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Energy communities, a new tool for sustainability

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Introduction

The trend in the literature shows an increased focus on the Sustainable Development Goals (SDGs). Sustainable education, energy and commodity independence, the development of new jobs, subsidies for the development of the green economy, environmental protection and energy communities are the pillars of a sustainable society. Energy communities can support a number of sustainable goals, such as SDGs 7, 11, 13 and 17 (Wuebben et al., 2020). Renewable energy communities (RECs) are not only able to assign greater responsibility to end-use customers in both urban and rural settings. However, the challenge is to value the interactions between different professionals, institutions and citizens and to define a new social model for the ecological transition (D'Adamo et al., 2023).

RECs are a response to the electricity consumption required for daily routines. However, the literature points to some critical issues. RECs are mainly conceptualised as places, instead of participatory processes, may have implementation problems due to the lack of initiative of local members, the cost of some information technologies and the issue of trust. Furthermore, the analysis of individual case studies does not only show strengths (Musolino et al., 2023). The willingness to join energy communities is strongly and positively influenced by environmental concerns and social trust. The social contexts that support the development of RECs are structural interactions with neighbours and civic norms with family members. The topic of participation in RECs is also proposed in other studies. Economic benefits, achievement of renewable energy goals and participation in social activities based on energy improvement support such initiatives. The economic theme prevails over social or political objectives; however, the most correct scope of analysis is to take a holistic view of the different dimensions. The development of RECs is linked to policy choices, which are considered more relevant than market factors (Petrovich et al., 2021), and it is evident that renewable energies result in more significant savings as electricity prices rise and as more conscious behaviour increases the percentage of self-consumption (D'Adamo et al., 2022). When the marginal price is higher than the levelised cost of electricity, any additional investment makes the project more profitable and, beyond the environmental benefits, such initiatives promote energy poverty reduction when low-income households are involved. Therefore, tools that can support the components of a REC during the planning and operational phases are also useful. Once the limitations and potential of RECs have been highlighted, it must be emphasised that within future strategies for their implementation, a key role is played by risk-benefit sharing. In this regard, economic analyses highlight how the issue of political incentives is crucial for assessing the profitability of such investments. This is where the gap in the literature emerges. Each country is developing new incentive decrees, replacing previous ones, or completely new ones. Therefore, the objective of economic analyses is to provide up-to-date profitability or otherwise, and these scenarios do not only vary according to political scenarios, but also market scenarios.

Materials and method

This work aims to propose an economic analysis of residential photovoltaic systems within a REC according to different incentive and market scenarios. For this scope, the Net Present Value (NPV) is used in both baseline and alternative scenarios showing a very good profitability, confirmed by sensitivity, scenario and risk analysis. It is therefore evident how the avoided cost in the bill has a decisive impact on the result and how this is amplified by virtuous behaviour in consumption synchronous to the production phase. Subsequent analyses concern how the profits obtained are divided among the prosumers and it is shown that revenues shared according to a partial energy consumption profile may be the right compromise. In order to consider a more realistic case an additional consumer is analysed within REC. Finally, incentives policies and citizens behaviour are key factors for sustainable cities based on green energy production and consumption. This study considers the Italian context, as an example of a mature photovoltaic market, in which the new incentives envisaged by the REC Decree 2023 are applied and evaluates how profitability varies as a function of several critical variables such as the percentage of self-consumption, the avoided energy cost in the bill, the energy selling price and the investment cost beyond the value of the incentive. In addition, prosumer benefit-sharing scenarios are proposed

in which the energy consumption of individual prosumers is considered (D'Adamo et al., 2023), to which new scenarios involving consumers are added in order to increase the real cases.

Results and conclusions

Sustainability has long been ignored first and underestimated later. The policies of many governments are pushing towards a green transition that directly involves both citizens and businesses. RECs are proposed as a social model to foster the green transition, placing the figure of the prosumer at the centre of change. The one who produces the renewable energy is also the one who consumes it, and since the source of production is green, this action counteracts climate change. RECs make it possible to extend this concept to a range of people.

The results show that the profitability is confirmed all considered scenarios and it is therefore concluded that building a residential PV system within a REC leads to significant economic returns and low levels of risk. The incentive provided plays an important role in this outcome, and clear and consistent planning over time can give investors security. However, it can be seen that a decisive role is played by the avoided cost on the bill, which leads some families into severe social hardship but is a positive element for those who join a REC because the greater the savings achieved by having adopted a green choice, the greater the savings. Here the first limitations of this work emerge. From an economic point of view to apply storage to the model to assess its cost-effectiveness, from an environmental point of view to assess the value of the most suitable subsidy, and from a political point of view to apply such investments in social housing or in any case in all those realities that are at risk of social hardship. The concept of pragmatic sustainability emphasises that in addition to clean energy, it is essential that it is also accessible (not only technically, but also economically).

Another decisive parameter in a profitability analysis is the percentage of self-consumption, which can be significantly large in a smart city model that has managed to optimise the needs of different citizens with the aid of sustainable technologies. In accordance with the literature, scenario models have been analysed in which the profits from the implementation of a residential PV system within a REC can be divided up, and the model of revenues distributed according to a partial energy consumption profile seems to be the most suitable from an optimisation point of view. Here the other limitation of this work emerges; on the operational side, it could be useful to identify a model that calculates the efficient energy exchange price. Indeed, this aspect could reduce the management issues between the different RSCs.

This work supports the policy maker as it estimates the impact that the planned incentives would have on the profitability of these PV investments, the investors as it allows them to have a benchmark. Furthermore, from a methodological point of view, it exemplifies application cases in which economic analyses, incentive decrees, market energy values and profit distribution models in a REC are correlated. Incentive decrees, defined in advance and lasting over time, are able to reduce risk and attract investors. They are also a tangible sign of a government's focus on green issues. RECs can support a nation's energy independence by mitigating risks related to geopolitics and financial speculation. Currently, RECs concern small realities but the challenges of the smart city require their development also in the context of large urban centres. Joining a REC, where there are significant profits and environmental mitigation is supported if supported by social awareness, would lead citizens to be part of a change that is not simple but strategic for the challenges of the future.

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