THE ENERGY SYSTEM OF ROMANIA IN THE CONTEXT OF ENERGY SECURITY AND SUSTAINABLE DEVELOPMENT

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Abstract

This paper examines energy security and sustainable development in the context of the transition toward a low-carbon energy system, with focus on Romania within the EU [9], [13]. Romania has a diversified energy mix, providing relatively strong energy security and a renewable share close to the EU average [12], but continued progress requires investment in infrastructure, storage, and system flexibility [13], [14]. The study emphasizes the role of public policy, technological innovation, and EU alignment in supporting a sustainable and resilient energy transition [7], [17].

Key words: energy system, energy security, energy mix, sustainability, renewable energy

1. INTRODUCTION

Sustainable development represents the ability to meet present needs without compromising future generations, integrating environmental protection into all development processes [27]. Energy plays a fundamental role in achieving these objectives, as it directly influences economic growth, social stability, and environmental quality [25]. Energy security has become a strategic concern for all countries, especially in the context of fluctuating global energy markets and geopolitical changes [9].

Within the European Union, energy policy has evolved from ensuring supply to addressing climate change and sustainability [7]. Today, energy and climate policies are strongly interconnected, requiring coordinated actions at regional and global levels [8].

2. GLOBAL ENERGY CONTEXT AND ENVIRONMENTAL IMPACT

Global energy consumption continues to be dominated by fossil fuels, despite the increasing share of renewable energy sources [5], [13]. This reflects both the growing global demand for energy and the slow pace of transition toward cleaner alternatives [19].

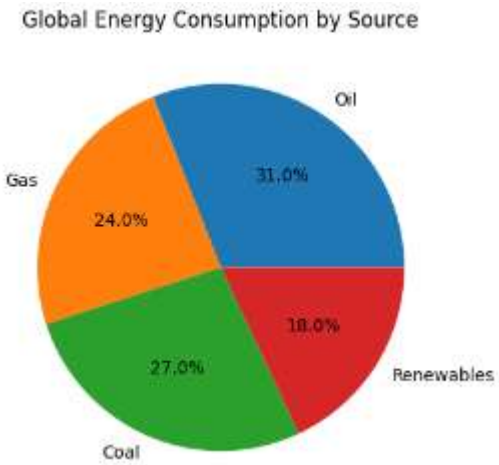

Figure 1. Global energy consumption by source

The environmental impact of this consumption pattern is significant, as the energy sector remains the largest contributor to greenhouse gas emissions worldwide [8].

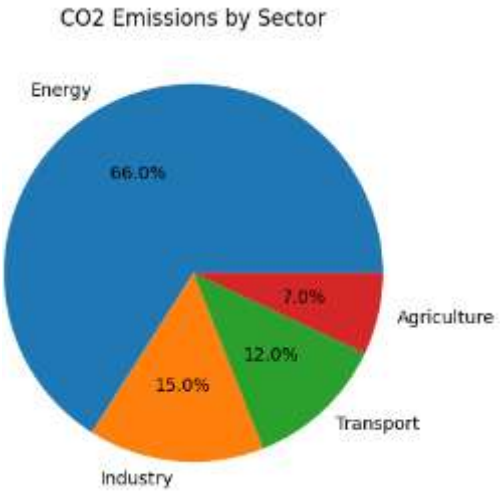

Figure 2. Global CO_2 emissions by sector

These trends highlight the urgent need to accelerate the transition toward low-carbon energy systems and improve energy efficiency at global level [13], [16], [28].

2.1. Sustainable development of the energy sector

The sustainable development of the energy sector involves reducing emissions, increasing the share of renewable energy, and ensuring economic and social stability [25].

This process requires balancing environmental objectives with the need for secure and affordable energy supply.

At the European level, there is a clear transition toward cleaner energy sources, supported by policies aimed at decarbonization and energy efficiency [7], [8].

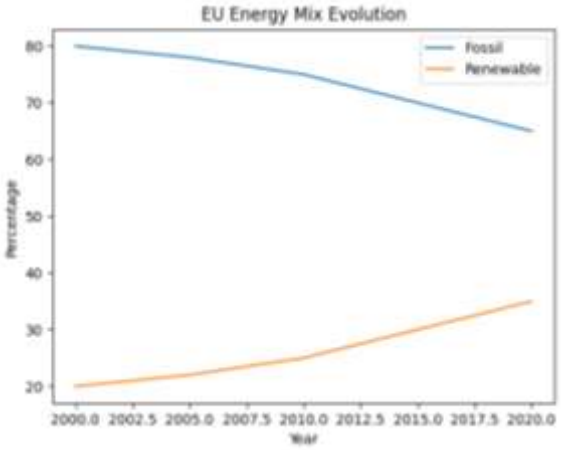

Figure 3. EU energy mix evolution (fossil vs renewable)

These policies significantly influence national energy strategies, investment decisions, and consumption patterns [17]. Key priorities include infrastructure modernization, expansion of interconnections, and electrification of consumption.

2.2. Energy mix and renewable potential in Romania

Romania benefits from a diversified energy mix, including coal, nuclear energy, natural gas, and renewable sources such as hydropower, wind, solar, and biomass [12], [17]. This diversity contributes to increased energy security and reduced dependence on imports [11].

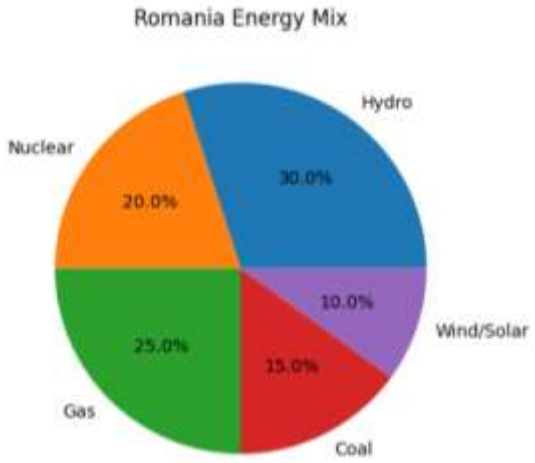

Figure 4. Romania energy mix by source

Among renewable sources, hydropower plays a crucial role due to its stability and ability to support system balancing. [10]. Other sources, such as wind and solar energy, have experienced significant growth but are characterized by variability, requiring flexible system management. [14]

In comparison with the European Union average, Romania holds a relatively strong position in terms of renewable energy share, reflecting its natural potential and previous investments in the sector.

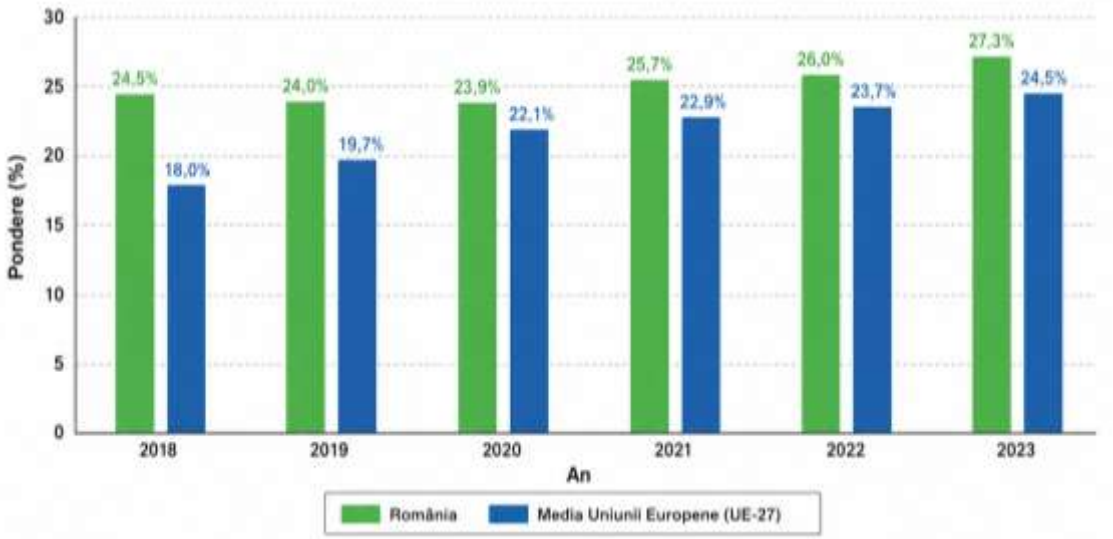

Figure 5. Renewable energy share: Romania vs EU average

The graph illustrates the comparison between Romania and the European Union average regarding the share of energy produced from renewable sources in gross final energy consumption [8], [14].

Romania registers a value close to the EU average, which highlights a relatively competitive level in the European context, supported by the hydropower potential and the gradual development of wind and solar sources.

This indicator reflects the degree of transition towards a sustainable energy system and the contribution of each entity to the decarbonization objectives assumed at European level [7]. However, further investments in infrastructure, storage technologies, and system flexibility are necessary to support the increasing integration of renewable energy [13].

3. ROLE OF THE STATE AND TECHNOLOGICAL PERSPECTIVES

The state plays a fundamental role in ensuring energy security and supporting the transition toward a sustainable energy system [17]. Through coherent energy policies, regulatory frameworks, and strategic planning, public authorities influence both the stability and long-term development of the energy sector [4].

In many cases, state intervention is essential in managing critical infrastructure and ensuring continuity of supply, particularly in strategic areas such as nuclear energy and hydropower, where large-scale investments and long payback periods limit private sector involvement [18], [10]. In addition, the state contributes

to creating a stable investment environment by offering incentives, subsidies, and funding mechanisms that support the development of low-carbon technologies and infrastructure modernization [2], [3], [6].

Energy security is therefore closely linked to the ability of public institutions to coordinate national priorities with European Union objectives, especially in the context of decarbonization and energy market integration [20], [23].

At the European level, current energy policies increasingly promote market liberalization, cross-border cooperation, and private sector participation [7].

These measures aim to enhance competitiveness, improve efficiency, and strengthen the resilience of the energy system against external shocks [21].

Romania, as part of the EU energy framework, aligns its national strategies with these principles, while maintaining state involvement in key strategic sectors.

Technological innovation represents a decisive factor in accelerating the energy transition [14].

Developments in renewable energy technologies—such as solar, wind, and biomass—along with improvements in energy storage systems, smart grids, and digitalization of energy networks, are transforming the structure of the energy sector [21], [23]. In parallel, advances in energy efficiency across industry, transport, and buildings contribute significantly to reducing overall consumption and emissions.

Overall, the combination of strong state involvement, European cooperation, and continuous technological progress forms the basis for a secure, efficient, and sustainable energy system capable of meeting both present and future demands.

6. CONCLUSIONS

Energy security and sustainable development represent core challenges for contemporary economies, requiring a delicate balance between environmental objectives, economic competitiveness and social stability [25].

The transition toward a low-carbon energy system is no longer optional, but a strategic necessity driven by climate commitments and long-term resource constraints [27].

Reducing greenhouse gas emissions, increasing the share of renewable energy sources and improving energy efficiency are central pillars of this transformation.

However, these objectives must be pursued without compromising the stability and affordability of energy supply, which remains essential for economic resilience and social welfare.

Romania benefits from a relatively diversified energy mix, including fossil fuels, nuclear energy and significant renewable resources such as hydro, wind and solar power [12], [17]. This structural advantage provides a solid foundation for advancing energy transition objectives compared to other countries with higher dependence on a single energy source.

Despite this favorable position, several structural challenges persist.

These include the need for modernization of energy infrastructure, limited storage capacity for renewable energy, and uneven regional development of energy systems [13].

Addressing these gaps is essential for improving system flexibility and integration of intermittent renewable sources. Long-term sustainability will

depend on sustained investment in energy infrastructure, research and innovation, and digitalization of the energy sector [21].

Smart grids, energy storage technologies and demand-side management systems will play an increasingly important role in ensuring system efficiency and reliability.

Furthermore, alignment with European Union energy and climate policies is a key driver for Romania's energy transition [7]. While this alignment supports modernization and access to funding, it also requires significant institutional adaptation and policy coherence at national level.

In conclusion, Romania has the potential to become a competitive player in the regional energy landscape, but this will depend on its ability to accelerate the transition toward a sustainable, low-carbon and resilient energy system, while maintaining economic stability and social equity.

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