic development (Figure 12), standard of living, or energy policy.

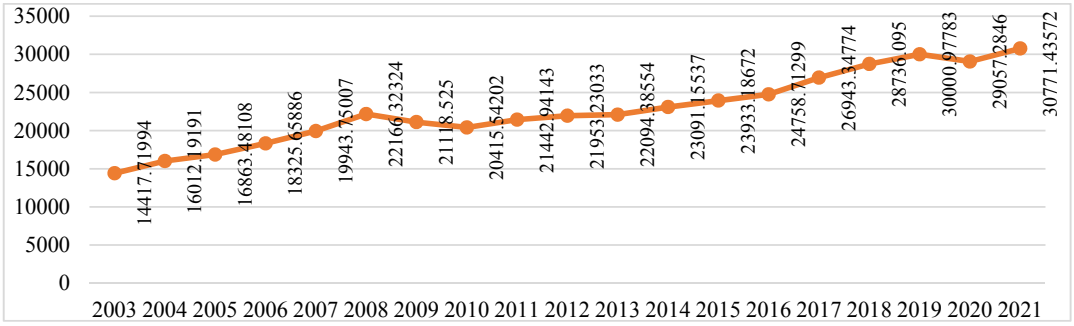

Fig. 12. GDP per capita (PPP) Romania and the EU between 2003 and 2021 ($)

Source: Our World In Data, accessed on 26.05.2023.

Romania managed to reduce its carbon emissions and at the same time had economic growth. To analyze the evolution of energy consumption versus GDP per capita in Romania between 2003 and 2021, we will use data on energy consumption per capita and GDP per capita expressed in purchasing power parity (PPP) for each year (Figure 13).

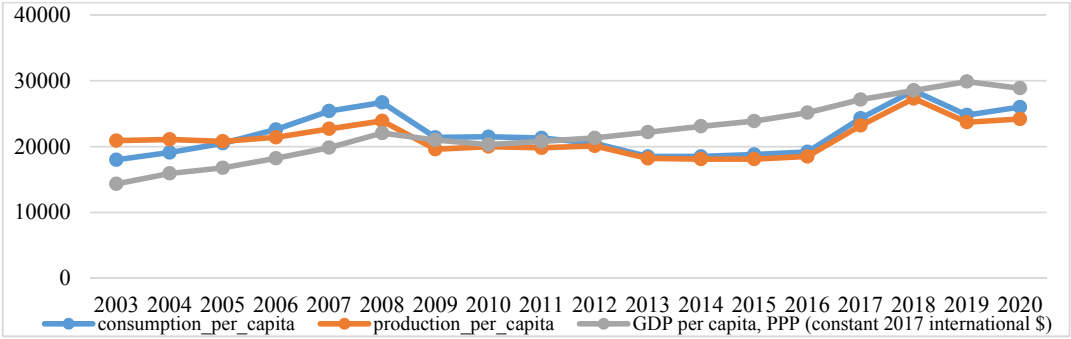

Fig. 13. Changes in the evolution of energy consumption vs GDP per capita (PPP) in Romania between 2003 and 2021

Source: Our World In Data, accessed on 26.05.2023.

Per capita energy consumption increased from 18,000 kWh in 2003 to 26,000 kWh in 2021, indicating a significant increase in energy consumption in Romania during this period.

GDP per capita in Romania increased from 14,338.35 international dollars in 2003 to 28,870.93 international dollars in 2021, indicating a significant increase in the country's level of economic development.

Putting the development of energy consumption in relation to GDP per capita, it is clear that energy efficiency in Romania has improved during this period. Although energy consumption increased, GDP growth was higher, indicating more efficient energy use and higher economic productivity.

Although energy consumption and GDP per capita have generally increased, there are some fluctuations in certain periods. For example, between 2008 and 2009, both values decreased in connection with the global economic crisis and Romania's accession to the EU in 2007. However, after this period, both values increased again.

In general, these data suggest that Romania experienced significant economic growth and more efficient energy use during the period studied. However, it is important to note that there are several factors that can influence energy consumption and GDP per capita, such as energy policies, infrastructure investments, and industrial sector development. A more comprehensive understanding would require a more detailed analysis and assessment of the specific causes of the increase in energy consumption and GDP per capita in Romania during this period.

A number of other factors may also contribute to the increase in energy consumption, such as increased industrialization, accelerated urbanization, higher living standards, and, last but not least, technological modernization.

On the other hand, the growth of GDP per capita may be influenced by foreign direct investment. Attracting foreign investment can promote economic development and help increase GDP per capita by creating new jobs, transferring technology, and increasing production capacity.

Energy and climate change are closely linked. Energy production and consumption account for a significant portion of greenhouse gas emissions that contribute to global climate change (European Court of Auditors, 2019). The processing and burning of fossil fuels such as coal, oil, and natural gas to generate electricity and heat results in significant emissions of greenhouse gasses, particularly carbon dioxide (CO2). Therefore, it is important to analyze per capita energy consumption, energy consumption from fossil fuels, energy consumption from renewable sources, greenhouse gas emissions, and CO2 emissions per capita in Romania and the EU (Figure 14; Figure 15 Figure 16; Figure 17).

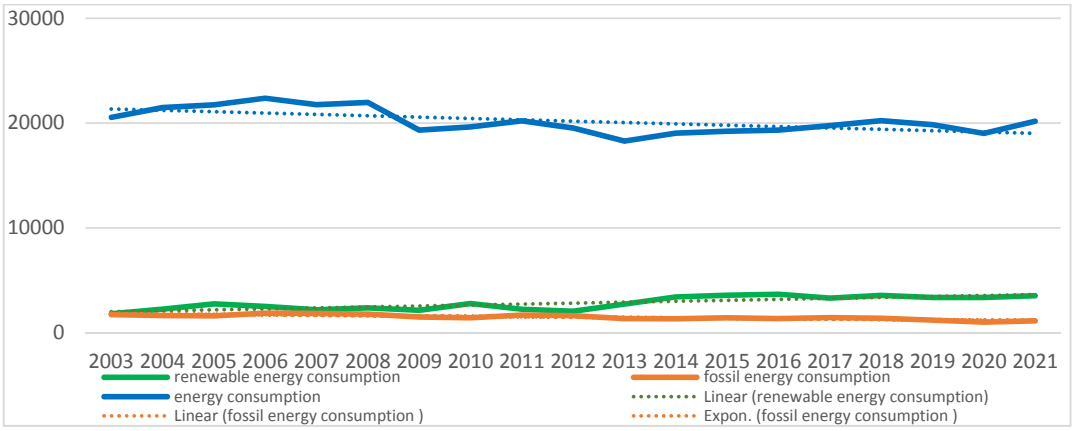

Fig. 14. Evolution of total/ fossil/ renewable energy consumption per capita in Romania (kWh) between 2003 and 2021

Source: Our World In Data, accessed on 26.05.2023.

In 2003, the per capita energy consumption in the EU was 43,273.69 kWh, while in Romania it was 20,540.85 kWh. This means that the per capita energy consumption in the EU in that year was about twice as high as in Romania.

Between 2003 and 2008, per capita energy consumption increased, but in 2009 it decreased by more than 2000 kWh compared to the previous year. Since 2010, except for minor fluctuations, per capita energy consumption has been rising steadily again. However, growth in Romania has been slower than the EU average.

These figures show that per capita energy consumption in Romania was lower compared to the EU average throughout the period studied. This can be influenced by several factors, including the level of economic development, the industrial structure, the level of energy efficiency and the energy policies applied in each country.

It is important to note that the development of per capita energy consumption does not directly reflect energy efficiency or the level of economic development, as it can also be influenced by other factors such as the total population and the structure of the economy.

Per capita fossil fuel consumption fluctuated throughout the period studied. A significant increase was observed in 2006 and 2007, followed by a decrease until 2009, after which fossil fuel consumption continued to fluctuate but showed a general downward trend until 2021.

Both the EU and Romania have attempted to reduce dependence on fossil fuels during this period. Lower fossil energy consumption in the EU reflects policies and investments in energy efficiency, renewables, and other alternative energy sources. However, fossil fuel consumption remains significant in both cases, indicating the need for further efforts to promote sustainable alternatives and reduce environmental impacts.

Per capita renewable energy consumption has increased significantly during this period. This is due to efforts to promote renewable energy sources and the implementation of sustainable energy policies.

In general, per capita renewable energy consumption in Romania was lower than in the EU in every year recorded. This may be due to differences in the development of renewable energy infrastructure and the level of investment in these sectors. In this case, the value of GDP plays an important role (Lean & Smyth, 2010).

In the case of Romania, the per capita consumption of renewable energy has fluctuated over the years. Although there was an overall growth during this period, there were some fluctuations depending on renewable energy policies and investments.

Given Romania's abundant natural resources, such as solar, wind, hydropower, and biomass, there is great potential for renewable energy development in the country. Appropriate investments and incentives could help accelerate the transition to a cleaner and more sustainable energy source.

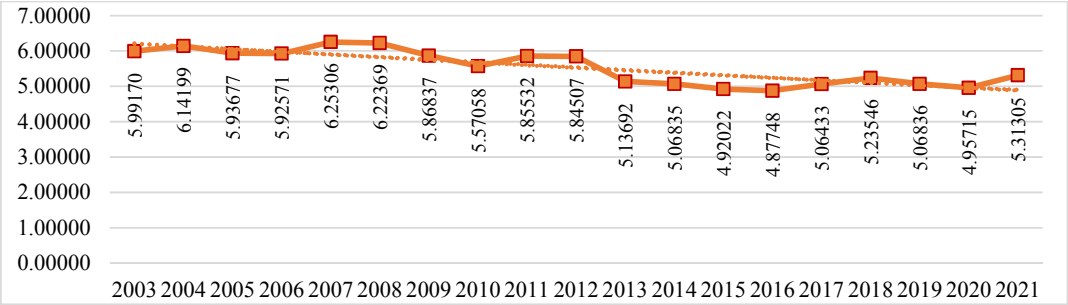

Fig. 15. Evolution of greenhouse gas emissions (GHG) per capita/tonnes eq. CO2 in Romania between the years 2003-2021

Source: Our World in Data, accessed on 26.05.2023.

Romania experienced a downward trend in per capita greenhouse gas emissions during this period. This is indicative of the efforts made to reduce the impact of climate change and transition to a more sustainable economy.

It is important to note that the trend of GHG emissions per capita in Romania is influenced by the economic structure of the country, with a significant share of the industrial and energy sectors generating higher emissions. Although Romania has made significant progress in reducing GHG emissions per capita over the last two decades, there are still challenges in addressing climate change and further efforts are needed to achieve environmental goals and promote sustainable development. Therefore, it is necessary to continue to invest in clean and sustainable technologies, promote energy efficiency, and adopt more ambitious environmental policies to meet EU commitments and climate change targets.

In 2003, Romania's per capita greenhouse gas emissions were 5.99170 tons of CO2 equivalent, while the EU average was 10.34231 tons. Thus, Romania is below the EU average in terms of per capita emissions.

Between 2003 and 2007, Romania recorded a slight increase in per capita GHG emissions, reaching a peak of 6.25306 tons in 2007. After 2007, Romania experienced a downward trend in GHG emissions per capita. This decrease was more significant in the period 2009-2014, when emissions decreased from 5.86837 tons to 3.92022 tons. Thereafter, emissions fluctuated slightly but generally continued to decline, reaching 5.31305 tons in 2021.

Overall, Romania has managed to reduce GHG emissions per capita, albeit at a slower rate than the EU average. However, it should be noted that Romania had a lower baseline for per capita emissions compared to the EU average, which could indicate a different economic and energy structure.

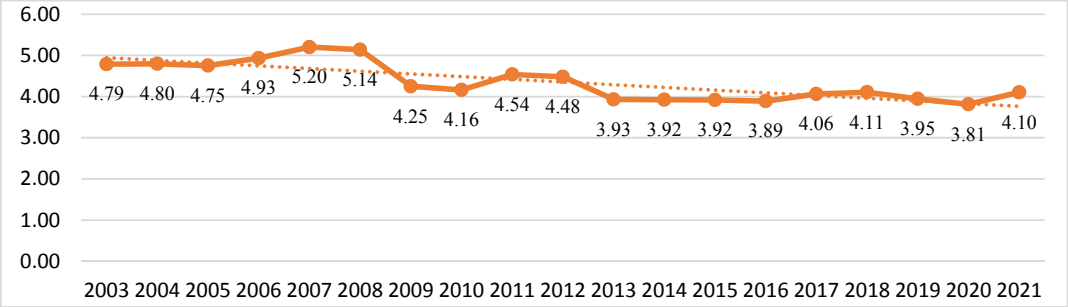

Fig. 16. Evolution of CO2 emissions per capita/tons in Romania in the period 2003-2021

Source: Our World in Data, accessed on 26.05.2023.

Romania experienced a downward trend in CO2 emissions per capita during this period, reflecting efforts to reduce pollution and transition to a greener economy.

In 2003, Romania had CO2 emissions per capita of about 4.79 tons, while the EU average was 8.71 tons. This placed Romania below the EU average. Between 2003 and 2008, CO2 emissions per capita increased slightly, reaching 5.20 tons in 2007, but after 2008 there was a significant decrease in CO2 emissions per capita, mainly due to the economic crisis and efforts to reduce greenhouse gas emissions.

It is important to point out that the evolution of CO2 emissions per capita in Romania is influenced by the economic structure of the country, with a significant share of the industrial and energy sectors, which generate higher emissions.

When analyzing the evolution of greenhouse gas emissions in Romania, a significant variation from one year to another can be observed. In general, emissions fluctuated significantly between 2003 and 2009, with sharp increases and decreases. After that, emissions registered a general downward trend, except for an occasional increase in certain years.

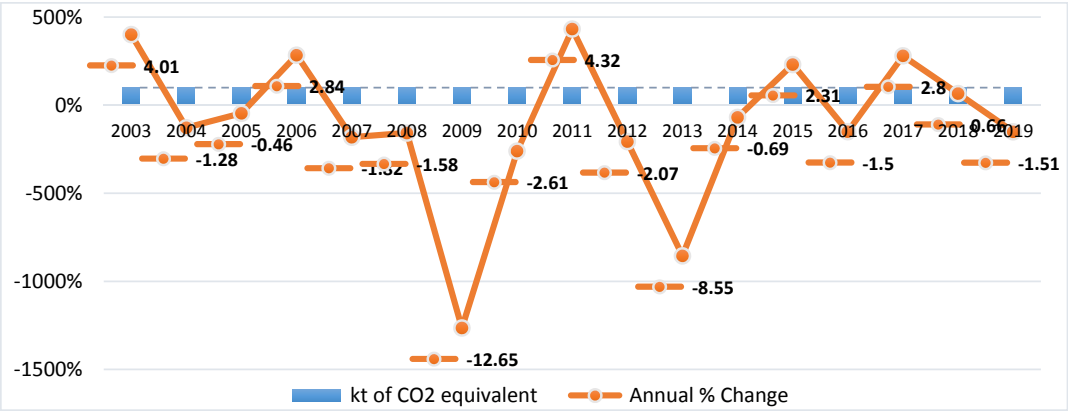

Fig. 17. Evolution of GHG emissions in Romania in kilotons (kt) of eq. CO2 and annual percentage changes (%), during the period 2003-2020

Source: Our World in Data, accessed on 26.05.2023.

The annual percentage changes show that in Romania there were periods with an increase in GHG emissions, followed by periods with a decrease. The most significant decreases were in the period 2009-2013, when emissions decreased significantly. In recent years, there have been fluctuations, but the general trend has been a decrease in emissions.

It should be noted that data for 2021 are not available, so we cannot draw conclusions about the trend in emissions in that year.

The causes of the occasional increase in greenhouse gas emissions in Romania can be influenced by various factors: industry, energy consumption, agriculture, transport, government policies and measures. Increased industrial production and energy consumption in various sectors can contribute to an increase in emissions. The agricultural sector can also influence GHG emissions through agricultural practices. In addition, increases in the number of vehicles and distances traveled in transportation can contribute to increases in emissions. It is important to analyze each one-time increase in GHG emissions in detail to determine the specific causes and possible ways to reduce them in the future.

The Influence of Demographic Changes on Energy Consumption and CO2 Emissions

According to studies in this field, there is a strong correlation between population size, energy consumption and CO2 emissions (Lozano & Gutierrez, 2008). This relationship is due to the fact that a larger population requires more energy to support daily activities and that energy production and consumption lead to carbon dioxide emissions (Begum et al., 2015; Dong et al., 2018). On the other hand, in certain cases, no clear relationship can be found between population growth or decline and CO2 emissions, due to low income, low purchasing power, and especially the increase in renewable energy consumption. The per capita renewable energy consumption increased by 1735 kWh in 2021 compared to 2003 in Romania and by over 4207 kWh in the European Union, but both energy consumption and per capita renewable energy consumption are lower in Romania than the EU average.

In contrast to the EU, Romania is going through a different evolution: the population has decreased by more than 2.4 million people, but the energy consumption has decreased by only 373 kWh. To support the previously mentioned aspects, we have analyzed the relationship between the two indicators population and per capita energy consumption with the Pearson correlation coefficient (Figure 18).

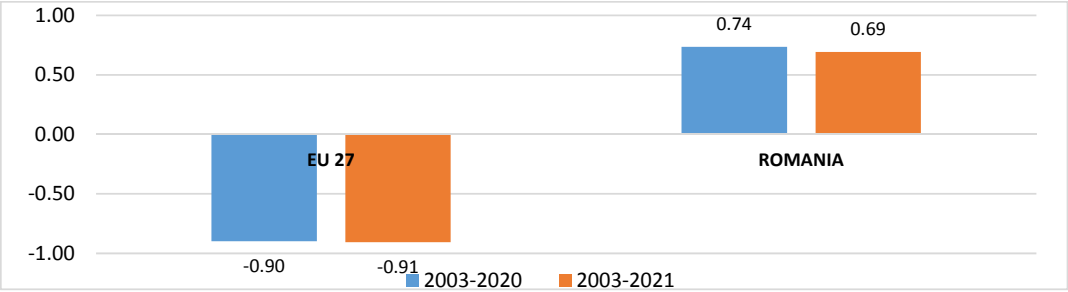

Fig. 18 The relationship between population size and energy consumption per capita in Romania and the EU between 2003 and 2021

Source: Author's calculations based on Eurostat and OUR WORLD IN DATA data.

In the case of the EU, the correlation for 2021 was high, with a negative coefficient of -0.91. For Romania, the correlation was positive at 0.69, making the correlation between the two indicators quite high. Since the year 2021 is atypical due to the partial lifting of the restrictions caused by the pandemic, the above graph also includes the analysis of the period 2003-2020, where a closer correlation between the two indicators is observed at the Romanian level.

Consequently, the population size can influence the energy consumption (in the case of Romania), but as can be seen in the case of the EU, there can be many other factors that determine the increase or decrease in consumption. For example, the population may increase and energy consumption may tend to decrease.

Demographic change can significantly affect carbon dioxide (CO2) emissions in several ways: Population growth can lead to greater demand for food, energy, and resources. Increased

production and consumption can lead to higher CO2 emissions; Urbanization as a result of population concentration in cities and urban areas can translate into higher energy consumption and CO2 emissions; Changing consumption patterns: as incomes and living standards rise, which is especially the case in large cities, consumption patterns may change; The average age of the population is another aspect that should be considered when monitoring trends in CO2 emissions; Demographic decline may have a positive impact on CO2 emissions. If individual and collective consumption is lower, CO2 emissions associated with the production and consumption of goods and services could decrease due to lower consumption.

In this sense, we will use the Pearson correlation coefficient to analyze the relationship between the two indicators, population and CO2 emissions, both at the level of Romania and at the level of the European Union (Figure 19).

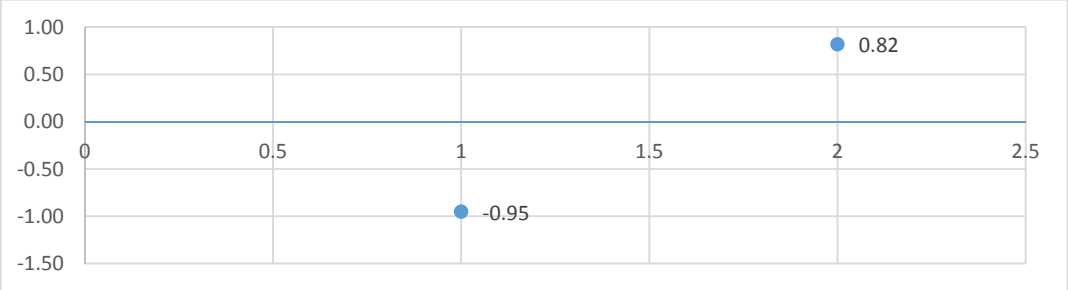

Fig. 19. The relationship between population size and CO2 emissions per capita in Romania and the EU between 2003 and 2021

Source: Author's calculations based on Eurostat and OUR WORLD IN DATA data.

In both cases we obtained a high correlation of the analyzed indicators. At the European Union level, the coefficient between the two variables is negative (-0.95), which means that CO2 emissions decrease when the population increases. In the case of Romania, the two indicators show a downward trend, except for 2021, when CO2 is higher than the previous year, due to the partial lifting of traffic restrictions from the pandemic period. As a result, the coefficient between the two variables is positive at 0.82.

Considering the obtained results, we can conclude that in the case of Romania, a correlation can be observed between the population decrease and the reduction of CO2 emissions. At the same time, energy consumption can influence CO2 emissions, so for Romania we obtained a Pearson correlation coefficient of 0.76, which can mean that we have not reached a high level of renewable energy consumption, so energy consumption no longer exerts such a great influence on CO2 emissions.

Therefore, we can conclude that the decrease in energy consumption and CO2 emissions may be related to the decrease in population (Figure 20).

Fig. 20. Link between population, energy consumption and CO2 emissions

Source: Author's conception.

It is important to note that the impact of demographic change on CO2 emissions may also be influenced by other factors, such as government policies, available technology, availability of renewable energy sources, and public awareness and commitment to climate change.

Conclusions

Romania has experienced a population decline in recent decades. This may be due to migration abroad, declining birth rates, and an aging population. A smaller population can lead to lower energy consumption and CO2 emissions.

Romania has made progress in reducing CO2 emissions per capita over the last two decades. However, further efforts are needed to achieve environmental goals and combat climate change in a sustainable way. Romania needs to invest in green technologies, renewable energy and energy efficiency in order to continue the trend of reducing CO2 emissions and to meet the commitments of the EU and international environmental agreements.

According to the data analyzed, there has been a decrease in population, energy consumption, and carbon dioxide (CO2) emissions at the national level, which may indicate a relationship between the three indicators. It is important to point out that population decline is not the only factor that has led to a reduction in energy consumption and, consequently, CO2 emissions.

Among the important factors that can influence energy consumption and thus emissions, we include: High energy efficiency, which leads to lower consumption; The economic transition from an intensive industry-based economy to one based on services and other less energy-intensive sectors; Large investments in renewable energy and an increase in the use of renewable energy, which can lead to a reduction in dependence on traditional energy sources and a decrease in CO2 emissions.

Of course, they may in turn be determined by other economic, political and technological factors. Therefore, monitoring energy consumption and CO2 emissions and continuing efforts to increase energy efficiency and the use of clean energy sources can help maintain these positive trends.

In conclusion, Romania is facing a rapid demographic change that affects the sustainable development of the country. The data analyzed underscore the importance of transitioning to a green economy in Romania. A shrinking population can offer advantages in implementing sustainable policies, but an integrated and coordinated approach is needed to achieve this transition. Population decline has had a positive impact on the environment, as fewer people consume fewer resources and generate less waste (Rodríguez & Bustamante, 2003). Romania has the opportunity to use resources efficiently and play an active role in mitigating climate change by promoting renewable energy and adopting long-term sustainable policies. Romania can contribute to the achievement of Goal 7, which concerns clean energy accessible to all. This includes promoting renewable energy, improving energy efficiency, and increasing access to green energy, which are critical to reducing dependence on fossil fuels and combating climate change. In addition, transitioning to a green economy can help achieve Goal 13 on climate change mitigation. By reducing CO2 emissions and adapting to climate change, Romania can play an active role in international efforts to limit global temperature rise and protect the environment.

While population decline may present some challenges, it may also present some opportunities. Although Romania's population has decreased over the period studied, the positive trends in the other indicators show that Romania is on the right track to achieve the Sustainable Development Goals. It is important for Romania to take a proactive approach to managing demographic change in order to maximize the benefits and minimize the risks.

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