



THE ROLE OF SUSTAINABLE ENERGY PRODUCTION FOR THE BIOECONOMY IN BULGARIA



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INTRODUCTION

The bioeconomy represents a system of production based on renewable biological resources and their conversion into energy, materials, and food (Mitov, 2024). Within the European Union, the bioeconomy is a central pillar for achieving climate neutrality, resource efficiency, and sustainable development. In Bulgaria, the bioeconomy is strongly linked to agriculture and forestry, which provide substantial biomass resources. However, the sector remains characterised by limited innovation uptake and fragmented governance structures (Kirechev, 2024). Renewable energy production—particularly from biomass, solar, wind, and hydropower—plays a critical role in supporting the transition toward a circular and low-carbon economic model. Recent research highlights that renewable energy contributes significantly to greenhouse gas reduction, energy security, and rural development (Kotseva, 2022). At the same time, the integration of energy systems within bioeconomic value chains remains incomplete, requiring further development of infrastructure, technology, and policy coordination. The objective of this study is to analyse the role of sustainable energy production in the development of the bioeconomy in Bulgaria using empirical data and policy insights.

MATERIAL AND METHOD

This research applies a mixed-method approach combining quantitative and qualitative analysis. The quantitative analysis is based on national data for renewable energy production in Bulgaria for the period 2012–2026. The following indicators are used:

- Number of energy facilities
- Installed capacity (MW)
- Electricity production (MWh)

The study employs combination of trend analysis, comparative analysis and system-based interpretation of energy-bioeconomy linkages that are also based on workshop with 32 participants. Policy insights are derived from the Bulgarian Bioeconomy Action Plan, which emphasises circularity, biomass valorisation, and system integration.

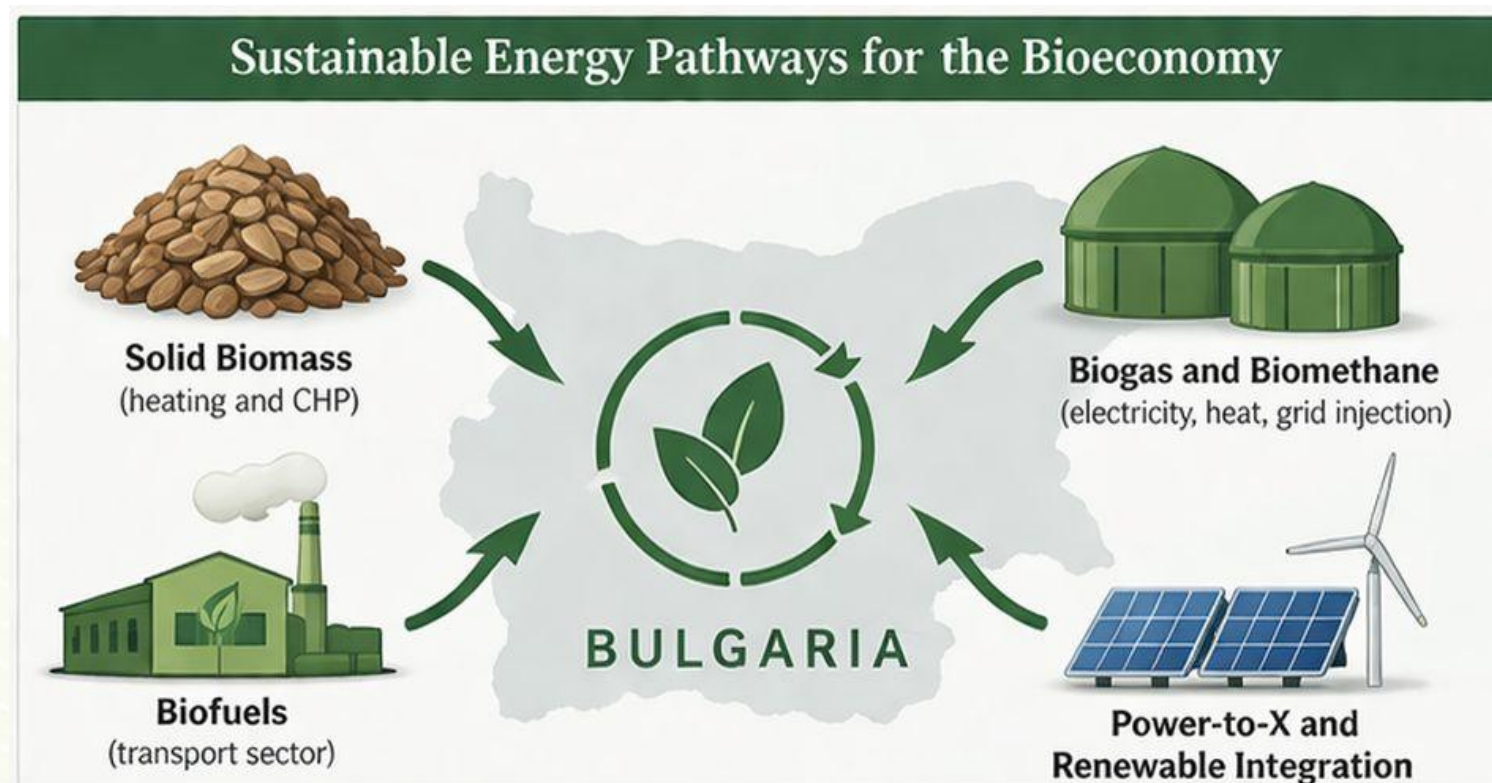


Figure 1. Installed capacity by source

RESULTS AND DISCUSSIONS

The results indicate a rapid increase in solar energy installations, particularly after 2020, while hydro and wind sectors remain relatively stable. Biomass-based installations show limited expansion. Solar energy capacity exhibits exponential growth, increasing from approximately 900 MW in 2012 to over 4,500 MW in 2025. In contrast, hydro and wind capacities remain relatively stable.

Hydropower remains the dominant source of electricity production, though it is subject to climatic variability. Solar energy shows significant growth, while wind energy maintains a stable contribution. The findings confirm that sustainable energy production plays a dual role in Bulgaria's bioeconomy.

The combined bioenergy potential exceeds 12 TWh annually, highlighting a substantial opportunity for integrating biomass-based energy production into the national energy mix. This potential is especially relevant in regions with high utilised agricultural area (UAA), where agricultural residues and livestock by-products are readily available

Bioenergy Potential in Bulgaria	
Source	Annual Potential
Agricultural residues	~6.5 TWh
Forestry biomass	~4.0 TWh
Animal manure (biogas)	~1.2 TWh
Organic waste	~0.6 TWh

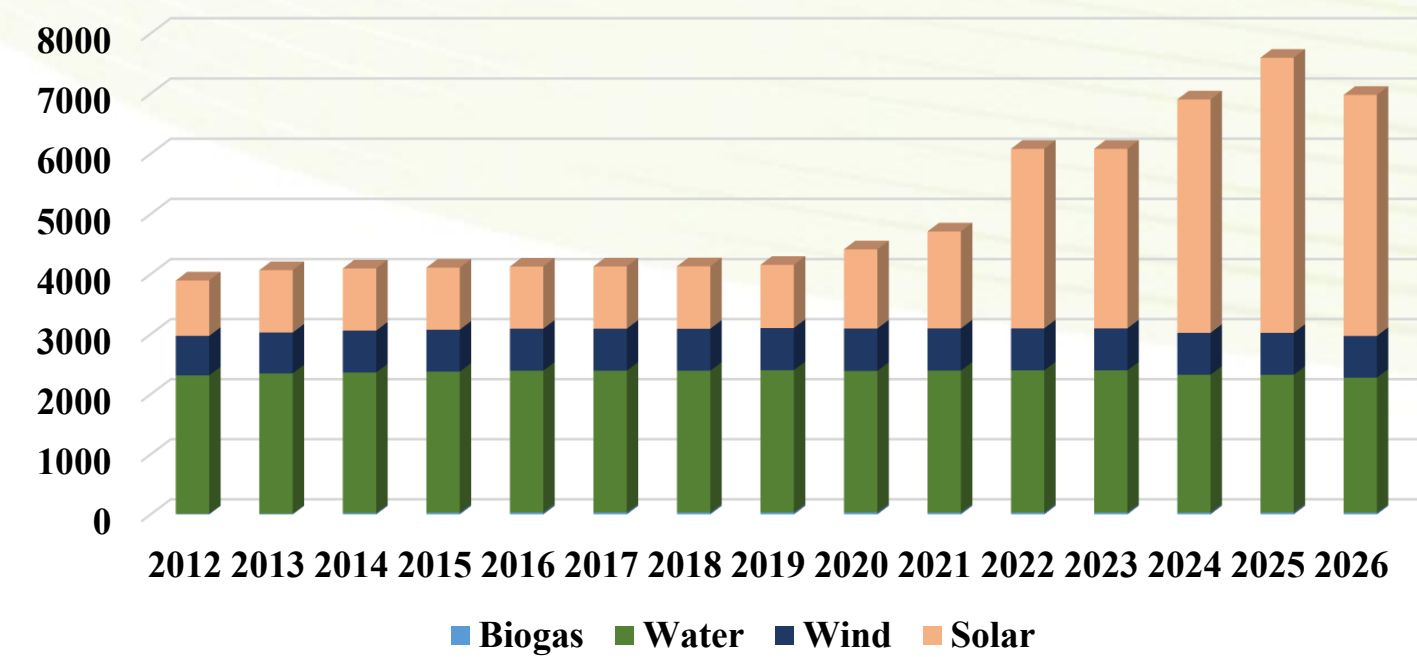


Figure 1. Installed capacity by source

First, it supports circular resource use by enabling the valorisation of biomass and organic waste. Bioenergy systems contribute to nutrient recycling and reduce dependence on fossil fuels, aligning with circular economy principles. Second, structural imbalances are evident. The rapid expansion of solar energy, while beneficial, does not fully support biomass-based circular systems. The bioenergy sector remains underdeveloped due to high investment costs, insufficient infrastructure, and fragmented supply chains. These findings are consistent with previous studies highlighting institutional and technological barriers in the Bulgarian bioeconomy (Kirechev, 2024). Furthermore, the Action Plan emphasises the need for improved system integration, innovation uptake, and stakeholder coordination.

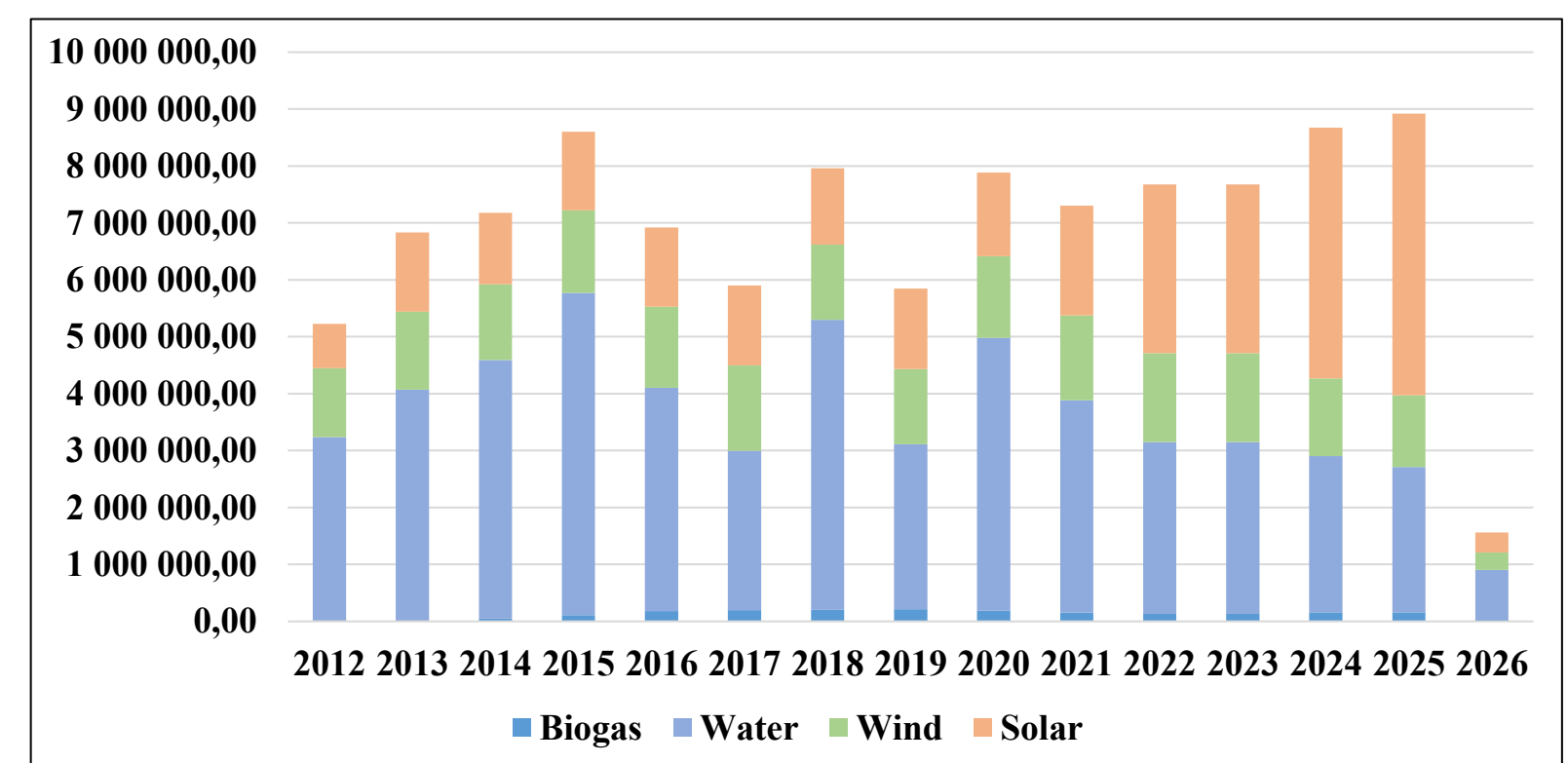


Figure 2. Energy produced (MWh)

The relationship between land use and energy production is particularly relevant in the context of the bioeconomy. Agricultural land serves as a primary source of feedstock for bioenergy, including crop residues, manure, and dedicated energy crops. At the same time, land is increasingly utilised for solar energy installations, especially in regions with high solar radiation and available agricultural or marginal land. The empirical data show that regions with extensive UAA are also those with higher potential for integrating circular bioeconomy practices. For example, large agricultural regions such as Plovdiv (251 424 ha), Stara Zagora (209 107 ha), and Yambol (211 954 ha) provide favourable conditions for the development of biogas installations and biomass-based energy systems. These systems enable the valorisation of agricultural residues and organic waste, contributing to both energy production and nutrient recycling.

However, the rapid expansion of solar energy infrastructure in Bulgaria raises important land-use considerations. From a bioeconomy perspective, optimal land use should prioritise cascading use of biomass, where resources are first utilised for high value-added products before being converted into energy. This approach enhances resource efficiency and aligns with circular economy principles.

CONCLUSION

Land use and energy production are deeply interconnected within the Bulgarian bioeconomy. Regions with large UAA have significant potential to support bioenergy systems and circular value chains, while strategic planning is required to ensure that the expansion of renewable energy does not compromise agricultural productivity or environmental sustainability. To fully realise the potential of the bioeconomy, Bulgaria must strengthen bioenergy infrastructure, promote integrated biomass value chains, and improve governance and policy coordination. Investments in innovation and technological diffusion are essential for achieving long-term sustainability goals. The transition toward integrated bioenergy systems and biorefineries will play a critical role in supporting energy security, reducing greenhouse gas emissions, and fostering rural development by 2040.