Politecnico di Torino

Honors Thesis

Master of Science in Sustainable Architecture

Abstract

Design and Modeling Renewable Energy Communities
A case study in Cagliari

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In the last decades, European countries shifted toward decentralized energy generation, which is a crucial step for enhancing the diffusion from centralized power systems to smaller-scale systems. These small-scaled systems include energy communities (ECs). The renewable energy communities (RECs) have a significant role and potential in this energy shift. Starting from the fact that using renewable energy sources (RES) reduces greenhouse gas emissions and the dependence on fossil fuels, the RECs are effective bodies, in means of scale and management, for the implementation of sustainable urban territories.

This work analyzes different EC scenarios, considering energetic, environmental, and economic perspectives. The energy concern is associated with improving the self-consumption and self-sufficiency indexes (SCI-SSI), the economic concern is associated with the payback time and the received incentive for energy sharing, and the environmental concern is related to the GHG emission produced by each EC scenario. The analyzed case study is in Cagliari (Italy), a typical Italian condominium of eight apartments with a low energy class for buildings (i.e., class G). The study also covers the energy efficiency improvements associated with the retrofit interventions which were identified during the energy audit.

The analysis scale includes both the share of energy between the eight apartments of the condominium and a REC composed of the analyzed building with a neighboring building.

The objective of this work is to contribute to the research studies and EC applications by providing an illustrative model, with numerical data and alternative scenarios, to give detailed analyses that can be used for the implementation of different sized ECs, and to demonstrate the significant role ECs can play in moving towards decentralized energy generation.

Considering the tested EC scenarios, all showed that battery storage systems have an effective role in increasing the self-consumption and self-sufficiency levels of the community since solar energy is intermittent and needs to be optimized for its usage by storing the surplus generation. The batteries are also important in avoiding the high peak demands and in improving grid flexibility, which results in more resilient energy grids.

Summarizing the analyzed scenarios, the condominium scale scenarios showed that aggregating the energy share from the PV generation into a single point of delivery (POD) showed better results than having two PODs. In a REC with a neighboring building scenario and after retrofit interventions the self-sufficiency was increased by 26% with a decrease of 23% in GHG emission, which shows the importance of having retrofitted and smart buildings in achieving a more sustainable built environment.

In this work, a small-scaled energy community was analyzed. But to reach the goals of lowering global emissions and achieving more sustainable cities, the recasts of the related directives must be considered. One of them is RED II (Renewable Energy Directive 2018/2001/EU). Now there is ongoing progress for the third revision which will include some updates, one of them is rising the percentage of using renewable energy sources in the overall energy mix from 32% to 40%,

which is a target set for 2030. Together with this, the RECs will probably go beyond small-scaled communities with more powerful generation plants and include diverse end-users, e.g., municipality buildings, schools, business centers. To achieve more comprehensive results, it is also important to include different RES and involve mixed end-users.

The methodology of this work with new software can be a useful decision-making tool to test the effectiveness of ECs based on given data, and it can be applied to different scaled ECs.

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