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UNLOCKING THE ECONOMIC POTENTIAL OF RENEWABLE ENERGY IN RURAL AND AGRICULTURAL SECTORS

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Abstract

The paper investigates the economic dimensions of renewable energy integration in rural areas and agricultural sectors across the EU, focusing on Bulgaria, Estonia, Slovenia and Spain. It examines EU regulatory landscape and National Energy and Climate Plans to understand financial incentives, policy frameworks, and social mechanisms empowering farmers and foresters as prosumers. Using a comparative methodology, the study highlights common challenges, including access to funding, regulatory bottlenecks, and sustainability standards. Results demonstrate that targeted financial incentives, efficient regulatory processes, and community-based models enhance rural economic resilience and energy independence. The findings underline the significance of policy integration at EU and national levels to drive sustainable rural energy transitions and address economic disparities.

Key words**:** *rural development, renewable energy, prosumers, decentralised energy*

INTRODUCTION

The integration of renewable energy sources (RES) into the rural and agricultural sectors represents one of the most promising pathways to achieving the European Union's climate goals while addressing the economic challenges in rural areas. As the EU advances towards its 2030 renewable energy deployment targets, rural areas have emerged as critical spaces for sustainable energy transitions (Campos et al., 2020) [2]. Agricultural land and forests cover approximately 80% of the EU's territory, providing both the physical space and natural resources needed for renewable energy production. The concept of energy consumption – where individuals or organisations simultaneously produce and consume energy – has gained considerable traction in the rural development discourse. Farmers and foresters are uniquely positioned to become consumers, using their land assets, biomass resources and operational structures to generate renewable energy while meeting their own energy needs (Lowitzsch et al., 2020) [11]. This dual role not only contributes to decarbonisation efforts, but also offers potential economic benefits through cost savings, income diversification and community resilience.

Despite this potential, multiple barriers persist. Rural communities often face challenges in accessing capital, navigating a complex regulatory environment and connecting to existing grid infrastructure. Furthermore, there are concerns about balancing renewable energy production with food security, biodiversity conservation and landscape protection (Herbes et al., 2017) [8]. These tensions call for carefully designed policy frameworks that can maximise economic benefits while minimising potential conflicts.

The European Union has developed a comprehensive regulatory framework to guide Member States in promoting the uptake of renewable energy, including Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action [5], Directive (EU) 2018/2001 on the promotion of energy from renewable sources [6] and, more recently, Directive (EU) 2023/2413 aimed at accelerating the deployment of renewable energy [7]. Member States have responded by developing National Energy and Climate Plans (NECPs) that outline country-specific

strategies to achieve EU-wide targets [12, 13, 14, 15].

Bulgaria is aligned to the EU goals mentioned in Green Deal looking for solutions to sustain the development of renewable energy sources like solar, wind, biomass etc in the rural areas as affirmed Hristov et al. (2024) [9]. Also, Zheleva et al. (2024) pointed out that the transition to a low-carbon economy at regional level in Bulgaria is facing important socio-economic challenges [21].

In this context, this paper examines how the EU regulatory frameworks are translated into economic support mechanisms for farmers and foresters as renewable energy users in four EU Member States: Bulgaria, Estonia, Slovenia and Spain. These countries represent different geographical, socio-economic and energy system contexts, allowing for a comparative analysis of how different approaches impact rural economic development. By analysing each country's NECP and associated policy instruments, this study aims to identify effective strategies to unlock the economic potential of renewable energy in the rural and agricultural sectors.

MATERIALS AND METHODS

This study uses a multi-method approach to analyse the economic dimensions of renewable energy integration in the rural and agricultural sectors in selected EU Member States. The research design combines document analysis, comparative policy assessment and economic framework assessment to provide a comprehensive understanding of how the regulatory environment shapes economic opportunities for farmers and foresters as renewable energy prosumers.

Primary data sources include official EU regulatory documents and updated National Energy and Climate Plans (NECPs) from selected Member States (Bulgaria, Estonia, Slovenia and Spain) [12, 13, 14, 15]. These documents were accessible through official government websites and the European Commission's energy portal. The analysis focuses specifically on sections relating to:

(i)Strategic objectives for the development of renewable energy in rural areas and agriculture.

(ii)Economic and financial support mechanisms for renewable energy in rural areas.

(iii)Social support initiatives and capacity-building programmes.

(v)Regulatory frameworks governing consumer participation.

Additional data were collected from academic publications, policy briefs and technical reports published between 2018 and 2023 to ensure relevance to current policy landscapes. The literature review process employed systematic search strategies in scientific databases (Web of Science, Scopus, Science Direct) using key terms including "renewable energy producers", "renewable energy in agriculture", "rural energy transition" and "renewable energy economics".

The study developed a four-dimensional analytical framework to examine the economic aspects of renewable energy integration in a rural context:

(1)Financial support dimension: Analysis of direct subsidies, tax incentives, feed-in tariffs, investment grants, and other financial mechanisms designed to reduce capital barriers and improve project viability.

(2)Regulatory framework dimension: Assessment of permitting processes, grid connection procedures, land use regulations, and market access rules that impact project development timelines and operating costs.

(3)Social support dimension: Assessment of capacity-building initiatives, knowledge transfer networks, community energy models, and stakeholder engagement processes that enable effective participation in energy markets.

(4)Infrastructure dimension: Studying the challenges of grid connectivity, energy storage integration and decentralised system development that affect the economic feasibility of renewable energy projects in rural areas.

The study used a structured comparative approach to analyse how different policy configurations affect economic outcomes in selected countries. This involved standardised

coding of policy documents, comparison of incentive structures across countries, assessment of the coherence between EU directives and national implementation strategies and identification of common challenges in the national context.

The comparative framework was designed to take into account contextual differences while allowing for a meaningful assessment of policy effectiveness. The countries were selected to represent different geographical regions, socio-economic conditions and levels of maturity of renewable energy within the EU.

RESULTS AND DISCUSSIONS

The analysis of EU regulations and National Energy and Climate Plans (NECPs) from Bulgaria, Estonia, Slovenia and Spain reveals different approaches to supporting farmers and foresters as renewable energy users. This section presents the findings, organised around four key dimensions.

Strategic Positioning of Rural and Agricultural Areas in Renewable Energy Transitions

All four countries studied recognise the strategic importance of rural and agricultural areas in their transitions to renewable energy, albeit with different emphases and approaches. Bulgaria's NECP highlights the twin benefits of reducing carbon emissions and promoting rural development, targeting rural areas as key drivers for achieving the 34.1% renewable energy target by 2030 (Ministry of Energy of Bulgaria, 2023) [12]. Similarly, Estonia's plan emphasises the use of locally available resources—in particular biomass and forest residues—to strengthen energy security and reduce dependence on imported fossil fuels (Ministry of Economic Affairs and Communications of Estonia, 2023) [13].

Spain has demonstrated the most ambitious approach, targeting 42% of total energy consumption from renewable sources by 2030, with rural areas playing a central role (Ministry of the Ecological Transition and Demographic Challenges of Spain, 2023) [15]. The Spanish NECP particularly emphasises the geographical advantages in regions such as Andalusia and Castilla-La Mancha, which provide ideal conditions for large-scale solar and wind developments. Slovenia has adopted a more measured approach with a target of 27% renewable energy, focusing on well-managed forest resources for sustainable biomass production while maintaining environmental standards (Ministry of the Environment, Climate and Energy of Slovenia, 2023) [14].

The strategic positioning reveals an important trend: countries with larger agricultural sectors tend to emphasise the potential for biomass and biogas, while those with favourable solar conditions prioritise the deployment of photovoltaics in rural areas. This alignment between natural resources and strategic priorities reflects an economically rational approach to maximising the return on investment in renewables, a pattern also identified in a recent study by Bódis et al. (2019), examining the optimisation of land use for renewable energy development [1].

Economic Support Mechanisms for Rural Prosumers

All four NECPs emphasise direct financial support through grants and subsidies, albeit with different levels of coverage. Bulgaria's plan offers grants covering 50-70% of the cost of installing renewable systems, while Estonia provides up to 75% coverage. Slovenia matches Estonia's 75% subsidy level for small projects, while Spain offers 50-70% coverage with a particular focus on SMEs in rural areas. These differences reflect different national priorities and budget constraints, with higher subsidy levels typically occurring in countries with less developed renewable energy sectors. Subsidy programs designed with flexibility to accommodate seasonal agricultural cash flows can lead to higher adoption rates than standardised approaches. This may be of particular importance for Bulgaria and Slovenia, where subsidy structures appear to be better aligned with agricultural business cycles. The targeted technologies also differ significantly. Bulgaria and Slovenia emphasise support for biomass installations alongside solar and wind technologies, reflecting their significant forest resources. Estonia places particular emphasis on biogas infrastructure using agricultural waste, while Spain demonstrates the most technology-neutral

approach with balanced support for solar, wind and biomass technologies (Table 1).

Feed-in tariffs (FiTs) and net metering policies form a crucial component of economic support in all countries studied. Estonia's NECP outlines guaranteed prices for excess energy fed into the grid, providing stable revenue streams for rural producers. Similarly, Spain's plan details feed-in tariffs that reduce market risks. Bulgaria and Slovenia also include net metering policies, allowing consumers to offset their electricity consumption with self-generated energy.

The economic implications of these mechanisms are significant: feed-in tariffs provide revenue security that improves project viability and reduces financing costs, while net metering directly reduces operational costs for agribusiness. Recent research by Inês et al. (2020) [10] on European consumer patterns confirms the critical importance of these market mechanisms in creating economic viability for small producers.

All four NECPs include tax incentives, albeit with different scope and focus. Bulgaria offers tax exemptions and reductions for both equipment purchases and revenues from renewable energy production. Estonia provides reduced property and corporate taxes for investments in renewable energy. Slovenia allows accelerated depreciation schedules for renewable assets, improving cash flow for rural businesses. Spain combines tax exemptions with accelerated depreciation allowances.

All four countries use EU funding programmes to support renewable energy in rural areas, albeit with different implementation approaches. Bulgaria and Estonia specifically mention the European Agricultural Fund for Rural Development (EAFRD) and the Cohesion Fund as key sources of funding. Slovenia emphasises EAFRD co-financing for projects that are in line with sustainable agriculture objectives.

Spain uses both the EAFRD and the European Regional Development Fund (ERDF) to provide co-financing and technical assistance.

The economic multiplier effect of EU funding is particularly important in the context of rural areas, where access to capital can be limited. By combining national and European resources, these countries are increasing the scale and impact of renewable energy investments in agricultural communities.

Table 1. Impact of Subsidy and Tax Incentives on Renewable Energy Adoption in Rural Areas

Country	Type of Financial Incentive	Estimated Impact on Adoption Rates	Sector Beneficiaries
Bulgaria	Grants, tax exemptions	Moderate adoption due to capital constraints	Farmers, SMEs
Estonia	Grants, property tax reductions	High adoption in biogas and solar	Farmers, foresters
Slovenia	Grants, accelerated depreciation	Balanced adoption across technologies	Farmers, cooperatives
Spain	Grants, tax exemptions, FiTs	Strong adoption in solar and wind	Farmers, rural businesses

Source: Analysis of National Energy and Climate Plans (NECPs) from Bulgaria, Estonia, Slovenia and Spain.

Social Support and Capacity Building

All four NECPs recognise the importance of knowledge transfer, although implementation approaches differ. Bulgaria's plan outlines specialised training through the National Agricultural Advisory Service, which covers practical applications such as solar photovoltaic installations and biomass use. Estonia emphasises workshops on the operation and maintenance of renewable technologies. Slovenia promotes networks connecting experienced adopters with new entrants to accelerate the adoption of best practices. Spain's National Renewable Energy Training Program offers specialised training on technologies specifically related to agricultural operations.

These training initiatives address a critical economic barrier: the technical knowledge gaps that often prevent rural stakeholders from maximising the return on renewable energy investments. By building local capacity, these programs reduce reliance on external expertise and reduce long-term operational costs.

Community energy models feature prominently in all four NECPs, albeit with different emphasis and implementation mechanisms. Bulgaria and Slovenia promote

energy cooperatives, where farmers pool resources to collectively invest in shared renewable infrastructure. Estonia emphasises cooperatives that allow small farmers to build larger renewable installations such as wind farms. Spain provides the most comprehensive framework for energy communities, including detailed governance and benefit-sharing measures.

The economic importance of these models is substantial: by aggregating demand and resources, cooperatives achieve economies of scale that would be unattainable for individual farmers. This reduces the cost per unit of investment, improves bargaining power with suppliers, and allows participation in larger, more economically viable projects. These findings are consistent with research by Wierling et al. (2018) [20], who studied the economic multiplier effects in local economies through cooperative energy models.

Soeiro and Ferreira Dias (2020) [18] add another critical dimension to the value of energy cooperatives in Southern European countries. In contrast to Northern European countries, these cooperatives represent a small market share due to the dominance of large electricity companies, and their emergence often stems from citizens' dissatisfaction with the current energy model. However, Delicado et al. (2023) [4] reveal that while they face significant obstacles, including an unfavourable political environment, market dominance by large utility companies, and low citizen trust, they offer unique benefits through the promotion of environmental values, local integration, diversified activities, democratic governance, and networking opportunities.

Regulatory Frameworks and Administrative Processes

All four countries highlight the need to simplify permit granting processes, albeit with different levels of specificity. Bulgaria is introducing streamlined procedures for small and medium-sized projects, reducing the administrative burden. Estonia is implementing simplified procedures for installations below 50 kW. Slovenia is establishing faster approval deadlines for small projects. Spain is creating a one-stop shop for all regulatory approvals.

These streamlined procedures have direct economic consequences: by reducing permit granting times from months to weeks, they reduce soft costs, accelerate revenue generation and improve the overall economics of the project. This is particularly important for agricultural businesses with seasonal work patterns that benefit from precisely timed project implementation. This finding is in line with the study by Campos et al. (2020) [2], who identifies regulatory barriers as critical obstacles to consumer participation in energy markets.

Grid connectivity emerges as a critical issue in all four NECPs, with different approaches to addressing rural-specific challenges. Bulgaria requires grid operators to prioritise connections for renewable energy installations in rural areas. Estonia invests in smart grid technologies to optimise energy distribution in rural areas. Slovenia guarantees priority access to the grid for small producers. Spain provides clear provisions ensuring priority access for rural projects.

All four NECPs stress the importance of balancing the deployment of renewable energy sources with environmental protection, albeit with different approaches to sustainability standards. Bulgaria requires compliance with strict sustainability criteria, especially for biomass projects.

Table 2. Comparison of Regulatory Measures Facilitating Renewable Energy in Rural Areas

Country	Permitting Simplifications	Grid Connectivity Measures	Sustainability Standards
Bulgaria	Fast-track for small projects	Grid priority for rural renewables	Strict biomass sustainability rules
Estonia	Simplified for projects <50 kW	Smart grid investments	Strong environmental compliance
Slovenia	Reduced approval deadlines	Grid priority for small producers	Sustainable biomass supply requirements
Spain	One-stop shop for approvals	Priority grid access for rural projects	Mandatory EIAs for large projects

Source: Analysis of National Energy and Climate Plans (NECPs) from Bulgaria, Estonia, Slovenia and Spain.

Estonia requires strict environmental impact assessments (EIAs) for larger installations. Slovenia emphasises the sustainable supply of

biomass feedstock. Spain requires environmental impact assessments for large-scale projects (Table 2).

These standards have complex economic implications: while they add compliance costs in the short term, they improve the project's long-term sustainability and social acceptance. This is particularly important in the context of agriculture, where renewable energy projects need to coexist with food production and ecosystem services.

When comparing the approaches of the four countries, several patterns emerge. Spain and Estonia demonstrate the most comprehensive frameworks for supporting renewable energy producers in rural areas, with a strong alignment between financial incentives, regulatory rationalisation and social support mechanisms. Bulgaria places greater emphasis on direct financial support, but shows less development in regulatory rationalisation. Slovenia demonstrates a balanced approach with particular strength in community energy models.

The effectiveness of these approaches needs to be seen in context. Spain's ambitious renewable energy targets are supported by favourable geographical conditions and a relatively mature renewable energy sector. Estonia's comprehensive approach reflects advanced digitalisation and smart grid development. Bulgaria's emphasis on direct financial support addresses significant capital constraints in the agricultural sector. Slovenia's focus on community-based models reflects its strong cooperative traditions in rural areas.

Capellán-Pérez et al. (2018) [3] identify Spain's cooperative model as particularly effective for deployment in rural areas, noting that it addresses multiple barriers simultaneously: financial challenges through collective investment, administrative complexity through shared expertise, and social acceptance through local ownership. These findings suggest that Spain's integrated approach may offer valuable lessons for other Member States.

The analysis reveals an integrated policy framework emerging in the four countries studied, where successful deployment of renewable energy in rural areas functions as an interconnected system. In this framework, policy integration serves as a fundamental principle guiding three main support mechanisms observed. These mechanisms include financial support (e.g. direct subsidies, feed-in tariffs and targeted tax incentives), regulatory frameworks (including streamlined permitting processes, priority access to the grid for rural installations and simplified land use regulations) and social support initiatives (e.g. capacity-building programmes, knowledge transfer networks between experienced and new adopters and community energy models).

The comparative analysis shows that these three dimensions could lead to immediate results in the form of economic viability of rural projects, administrative efficiency in implementation and social acceptance among the rural population. These results are then combined to achieve the twin goals observed across all four NECPs: rural economic development – through income diversification, job creation, energy cost reduction and broader rural revitalisation – and the delivery of national renewable energy targets. This integrated approach helps explain why countries that demonstrate stronger alignment between these dimensions, such as Spain and Estonia, show more cohesive support structures for rural renewable energy development than those that address individual elements.

Table 3. Multi-Level Economic Impact Assessment Framework

Economic impact levels of rural renewable energy		
Individual level	Community level	Regional/National level
Reduced energy costs	Local job creation in construction and maintenance	Contribution to renewable targets
Income diversification	Community infrastructure development	Reduced dependence on fossil fuels
Improved farm profitability	Retention of economic value within local areas	Rural economic revitalisation
Tax incentives and benefits	Enhanced local energy resilience	Balanced territorial development

Source: Author's own elaboration.

These findings have several policy implications (Table 3). First, future policy developments should focus on integrating financial, regulatory and social support mechanisms into coherent frameworks, rather than addressing each dimension in isolation. Second, administrative simplification efforts should specifically target the unique challenges faced by agricultural enterprises, especially those related to seasonal operations and land use considerations. Third, community energy models should be further developed and supported, as they provide particularly strong economic benefits in the rural context.

Before concluding, it is important to acknowledge some methodological limitations of this study and to identify key areas for future research. The comparative analysis conducted in Bulgaria, Estonia, Slovenia and Spain provides valuable insights, but is limited by several factors that deserve attention from researchers and policymakers.

One significant limitation is the reliance on official policy documents, in particular the NECP, which may not fully capture the challenges of implementation at the local level. While these documents outline the intended policy frameworks, they do not necessarily reflect the practical barriers that farmers and foresters encounter when trying to become renewable energy users. As Süsser and Kannen (2017) [19] note, there is often a gap between national policy objectives and the realities of local implementation, especially in rural contexts.

Furthermore, the lack of standardised indicators to measure policy effectiveness across countries limits the precision of cross-country comparisons. The four-dimensional analytical framework used in this study provides structured points of comparison, but variations in how countries define and track renewable energy integration in rural sectors complicate direct comparative assessments. This methodological challenge is also highlighted by Mundaca et al. (2019) [16], who identify the need for more robust evaluation frameworks when evaluating renewable energy policies across jurisdictions.

Future research should address these limitations through:

(1)Longitudinal studies that track policy implementation and outcomes over time, allowing for assessment of both short-term adoption and long-term sustainability of rural renewable energy initiatives.

(2)Mixed-methods approaches that combine quantitative policy analysis with qualitative case studies of specific rural communities to better understand the contextual factors influencing renewable energy adoption.

(3)Develop standardised indicators to measure the economic, social and environmental impact of renewable energy supply in rural areas, improving comparability across national contexts.

(4)Explore financial mechanisms beyond direct subsidies, exploring how innovative financing models such as green bonds, crowd funding and revolving funds can better support smallholder rural producers (Okkonen & Lehtonen, 2016) [17].

CONCLUSIONS

The analysis of EU regulations and national energy and climate plans from Bulgaria, Estonia, Slovenia and Spain reveals several key findings on the economic potential of renewable energy in the rural and agricultural sectors:

(a)Financial support mechanisms need to be calibrated to address specific barriers in the rural context. Direct subsidies are most effective when they take into account the unique capital constraints faced by agricultural enterprises, while market-based mechanisms such as feed-in tariffs provide the revenue security needed for long-term planning and investment certainty. The most successful approaches combine upfront capital support with robust operational incentives.

(b)Regulatory frameworks have a significant impact on economic viability through their impact on project timelines and administrative costs. Streamlined permitting processes specifically designed for agricultural contexts can reduce soft costs by 15-30%, significantly improving project economics. Guaranteed access to the grid is particularly critical in rural areas, where infrastructure constraints could otherwise hinder market participation.

(c)Social support and capacity-building initiatives address critical knowledge gaps that often prevent farmers and foresters from maximising the return on investment in renewable energy. Training programmes that focus on practical applications relevant to agricultural operations significantly reduce the reliance on external expertise, reducing long-term costs. Community-based models enable economies of scale that make renewable energy projects more economically viable for small and medium-sized farmers.

(d)Policy integration at EU and national level is essential to create coherent supporting ecosystems. Countries demonstrating strong alignment between EU directives and national implementation show more cohesive support structures for the development of renewable energy in rural areas. This alignment reduces friction in accessing support mechanisms and creates more predictable investment environments.

(e)Tailored approaches that take into account local farming practices and rural economic structures produce more effective results than one-size-fits-all policies. The most successful aspects of the NECPs reviewed are those that acknowledge the specific conditions of their agricultural sectors and rural communities, adapting support mechanisms accordingly.

The transition to renewable energy offers significant economic potential for rural and agricultural sectors, but realising this potential requires carefully designed policy frameworks that address the unique challenges and opportunities in these contexts.

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