GREEN HYDROGEN BASED RESIDENTIAL HYDROGEN SYSTEMS

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Overview

The application of renewable energy sources (RES) in the residential sector is one of the key solutions considered by the European Community [1] to drive the energy transition and the reduction of greenhouse gas emissions. In particular, photovoltaic (PV) panels are considered as the most suitable and affordable technology in the residential segment [2]. Closely related to RES is the issue of storage, given that their production depends on weather conditions and the mismatch between energy production and consumption, and batteries are the most common storage facility, characterised by high electrical round-trip efficiency. This aspect is of particular relevance for Renewable Energy Communities (REC) sharing their own produced energy. Speaking of REC, only the supply of electricity is usually considered, forgetting that in residential applications both electricity and heat are needed. However, RES electric generation and RES thermal generation are not so simple to be coupled, so that solar heater and PV are usually considered separately. In recent years, interest in hydrogen (H_2) systems as competitive storage devices has been growing significantly [3, 4]. This approach allows for the introduction of a new paradigm [5] combining the generation of electrical and thermal energy. This because both the electrolyser and the fuel cell can generate heat, during H_2 production and H_2 consumption, respectively. Starting from this perspective, we considered green hydrogen energy communities as an opportunity for further penetration and diffusion of RES technologies [6]. In order to assess the practical implications of this system, we carried out an energy balance and an economic-financial analysis to check its cost-effectiveness. The comparative study battery/ H_2 was carried out for a REC of 10 families having a photovoltaic system installed in. In order to understand the system's operating performance according to different weather conditions, the analysis is applied by considering three different Italian cities.

Methods

The case study concerns an energy community formed by 10 families and located in Italy, sharing both electric and thermal energy. For family size and consumption of electricity and hot water, data from the annual resume of Italian Statistic Institute (ISTAT) [7], Italian Regulatory Authority for Energy, Networks and Environment (ARERA) [8] and the tool "kilovattene" by ENEA[9] have been used. A comparison was carried out between the common configuration in a residential house consisting of 'PV + battery storage + solar heater' (PVBS) and the proposed configuration 'PV + electrolyser/hydrogen storage + fuel cells + solar heater' (PVHFS). Due to the fact that PV generation is largely dependent by geographic location, the simulation was carried out in 3 Italian towns Milan, Rome and Siracuse, located in the North, Centre and South Italy. Three different sizes of installed PV, with optimal exposition, were considered: 20, 30 and 40 kWp. While for the solar boiler, we considered a standard size of 40 m2 of surface with a 2000 litres hot water reservoir tank. In our analysis, only domestic hot water production was included, no air-conditioning. For the H2 based system, metal hydride storage technology was chosen because it can work without compressors. As the Italian regulation for residential applications allows just up to 750 geometric litres flammable gas storage without undergoing to specific authorisations and controls, this size was chosen for all cases independently by the PV roof and electrolyser sizes. The battery size was chosen on the basis of average daily storage needs, considering that the DOD (Depth of Discharge) should not exceed 70% on regular runs. The power of the electrolyser was chosen to consume as much energy as the battery can store and the FC size was selected to consume all the hydrogen produced on average each day. Since the daily energy production averaged over a year was used, it can be assumed that both the battery pack and the electrolyser are undersized in summer and oversized in winter. Our current research is focusing on analyses based on the monthly average of daily energy production. On this basis, the energy balance simulation was carried out and the energy savings were calculated for each case for a total of 18 cases. Energy balancing and technical aspects are not the subject of this article. Here, the results are used to evaluate the economic-financial aspects of the simulated system and its possible application within an energy community. The approach of the financial analysis is in line with our previous work [10-12]. The CAPEX and OPEX were calculated, while the rate of return on equity, inflation rate and investment tax refund were set at 5.0%, 1.2% and 5% respectively (for the first 10 years). The revenues from energy savings compared to full grid and gas dependency were estimated according to ARERA data for the beginning of 2022, electricity at 0.30 €/kWh, and gas at 0.91 €/m3.

Results

The NPV behaviour on 15 years is reported in Figure 1 for PVBS and PVHFS systems, left and right respectively.

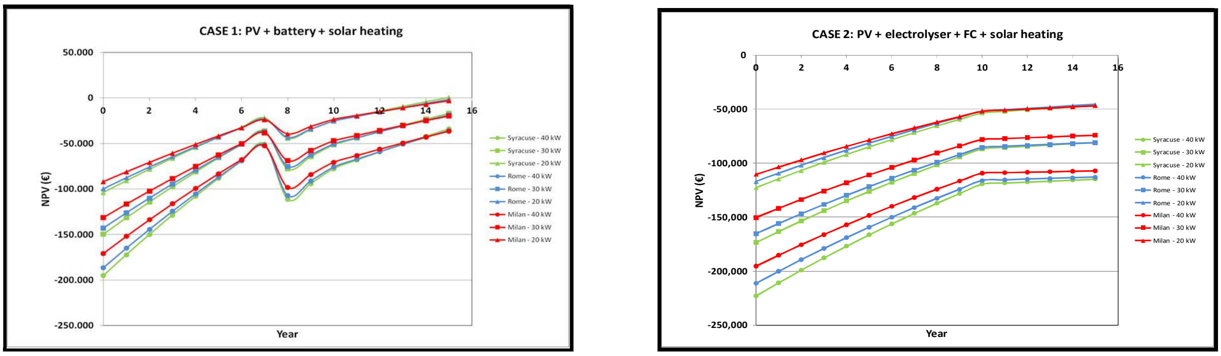

Figure 1: Net present value (NPV) calculated for the PBVS, left, and PVFHS (right) systems.

Although by using CHP approach the total energy efficiency of battery and H_2 system are closed, H_2 approach needs more complex system and management. This results in a small increase of CAPEX and OPEX. Moreover, for end user the heat energy has a lower value in respect to electric one. While batteries are able to reach NPV close to 0 after 15 years for low power installation, hydrogen storage it is not able to reach this parity. The need to replace batteries periodically is not sufficient to allow a real economic advantage of the hydrogen-based system**.**

Conclusions

A technical and economic comparison of battery and hydrogen based RES power and heat systems located in Italy was made. Both systems do not allow to reach a NPV=0 in 15 years. This is due to the necessity to replace the batteries for PVBS system and the very high CAPEX of PVHFS system. But has to be noticed that if, in the future, the CAPEX of hydrogen based system will drop down of about 30-40% [14], the PVHFS system will become comparable with the PVBS system. We should also point out that a further short-term innovation is expected for batteries with increased life cycles, which could avoid their replacement in addition to a reduction in battery costs. In this way, the two systems will continue to be in competition for a long time. Finally, our results confirm our previous analyses: hydrogen costs can be reduced by exploiting the by-products of its cycle, oxygen and heat. Furthermore, the hydrogen storage system can be a viable solution to optimise and make the most of the energy produced by a photovoltaic system in an apartment building, increasing its autonomy from the electricity and gas grid. However, the current costs involve a very high financial commitment that requires a system of public incentives to cover the initial investment.

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