The Role of Renewable Sources and Emerging Energy Technologies in Supporting Sustainable Economic Growth: Case Study on Energy Communities

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Abstract*: The energy transition based on renewable sources and emerging energy technologies became an important element of contemporary sustainable development strategies in the context of increasing environmental pressures and the need to limit the link between economic growth and resource-intensive consumption. The paper examines how renewable sources and emerging energy technologies can support sustainable economic growth through the contribution of a pilot energy community project in relation to SDG indicator 7.1, SDG indicator 8.1.1 and SDG indicator 9.4.1. The topic is motivated by the difference between the macro level of defining the SDGs and the need to understand the micro mechanisms through which local initiatives can contribute directly or indirectly to their achievement. The research methodology combines qualitative analysis of the specialized literature with the case study method. The results show that the project contributes to the improvement of the access quality to energy through local renewable production; it partially reduces energy costs and also reduces emissions associated with electricity consumption from the grid. The analysis also highlights the limits of using SDG indicators at a micro scale, especially in the case of macroeconomic indicators. The contribution of the paper is to propose a cautious approach in appliance of SDG indicators at the local level and uses them as interpretative tools and not as direct causal measures. The recommendations aim to strengthen the legislative and economic framework for energy communities, stimulate self-consumption and energy sharing, and integrate these initiatives into national energy transition and sustainable development strategies.*

Key words: Energy communities, Renewable energy transition, SDG indicators, Sustainable economic growth

JEL: Q42, Q48, O13, O33

Introduction

In recent decades, at a global level, progress was recorded in all economic areas, which led to high pressures on natural resources, environmental degradation, and social imbalances. Thus, it became evident that development approaches focused predominantly on economic growth do not consistently integrate the ecological and social spheres. In this situation, sustainable development highlighted that public policies and long-term development strategies need to be reoriented (United Nations, 2015). The emphasis is on economic performance analysed in relation to the capacity of ecosystems to support human activity and the impact on social well-being. Given the global context marked by climate change, economic volatility and structural inequalities, this perspective is important because the implementation of resilient solutions is required (Hopwood et al., 2005). Institutional quality and macroeconomic conditions shape poverty dynamics across European countries and highlight the structural role of governance in socio-economic resilience (Jula et al., 2025). In the aforementioned transition, the energy sector has a direct influence on the level of emissions, resource security and economic competitiveness. The transformation of energy systems is main in sustainable development strategies as the modality energy is produced and consumed has effects on all dimensions of development (International Energy Agency, 2021). In this way, renewable sources and emerging energy technologies are associated with environmental benefits and opportunities for economic modernization and strengthening socio-economic resilience.

The international community recognized the need to implement a sustainable development model. In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development. It is a commitment that guides states towards transformation and towards a more environmentally friendly, equitable and prosperous place and targets developed and developing countries alike.

The 2030 Agenda is based on 17 Sustainable Development Goals which cover a wide range of economic, social, and environmental issues: decrease of poverty and inequalities, improve access to education, health and basic services, and protect ecosystems. These are treated as interlinked objectives, where economic progress cannot be separated from social inclusion and environmental protection.

The interdependencies can generate both synergies and trade-offs. For example, investments in industrialization, infrastructure and economic growth can support poverty reduction and job creation, but at the same time can have negative environmental impacts if clean technologies are not used and appropriate regulatory frameworks are not applied. Similarly, environmental protection policies may entail short-term economic costs, but can contribute to increasing economic resilience and reduce vulnerabilities in the long term (Nilsson et al., 2016).

In September 2015, Romania joined the other 192 UN Member States and adopted the 2030 Agenda for Sustainable Development. Our country committed to implementing the Sustainable Development Goals at the national level and revised the National Sustainable Development Strategy to integrate the Sustainable Development Goals.

Emerging energy technologies accelerate the process towards achieving the SDGs. The development of renewable sources, energy storage solutions, smart grids and the digitalization of energy systems contribute to increased efficiency, flexibility, and resilience of energy infrastructures (International Renewable Energy Agency, 2022). Their integration strengthens the link between the energy transition and sustainable economic growth by generating green jobs and the emergence of new business models. Emerging energy technologies reduce environmental impact and can transform potential constraints into long-term competitive advantages (Intergovernmental Panel on Climate Change, 2023). The European energy transition is closely linked to the objective of reducing carbon emissions, but its efficiency depends on the mix of policies, technologies, and economic structure of the member states (Apostu et al., 2022).

The objective of the research is to assess the contribution of a pilot project of a local energy community based on photovoltaic production on indicator 7.1 of SDG 7, indicator 8.1.1 of SDG 8, and indicator 9.4.1 of SDG 9. The analysis is carried out at the micro level through the case study implemented in a local community in the Alps, but without generalizing the results at the macroeconomic or national level.

In this context, the research aims to answer the following questions:

1) Does the local energy community project contribute to improving access to clean energy according to SDG indicator 7.1?

2) What is the relationship between the functioning of the energy community and the local economic performance reflected by SDG indicator 8.1.1 in the context of a micro-level case study?

3) Does the local energy community project support the reduction of emissions intensity according to SDG indicator 9.4.1?

4) Under which legislative, economic and sustainability conditions can the analysed model be replicated in Romania?

1. Literature review

The academic literature addresses energy sustainability because of the interaction between the transition to renewable sources, energy efficiency and socio-institutional transformations of energy systems. Simply substitute of fossil fuels with renewable energy sources is not enough to achieve sustainability. A reorganization of the way energy is produced, distributed, and governed is needed (Bridge et al., 2013; Jenkins et al., 2016). Oprea and Nicula (2026) highlight the rapid expansion of research on digitalization in emerging economies, indicating a structural shift toward technology-driven intermediation. Decentralized energy systems and green energy production result in reduced greenhouse gas emissions and increased energy resilience at local and regional levels (Parag & Ainspan, 2019; IEA, 2023). Renewable energy is associated with environmental benefits and economic and social impacts, such as cost stabilization and reduced consumer vulnerability to global market volatility (Sovacool et al., 2020). The social dimension of energy sustainability is becoming increasingly important because social acceptance, participation of local actors and equitable distribution of benefits determine the long-term success of the energy transition (Dall'Orsoletta et al., 2022).

Regarding sustainable development, the literature moved from general formulations to operational frameworks focused on the integration of economic, social, and environmental dimensions, since 2000. A useful contribution to positioning is the typology of sustainable development approaches. There are tensions between paradigms oriented towards the status quo, reforms, and transformation, including in the way public policy manages the link between economic growth, equity, and ecological limits (Hopwood et al., 2005). Due to this evolution, the 2030 Agenda for Sustainable Development introduced an analytical, normative framework and a common language structured around the 17 SDGs, which reflect the connection between economy, society, and environment (United Nations, 2015).

Independent analysis of the Sustainable Development Goals is rarely done in practice. Nilsson et al. (2016) propose the mapping of the interactions between these goals to avoid policies "in silos", and Weitz et al. (2018) create tools for contextual and systemic assessment of these interactions, which are very useful in design and prioritization (Nilsson et al., 2016; Weitz et al., 2018). Quantitative research that analysed SDG indicators shown that synergies and trade-offs are statistically detectable and vary between countries. This supports the need for context-dependent approaches (Pradhan et al., 2017). Along the same lines, in their paper, Kroll et al. (2019) discuss whether policies manage to transform trade-offs into synergies and which institutional conditions favour integration (Kroll et al., 2019). Regional competitiveness analysis highlights the role of structural variables of the local economy in differentiating territorial performance in periods of economic convergence and divergence (Jula & Jula, 2000). Energy is a cross-cutting "node" in these works because it influences competitiveness, production costs, employment structure and emissions. From the perspective of SDG 7, recent research argues that the transition to renewables and energy efficiency is a necessity to reduce energy intensity and decarbonization, but, at the same time, performance depends on investments in networks, flexibility and governance (IEA, 2021; IRENA, 2022). The Intergovernmental Panel on Climate Change directly connects the transformation of energy systems with limiting global warming, which makes SDG 7 an anchor goal for the rest of the agenda (IPCC, 2023). The connection between SDG 7 and SDG 8 is analysed in the specialized literature as "green growth", just transition and the labour market. OECD analyses show that investments in low-carbon technologies and modern infrastructure can generate long-term productivity and competitiveness, but, of course, provided that coherent innovation and human capital policies are implemented (OECD et al., 2015). At the same time, the green transition can create jobs, but without retraining and social protection policies, concentrated regional and sectoral losses occur (ILO, 2018).

Research addresses SDG 9 in relation to technological development and change and the capacity of infrastructures to integrate distributed generation, digitalization, and new market models. In their paper, Bridge et al. (2013) analyse the energy transition and observe that the shift from centralized systems to more decentralized architectures requires investments in networks, metering, flexibility, and governance (Bridge et al., 2013). Oprea and Draghici (2024) show that digitalization strengthening access and effective participation in modern financial services. Regarding energy communities, the literature places them at the intersection of energy transition and social innovation. The first community initiatives in the field of energy emerged in the context of the environmental movements of the 1960s and the oil crises of the 1970s. They were motivated by the need for energy autonomy, civic participation, and reduced dependence on centralized energy structures (Hewitt et al., 2019) and emphasized the direct involvement of citizens as active actors in energy production and management. The report by the Joint Research Centre of the European Commission shows that these new structures contribute to the democratisation of access to renewable energy and the distribution of economic benefits at the local level, independent of individual income levels (Caramizaru & Uihlein, 2020). Although energy communities are studied in specific local contexts, their emergence and development were supported by a set of common factors, independent of location, such as the existence of appropriate policy schemes (Lode et al., 2022).

The conceptual framework was strengthened by Directive (EU) 2018/2001 (RED II), which formally introduced the concepts of citizens' energy communities and renewable energy communities (European Parliament & Council, 2018). Thus, energy communities appear in the specialist literature after 2010 as a mechanism for accelerating renewable energy systems, civic engagement, and local value retention. A landmark study presents the plurality of objectives of community initiatives: economic, social, environmental, infrastructural and the role of networks in strengthening the energy sector (Seyfang et al., 2013). Other empirical and comparative studies show that the good development of community energy systems is influenced by support frameworks, ownership models and institutional conditions (Bauwens et al., 2016).

Recent literature analyses this area in two directions. The first direction is represented by the analysis of energy communities as a social innovation and the effects on civic empowerment, local governance and social objectives are discussed (Dall-Orsoletta et al., 2022). The second direction focuses on energy and economic performance and the technical conditions of collective self-consumption and virtual sharing. The Magliano Alpi case study, the first pilot project in Italy, is a directly relevant example. The alternative of joining the energy community and the performances after one year of piloting are analysed and empirical arguments are provided about the role of the overlap between PV production curves and consumption profiles (De Santi et al., 2022; Ghiani et al., 2022).

In the same vein, recent review papers support the positioning of the architecture and systemic impact of energy communities as a policy tool for transition objectives (Barabino et al., 2023).

2. Methodology

The paper adopts a qualitative research based on the analysis of specialized literature and the case study method and aims to investigate the role of renewable sources and emerging energy technologies in supporting sustainable economic growth in relation to indicator 7.1 of SDG 7, indicator 8.1.1 of SDG 8 and indicator 9.4.1 of SDG 9. The selection of this research method is justified by the exploratory nature of the topic and the need to analyse the mechanisms through which local energy initiatives contribute to achieving sustainability objectives.

The literature review was used to present the main theoretical and empirical contributions related to a very current topic in the energy sector and sustainable development. This method was selected because it favours the recognition and understanding of what is currently known and what needs to be known about this topic (Webster & Watson, 2002; Oprea, 2024). The search for specialized works was carried out in the Web of Science, Scopus, Springer and Google Scholar databases. The search terms were: “Sustainable Development Goals”, “SDG indicators”, “renewable energy transition”, “energy access”, “energy communities”, “distributed energy systems”, “economic growth sustainability”, “real GDP per capita growth”, “infrastructure modernization”, “CO_2 emissions reduction” and “low-carbon energy systems”. The Boolean operator “AND (and/or OR)” was applied in the search process to expand and narrow the search accordingly. The analysis of titles, abstracts and keywords followed to verify whether the works research the subject of study of this paper.

The reports of important institutions in the energy field were also analysed: The International Energy Agency, the International Renewable Energy Agency, the Organization for Economic Cooperation and Development, the International Labor Organization, the European Commission, and the Intergovernmental Panel on Climate Change. This stage helped to outline the conceptual framework of the research and to demonstrate the selection of indicators of SDG 7, SDG 8 and SDG 9 as the objectives of the analysis.

Both standard academic literature and grey literature were analysed with the aim of exposing the relationships between renewable energy, energy security, economic growth, and infrastructure innovation. In addition to the theoretical analysis, the research uses the case study method in which the energy community of Magliano Alpi (Italy) is examined. The paper analyses this community since it was one of the first initiatives of its kind in Europe and the first pilot project in Italy. Thus, the case study allows for the detailed analysis of a real pilot project created in a specific context, to examine the interaction between project participants, green energy technologies and institutional frameworks. Data from the public documentation of the project, from official institutional sources and from academic articles analysing the energy and economic performance of the community were used for the case study. The case study analysis is carried out by relating the project characteristics to the selected indicators of SDGs 7, 8 and 9 (7.1, 8.1.1 and 9.4.1) and aims to identify qualitative contributions complemented by quantitative estimates at the case study level, where data allow.

The selection of indicators 7.1, 8.1.1 and 9.4.1 was carried out to ensure the link between the research objectives, the nature of the case study and the level of analysis allowed by the available data. The indicators were chosen due to the possibility of being operationalized at the micro level through indirect indicators for the functioning of an energy community. Indicator 7.1 allows the analysis of the functional aspect of access to energy, by assessing the quality of the energy service and the use of renewable sources. Indicator 8.1.1 is used as a framework indicator of SDG 8, with a contextual role, to anchor the study in a macroeconomic framework of sustainable growth, without assuming direct causal relationships. Indicator 9.4 is relevant for assessing the modernization of energy infrastructure and the reduction of climate impact, being supported by quantitative estimates of CO_2 emissions.

3. Case study

Today's technology allows the creation and implementation of innovative energy management models. European legislation focuses on the consumer and producer, who must be guaranteed fairer and more sustainable access to the electricity market. At the heart of this evolution are "energy communities". Currently, there are several definitions of energy communities, each with its own history and different legislative and regulatory references, in a regulatory framework that is constantly evolving. The objective of this entity, beyond the terms used is to help citizens to create innovative forms of aggregation and governance in the field of energy, in order to generate benefits for individuals and the community, both economic and in terms of quality of life and to provide services in the local area (CER Magliano Alpi, 2021). In November 2016, the European Commission presented a package of proposals, called the "Clean Energy for All Europeans Package" (CEP), with the aim of contributing to the EU's commitments under the Paris Agreement. The proposal led to the adoption of eight pieces of legislation between 2018 and the first half of 2019, through which the EU reformed its energy policy framework. Of particular importance are Directives 2018/2001 (which introduced "renewable energy communities") and 944/2019 (which defined "citizens' energy communities"), which are currently being transposed by the Member States.

The creation of the Magliano Alpi energy community must be seen in the light of the energy transition processes at European level and how these have been felt in small communities. The literature (Ghiani et al., 2022) argues that, in Italy, Renewable Energy Community (REC) projects emerged as a necessity to reduce dependence on the centralized energy system.

In Magliano Alpi, from a socio-economic point of view, public administration, households, and small businesses coexist in an economic ecosystem vulnerable to the volatility of energy prices. Subsequent analyses of the project implementation show that it resulted in a reduction in energy expenses and the retention of economic value at the local level, important aspects for the public budget and small businesses (Ghiani et al., 2022; De Santi et al., 2022). The energy context was influenced by the introduction of the Italian experimental legislative framework in 2020, which allowed the development of the first energy communities based on distributed generation. Thus, opportunities were created to test alternative models of energy production and consumption through utilization of local renewable resources and by distributing the benefits among the participants.

The Magliano Alpi energy community was created as a pilot project, in a period characterized by still incipient regulations. The literature also highlights the importance of social factors in the configuration of this project, in addition to the economic and technical dimensions. Magliacani et al. (2025) highlight that the emergence of the first energy community in Italy was the result of the aspiration of local authorities to promote new forms of energy governance, based on cooperation, transparency, and collective responsibility. Energy was treated as an asset for local development and for strengthening relations between public institutions and citizens.

3.1. Description of the energy community in Magliano Alpi (Italy)

The Magliano Alpi energy community is one of the first European projects to implement a model for collective production and consumption of renewable energy. The energy community was developed in 2020, as a direct response to the changes introduced by Italian legislation that allowed the testing of energy communities. The project was designed to assess the technical, economic, and organizational feasibility of this type of initiative under real operating conditions (De Santi et al., 2022; Ghiani et al., 2022). The town of Magliano has approximately 2200 inhabitants and is in the Piedmont region of northern Italy, close to the French border. In the pilot phase, the Magliano Alpi energy community included three public institutions, three households and one small economic consumer, all connected to the same branch of the low-voltage network (Ghiani et al., 2022).

3.2. Actors involved in the energy community in Magliano Alpi

The structure of the energy community is built around the Magliano Alpi town hall, which initiated the pilot project and provided the necessary infrastructure for energy production. The local government participates as a prosumer and institutional coordinator and facilitates the relationship with the distribution operator and regulatory authorities (Comunità Energetica Rinnovabile Magliano Alpi, 2021). The community also includes residential consumers and a small economic consumer. Participation was voluntary and did not involve the modification of individual energy supply contracts. The literature highlights that this mixed architecture was important for the social acceptance of the project and for its stable operation during the pilot phase (De Santi et al., 2022). The municipality has also signed the "Manifesto of energy communities for an active central role of citizens in the new energy market", promoted by the Energy Center of the Polytechnic University of Turin. Thus, the project was also technically supported by this institution. The energy community is a member of the Italian Forum of Energy Communities (IFEC), but it did not have an operational role in the implementation of the Magliano Alpi energy community. The institution only contributed to disseminate the project as an example of good practice and facilitate the exchange of knowledge between the actors involved in the development of energy communities in Italy.

3.3. Technologies used and their emerging character used in the energy community of Magliano Alpi

From a technological point of view, the Magliano Alpi energy community is based on a photovoltaic system connected to the distribution network, installed on a public building. The system has an installed power of approximately 19.8 kWh, which was sized in relation to the consumption profiles of the community members and with the objective to maximize the local use of the energy produced (Ghiani et al., 2022). Photovoltaic technology is already mature. The emerging character of the project is given by the way in which renewable energy is integrated into an energy community model. Virtual energy sharing is an emerging element of the functioning of energy communities, consisting in the accounting allocation of locally produced energy to several members of the community, without direct physical transfer of energy. In the case of the Magliano Alpi energy community, this mechanism is implemented by calculating the shared energy based on production and consumption data, which is used to determine the economic benefits of the members (Ghiani et al., 2022; De Santi et al., 2022).

Based on the project, smart meters were installed at the premises of the end users. According to Barai et al. (2015), smart meters record energy consumption and production and thus concentrate information for the energy market (Barai et al., 2015). These systems respond immediately to demand and connect users, network operators and the energy market (Kochański et al., 2020). They are used to continuously save bidirectional information on active and reactive power in both single-phase and three-phase mode (Ghiani et al., 2022).

The Magliano Alpi energy community project used an energy community management system through digital energy management platform to collect, process and analyse the production and consumption data needed to calculate shared energy and performance indicators. This system, mentioned in the community's technical and economic analysis, was developed as part of scientific collaboration with specialised research laboratories and research infrastructure projects for energy communities (ERIGrid 2.0, 2022), supporting the planning, optimisation and estimation of the economic impact of energy operations.

The community does not use energy storage systems, and the optimisation of self-consumption is achieved exclusively by correlating photovoltaic production with the consumption profiles of the users. Jula et al. (2023) show that electricity consumption patterns exhibit significant structural changes under systemic shocks, emphasizing the sensitivity of demand profiles to economic and social disruptions. This aspect is important, as it highlights the technical limitations of the first generation of energy communities and the importance of digital energy management in the absence of storage (De Santi et al., 2022). The project included limits on the location of consumers and producers, who had to be connected to the same medium/low voltage substation. The maximum production power of 200 kW of the installations serving the community was also set as a constraint.

3.4. Energy and economic performance of the Magliano Alpi energy community

Given that the Magliano Alpi project was a conceptual one, without annual reporting, the energy performance analysis of the Magliano Alpi energy community was carried out based on data obtained by Ghiani et al. (2022). Raw data was collected between March 2021 and February 2022 for the first full year of operation of the project. The community recorded a total electricity consumption of 49,288 kWh, while the total energy production from photovoltaic sources was 27,137 kWh, indicating that, from a technical point of view, the local production system would have the capability to cover over half of the community's annual energy needs, under conditions of better synchronization between production and consumption.

Of the energy produced, 9,642 kWh (35%) were consumed instantly by the public building on which the photovoltaic system is installed, and 7,797 kWh (approx. 15% of total consumption) were identified as shared energy between community members, according to the rules established by the national operator GSE. The rest of the energy produced, namely 17,495 kWh, was injected into the public grid, highlighting the existence of local value losses caused by the limited use of renewable energy within the community.

From an economic point of view, the analysis shows that the operation of the energy community generated financial benefits, although these are still below the maximum potential. During the period analysed, the community obtained 2,326 euros from the mechanism for capitalizing on energy injected into the grid (Ritiro Dedicato – RID) and 927 euros from the incentive granted for shared energy, calculated at a value of 0.119 euros/kWh.

The total electricity expenditure for community members was estimated at 11,130 euros, which leads to a negative economic balance of –7,875 euros in the initial configuration. The negative balance shows the pilot nature of the project and the lack of operational optimization. However, the authors demonstrate that, through behavioral optimization measures, in particular through load shifting, the shared energy could increase to 17,000 kWh/year, which would lead to an increase in economic incentives by 118% and an improvement in total economic performance by 13.9%, without additional infrastructure investments (Ghiani et al., 2022).

The energy and economic performance of the Magliano Alpi energy community is summarized according to Ghiani et al. (2022) in Table 1.

Table 1. Energy and economic performance of the Magliano Alpi energy community

Category	Indicator	Value	U.M.	Description
Energy Performance	Total annual electricity consumption	49,288	kWh/year	Aggregate consumption of all community members in the first year of operation
	Total photovoltaic energy production	27,137	kWh/year	Energy produced by the community photovoltaic system
	Physical self-consumed energy	9,642	kWh/year	Energy instantaneously consumed by the public building
	Energy shared within the community	7,797	kWh/year	Energy recognized as shared according to GSE rules
	Energy injected into the grid	17,495	kWh/year	Surplus energy delivered to the public grid
	Self-Consumption Ratio (SCP)	35	%	Share of self-consumption in total production
	Shared-to-Consumption Ratio (STC)	15	%	Share of shared energy in total consumption
	Energy from Energy Transition (EFET)	44	%	Share of renewable energy used locally
	Shared-to-Self-Consumption Ratio (SCSTC)	35	%	Degree of local utilization of produced energy

Economic Performance	Revenues from Ritiro Dedicato (RID)	2,326	€ / year	Revenues from energy injected into the grid
	Incentives for shared energy	927	€ / year	Revenues obtained from the GSE support scheme
	Total annual electricity cost	11,130	€ / year	Total community expenditure
	Annual economic balance	–7,875	€ / year	Difference between costs and revenues
	Potential increase in shared energy (optimized scenario)	~17,000	kWh/year	Estimated value through load shifting
	Estimated increase in economic incentives	+118	%	Increase in revenues from shared energy
	Estimated improvement in economic performance	+13.9	%	Impact of optimization without additional investments

Source: author's processing based on data from Ghiani et al. (2022).

The table highlights both the renewable energy use indicators and the economic impact of the project in the first year of operation.

3.5. Relevance of the project in relation to selected SDG indicators

From a sustainability perspective, the Magliano Alpi pilot project integrates energy, economic and institutional dimensions at the same time. Local production of renewable energy reduces emissions associated with electricity consumption, and sharing mechanisms allow the economic value generated by energy to be retained at local level (Ghiani et al., 2022). In institutional and social terms, the project is based on cooperation between public administration and citizens and promotes a participatory governance model. Magliacani et al. (2025) underline that this multi-component organizational and accounting dimension transforms the energy community into an instrument of technical and social innovation. Thus, the Magliano Alpi energy community can be interpreted as a demonstration project that highlights the potential of emerging energy technologies to support the transition to more sustainable energy systems by integrating distributed generation, digitalization, and local governance.

a. Project relevance for indicator 7.1 on access to secure, modern, and affordable energy services

SDG 7 indicator 7.1 (proportion of population with access to electricity) aims to ensure universal access to modern energy services (United Nations, 2015). In developed economies, of which Italy is a part, formal access to electricity is almost universal. In this case, an adapted analytical approach is required, since the relevance of indicator 7.1 no longer lies in the existence of a connection to the grid, but in the quality of access to it, the stability of energy supply and the economic affordability of energy.

The case study of the energy community of Magliano Alpi highlights how local initiatives can strengthen the qualitative dimension of energy access. In the first full year of operation, the community recorded a total consumption of 49,288 kWh and a photovoltaic production of 27,137 kWh, of which 9,642 kWh were self-consumed by the public institution and 7,797 kWh were shared among community members (Ghiani et al., 2022). In this way, approximately 17,439 kWh, which constitutes over a third of the annual energy needs, were covered by locally produced renewable energy. This performance has direct implications for the interpretation of SDG indicator 7.1. Local renewable energy production reduces dependence on the centralized grid and limits consumers' exposure to energy price volatility. Therefore, it contributes to increase energy security at the community level. For public institutions, households and small businesses, access to electricity becomes more predictable and economically affordable (International Energy Agency, 2021).

In this respect, the Magliano Alpi energy community functions as a mechanism to deepen SDG 7.1 in countries with universal access to electricity, by improving the quality of access and by democratizing energy use. The contribution of the project is indirect and qualitative. It has no effects that impact national statistics but provides empirical evidence regarding the role of energy communities to achieve the goals of the 2030 Agenda.

b. Project relevance for indicator 8.1.1 regarding the growth rate of real GDP per capita

SDG 8 indicator 8.1 aims to promote sustained economic growth and is operationalized through indicator 8.1.1: real GDP growth rate per capita (United Nations, 2015). By its nature, this indicator is strictly macroeconomic in nature and cannot be directly influenced by small-scale local initiatives. However, its use in the analysis of the Magliano Alpi case study is justified from a conceptual perspective, as it allows the assessment of the structural compatibility between energy transition projects and the objective of sustainable economic growth. The Magliano Alpi energy community does not generate measurable effects on GDP at national or regional level, but it indirectly contributes to the mechanisms that support the premises of stable economic growth. The economic performance analysis shows that the project has partially reduced energy costs for community members and retained economic value at the local level, through self-consumption and shared energy (Ghiani et al., 2022). In the first year of operation, locally used renewable energy covered approximately 35% of the community's energy needs and reduced dependence on energy purchased from the market.

From the perspective of SDG 8.1.1, the results are important because energy costs are the most important for local economic activities, especially for small businesses and for public budgets. Reducing exposure to energy price volatility contributes to increasing economic predictability and stabilizing productive activities (OECD, 2017). The literature also shows that investments in renewable energy and local infrastructure can have multiplier effects on local economies, even if their impact on macroeconomic indicators is diffuse and long-lasting (International Energy Agency, 2021). Oprea et al. (2025) argue that digital banking and capital market development contribute to economic growth when supported by coherent public–private partnerships and financial education policies.

Energy communities contribute to reduce energy costs, stabilize local economic activities and increase economic resilience. Jula et al. (2026) provide evidence that investment–output relationships are nonlinear and adjustment dynamics are asymmetric, suggesting that structural transformation processes require sustained capital allocation and institutional support. At the aggregate level, these mechanisms are consistent with the assumptions of a favourable evolution of real GDP per capita. The approach avoids the attribution of unjustified causal effects and emphasizes the role of local initiatives as complementary elements to macroeconomic policies aimed at sustainable development.

In this sense, the Magliano Alpi energy community can be interpreted as a complementary instrument to macroeconomic policies aimed at SDG 8.1.1. The project illustrates how local energy transition initiatives can support the micro-level conditions necessary for sustainable economic growth, without unjustifiably attributing direct causal effects on the evolution of real GDP per capita.

c. Project relevance for indicator 9.4.1 on resilient infrastructure

SDG 9 indicator 9.4 aims to modernise infrastructure and increase industrial sustainability, operationalised through indicator 9.4.1 – CO_2 emissions per unit of value added (United Nations, 2015). This indicator reflects efforts to decouple economic activity from carbon emissions, through technological modernisation and the adoption of low-emission solutions. Emissions indicators are representative to assess the relationship between economic activity and climate impact (Vasile & Balan, 2008). Although the indicator has a macroeconomic dimension, its analysis at the case study level is relevant for identifying the micro mechanisms that support this trajectory. The energy community of Magliano Alpi is an example of modernising local energy infrastructure by integrating photovoltaic production, smart metering, and digital energy management.

The calculation below was made based on data from Ghiani et al. (2022). In the first year of operation, the community produced 27,137 kWh of electricity from renewable sources, of which 9,642 kWh were self-consumed and 7,797 kWh were shared among community members (Ghiani et al., 2022). The locally utilized renewable energy thus amounts to 17,439 kWh (≈17.44 MWh/year).

Based on these data, the project's contribution to reducing CO_2 emissions can be estimated as follows:

Avoided CO_2 emissions (t) = Erenewable (MWh) × EFelectricity mix (t CO_2/MWh)

where: Erenewable = renewable energy self-consumed + shared and EFelectricity mix means average emission factor of the national electricity mix.

An average emission factor of the Italian electricity mix of approximately 0.30 t CO_2/MWh was applied, frequently used in the European literature for the period 2021–2022 (IEA, 2021; IPCC, 2023), resulting in an estimated annual reduction of:

Avoided CO_2 emissions (t) = 17.44 MWh × 0.30 t CO_2/MWh = 5.2 t CO_2/year avoided.

The result shows the indirect contribution of the energy community to the decrease of the carbon intensity associated with the electricity consumption. From the perspective of SDG indicator 9.4.1, the project demonstrates how the modernization of the local energy infrastructure and the use of green technologies can reduce emissions without affecting the functioning of local economic activities. The energy community of Magliano Alpi is a demonstration project that illustrates at a micro scale the objectives of SDG 9.4.1. Although the impact on the national indicators is limited, the observed mechanisms are aligned with the decarbonization and modernization strategies promoted at European and global level.

4. Discussions

The paper analyses the indicators associated with SDG 7, SDG 8 and SDG 9 as they represent the operational tools through which the contribution of a local demonstration project can be interpreted. The analysis targets indicators 7.1, 8.1.1 and 9.4.1 and aims to highlight the synergies, limitations, and replication potential of the project without extending macroeconomic impacts that cannot be empirically supported.

4.1. Synergies between indicators 7.1, 8.1.1 and 9.4.1

Indicator 7.1 is directly influenced by increasing the quality of access to energy, in terms of cost stability and the use of locally produced renewable energy. The Magliano Alpi energy community does not expand physical access to electricity because it is already connected to a low-voltage grid. It strengthens the level of permissiveness of access through decrease of exposure to price volatility and increase the predictability of energy consumption.

Indicator 9.4.1, which aims to modernize the infrastructure and reduce the intensity of CO_2 emissions per unit of value added, is important by integrating distributed renewable energy production into the existing infrastructure. Although the energy community is not an industrial facility in the strict sense, the mechanisms of local production, self-consumption and virtual sharing lead to the reduction of emissions associated with electricity consumption and to the increase of the efficiency of the use of energy infrastructure.

Infrastructure modernization creates premises for synergies with indicator 8.1.1. The decrease in energy costs and increase in local energy resilience can support existing economic activities and improve the capacity of public administration and small consumers to allocate resources to productive activities. The impact on real GDP growth per capita is indirect and cumulative but is part of the logic of more resource-efficient economic growth.

4.2. Limitations and constraints in relation to the analysed indicators

The main limitation of the analysis is related to the scale of application of the indicators. In the case of indicator 7.1, the limitation is that it does not explicitly capture dimensions such as local energy autonomy or participatory governance, which are central to the functioning of energy communities. For indicator 8.1.1, the major constraint is the lack of a direct causal link between a local project and the dynamics of GDP per capita. The indicator is used exclusively to place the analysis in a broader macroeconomic context and to discuss indirect and cumulative contributions. It is used exclusively as a reference for economic compatibility.

The limitation results from the local scale of the case study, which does not allow the identification of causal effects on the dynamics of real GDP per capita.

4.3. Project replication potential in Romania

The replication in Romania of the pilot energy community project analysed in the Alps must be assessed with caution because its implementation and proper functioning were conditioned by a specific legislative and institutional context, in an experimental phase and supported by mechanisms to stimulate shared energy. The European framework offers common principles, but the degree of replicability is determined by the application of the rules at national level. From a legislative perspective, Romania took an important step and introduced energy communities into national legislation (Government of Romania, 2025), in the context of the transposition of the provisions of Directives (EU) 2018/2001 and 944/2019. The Magliano Alpi pilot project benefited from the accounting recognition of shared energy and a specific financial incentive for collective self-consumption. On the other hand, the Romanian framework remains incomplete from an operational point of view. In Romania, secondary regulations have not yet been implemented regarding registration procedures, energy allocation between members, settlement, or access to metering data. This generates legal uncertainty and discourages local initiatives (Lowitzsch et al., 2019).

From an economic point of view, the analysis of the pilot project in the Alps shows that the longevity of small-scale energy communities depends on a favourable price for locally shared energy. Even if incentives are granted, part of the photovoltaic energy production is injected into the grid with a low economic value. Thus, the financial performance of the project is limited. In Romania, there is no similar mechanism to stimulate shared energy, and replication would have to rely almost exclusively on individual savings of prosumers, which reduces the accessibility for lower-income households and local economic actors (Caramizaru & Uihlein, 2020). Also, the non-technical costs associated with community administration and governance can become disproportionately high on a small scale, which affects economic sustainability in the medium term.

An additional risk is the possibility that the energy community model could be taken over by large players with superior financial and legal capacity, which could transform these initiatives into a commercial instrument with limited citizen participation. This scenario would contradict the objectives of energy democratization and social cohesion promoted at European level and illustrated by the case study analysed, where the role of the local authority was central to the legitimacy and social acceptance of the project.

From a sustainability perspective, the replication of the project is a complex socio-technical process. From a technical point of view, the Alpine energy community operates without storage systems, which limits the degree of local valorisation. The replicability of the project may increase the pressures on the distribution networks, especially in areas with undersized electricity infrastructure. Socially, the success of the implementation of such a project depends on the existence of transparent governance and the capacity of the communities to include vulnerable consumers. From an environmental perspective, reducing CO_2 emissions is very important, but it must be assessed in relation to the emission factors specific to the national energy mix and the effective degree of substitution of conventional production to avoid overestimating the climate impact (IRENA, 2023). In conclusion, the replicability of the pilot project in the Alps in Romania may represent a strategic direction, but it cannot be seen as an automatic result. The potential is maximum in communities where local authorities are involved in the implementation of such projects. In the absence of complete and clear legislation, dedicated economic mechanisms and an integrated approach to sustainability, energy communities risk remaining one-off initiatives, with limited impact on the energy transition and social inclusion.

Conclusions

The paper analysed, through a community-level case study, how energy community projects can contribute to achieving selected sustainable development goals. The research highlighted both the potential and the limits of using SDG indicators at the micro-scale.

In the analysis, for SDG 7, indicator 7.1 was interpreted qualitatively and the fact that the case study is carried out in a context with universal access to electricity was considered. The results show that the project contributes to improvement of the quality of energy access by increasing local energy autonomy and reducing grid dependency. The annual production of 27,137 kWh and self-consumption of 9,642 kWh show that local use is high, even if the self-consumption and sharing rate (17,439 kWh cumulated) remains below the maximum technical potential. The result supports the relevance of indicator 7.1 as a proxy indicator for the security and quality of energy access at the community level. Regarding SDG 8, the analysis used indicator 8.1.1 in a cautious manner, as an indirect indicator. The project does not generate measurable economic growth in terms of local GDP, but creates favourable conditions by reducing energy costs, stabilizing expenditures, and retaining part of the economic value in the community. The contribution is not directly quantifiable, which confirms the complementary nature of indicator 8.1.1 in relation to the case study. For SDG 9, the assessment focused on indicator 9.4.1, and the results show that the project contributes to the decarbonization of local infrastructure, by reducing emissions associated with grid consumption and by integrating a photovoltaic capacity that exceeds 50% of the annual consumption of the community. The decarbonization effect is supported by an estimated reduction in CO_2 emissions associated with grid consumption, calculated based on renewable energy produced and used locally.

Public policies on energy communities should go beyond the strictly installed capacity-oriented approach and also focus on maximization of the local use of the energy produced through incentives for self-consumption, sharing and demand flexibility. Explicit integration of energy communities into national energy transition strategies can strengthen the link between the objectives of decarbonization, local energy security and sustainable economic development, especially in transition economies such as Romania.

The contribution of the paper is to create an interpretative framework for the synergies between selected indicators of SDGs 7, 8 and 9 in the case of energy communities. It explicitly shows where global indicators are appropriate (SDGs 7.1 and 9.4, in a qualitative sense) and where they should be used with caution (SDG 8.1.1, strictly contextual).

The limitation of the research is that there is a difference in scale between the SDG indicators (designed macro) and the case study (micro), which restricts the causal interpretation, especially for SDG 8.1.1. Also, the lack of storage may limit the generalization of performance. For Romania, the replication of the project is conditional on the completion of the legislative framework and secondary regulations for registration, allocation, settlement, data access, economic mechanisms dedicated to shared energy and the capacity of the distribution networks. Future research can comparatively test models with storage, dynamic tariffs, digital platforms, and scenarios for the inclusion of vulnerable consumers, as well as cost-benefit assessments for pilot projects in Romanian communities.

The conclusions of the paper should be interpreted as exploratory results for understanding the mechanisms of operation and evaluation of energy communities.

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