Evaluating Energy Communities: A New Social and Economic Model for Implementing the Ecological Transition

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Abstract. The European Directive on the promotion of the use of energy from renewable sources, establishes the possibility of creating 'Renewable Energy Communities (REC)' for the production and consumption of energy from renewable sources, stimulating the transition from a centralized to a decentralized energy system.

By putting citizens at the center of the energy transition, REC represent a virtuous socio-economic community model in which citizens, businesses and administrations become 'prosumers', actively integrated in a participatory and democratic process to support the energy transition.

Considering both the complexity and the variety of factors that influence the evolution of this phenomenon and also the multidimensional implication of this new socio-economic model, this study aims to provide the Key Performance Indicators (KPIs) that influence citizens' energy communities and to establish a methodology to quantify or qualify these impacts.

In this study, 26 KPIs were identified and divided into three dimensions: environmental, economic and social.

The proposed KPIs were applied on two Italian case studies, selected as 'pioneers' examples of REC, allowing their comparison at multidimensional level.

The findings confirm that REC represent a model able to generate multiple benefits and, for this reason, their evaluation become a necessary step in monitoring progress (in itinere) and results (ex post).

This aspect makes KPIs particularly useful not only as an ex post evaluation tool but also as a method to support decision-making. Future research could test more case studies and verify the variation of the results obtained in relation to the different contexts considered.

Keywords: Energy Communities · Ecological Transition · Sustainable Development · Multidimensional Assessment · Key Performance Indicators

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1 Introduction

The European Commission's Clean Energy for All Europeans Package [1] affirms the prominent role that communities will play in the future energy system.

The package will contribute to decarbonizing the EU energy system in line with the objectives of the European Green Deal. Based on Commission proposals published in 2016, the package consists of 8 new laws. One of these laws is the Renewable Energy - Recast to 2030 (RED II) Directive (EU) [2], which aims to promote the use of energy from renewable sources: in Article 3 it sets an overall binding target for the Union by 2030, i.e. that Member States collectively ensure that the share of energy from renewable sources in the Union's gross final energy consumption in 2030 is at least 32%. The Commission will assess this target with a view to presenting, by 2023, a legislative proposal to increase it in case of further substantial reductions in the costs of renewable energy production, if this is necessary to meet the Union's international commitments to decarbonization or if such an increase is justified by a significant decrease in energy consumption in the Union.

Article 22 of the same Directive introduces the concept of a Renewable Energy Community, better known as the Energy Community. The Directive not only stipulates that by 2030 at European level, renewable energies should account for at least 32% of gross final energy consumption, but also sets the target that by 2050, 16% of electricity should come from community initiatives such as Energy Communities [3, 4].

In Italy, the term 'energy communities' only entered the official language in December 2020, when Parliament approved an amendment to the so-called 'Decreto Milleproroghe 162/2019' [5] that establishes the possibility of creating communities between several entities for the production and consumption of energy from renewable sources.

The reception of the European RED II Directive, therefore represented a fundamental step with which the Italian government in a timely manner aligned itself with several virtuous countries such as Denmark and Germany where the reality of energy communities has been present for years [6].

The excellent work of the 'GSE - Gestore dei Servizi Energetici' (Energy Services Manager) [7] during the consultations has provided the technical basis for standardization and for the effective and widespread implementation of these important innovations in Italy.

In fact, our country was quick from a regulatory point of view to transpose the European legislation, first by experimentally introducing small energy communities with plants up to 200 kW, and then definitively at the end of 2021 with the law transposing the European Directive, extending the possibility to plants up to 1 MW.

On the basis of the European Climate Law goals [8], investments and reforms contained in the Italian Green Transition Recovery and Resilience Plans (PNRRS) have been developed [9]. The PNRR foresees numerous investments in the renewable energy sector with the aim of ensuring clean and efficient energy use and sustainable public transport. Energy Communities are included in the social and territorial cohesion theme in order to support small territories at risk of depopulation. It is also important to take into consideration the Italian PTE (Plan for Ecological Transition) [10] in which the reduction of climate-changing emissions by 2030 is foreseen; this Plan - based on the objectives indicated in the PNRR - provides a framework for environmental and energy

policies. It goes without saying that the progressive and capillary diffusion of Energy Communities is in line with the decarbonization objectives, but in order to evangelize them, it will be necessary to carry out targeted interventions on transmission, distribution and storage networks..

2 Energy Communities as a New Socio-economic Model

An energy community can be formed when individual citizens, local authorities or small companies and cooperatives join together to become co-owners of 'neighborhood' renewable energy plants, thus exchanging energy for self-consumption, but also with the possibility of feeding energy into the grid and receiving an incentive from the GSE. The latter can be shared (as in the case of a photovoltaic or wind power plant at the disposal of the community) or individual (as in the case of a photovoltaic plant installed on the roof of a house, a company, a public administration building or an apartment block).

In this way, a participatory form of renewable energy production is realized because passive consumers, consumers, are transformed into active consumers and producers, prosumers [11], as they have their own system to generate electricity for self-consumption, selling excess energy to other actors managed by a smart grid [12]. The smart grid paradigm suggests tackling energy management by increasing the flexibility of the electricity grid, using data and IT to remotely coordinate distributed generation and storage technologies so that they can actively respond to changing grid conditions. The infrastructure consists of a network that connects all actors in the energy community, monitored and controlled by state-of-the-art digital technologies to optimize every stage of energy production, consumption and exchange through innovative hardware and software solutions [13].

On this basis, new ways of governing energy communities are also being explored, for instance by coupling classical grid control methodologies with block chain technology [14].

According to the definition of Article 2(14) of the European Directive, a 'self-consumer of renewable energy' is a final consumer who, operating on its own site within defined boundaries or, if permitted by a Member State, on other sites, produces renewable electricity for its own consumption and may store or sell self-produced renewable electricity, provided that, for a self-consumer of renewable energy, other than a household (e.g. a business), these activities do not constitute its principal commercial or professional activity. In the next point, the Directive also specifies that 'self-consumers of renewable energy acting collectively' are constituted by a group of at least two self-consumers of renewable energy acting collectively and located in the same building or apartment block.

Point c of Article 2(16) of the European Directive explicitly states that the main objective of renewable energy communities is to provide community-wide environmental, economic or social benefits to their shareholders or members or to the local areas in which they operate, rather than financial profits.

RECs can represent a regenerative model not only for individual communities, at the local scale, but also at the territorial scale, emphasizing the role of communities as drivers of inclusive and sustainable development processes.

RECs can enable the development of local production chains, providing networking and employment opportunities for local communities and reducing energy dependency on other countries or regions. Moreover, RECs also contribute to the fight against energy poverty by reducing energy consumption, lowering supply tariffs and making the use of renewable energy sources more equitable and affordable [15].

The shift to decentralized energy production has many advantages, including the use of local energy sources, greater security of energy supply at the local level, shorter transport distances and less energy dispersion. This shift also promotes community development and cohesion through the availability of income sources and the creation of local jobs.

3 Case Studies Comparison: The Energy Communities of East Naples (NA, Italy) and Turano Lodigiano (LO, Italy)

According to the Symbola Report [16], there are currently around 7,000 active energy communities in Europe, involving 2 million inhabitants. This is a growing phenomenon, so much so that some estimates hazard a growth potential that could reach 264 million European citizens, generating 45% of the expected electricity demand by 2050 [17].

Enel relieved that the EU country with the largest number of Energy Communities, according to a study by the EU 2020 Joint Research Centre, is Germany, with 1,750 Communities, followed by Denmark (700) and the Netherlands (500) [6].

In Legambiente's 'Comunità Rinnovabili 2022' report [18], a census is made of 100 mapped practices. However, it argued that these numbers still appear to be totally insufficient to reach the target of 70 GW envisaged by 2030, pushing the time horizon of its realization further and further away.

Despite this, it is undeniable not to note how this phenomenon is growing rapidly and how the awareness of institutions and citizens is increasingly materializing in favor of virtuous initiatives and experiences of dialogue and collaboration.

In order to apply our evaluation methodology, we have therefore considered two case studies, the first being the energy community of San Giovanni a Teduccio, in the eastern suburbs of Naples, which was one of the first experiments of Renewable Energy Communities (RECs) in Southern Italy, and the other being that of Turano Lodigiano, where the first renewable energy community in Lombardy was born.

3.1 The Energy Community of San Giovanni a Teduccio (NA, Italy)

In the case of San Giovanni a Teduccio the proposal was initiated by Legambiente and was supported by the Fondazione con il Sud, which finances social development projects, with an initial contribution of 100,000 euros [19]. The cost of the installation is partially borne (42%) by tax deductions under the renovation bonus [20].

The first step in establishing the energy community was to start involving local people, breaking the initial sense of mistrust and illustrating the advantages of this model. In this phase, the intermediation of people already active in the area and recognized by the population for their civic commitment through environmental education projects, recovery of abandoned public areas, workshops with children and cultural initiatives

was important. In fact, the president both of Legambiente Campania and the Fondazione Famiglia di Maria (a socio-educational center in the neighborhood) were personally involved in a local awareness campaign, emphasizing the great opportunity for redemption offered to this area. The project aroused enthusiasm in the community, which was willing to set up as an Energetic Community with an initial founding nucleus, formalized before a notary, and made up of three families of users, together with Mariateresa Imparato and Anna Riccardi (as representatives of Legambiente and the Foundation)[21]. Subsequently, the association expanded with the entry of twenty families from the neighbourhood. Thanks to the transposition of the European 'Red II' Directive in Italy, it was able to rely on a primary cabin, which would allow up to 40 families.

All the stakeholders involved started from the real needs of the local community, beginning with an analysis of the household's waste and energy expenditure management, and ending with the prediction of energy and economic savings as a solution to the energy poverty experienced by Ponticelli households.

From the outset, the proposed intervention targeted 40 families in distressed conditions, living in flats adjacent to the foundation, which would be easily connected to the same electricity box. These families were in absolute or near-absolute poverty, and very often live in conditions of 'energy illegality', so their joining the energy community had a social purpose even more than an environmental one, investing in their awareness as an active engine of change in the neighborhood's culture.

The next step was to install the photovoltaic system on the roof of the building of the Family of Mary Foundation, a 19th century building. The Foundation was active in the 19th century as an orphanage run by nuns. Today it is a secular educational institution, well known in the neighborhood, which cooperates with the social services of the municipality for the right to education.

The system consists of 166 panels with a total output of 53 kilowatts and is guaranteed for 25 years. It will be able to produce around 65,000 kilowatt hours in a year, 18% of which will be self-consumed by the Foundation, with the remainder being shared with the 40 local households. A storage system allows the energy to be stored and the extra energy to be fed into the grid and sold to the national grid. The proceeds will be distributed to the members at the end of the year for a return of between two hundred and three hundred euros per year per household, equivalent to the savings of two utility bills. In addition to this, households also benefit from the 20% discount that is applied on the utilities of those who have joined the energy community [7].

Over 25 years, the total incentives received, net of running costs, would amount to over 200,000 euros [19]. It is also estimated that real savings, in terms of reduced electricity consumption by all ERC members, would amount to around 300,000 euros [19].

This case study also emphasized the fundamental role of institutions as facilitators of the ecological transition, through an important assistance activity to the project's target households (a training course on renewable energy supply methods and the monitoring of electricity consumption and building quality in terms of heat dispersion) and an intensive information campaign on the benefits and potential of energy communities, in order to identify additional members.

3.2 The Energy Community of Turano Lodigiano (LO, Italy)

The second case study under analysis is that of Turano Lodigiano, a small municipality of just over 1,500 inhabitants. Here the first renewable energy community in Lombardy was born.

The ERC of Turano Lodigiano consists of 23 families, 1 parish and 9 municipal utilities, united in the free association called 'Solisca'. Established one year after the first project presentation on 2 October 2020, Solisca applied to the GSE for authorization to operate as an Energy Community in mid-January 2022. The shared energy is produced by two photovoltaic systems located on the roof of the locker rooms of the gymnasium and the municipal sports field, of 34 kW and 13 kW each respectively, totalling 46.5 kWp. The energy not self-consumed by the two PODs below the plants is shared by 23 residential consumers, the parish and 7 other municipal consumers.

In a first phase, only 10 of the 23 residential users shared energy: the next 13 were activated with the entry into force of the implementing regulations of Law 199 of 8/11/2021, which extended the scope of RECs to the primary cabin.

The initial investment in the plants covered the costs of the Energy Community's establishment and authorization process with 70,000 arriving to the municipality of Turano as ecological compensation for the construction of the turbogas power plant located in the municipality.

Supporting the Solisca community is a digital platform, which records real-time data - certified by block chain technology - of production and consumption, power flows, energy exchanges - produced, withdrawn, shared - and bill savings.

Members of the community are provided with an energy profile that can be accessed via an app, to receive advice on how to use the energy produced and exchanged and achieve even greater savings and efficiency.

Through the energy profile, users are also invited to adopt more conscious and sustainable consumption behavior through gamification initiatives.

Among the opportunities offered by the digital platform, there is also an estimated climate mitigation contribution generated by REC The system, in fact, calculates some environmental sustainability indicators such as CO2 emissions not produced and the number of equivalent trees planted.

4 Assessing Energy Communities: KPIs for a Multi-criteria Assessment

As abovementioned, the energy communities are a promising model able to generate benefits at multidimensional level. However, to assess the effectiveness of an energy community, Key Performance Indicators (KPIs) need to be defined and monitored.

This study aims to provide the main indicators that influence citizens' energy communities and to establish a methodology to quantify or qualify these impacts.

To date, several studies have addressed the topic of evaluating energy communities. In many of them, the definition of Key Performance Indicators (KPIs) is adopted as an established method to provide an objective assessment of complex issues, such as energy communities and smart grids. A Key Performance Indicator (KPI) is a value that can be

measured, evaluated and demonstrated in order to assess performance towards a specific goal [22].

KPIs can be expressed either as absolute values (e.g. energy production from renewable sources, carbon dioxide emissions, etc.) or as percentage values calculated with respect to a reference scenario (e.g. carbon dioxide reduction, increase in the share of renewables in the energy mix, etc.). They can be used to define high-level targets (linked to national and international energy visions) and local targets in the case of micro grids and energy communities [23]. Many authors suggest the use of KPIs in the design phase of a micro grid, as in Chan, where energy consumption savings and emission reductions are highlighted.

Community self-sufficiency and the self-consumption ratio are indicators most commonly identified [24–27] alongside other indicators more properly focused on environmental impact in terms of tons per year of avoided CO2, NOx and SO2 [28, 29]. Other studies have also focused on the issue of identifying stakeholders as a determining factor in resolving the complexity of issues and needs related to each of them and to identify a multi-level energy performance analysis system, based on three different hierarchical levels - strategic, tactical and operational - and distributing KPIs among the different stakeholders in the system while maintaining their interdependence [30]. Cuesta et al. [31] conduct an extensive literature review to emphasize the need of considering social indicators in addition to the usual considerations of economic, technical, and environmental criteria, in order to refine the design of Hybrid Renewable Energy Systems (HRES).

In some studies, environmental and economic KPIs are considered in decision-making as a support system for strategic investment decisions in the field of micro grids [32–34], while in other studies, the focus is on how these decisions are conditioned by very heterogeneous factors [35].

Other authors have pointed out the interconnection between energy communities and other sectors positively influenced by them, such as mobility, economy, quality of space and innovation [24, 36].

In this regard, [37] et al. also emphasize the importance of taking a systemic approach in measuring the energy efficiency of communities, considering the entire life cycle of all components involved in the activation of an energy community (i.e. buildings, infrastructure and transport) [38, 39]. The authors propose indicators for each of these three categories.

Furthermore, both the Efkarpidis et al. study [27] and the Lightness project [40] introduce interesting indicators concerning the efficiency of energy consumption monitoring and detection tools, thus also including a dimension related to the possible distortion of results caused by technical error.

The potential KPIs that can be included in a multi-criteria evaluation framework are many and varied. For this reason, a filtering procedure was adopted in this study based on a number of basic criteria identified in the literature [41] concerning relevance, completeness, availability, measurability, reliability, familiarity, complementarity, non-redundancy and benchmarking capacity. Above all, they are interpreted as a tool within the reach of the consumer, and thus as a potential tool for self-assessment by the communities themselves, assisted by appropriate experts. For this reason, very significant

indicators found in the literature (such as those concerning the calculation of emissions or technical aspects relating to energy production and consumption) were excluded and those of more immediate compilation and greater availability of information were considered, especially in view of the two case studies analyzed.

Furthermore, it is important to highlight that the definition of KPIs is fundamental to identify the main areas of impact of the Energy Community phenomenon, which is so dynamic and so variable with respect to so many different factors (types of users, environment, location, political framework, economy, etc.) [35, 40], constituting a valid support not only as an ex post evaluation tool but also as a method to support decision-making. In this sense, they express the performance expected from a given project and can then be used as part of a multi-criteria evaluation for decision-making, aimed at determining the best choice between different project scenarios.

In this study, 26 KPIs were identified, deduced from scientific studies, reports and projects and revised by the authors. They were divided into three dimensions: environmental, economic and social.

Environmental KPIs include issues related to both the energy performance of the community, in terms of the amount of renewable energy integrated and self-consumed, and the reduction of emissions. The latter is of particular relevance because it is a central issue in the energy transition [42, 43].

The economic KPIs focus on the financial viability and sustainability of the proposed solution for stakeholders and investors, but also on the convenience for users in terms of savings on electricity bills and tax deductions, as well as redistributive mechanisms whereby economic surpluses are reinvested in further community initiatives with consequent benefits.

Social KPIs highlight the importance of Energy Communities as a new model of active involvement and awareness-raising of citizens on sustainability issues, renewing the sense of cohesion and belonging even in the most degraded and marginalized places. This model also has an impact on the democratization of knowledge, widening access to specific content, stimulating the exchange of information and enabling citizens in the use of technologies. Therefore, it is important to consider feedback from users and community members, who are the first interlocutors to be addressed in order to detect the actual effectiveness of the implemented model. Lastly, the social aspects also include indicators, which in the literature are included in the category of 'legal' indicators, and which concern the transparency of the institutions on the data collected and shared by the other stakeholders and the consistency of the legislative framework adopted at the local level by the energy community with the national and European directives, since, in our opinion, they influence the social aspect of the overall satisfaction with the project and the relationship established between institutions and users.

The evaluation is based on both qualitative and quantitative indicators. Qualitative indicators were expressed using the Likert scale (5 = very high performance; 4 = high performance; 3 = medium performance; 2 = low performance; 1 = very low performance), while quantitative indicators were expressed through diverse units of measure.

Table 1 shows the 26 KPIs proposed in this study for the evaluation of Energy Communities and applied for the evaluation of the two selected Italian case studies.

Table 1. Proposed KPI framework for the evaluation of Energy Communities and their application on the two selected Italian case studies

Dimension	Indicatot	Description	Unit of Measure	Case study 1	Case study 2
Environmental	EN.1 Plant catchment area	Number of households using locally produced renewable energy	n	40	23
Environmental	EN.2 Size of the photovoltaic system	Number of photovoltaic panels	n	166	2
Environmental	EN.3 Total output of the photovoltaic system	The peak power, or nominal power of a photovoltaic system, is the maximum electrical power that the PV system is capable of producing under standard conditions of a temperature of 25 °C and incident solar radiation of 1000 W/m2. It is the sum of all the individual peak powers of each photovoltaic panel installed in the system	kWp (kilowatt peak)	53	46.5
Environmental	EN.4 Total energy produced	Amount of renewable energy produced locally by the energy community in a year	kWh/year	63,600	54,000

(*continued*)

Table 1. (*continued*)

Dimension	Indicatot	Description	Unit of Measure	Case study 1	Case study 2
Environmental	EN.5 Self-consumed energy	Total amount of renewable energy consumed locally (compared to all energy consumed) and not fed back into the grid	kWh/year	49,200	12,000
Environmental	EN.6 Exported energy	Amount of energy exported from the community to the grid compared to all energy generated locally	kWh/year	10,800	42,000
Environmental	EN.7 Energy payback time	Number of years required for the photovoltaic to produce the energy that was needed for its realisation	n	n.a.	n.a.
Environmental	EN.8 Reduction of GHG emissions	Amount of GHG emissions reduced in one year after installation of the photovoltaic system	tCO2eq/year	33.7[a]	29.6[b]
Economic	E.1 Economic Incentive	Annual incentive received by households from the GSE for energy produced and consumed collectively	€/year	200–300	1,428
Economic	E.2 Cost Savings	Euro per year saved overall by all member households of the energy community	€/year	12,000	15,000

(*continued*)

Table 1. (*continued*)

Dimension	Indicatot	Description	Unit of Measure	Case study 1	Case study 2
Economic	E.3 Payback period	Number of years needed to recover funds spent on an investment or to reach the break-even point	n	10	n.a.
Economic	E.4 Initial Economic Investment	Incentives received as initial investment for the installation and activation of the energy system	€	100,000	70,000
Economic	E.5 Tax Deductions	Percentage of tax deductions on total investment cost	%	42	n.a.
Economic	E.6 Level of local co-investment activated	Level of involvement of different stakeholders as investors in the activation of the energy community	Likert scale (1–5)	3	1
Economic	E.7 Redistribution of wealth	Percentage of economic surpluses reinvested in public benefit funds and other activities	%	n.a.	n.a.

(*continued*)

Table 1. (*continued*)

Dimension	Indicatot	Description	Unit of Measure	Case study 1	Case study 2
Social	S.1 Level of local community involvement	Awareness and involvement of tenants regarding the impact of its actions on energy consumption and consequent virtuous behaviour aimed at maximising collective self-consumption (surveyed through interviews)	Likert scale (1–5)	5	4
Social	S.2 Diversity of stakeholder categories involved	Number of different categories of stakeholders involved as co-producers of services	n	4	3
Social	S.3 Number of members of the energy community	Number of households in the energy community	n	20	33
Social	S.4 Social Cohesion	Improved sense of social cohesion and belonging among community members as a result of the activation of the energy community	Likert scale (1–5)	5	4
Social	S.5 Level of awareness	Activation of training, dissemination and awareness-raising activities following the activation of the energy community	Likert scale (1–5)	5	5

(*continued*)

Table 1. (*continued*)

Dimension	Indicatot	Description	Unit of Measure	Case study 1	Case study 2
Social	S.6 Level of acceptance	Level of acceptance of the use of new technologies (apps, sensors, etc.) by users in the energy community (surveyed through interviews)	Likert scale (1–5)	4	5
Social	S.7 Level of assistance to stakeholder	Support actions by promoters in accompanying members of the ERCs in the various fulfilment and authorisation processes required	Likert scale (1–5)	2	4
Social	S.8 Number of new jobs	Number of jobs directly generated as a result of the activation of the energy community	n	n.a.	n.a.
Social	S.9 Level of satisfaction with quality of life and well-being	Level of satisfaction of members of the energy community with respect to the improvement of their quality of life and perception of their level of well-being (surveyed through interviews)	Likert scale (1–5)	5	n.a.
Social	S.10 Level of data transparency	Level of user awareness regarding transparency on data collected and shared by other stakeholders (surveyed through interviews)	Likert scale (1–5)	n.a.	5

(*continued*)

Table 1. (*continued*)

Dimension	Indicatot	Description	Unit of Measure	Case study 1	Case study 2
Social	S.11 Level of consistency of the legislative framework	Level of coherence of the legislative framework adopted at local level by the energy community with national and European directives	Likert scale (1–5)	5	5

[a]In the case of the East Naples Energy Community plant:
1) Considering that 1,200 kWh per kWp [48] and that the plant in Naples is 53 kWp, this will result in a production of 63,600 kWh per year (1,200 kWh × 53 kWp).
2) If 1 Tonnes Oil Equivalent (TOE) is equivalent to 11,628 kWh [49]. The fuel saving will therefore be about 5.4 toe per year (63,600 kWh: 11,628 kWh).
3) The carbon dioxide emission 'avoided' each year can be calculated by multiplying the value of electricity produced by the photovoltaic system by the Italian electricity mix factor: 0.53 kg of CO2 avoided for every kWh produced by photovoltaics [48]. Thus, the Co2 saved through the use of the photovoltaic system will be equal to: 63,600 kWh × 0.53 = 33,708 kg of CO2 = 33.7t.
[b]In the case of the Turano Lodigiano Energy Community plant:
1) Considering that 1,200 kWh per kWp [48] and the fact that the Turano Lodigiano plant is 46.5 kwp, this results in a production of 55,800 kWh per year (1,200 kWh × 53 kWp).
2) If 1 Tonnes Oil Equivalent (TOE) is equivalent to 11,628 kWh [49]. The fuel saving will therefore be about 4.8 toe per year (55,800 kWh: 11,628 kWh).
3) The carbon dioxide emission 'avoided' each year can be calculated by multiplying the value of electricity produced by the photovoltaic system by the Italian electricity mix factor: 0.53 kg of CO2 avoided for every kWh produced by photovoltaics [48]. Thus, the Co2 saved through the use of the photovoltaic system will be equal to: 55,800 kWh × 0.53 = 29,574 kg of CO2 = 29.6t.
4) The annual economic incentive was calculated considering that of the 54 Mwh of energy produced, 30% is shared energy and receives an annual incentive of 119 €/Mhw given the current regulations.
5) The cost savings came from https://www.thegoodintown.it/solisca-la-comunita-energetica-di-turano-lodigiano/

The application of the proposed set of REC evaluation indicators on the two case studies showed that through this framework it is possible to compare different REC experiences through not only the energy or economic dimension, but also through a social and community involvement dimension.

Both case studies demonstrated the multiple benefits of REC.

The case of San Giovani a Teduccio has become a model to be copied and replicated in other cases, above all because it has shown that bottom-up approaches work as social activator, stimulating the creation of new communities based on a more raise awareness of the social, economic and environmental value of using renewable energy.

In the case of Turano Lodigiano emerged the role of technologies not only as a tool able to quantify the environmental benefits, but also as educational enabler of sustainable behaviour, opening to people the opportunity to better know and manage the impact of their own actions and thus, representing a real way to change the mindset towards a more ecological approach.

The involvement of citizens and local authorities in renewable energy projects through Renewable Energy Communities has brought significant added value in terms of local acceptance of renewable energy and access to additional private capital, resulting in local investment, greater consumer choice and increased citizen participation in the energy transition. This local involvement is even more important in a context of increasing renewable energy capacity. Measures to enable renewable energy communities to compete on an equal footing with other producers also aim to increase the participation of local citizens in renewable energy projects and thus increase the acceptance of renewable energy [44, 45].

5 Conclusions

The transition towards a more sustainable energy system requires a profound reform of economic and social models. Energy communities represent a new socio-economic model that can contribute to this transition process.

Energy communities offer several benefits, such as creating local jobs, lowering energy costs, increasing the security of energy supply and reducing greenhouse gas emissions. RECs are considered as activators of 'community resilience' [44, 46], because they stimulate participation in community life, strengthening the sense of individual and community responsibility and projecting actions towards the achievement of the common good [45].

However, there are also some challenges to be addressed in the creation and management of energy communities, such as the need to develop a clear and uniform legal framework at national and European level, the promotion of active participation of community members and the need to ensure fair access to energy for all community members.

The development of energy self-production and energy efficiency policies represent the best welfare policies for households, helping to reduce costs in energy bills and improve the social life of their members, especially in a context of energy and health crisis.

For this reason, RECs can be considered as a regenerative model that paves the way for processes of 'democratisation' and inclusion of citizens in the energy transition.

The motivations behind the activation of energy communities are varied, from the reliability of energy supply to self-sufficiency and the fight against energy poverty through the involvement of energy companies. But monetary benefits are not the only ones: environmental concerns and the desire for energy independence are equally strong motivations. For the first time, in fact, citizens can feel themselves to be real contributors to the energy transition process [4], implementing sustainable behavioral models in their lives and opening themselves up to welcome a change of mindset that offers real opportunities for integration and social development through the creation of new jobs. Bringing topics of global scope closer to the needs of specific local communities

is the real strength of this model that reorganizes traditional market rules and relations between stakeholders that for a long time have had non-communicating objectives and fields of action.

To assess the effectiveness of an energy community, Key Performance Indicators (KPIs) need to be defined and monitored.

This study provides the main indicators that influence citizens' energy communities and to establish a methodology to quantify or qualify these impacts.

The application of the proposed set of REC evaluation indicators on the two case studies showed that through this framework it is possible to compare different REC experiences through not only the energy or economic dimension, but also through a social and community involvement dimension.

In addition, the KPIs identified can be a model for self-assessment as they allow organizations to assess their performance objectively and systematically against pre-established targets in order to identify areas for improvement and define future development objectives. In addition, KPI-based self-assessment facilitates the identification of the organization's strengths and weaknesses and allows it to focus on critical aspects for success [47].

The framework presented in this study is susceptible to future modifications and additions, especially considering that it was tested on only two case studies. Future research could test more case studies and verify the variation of the results obtained in relation to the different contexts considered.

Finally, it would be interesting to address the issue of self-assessment by trying to submit such a framework to a few sample communities and getting feedback on the real perceived usefulness of users as well as its ease of compilation.

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