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Editorial

Renewable Energy Communities as an Enabling Framework to Boost Flexibility and Promote the Energy Transition

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Undelayable environmental requirements and the energy crisis following the pandemic, further increased by international contingencies, have evidenced the need to push forward with the energy transition and intensify the use of renewable energy to satisfy energy needs, with more flexible, resilient, and sustainable energy being required. The renewable generation, energy storage, demand–response, electrification of transports, and sector coupling are particularly key to leading the energy transition towards low-carbon paradigms. In this framework, renewable energy communities (RECs) could provide the conditions necessary to exploit the potential of the above resources. The enhancement of the economic and operational participation and member ownership of communities in renewable energy projects can indeed attract and coordinate distributed resources, letting them interact with one another as well as with the electrical upstream network to which they can deliver both power and other ancillary services. In terms of a reduction in electricity costs, RECs can give a significant contribution by (i) increasing community self-consumption, (ii) enhancing demand-side flexibility by applying load shifting in sector-coupled systems (e.g., electric vehicle charging appliances and heat pumps), and (iii) leading community investments that, through cost-sharing, allow larger PV systems at lower prices. However, RECs require the implementation of novel strategies and methods to boost the integration of various distributed assets into power grids, considering several aspects involving environmental, social, technical, and economic issues. This approach would assure not only technical flexibility in terms of the availability of technologies, but also operational flexibility, which would allow power flow optimization taking into consideration technical, regulatory, and market constraints.

This Editorial presents some research analyses that, faced with these aspects, attempt to provide possible solutions for the implementation of RECs. Critical aspects of RECs are those related to their design and scheduling, which also require considering the uncertain nature affecting REC resources. One of the problems associated with RECs is the availability of renewable sources, which are typically very variable due to their dependency on weather conditions, thus, leading to economical and grid operation security issues. In addition, uncertainties affecting load requests can represent a further issue in the operation of RECs, an aspect that needs to be carefully dealt with in research analyses and scheduling procedures involving RECs. In [1], an energy analytics tool is proposed, aimed at providing information on the day-ahead estimates in terms of the local renewable energy generation and electricity consumption profiles of RECs. The developed data were also deployed in a pilot REC established in an industrial area and connected to a medium voltage network, including wind generation and small and medium enterprises. However, the lockdown caused by the COVID-19 pandemic masked the potential benefits of the data deployed by the authors, who envisaged further work to extend the duration of similar REC pilots to more than one year to better understand the yearly seasonal effects and to better quantify the impact on member consumption behavior.

When developing a hybrid energy system at a community level, an assessment of the viability of the energy system to meet the local energy demand is necessary. Thus, technical and economic aspects, as well as environmental and social effects, have to be taken into account. For this purpose, Ref. [2] considered an important aspect of REC design, referring to the evaluation of technologies expected to be included in RECs and the identification of optimal energy mixes. Since REC energy planning is a multifaceted problem, the authors proposed a multiattribute decision-making approach to define the optimal energy system. Specifically, they developed a multistage energy selection framework and used a fuzzy multicriteria decision-making approach to rank the technologies, considering the conflicting requirements, the stakeholder priorities, as well as the uncertainties. Interesting conclusions were drawn by the authors regarding the performance of the technologies referring to different scenarios emphasizing, alternatively, environmental, social, and economic aspects. Small hydro, onshore wind, and biomass combustion technologies have been identified as being more performant under proenvironment scenarios, while biomass combustion, small hydro, and landfill gas have been proven to have the best rankings under a proeconomic scenario. As stated by the authors, these outcomes were based on the current maturity of the considered technologies, and could change in the future if conditions change.

Some of the economic studies aimed at analyzing the demand-side management and sector coupling, referring to specific legislative frameworks [3] or based on the optimal integration of an intermittent supply with demand-side flexibility [4]. The economic analysis provided by [3] referred to the novel legislative framework in Europe, with specific reference to the transposition of the European guidelines for RECs into Austrian law. In the paper, the potential, induced by REC participation, to generate cost-savings was evaluated for different residential REC configurations characterized by increasing values of photovoltaic power production. The results showed that the economic viability of RECs for residential customers depended on the specific situation of the communities, such as the private or public ownership of the PV generation units, the composition of participants within the REC, and the price for the purchase of energy from the grid. The authors also provided a few insights into the possible actions required to exploit the benefits deriving from RECs and suggested the use of spatial planning to ensure the increased profitability of REC participation in the future. The authors of [4] evaluated the potential savings that could be realized through varying the levels of energy generation from renewable sources and demand flexibility. With this aim, an optimization procedure was proposed that could achieve optimal performance by coupling the intermittent supply with the demand-side flexibility. Computer simulation results showed the effects on savings of renewable generation and demand flexibility, which, in the simulations, were decoupled to analyze their mutual relationship. Several scenarios were considered referring to variable pricing schemes for both energy import and export, variable weather conditions (i.e., variable renewable production profiles), and constraints related to demand flexibility and user comfort. The analysis showed that demand flexibility without significant disruptions to user comfort produced noticeable savings in operational costs and increased the supply security, allowing for a more resilient energy supply network.

Taking into consideration unavoidable uncertainties capable of affecting the procedure, algorithms aimed at scheduling REC resources (i.e., generation, consumption, and storage resources) were proposed in [5–8].

In [5], a dispatch model was proposed for an integrated community energy system including various renewable energy sources and energy conversion units. Uncertainties in renewable energy sources and internal loads were also considered. The proposed dispatch model was divided into two stages, allowing for coping with impacts caused by errors in short-term forecast data. The results of computer simulations demonstrated that uncertainties surrounding renewable energy sources and loads had a significant influence on the dispatch results.

Scheduling procedures should carefully consider the important issue of RECs' market participation, taking also into account the ancillary service market, a specific pool of flexibility provided by RECs. In [6], a bilevel scheduling method was proposed to optimally coordinate the flexible demand response and renewable generation uncertainties. The proposed model allowed for balancing the interests between the community and electric vehicle charging stations. For the provision of flexibility, an integrated demand response program was considered involving a dynamic pricing mechanism. Through the use of the computer simulation results, the considered dynamic pricing was proven to flexibly drive energy consumption, while reducing the joint operation costs of the vehicle charging stations and of the whole community.

Ref. [7] also proposed a scheduling model based on dynamic pricing, with the authors starting with the assumption that existing dynamic pricing programs may fail to encourage end-users to adapt their power demand based on fluctuations in renewable generation power outputs. Their proposal combined the fluctuations of the residential electricity demand with those characterizing wind and solar power outputs, and utilized bilevel optimization to coordinately dispatch flexible loads. The technoeconomic effectiveness of the proposed dynamic pricing model was also evaluated using four indicators, namely, the net grid demand profile standard deviation, peak-to-average ratio, renewable energy consumption rate, and residential electricity bill savings, which were assessed under different power demand and generation scenarios.

In [8], an optimization model was proposed, based on the concept of the peer-to-peer market, where the excess energy generation of various small-scale community energy resources were traded among local customers. Particularly, the optimization model aimed at scheduling (i) peer-to-peer transactions via the local electricity market, (ii) grid transactions in the retail market, and (iii) battery management based on the photovoltaic production of each prosumer of the community. The authors explored various operating scenarios to analyze both the impact of peer-to-peer transactions and the use of battery energy storage systems. The results showed how the combined use of this market approach and storage could lead to community members saving up to 25% in energy costs.

A comprehensive approach involving both planning and operation was proposed in [9], with these stages optimally interconnected to obtain maximum economic and ecological benefits. Energy market fairness was considered to assure the aggregation of various community actors through the combined use of bilevel optimization and reinforcement learning, allowing for the effective implementation of flexibility resources at the community level for their successive involvement at the external power grid level. In the bilevel model proposed by the authors, the lower level solved the problem of the local market equilibrium of the community microgrid to maximize its social welfare. At this level, the amounts of power imported and exported, the community electricity prices, and the peak power of the community were determined. The upper level aimed at dividing the community profits among microgrids interfacing with the main grid, ensuring that none of the microgrids were financially penalized. Numerical simulation results showed an increase in the welfare of community members that received a reduction of 20% to 40% in the levelized cost of energy by applying the proposed approach.

Based on the analysis of the technical literature, it appears that RECs are an important response to currently arising energy and environmental challenges, and the papers collected for this Editorial provide a trace of some of the specific actions from the electrical energy system point of view that need to be undertaken, as well as the tools to be provided to enhance the beneficial impacts of RECs on energy transition. The approaches introduced in this Editorial, as well as other research investigations proposed in the technical literature, allow for evidencing the opportunities that community organizations can actively participate in regarding energy transition, i.e., by investing in the generation, selling and distribution of energy, and in providing flexibility services. RECs have complex aspects that go beyond the problem of managing energy vectors, including social, economic, and legal aspects. By involving these multiple aspects that need to be contemporaneously considered in real applications, the REC paradigm could truly and successfully cope with the actual challenges posed by the energy crisis.

Conflicts of Interest: The author declares no conflict of interest.

References

1. De Grève, Z.D.; Bottieau, J.; Vangulick, D.; Wautier, A.; Dapoz, P.-D.; Arrigo, A.; Toubeau, J.-F.; Vallée, F. Machine Learning Techniques for Improving Self-Consumption in Renewable Energy Communities. *Energies* **2020**, *13*, 4892. [CrossRef]
2. Karunathilake, H.; Hewage, K.; Mérida, W.; Sadiq, R. Renewable energy selection for net-zero energy communities: Life cycle based decision making under uncertainty. *Renew. Energy* **2019**, *130*, 558–573. [CrossRef]
3. Fina, B.; Auer, H. Economic Viability of Renewable Energy Communities under the Framework of the Renewable Energy Directive Transposed to Austrian Law. *Energies* **2020**, *13*, 5743. [CrossRef]
4. Jelić, M.; Batić, M.; Tomašević, N.; Barney, A.; Polatidis, H.; Crosbie, T.; Abi Ghanem, D.; Short, M.; Pillai, G. Towards Self-Sustainable Island Grids through Optimal Utilization of Renewable Energy Potential and Community Engagement. *Energies* **2020**, *13*, 3386. [CrossRef]
5. Liu, X.; Xie, S.; Geng, C.; Yin, J.; Xiao, G.; Cao, H. Optimal Evolutionary Dispatch for Integrated Community Energy Systems Considering Uncertainties of Renewable Energy Sources and Internal Loads. *Energies* **2021**, *14*, 3644. [CrossRef]
6. Li, Y.; Han, M.; Yang, Z.; Li, G. Coordinating Flexible Demand Response and Renewable Uncertainties for Scheduling of Community Integrated Energy Systems With an Electric Vehicle Charging Station: A Bi-Level Approach. *IEEE Trans. Sustain. Energy* **2021**, *12*, 2321. [CrossRef]
7. Cai, Q.; Xu, Q.; Qing, J.; Shi, G.; Liang, Q. Promoting wind and photovoltaics renewable energy integration through demand response: Dynamic pricing mechanism design and economic analysis for smart residential communities. *Energy* **2022**, *261*, 125293. [CrossRef]
8. Faia, R.; Soares, J.; Pinto, T.; Lezama, F.; Vale, Z.; Corchado, J.M. Optimal Model for Local Energy Community Scheduling Considering Peer to Peer Electricity Transactions. *IEEE Access* **2021**, *9*, 12420–12430. [CrossRef]
9. Tomin, N.; Shakirov, V.; Kozlov, A.; Sidorov, D.; Kurbatsky, V.; Rehtanz, C.; Lora, E.E.S. Design and optimal energy management of community microgrids with flexible renewable energy sources. *Renew. Energy* **2022**, *183*, 903–921. [CrossRef]