USE OF RENEWABLE ENERGIES IN RURAL TOURISM INFRASTRUCTURE – TECHNOLOGICAL SOLUTIONS FOR SUSTAINABLE TOURISM

Iuliana MERCE[1], Anda MILIN[1], Gabriela POPESCU[1], Marius GORDAN[1], Dragoș CHENDE[1]
[1] University of Life Sciences "King Mihai I" from Timisoara

RESEARCH ARTICLE

Abstract
The use of renewable energy in rural tourism infrastructure represents a strategic direction for sustainable community development and for reducing environmental impact. This paper analyzes Romania's current energy landscape, highlighting its gradual transition toward clean energy sources in line with European decarbonization policies. The main renewable technologies applicable in rural areas—solar, wind, geothermal, biomass, and micro-hydropower—are presented, along with the advantages of integrating them into guesthouses, agritourism farms, and traditional rural households. The study also emphasizes the economic, social, and cultural effects of implementing renewable energy in rural tourism: job creation, diversification of the local economy, promotion of environmental education, and improvement of the ecological image of tourist destinations. By using local energy resources and strengthening energy autonomy, rural tourism villages can become models of good practice in sustainable tourism. The conclusion shows that large-scale adoption of renewable energy is essential for a competitive, responsible, and future-oriented rural tourism sector.

Keywords: (max. 5) renewable energy; rural tourism; sustainability; energy efficiency
#Corresponding author:
iulianamerce@yahoo.com

INTRODUCTION

The economic development of a country largely depends on the creation and optimization of access to energy sources. Energy consumption is directly proportional to the population size, and with demographic growth, an increasing amount of resources is needed to cover the minimum needs of consumers. Globally, the energy sector has a significant impact on the environment, compelling authorities to implement measures that ensure a stable level of greenhouse gas emissions released into the atmosphere, as well as to initiate strategies to reduce them (Purece C., 2020). Rural tourism is one of the forms of tourism with the highest potential for sustainable development, as it capitalizes on local natural and cultural resources without degrading them. In the current context of climate change and the transition toward a green economy, the use of renewable energy in rural tourism infrastructure becomes essential for reducing environmental impact and increasing the energy efficiency of tourism activities.

MATERIAL AND METHOD

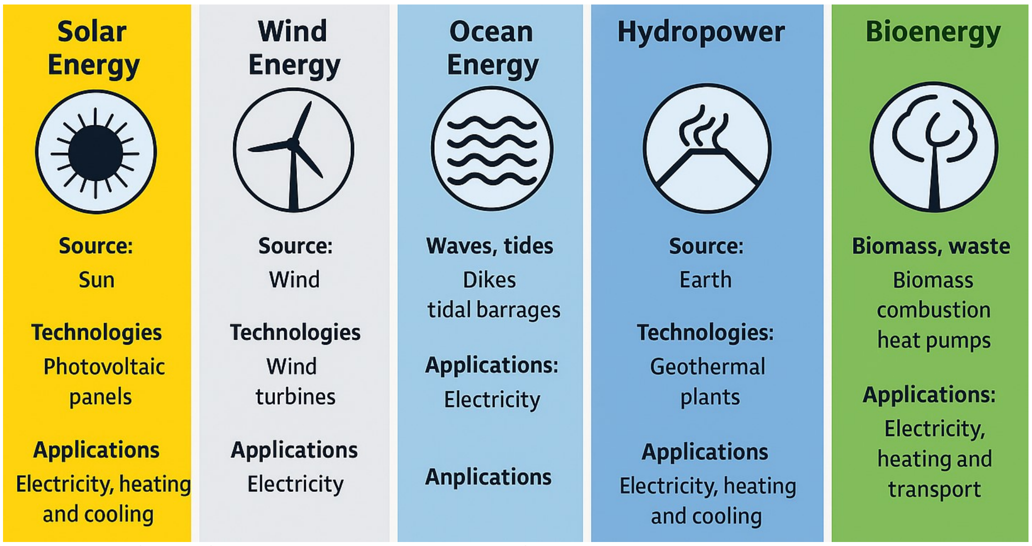
Romania's energy situation lies at the intersection of tradition and transformation, reflecting both its historical dependence on conventional energy sources and its commitment to transitioning toward a sustainable, low-carbon future. As a member state of the European Union (EU), Romania aligns its energy system and policies with the broader European framework, while also considering its specific national challenges and opportunities.

Romania's energy mix is characterized by diversity, including a combination of fossil fuels, renewable sources, and nuclear energy. Historically, the country has relied heavily on fossil fuels—especially coal and natural gas—to meet its energy needs. Its extensive coal reserves have played a crucial role in ensuring energy security, while natural gas has served as a vital, cleaner alternative for electricity production and heating. In recent years, EU legislation and sustainability goals have driven Romania to diversify its energy sources, with renewable energy becoming a key element of this transformation (Ministry of Energy, 2023). Fossil fuels remain the primary sources for electricity and heat production, particularly coal and natural gas. However, renewable energy sources have steadily increased their share in the national energy mix, reaching 24% in 2018.

he implementation of public policies supporting renewable energy—whether through EU directives or local initiatives—has produced positive outcomes (Sandbag Smart Climate Policy).

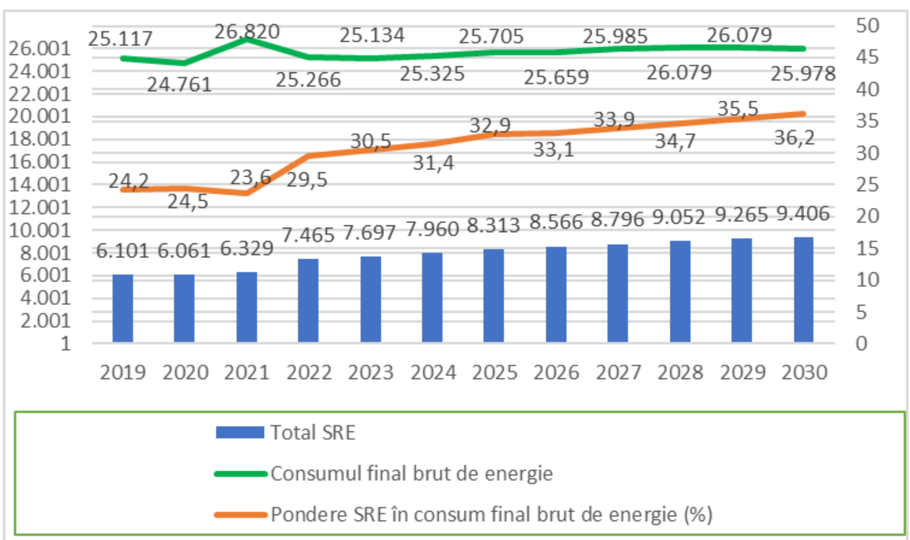
RESULTS AND DISCUSSIONS

Renewable energy refers to energy produced from non-fossil, naturally replenished sources on a human timescale. Renewable sources include solar and wind energy, ocean energy, hydropower, geothermal energy, and bioenergy. The main types of renewable energy, relevant technologies, and typical applications are presented in Figure 1 (European Court of Auditors, 2018).



Source: European Court of Auditors – Renewable energy for sustainable rural development: potential synergies are considerable but remain largely untapped, Special Report No 5 of 2018

Figure no. 1 Renewable energy sources, technologies and applications



Source: Ministry of Energy - National Integrated Plan for Energy and Climate Change 2021-2030, version 2023

Figure no. 2 Target and estimated trajectory regarding the share of energy from RES in gross final energy consumption

The comparative analysis of the evolution of total energy from renewable sources (RES), gross final energy consumption and the share of renewable energy in gross final consumption, for the period 2019–2030, allows the assessment of the coherence of national policies in the field of energy transition, as well as Romania's estimated progress in aligning with European objectives on decarbonization and green energy

The share of renewable energy in gross final consumption shows a sustained increase, from 24.2% in 2019 to 36.2% in 2030. This evolution indicates that Romania aims not only to meet, but also to exceed the objectives set by the European Green Deal and the Renewable Energy Directives. The continuous increase in the share of RES reflects the implementation of efficient strategies, oriented towards sustainable production, energy independence and carbon emissions reduction.

Renewable energy plays an essential role in modernizing and ensuring the sustainability of the rural tourism sector. By capitalizing on the available natural resources, rural communities can develop a competitive tourism model that respects both the environment and local traditions.

Renewable energy thus becomes not only a source of clean power but also a symbol of a new way of practicing tourism—one based on balance, responsibility, and respect for nature.

Rural tourism generally takes place in less industrialized areas, with modest technological infrastructure and limited access to conventional energy resources. At the same time, these regions possess significant natural potential—sun, wind, water, and biomass—which can be harnessed through modern technologies that produce clean energy.

By using renewable energy sources, rural tourism becomes an active driver of sustainable development, contributing to environmental protection and improving the quality of life in local communities.

The adoption of renewable sources results in reduced pollution, lower operating costs, and greater energy autonomy for rural households and guesthouses. Meanwhile, tourists are increasingly drawn to ecological destinations where they can experience a sustainable lifestyle in direct contact with nature.

Renewable energy supports the development of responsible tourism that does not harm the environment and respects local ecosystems. Key benefits include:

- reducing dependence on conventional energy sources, such as fossil fuels, which are both polluting and costly.
- improving the energy efficiency of tourism facilities through the use of modern and intelligent energy systems.
- protecting the environment by lowering greenhouse gas emissions and reducing waste resulting from traditional energy use.
- enhancing the ecological image of rural tourist destinations, making them more attractive to environmentally conscious visitors.
- stimulating the local economy, as investments in renewable technologies generate new jobs—installers, electricians, technicians, equipment suppliers, etc.

In addition, integrating renewable energy in rural tourism has an educational dimension. Tourists can directly observe how solar panels, wind turbines, or biomass systems work, increasing their awareness of responsible resource consumption.

The use of renewable energy is not only a technological solution but also a social and cultural one. In rural areas, these technologies contribute to preserving the natural landscape by reducing pressure on forests and traditional fuel resources. They offer communities the possibility to develop economically without compromising natural heritage or traditional architecture.

By using local energy sources—sun, wind, water, biomass—rural tourism villages can achieve energy independence, which is particularly important in remote areas where connection to the national grid is difficult or costly. Thus, renewable energy becomes a form of sustainable autonomy, supporting both economic activities and the comfort of tourists and residents.

Rural areas can also play a key role in energy innovation. These locations often serve as testing grounds for new renewable energy technologies, as they are the places where installations are implemented and evaluated.

Romania has a wide range of renewable energy resources: wind, solar, biomass, hydropower, and biogas. However, the use of these resources requires appropriate financing, regulatory frameworks, dedicated infrastructure (electricity distribution networks, biomass processing and storage facilities), fair energy tariffs, and qualified personnel (engineers, auditors, energy service companies) (Isarie C. et al., 2023).

The integration of renewable energy in rural tourism infrastructure involves implementing technologies adapted to local conditions, ensuring both tourist comfort and environmental protection. Selecting appropriate solutions depends on geographic conditions, available natural resources, and the type of tourism activities in the area.

Main Renewable Energy Technologies Applicable in Rural Tourism

1. Solar Energy – Photovoltaic Panels and Solar Thermal Systems

Solar energy is the most accessible and widespread form of renewable energy in rural environments. It can be harnessed in several ways: concentrated solar power for heat generation, photovoltaic conversion into electricity, or passive systems using natural climate conditions. Solar energy can be used at very small local scales or in large installations. One major obstacle is its intermittent availability, which requires the use of storage systems or hybrid solutions, increasing costs (Gusa M. et al., 2011).

According to Isarie C. et al. (2023), solar thermal energy can operate at:

- low temperatures – for space heating;
- medium temperatures – for domestic hot water;
- high temperatures – even for electricity production.

Advantages: low long-term costs, minimal maintenance, silent operation, aesthetic integration into the natural landscape.

2. Wind Energy – Small-Scale Wind Turbines

Wind energy is a clean source of electricity obtained by transforming wind power into mechanical energy and then electricity. In rural areas exposed to strong air currents—plains, plateaus, coastal or hilly regions—micro wind turbines can produce electricity for the daily needs of guesthouses or farm stays. These systems can be grid-connected or operate autonomously (CAISIN S., 2014).

Advantages**:** operation at night, low maintenance, ideal for isolated areas lacking access to the electric grid.

3. Geothermal Energy – Heat Pumps and Natural Climate Systems

Geothermal energy represents the thermal energy stored within the Earth's crust. Temperatures increase with depth, making geothermal sources more efficient at greater depths, though access is limited by drilling constraints (CAISIN S., 2014).

Geothermal or air-water heat pumps allow guesthouses and cabins to maintain constant indoor temperatures, significantly reducing consumption of natural gas or wood. These systems can be fully automated and integrated into both new buildings and rehabilitated traditional structures. Regions such as Băile Felix, Sovata, and Covasna already use geothermal energy for heating tourism facilities and supplying thermal water to pools.

Advantages**:** high energy efficiency, year-round stability, zero pollutant emissions.

4. Biomass Energy – Ecological Boilers and Stoves

Biomass refers to organic matter that can be converted into energy. This includes wood, agricultural residues, animal waste, and dedicated energy crops, as well as municipal residues such as park maintenance waste or certain food-industry by-products (Maican E., 2015).

Biomass systems can heat entire guesthouses or only domestic hot water and can be combined with solar systems for hybrid solutions. Biomass is especially suitable for mountainous and forested rural areas where raw materials are easily accessible.

Advantages**:** low operating costs, energy independence, use of local resources.

5. Micro-Hydropower Plants and Hydraulic Turbines

In many developing countries, micro-hydropower plants play a key role in rural—especially mountainous — economic development. They can supply energy for industrial, agricultural, and domestic uses, either mechanically or through coupled electric generators. Micro - hydroturbines are among the most efficient and affordable generators of electricity (Dulgheru V., 2021).

In Romania, such systems have been tested in the Apuseni and Fagaraș Mountains, where they can cover up to 70–80% of a rural tourism facility's annual energy needs.

Advantages**:** constant energy supply, low operating costs after installation, long service life.

Advantages of integrating renewable energy into rural tourism infrastructure

The integration of renewable energy into rural tourism infrastructure brings multiple economic, ecological, social, and cultural benefits, contributing to the transformation of tourist villages into models of sustainable development. The use of these clean energy sources not only ensures the reduction of pollution, but also the modernization of tourism services, the decrease of operating costs, and the improvement of the image of rural destinations.

The adoption of technologies based on renewable energy generates significant long-term savings. Although the initial investment may be high, operating and maintenance costs are low, and the payback period is achieved within a few years.

By installing solar panels, small wind turbines or biomass-fired plants, guesthouses and agritourism farms can produce their own electric and thermal energy, significantly reducing their monthly utility expenses. In addition, units that use renewable sources can benefit from tax incentives, financial support through European programs (PNDR, PNRR, Environmental Fund) and official recognition as "green units" or "eco-tourist" facilities.

Besides cost reduction, renewable energies contribute to the economic stability of rural communities, offering the possibility to reinvest the savings achieved into the modernization of services or the development of local tourism infrastructure.

The most important benefit of using renewable energy is its positive impact on the environment. These sources do not emit carbon dioxide and other greenhouse gases, thus significantly reducing the carbon footprint of tourism activities. They also do not generate hazardous waste and do not affect soil, water or air.

The implementation of renewable systems contributes to the conservation of natural resources and to the reduction of dependence on fossil fuels. In mountainous areas, for example, the use of modern biomass plants reduces illegal logging and encourages the rational management of forest resources. Moreover, clean energy supports the protection of biodiversity and of the natural landscape, which are essential elements for the tourist attractiveness of rural villages and regions. Thus, tourism powered by renewable energy becomes a form of tourism with a minimal environmental footprint, compatible with the principles of ecotourism and nature conservation.

The integration of renewable energy into rural tourism also has an important social dimension. Firstly, it contributes to the creation of new jobs in the field of installation, maintenance and management of energy equipment. Local communities can become directly involved in the production and consumption of green energy, developing new skills and diversifying their sources of income. Secondly, the adoption of renewable technologies increases the quality of life in rural areas. Access to clean and constant energy ensures greater comfort for residents and tourists, encouraging the development of other complementary services (gastronomy, agritourism, handicrafts).

The use of renewable energy also contributes to the environmental education of the population and tourists, fostering responsible attitudes toward resource consumption. Visitors can directly observe how solar, wind or biomass systems work, and thus become, in turn, promoters of sustainable behavior.

Rural tourism is deeply linked to the cultural identity of the Romanian village. By integrating renewable energy, traditional households and guesthouses can harmoniously combine technological modernity with the authenticity of local architecture. Solar panels can be discreetly integrated into roofs, wind turbines can be placed so as not to disturb the landscape, and biomass systems can use resources coming directly from local agricultural activities.

In this way, the ecological and authentic image of rural destinations is strengthened, making them increasingly attractive for tourists concerned with environmental protection and genuine experiences.

Tourism units that adopt these solutions can obtain ecological certifications (such as Eco-Romania or Green Key), increasing their visibility and prestige on the tourism market.

CONCLUSIONS

The use of renewable energy in rural tourism infrastructure is not just a technological option but a necessity for environmental protection and sustainable tourism development. By adopting these solutions, rural areas can achieve a balance between tradition and innovation, between natural heritage conservation and the modern needs of tourists.

Large-scale implementation of green technologies reduces the carbon footprint of tourism and increases the attractiveness of rural destinations, strengthening Romania's image as an ecological European destination. Renewable energy solutions offer rural tourism infrastructure a clear direction toward energy autonomy, efficiency, and sustainability. When properly adapted to local conditions and supported by public policies and European funds, rural tourism villages can become models of good practice for Romania's green economy.

Renewable energy integration represents a fundamental step toward transforming tourism into a sustainable, competitive, and responsible sector. Economic, ecological, and social benefits interact, generating positive effects for both the environment and local communities. Through the adoption of clean energy, rural tourism villages become examples of balance between tradition and innovation, contributing to building a green future for Romanian tourism.

On the long term, investments in renewable energy support sustainable economic development in rural areas, reduce energy poverty, increase resilience, and provide a stable foundation for ecological and cultural tourism.

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