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To cite this article: Johan Augusto Bocanegra *et al* 2024 *J. Phys.: Conf. Ser.* **2893** 012123

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Energy Balance of a Renewable Energy Community Using Stochastic Methods, a Case Study in Genoa City

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Abstract. Renewable energy is at the core of decarbonization; some strategies that could impulse a rapid adoption of those energy systems implies the sharing of the produced energy. Renewable Energy Communities are organizations of different stakeholders (citizens, public entities, authorities, companies) that share energy produced in one or more renewable energy implants of some prosumers that participate in this collective. In this paper, we perform some numerical analysis based on a stochastic analysis of energy consumption and production data; this methodology was implemented to study the performance of a community located in Genoa; in this case, study, the focus is on the energy balance and derive an approximative self-consumption factor.

1. Introduction

The global energy transition necessitates rapidly integrating renewable energy resources into electricity production. However, the intermittent nature of renewable energy sources, such as wind turbines and PV panels, poses challenges for optimizing energy utilization. For example, PV panels produce a surplus of electricity during the midday, when the energy demand is generally low, and production during the night, when the common demand increases. Solutions such as using batteries or joining an energy community could be of interest as ways to enhance efficient energy use. The effective adoption of RECs faces challenges across regulatory, technical, and financial dimensions [1]. This paper uses stochastic methods to explore the energy balance of a Renewable Energy Community (REC) in Genoa City, drawing on consumption statistics and in-situ weather data. The study is based on the EnerCmed project, a European collaboration project aiming to implement six REC pilots in five Mediterranean cities, with one pilot project located in Genoa.

The transition to renewable energy is critical to global efforts to mitigate climate change and ensure energy security [2]. Renewable Energy Communities (RECs) offer a promising avenue for decentralized energy production and consumption, enabling individuals and communities to participate actively in the energy transition. However, optimizing the energy balance within RECs remains complex, particularly amid intermittent energy production and varying consumption patterns. REC In this study, we investigate the energy balance of a REC in Genoa City, employing stochastic methods to model the dynamic interactions between renewable energy production, consumption, and sharing. The core of a REC is the share of produced



electricity; in Italy, the regulation has been recently established, and an economic incentive has been approved that depends on the shared electricity [3]; the normative framework is extensively presented [4].

In this paper we aim to illustrate a methodology to calculate the energy balance (hourly based) applied to a case study on Genoa city conformed by one implant and 35 consumers.

2. Methods

Our methodology involves a stochastic analysis of energy consumption and production data, supplemented by in-situ weather data, to capture the variability of renewable energy sources. We calculate the virtual and real self-consumption components within the REC, considering factors such as the number of participants and the installed capacity of renewable energy systems. The virtual self-consumption can be calculated as the minimum between the produced electricity available, $E_{pa} = E_p - E_{sc\ real}$, and the aggregated energy consumption, E_c , of the REC, see Eq. (1). The energy balance must be achieved hourly.

$$E_{sc\ virtual} = \min(E_{pa}, E_c) = \min(E_p - E_{sc\ real}, E_c) \quad (1)$$

Considering one producer (with a solar implant of nominal peak power $P = 50$ kW and 35 consumers), diverse hourly consumption profiles were generated for each consumer using reports from a local entity ARERA [5]. The produced energy was calculated using the PVGIS Photovoltaic Geographical Information System [6].

3. Results

The shared electricity profile in a winter week is presented in Fig. 1. The shared electricity corresponds to the calculation using Eq. (1). As can be seen the production occurs only during daytime, the total consumption of the 35-apartment cluster varies along the day, and for this week only a small fraction of the produced energy is not consumed.

Results of the shared electricity profile in a typical year are presented in Fig. 2. The figure presents the produced energy, E_p , the aggregated consumption, E_c , and the shared electricity E_{sc} . In this figure the seasonal effect is showed, during summer the production surplus respecting to the aggregated consumption, this energy can be sold to the grid or stored for night use.

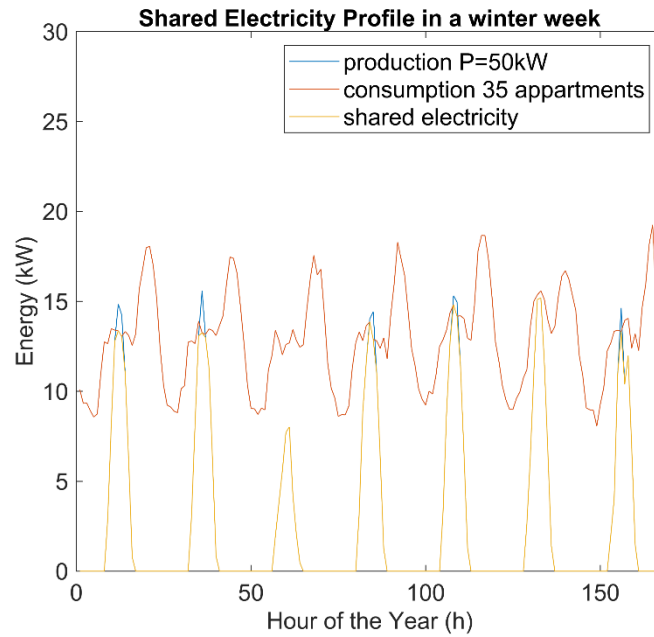


Figure 1. Shared electricity profile in a winter week.

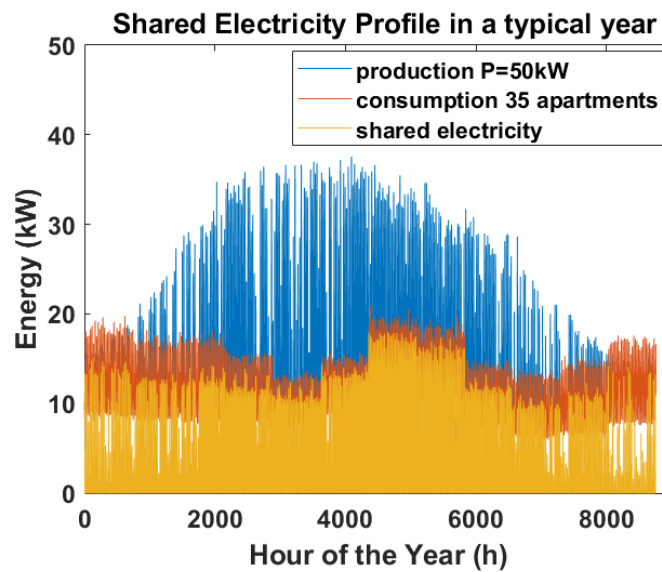


Figure 2. Shared electricity profile in a typical year.

The approximative self-consumption factor is the fraction between the self-consumed energy, E_{sc} , and the produced energy, E_p , as shown in Eq. (2):

$$a = \frac{E_{sc}}{E_p} = \frac{E_{sc.real} + E_{sc.virtual}}{E_p} \approx 0.60 \tag{2}$$

Our analysis reveals significant variability in the energy balance of the REC, influenced by factors such as weather conditions, consumption patterns, and the level of renewable energy

penetration. The self-consumption factor fluctuates between different scenarios, with approximately 60% being a typical value in the simulated case. However, this factor is subject to change based on the number of participants and their consumption profiles. Moreover, we identify trade-offs between maximizing self-consumption and ensuring equitable energy distribution within the REC. The self-consumption factor depends on the number of consumers that adhere to the REC; augmenting the self-consumption could benefit the REC, but the benefit perceived by the single consumer could diminish. The optimal number of participants is an open problem. It depends on the REC aim, beyond the economic profit derived from self-consumption and pursuing other objectives such as social (prevent energy poverty) or environmental (decrease CO₂ emissions).

4. Conclusions

In conclusion, our study provides valuable insights into the energy balance of renewable energy communities, highlighting the challenges and opportunities associated with energy sharing and self-consumption. By employing stochastic methods and case studies, we offer practical recommendations for optimizing REC performance and advancing the energy transition agenda. Our findings underscore the need for holistic approaches that integrate technical, economic, and social considerations to foster sustainable energy communities.

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