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Technical and economic assessment of a battery storage system for a nZEB in the Mediterranean climate

F Causone^{1,*}, A Tatti¹ and L Pagliano¹

¹End-use Efficiency Research Group, Department of Energy, Politecnico di Milano, Via Lambruschini 4a, Milano 20156, Italy

*francesco.causone@polimi.it

Abstract. In recent years, the promotion of nearly-Zero Energy Buildings (nZEB), has become a priority for European member states. In order to get this label, typically, a monthly or yearly energy balance of energy use through the exploitation of renewable energy sources (RES) is required, but not a hourly balance. This approach may determine a low exploitation of the RES on site in the case of solar and wind energy, because they are intermittent by nature. Moreover, energy production and energy use peaks are often in mismatch during the day. Battery energy storage systems (BESS) offer a solution to better integrate RES into buildings as well as into the grid, increasing its reliability and minimizing interactions. The cost of these systems is rapidly decreasing, opening new economic opportunities for investors. However, for many applications they do not yet represent the optimal cost-effective solution due to the lifespan of their short-lived components. The paper investigates the technical and economic feasibility of integrating a BESS into a high-performance residential building in the Mediterranean climate based on the outcomes of an original case study based research. The existing photovoltaic system combined with the BESS may substantially optimize the energy use, maximizing the self-consumption and minimizing grid interactions; nevertheless, the pay-back time may become fully-attractive for the analysed building, only if BESS costs will halve by 2030.

1. Introduction

The Energy Union and the Energy and Climate Policy Framework for 2030, outlined the basis to develop a sustainable, secure and decarbonized energy system in EU, to reduce greenhouse gas emissions by at least 40 % as compared with 1990 and to increase energy savings and the share of exploited renewable energy sources (RES) [1]. Therefore, European directives and protocols aim to promote high performance buildings whose energy needs are met primarily through the exploitation of RES; these directives encourage the spread of increasingly autonomous buildings able to produce energy on site and to maximize energy self-consumption also using electric and/or thermal energy storage systems. Although the increase in energy production from RES is an extremely positive result, it implies considerable complexity in the management of the energy grids, especially due to the uncertain and intermittent nature of these sources. This is a particularly relevant topic when it comes to countries where RES play a crucial role in electricity production. For instance, according to the *Renewables 2018 Global Status Report* [2], Italy is the fifth country in the world for solar photovoltaic (PV) capacity installed and the fourth for PV capacity installed per capita. In cases like this, it can be challenging to accurately forecast the power generations and ensure a high level of grid stability and reliability [3].



Energy grid management, in case of grid-connected buildings, require in-depth studies on buildings' consumption and production dynamics also in perspective of a wider diffusion of high-performance buildings capable of compensating, or even overcoming, the energy demand with RES integration. Moreover, buildings, being the major end-users at power demand side (around 40 % of total end-use energy all over the world and over 90 % of total electricity in high density urban areas) [3] [4], can play a significant role in the energy grid management. All these factors require, on the one hand, a strengthening of the power grid and, on the other, the development of different consumption models encouraged, for example, via demand-response programs. For these reasons, an increased flexibility has been identified as a key requirement for future power systems [5] and for the building sector as well.

Battery energy storage systems (BESS) may help enabling this energy transition in buildings, increasing grid and buildings' flexibility and limiting the investments for new power plants. If coupled to energy management systems (EMS), storage systems can optimize energy usage and maximize energy self-consumption. RES can be fully exploited on site and integrated into the power grid reducing peak demands and increasing the power quality and the reliability of the grid.

Although several studies estimated the potentiality of these systems [6] [7] [8], the cost and the limited lifespan of the batteries and of the technical system components, still hinder their economic convenience. It is worth noting that battery systems are, nonetheless, developing rapidly with falling costs and improving performance. By 2030, the installed costs of battery storage systems could fall by 50-66 % opening up new economic opportunities [9].

This paper reports results of a yearly energy monitoring campaign conducted by the research team of Politecnico di Milano on a certified Passivhaus building in Sicily and includes the estimation of the technical and economic feasibility of the installation of a BESS in the building already equipped with a PV system. The Passivhaus, monitored with an advanced control system, provides fundamental operational data to characterise the building energy performance, the BESS and thus to inform energy policies toward the development of flexibility services such as demand-side response programs.

Sections 2 and 3 report information about the case study and the performed yearly monitoring campaign. Section 4 reports the results of the technical and economic assessment of the BESS and sections 5 and 6 report discussions and conclusions on the performed analysis.

2. Case study

The case study is a detached single family house located in the municipality of Mascalucia (Catania), in Sicily (Figure 1). The building, conceived as a living lab, has achieved the Passivhaus certification, respecting its limits¹, and it represents an example of nZEB in Mediterranean climate [10] [11] [12] [13]. It is equipped with a Building Automation and Control System (BACS) that offers the possibility to set different control logics and to study their effects on building performance and occupants' preferences. Environmental and energy performance are, indeed, continuously monitored to provide an adequate control of the internal microclimate (thermal comfort and air quality) and of the building's services systems. The high-performance envelope is characterized by very low values of thermal transmittance: 0.13 W/(m²K) for the walls and the roof, 0.23 W/(m²K) for the basement floor and 0.90 – 1.10 W/(m²K) for the windows. The outdoor window surfaces are protected by motorized solar shading systems, controlled manually or through a control logic.

Renewable energy is exploited by means of photovoltaic panels - PV (75 m² of polycrystalline panels for 8.14 kW_p) and solar thermal modules (7 m² of flat collectors) installed on the roof; in addition, an earth to air heat exchanger (EAHE) is installed for pre-heating or pre-cooling the ventilation air by exploiting the thermal inertia of the soil, before passing in the air conditioning system. The EAHE can be by-passed according to the external air conditions and the weather-soil-building conditions [11][12] [13] [14]. An electrical and reversible air to water heat pump provides the domestic hot water and serves the heating/cooling coil for the ventilation system and the 500 liters thermal storage tank, also fed by

¹Energy need for space heating lower than 15 kWh/m²/year, energy need for cooling lower than 15 kWh/m²/year, air infiltration at 50 Pa lower than 0.6 ACH and total primary energy demand for all domestic electric services lower than 120 kWh/m²/year (requirements introduced in 2015).

thermal solar panels. The PV system is continuously monitored, together with the electric energy use for all the services of the building in order to study, in terms of grid interaction, the interplay between the renewable energy generation and the energy use of the building.



Figure 1. External (a) and aerial (b) view of the building [13].

The monitoring and control system is based on two communication protocols, the Konnex (KNX) and the BACnet [15] [16]. The two control parts monitor the main indoor environmental parameters (e.g. air temperature, relative humidity, CO₂ concentration), the solar shading devices status, the total energy use of the building, the energy use of the main electric appliances, the PV and the solar thermal production and the EAHE performance. All the parameters are monitored with a frequency of 5 minutes, and the integrated building management platform Desigo™, through which the data and the alarm states of the building are gathered and displayed, stores all the data for off-line analyses.

3. Monitoring campaign

The building energy performance has been monitored, with a frequency of 5 minutes, for a whole year, starting from the 1st July, 2017 (01/07/17) to the 30th June, 2018 (30/06/18). In addition, weather, building's occupation and systems' setting, have been monitored, since they may influence the building performance and the operation of the implemented control logics. The results of the monitoring campaign, in terms of boundary conditions and energy performance, are described in the following sections.

3.1. Boundary conditions

The building is occupied by a family composed of three people, two adults and one child. The building has been occupied quite regularly during the whole monitored year, except during July 2017 and June 2018. Different control logics have been set to provide thermal comfort for the occupants; in general, low-energy strategies have been primarily used to regulate thermal comfort, as the control of solar shadings by setting the orientation of the louvres or the use of natural ventilation [17] and mechanical ventilation without the activation of the heat pump to cool down the building. In the other cases, active conditioning has been used (activation of the heat pump to heat/cool the building).

Figure 2a) and b) reports the maximum and minimum values and the interquartile range of the outdoor air temperature and relative humidity, per each month. The upper and the lower dots represent the maximum and the minimum values recorded per each monitored month, while the horizontal line inside each bar represents the median. The horizontal axis represents the month's axis from July 2017 to June 2018.

The variation of temperature has been much higher in the summer months, with a monthly fluctuation of about 22 °C compared to the fluctuation of about 15 °C in the winter and the intermediate months. July and August 2017 have been the warmest months of the whole monitoring period. However, even though the highest temperature has been reached in July, the temperature in August was on average

higher, especially during the night. The lowest temperature, equal to 0.5 °C, has been reached in December and February. The external relative humidity during the whole monitored year varied between 11 % and 100 % and was highly influenced by the precipitation events recorded during the entire monitoring period.

Figure 3c) reports the trend of the global hourly solar irradiance from July 2017 to June 2018, the red dotted vertical lines indicate the sub-division between the months. The highest value of solar irradiance, equal to around 950 W/m² has been reached during April and May 2018, while during the colder months, the solar irradiance reached a value of about 500 W/m².

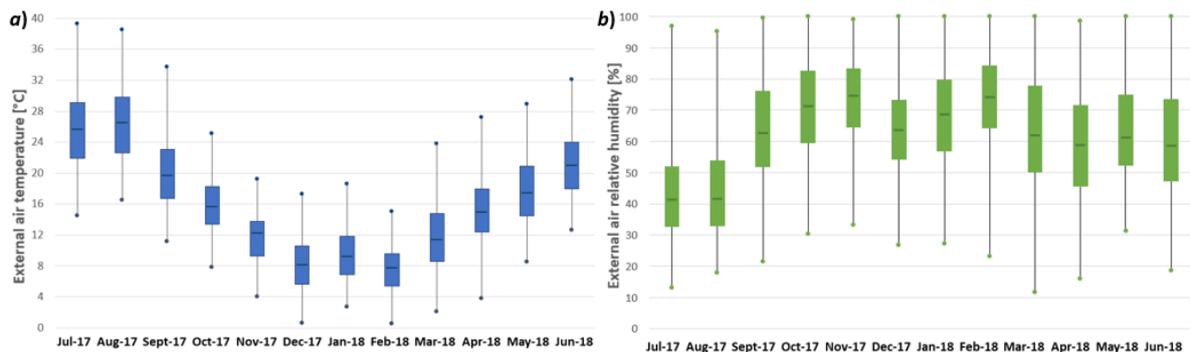


Figure 2. Maximum, minimum and the interquartile range values of the outdoor air temperature (a) and of the outdoor relative humidity (b) from July 2017 to June 2018.

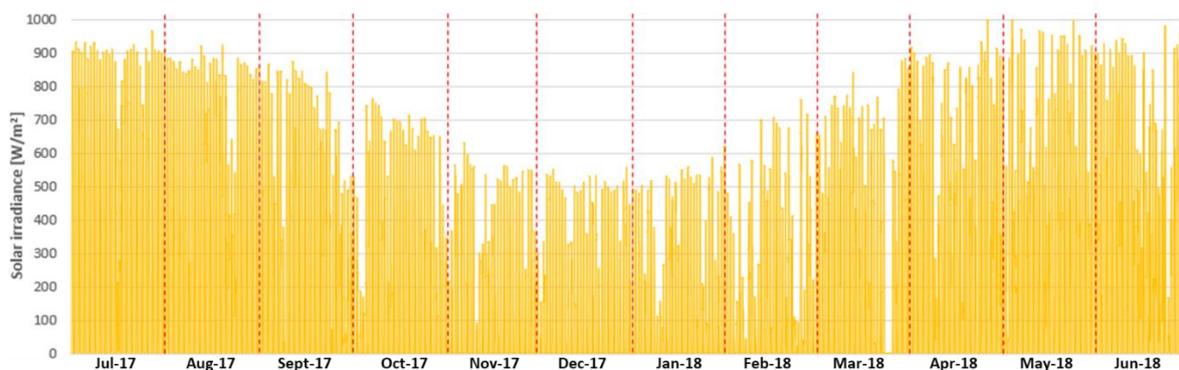


Figure 3. Global hourly solar irradiance from July 2017 to June 2018.

3.2. Energy results

The total energy use of the building and the PV production have been monitored during the whole year and compared in terms of grid interaction in order to quantify the degree of overlap between the two. The building is all-electric, therefore, the total energy use comprises the energy use for all services, including those related to the conditioned spaces, the external spaces of the building (external lighting and garden irrigation), the service spaces (parking space and basement floor), the control and monitoring system and the anti-theft and Closed Circuit TV system.

Figure 4 reports the daily energy production by PV (above the x-axis) contrasted with the daily total energy use of the building (below x-axis), divided between daytime (7:00 – 20:00) and night-time (20:00 – 7:00) hours. In the majority of the days during the intermediate period and during the month of March 2018, the energy produced on-site overcomes the total electric energy use for all the services of the building and in most of the days the overproduction could counterbalance also the night-time energy use. As far as the heating period is concerned (excluding the month of March 2018), the remarkable reduction of the energy production, due to the outdoor weather conditions, in combination with the

slightly higher energy demand for all the uses, especially for the activation of the heat pump to provide heating, results in a negative energy balance. In this period, the building is highly dependent on the power grid.

On a yearly basis the balance between the PV production and the total energy use is positive (PV production of 10946.4 kWh/year or 76.0 kWh/m²_{net}/year of conditioned floor area against a total energy use of 8598.7 kWh/year or 59.7 kWh/m²_{net}/year of conditioned floor area) [13], however, considering the heating season, from 15/11 to 31/03 for Mascalucia [18], the balance is slightly negative with a production of 2932.6 kWh or 20.4 kWh/m²_{net} of conditioned floor area against a total energy use of 4333.2 kWh or 30.1 kWh/m²_{net} of conditioned floor area. The installation of a BESS may improve the daily energy balance of the building, maximizing the energy self-consumption of the energy produced on site by PV and limiting, at the same time, the interaction with the power grid.

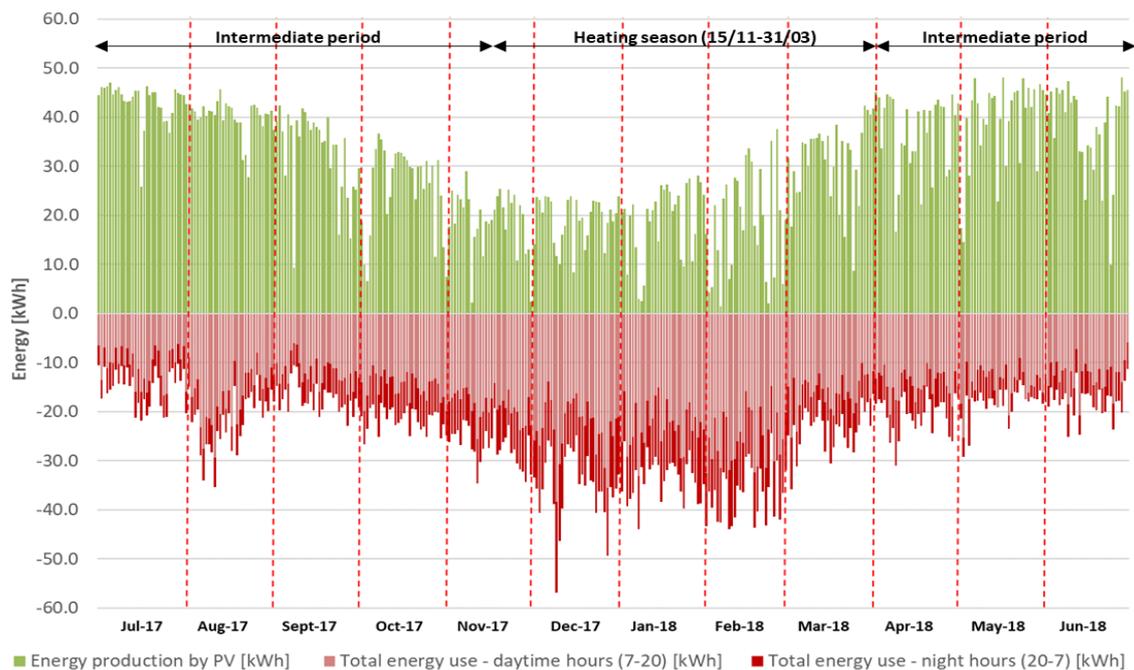


Figure 4. Daily energy production by PV (green) and total electric energy use (daytime hours and night-time hours) during the investigated year.

The Energy Performance of Buildings Directive (EPBD) 2010/31/UE [19] has introduced the concept of nZEB as a crucial aspect of the EU energy policy, and the Italian definition for nZEB [20] [21] [22] takes into account a monthly balance between the energy production and the total energy use of the building. Nevertheless, a fundamental aspect to be considered for high efficiency buildings should be the interplay between the energy load of the building and the production from RES [13] [23] at higher frequencies. The updated 2018 version of the EPBD [1] takes a step forward in this direction, introducing the smart readiness indicator that “*measures the capacity of buildings to use information and communication technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of buildings*”. The analysis of the interaction between the building and the power grid, indeed, may determine a higher exploitation of the renewable energy on site, minimizing at the same time grid interactions.

Salom et al. [23] [24] [25] provide a review of different load match and grid interaction indicators that are useful to measure the degree of overlap between production and load profiles and to take into account unmatched parts of production or load profiles. To analyse the interaction of the building with the grid, Salom et al. use the Load Cover Factor [24] [25], that represents the percentage of the energy

use covered by on-site electricity production. This index, however, does not provide a comprehensive quantification of the potential of the building in terms of compensation and overcoming of electrical loads, because it just describes when the load is covered, but not when it is overcome and in what proportion [13]. The interaction between the building load and the grid has been therefore here described with the Balance Factor (BF) that is defined as the percentage of the energy use covered by on-site electricity production and takes into account the degree of overcoming between the production and the energy use:

$$BF = \frac{\int_{t_1}^{t_2} [g(t) - S(t) - \zeta(t)] dt}{\int_{t_1}^{t_2} l(t) dt} \quad (1)$$

Where:

$l(t)$: energy load,

$g(t)$: on-site electricity production,

$S(t)$: stored energy,

$\zeta(t)$: energy losses.

The BF is equal to 1 when no loss is experienced, i.e., when the energy load and the on-site production are equivalent, instead, when the production is higher than the energy use, the BF is higher than 1. It is worth mentioning that, in the case under analysis, the terms related to energy storage and losses are equal to zero.

Figure 5 shows the BF calculated on hourly frequency for the whole monitored period. The plotted points represent the values of the BF and they show a great variability over the year. The vertical axis reveals how much higher or lower is the PV production compared to the total energy use of the building. Therefore, when there's no PV production, i.e. at night, the BF is 0. In the remaining time, when the BF reaches values higher than 1, the hourly ratio expresses the overproduction of energy, whereas it expresses the amount of interaction with the grid when it does not surpass 1. During the intermediate period there is a significantly high overproduction of energy, compared to the energy use, that can reach even 17.5 times the demand. However, during the heating season, there is a higher concentration of values lower than 1. Finally, the values ranging between 0 and 1 are usually observed in the early morning and the late afternoon hours during the summer months, instead, in the winter months, the frequency of values between 0 and 1 is higher all along daytime hours.

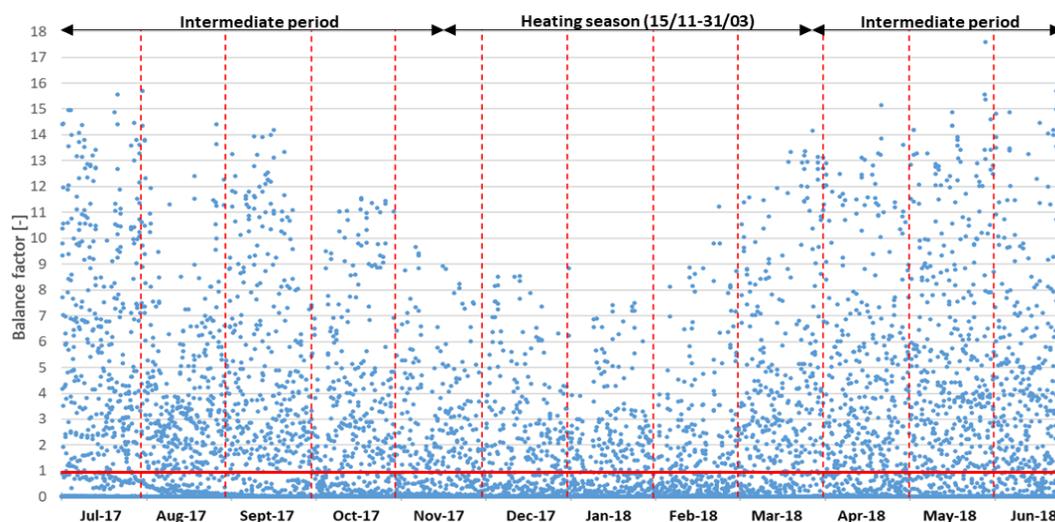


Figure 5. Balance Factor calculated on hourly frequency for the whole monitored period.

4. Technical and economic assessment of a battery storage system

Previous analyses showed the potential for BESS in the case study. In order to assess the energy performance improvement of the building, a technical and economic evaluation has been conducted for an electrical storage system to be integrated with the existing PV system. The objective of the analysis is the identification of the most cost-effective solution for the maximization of the self-consumption of energy produced by PV on site, and the minimization of the interactions with the power grid. The BESS allows indeed, to store the electric energy produced and not immediately used during the day, to compensate the electric energy demand in absence of solar radiation. This is an advantageous aspect in case of significant mismatch between production and use as in winter months. In addition, a BESS can also operate according to peak shaving logics to reduce electrical peaks demand of customers [26] and then, to avoid unexpected peaks demand for the grid.

To estimate the possibilities and limitations of a BESS integration in the case study and in order to identify the optimal size of the system for the minimization of the grid interaction, an energy simulation has been carried out through the software Homer Pro [27], originally developed at the National Renewable Energy Laboratory and enhanced and distributed by HOMER Energy. The simulation has been carried out considering the load power curve and the PV production power curve monitored during the whole investigated year for five sizes of battery storage (5, 10, 15, 20, 25 kWh), besides the case without battery (0 kWh).

The BESS technologies used in buildings are typically made with lithium or lead-acid; the latter are cheaper (400-700 € per kWh of capacity) than lithium-ion ones (900-1600 € per kWh of capacity) [9,28,29]; however, Li-ion batteries are lighter and more compact than lead acid batteries. Moreover, lead-acid batteries should be installed in a well ventilated space due to the production of hydrogen during the charging phase and they also have a lower depth of discharge (DoD, i.e. 50 % against 80 % of Li-ion batteries) and lower lifespan when compared to Li-ion batteries [9] [28] [29] [30] [31]. Therefore, Li-ion battery technology has been chosen to perform the simulation with Homer Pro.

Results of simulations are reported in Table 1 and in Figure 6. As previously seen, the yearly total energy use of the building is equal to 8598.7 kWh/year and the PV production is 10946.4 kWh/year. The 25 kWh Li-ion battery size allows to reach 87 % self-sufficiency (i.e. to cover 87 % of the energy use via PV generated and on-site used energy), substantially increasing the self-consumption; however, it requires large technical spaces and high investment costs (economic aspect will be considered in the following). A 15 kWh battery could represent a trade-off solution for the case study, since it still drastically increases the self-consumption, compared to the reference case (0 kWh), of about 85 %. The incremental improvements of higher sizes of battery (i.e. 20, 25 kWh) result to be much lower, and respectively 6 % between 15 and 20 kWh and 3 % between 20 and 25 kWh. In the case of a battery storage of 15 kWh, the self-sufficiency reaches a remarkable value of 83 %, compared to 45 % in the case without battery system.

Table 1. Storage system simulation results for five battery sizes through HOMER Pro Software.

Storage size [kWh]	Total energy use [kWh/year]	PV Production [kWh/year]	Energy purchased [kWh/year]	Energy sold [kWh/year]	Self-consumption [kWh/year]	Self-consumption increasing [%]	Self-sufficiency [%]
25 kWh	8598.7	10946.4	2089	3449	7497.4	94 %	87 %
20 kWh	8598.7	10946.4	2174	3540	7406.4	91 %	86 %
15 kWh	8598.7	10946.4	2403	3790	7156.4	85 %	83 %
10 kWh	8598.7	10946.4	3035	4489	6457.4	67 %	75 %
5 kWh	8598.7	10946.4	4124	5694	5252.4	36 %	61 %
0 kWh	8598.7	10946.4	5372	7077	3869.4	0 %	45 %

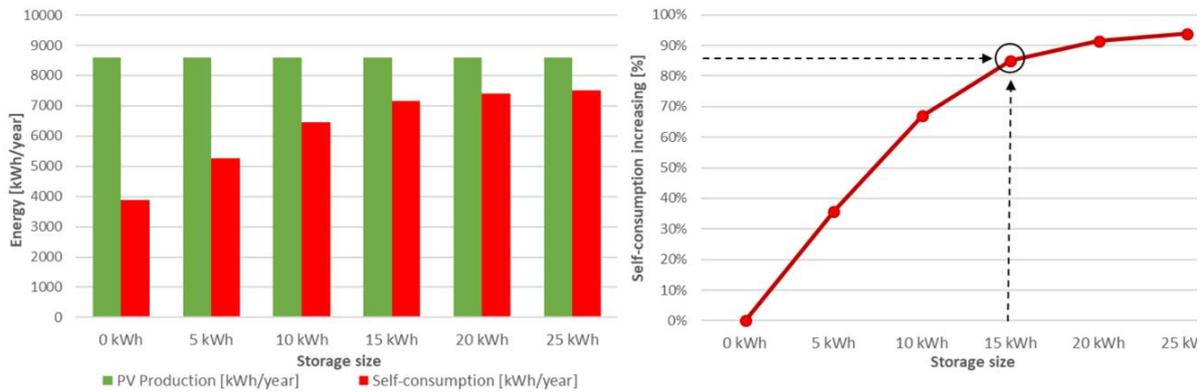


Figure 6. PV energy production vs energy self-consumption for different size of battery storage (left), self-consumption increasing for different size of battery storage (right).

The study carried out with Homer Pro, allowed the identification of the best technical option for the BESS to be applied to the case study, however, in order to assess the financial feasibility of the investment, an economic analysis has been carried out using the net present value (NPV) approach. This approach allows assessing long-term investments taking into account both the initial investment cost and the discounted cash flows during the overall lifetime of the considered investment [32]. The investment will be convenient if, at the end of the lifespan of the storage system, the NPV will be greater than zero, i.e. if the payback time of the investment will be less than the lifespan of the chosen storage system:

$$C_g(\tau,r)=I_0+\sum_{i=1}^n\frac{CF(i)}{(1-r)^i}=I_0+\sum_{i=1}^{\tau}CF(i)\cdot R_d(i) \quad (2)$$

Where:

$C_g(\tau,r)$: Global cost

τ : Calculation period

r : Discount rate

I_0 : initial investment cost

$CF(i)$: Annual cash flow at year i

$R_d(i)$: Discount factor

The economic analysis has been conducted for each storage size analysed previously (from 5 kWh to 25 kWh), the ones requiring investments costs. The NPV has been calculated considering 10-years lifespan for batteries, with an annual efficiency loss of 0.05 %, [28] [29]. Nevertheless, considering a 25-years lifetime of the existing installed PV system, and since it has been installed for 5 years already, the NPV has also been calculated on a period of 20 years, in order to verify the economic feasibility of the investment until the end of the PV system's lifetime. The BESS cost has been evaluated considering an average price equal 1000 €/kWh [9] [29] and an average price of the new inverter equal to 9 % of the BESS cost [33]. Annual operation and maintenance costs, equal to 1.5 % of the initial investment cost, has been taken into account [34] and, for the NPV analysis at 20 years, the substitution of the inverter (9 % of the initial investment cost; [33]) and of the storage system, have been considered after 10 years, as extraordinary maintenance.

A discount rate equal to 4 %, necessary to consider economically attractive an investment in a renewable energy production [35], has been applied to calculate the discounted cash flows over the years. However, it is worth mentioning that this study did not take into account costs optimization logics related to the different hourly energy costs, but a fixed energy tariff equal to 0.19 €/kWh (average cost of the energy from January 2018 to June 2018 calculated according to real bills of the building), which corresponds to the projections of the Energy Policy Scenarios to 2050 model [36]. Finally, according to

the energy bills of the building, a tariff equal to 0.11 €/kWh has been applied for the energy sold to the grid.

Table 2 shows costs, revenues, tax deductions and 10- and 20-years NPV analysis results for the chosen different sizes of battery storage according to the energy tariffs and the other data listed above. For the NPV calculation, the cost of the ordinary maintenance, the energy savings for self-consumed energy and the revenues for the energy sold to the grid have been considered annually, while the extraordinary maintenance costs have been considered after a 10-years in correspondence of the BESS and the new inverter substitution. For the 20-years NPV analysis, an additional scenarios in which cost for BESS will be halved by 2030, as indicated by IRENA [9], has been considered (i.e. 500 €/kWh). As already seen from the technical analysis, also in terms of savings for self-consumed energy and revenues for energy sold to the grid, the 15 kWh battery can be considered as the trade-off solution for the case study, allowing an annual saving for self-consumed energy of 1,359.72 €/year and an annual revenue for the energy sold to the grid equal to 416.90 €/year.

At the moment, in Italy, tax deductions equal to 50 % of the initial investment cost (for a maximum investment of 96,000.00 € for PV and BESS) are applied for the installation of a BESS on an existing PV system or in case of installation of a PV system coupled with a storage system. These deductions are refundable in equal instalments over 10 years if the PV peak power system does not exceed 20 kW_p and it is installed at the service of the building [35]. In this case, all the conditions for applying the tax deductions are met, therefore, the tax deductions of 50 % have been considered as shown in Table 2.

Table 2. Costs, revenues and NPV analysis results for different size of battery storage.

Storage size [kWh]	5 kWh	10 kWh	15 kWh	20 kWh	25 kWh
Costs					
Initial investment costs	5,450.00 €	10,900.00 €	16,350.00 €	21,800.00 €	27,250.00 €
Operating and ordinary maintenance costs	81.75 €	163.50 €	245.25 €	327.00 €	408.75 €
Extraordinary maintenance - storage battery and inverter substitution after 10 years	5,450.00 €	10,900.00 €	16,350.00 €	21,800.00 €	27,250.00 €
Revenues					
Savings for self-consumed energy	997.96 €	1,226.91 €	1,359.72 €	1,407.22 €	1,424.51 €
Revenues for energy sold to the grid	626.34 €	493.79 €	416.90 €	389.40 €	379.39 €
Tax deductions					
50 % deduction on the initial cost of the investment (paid in 10 years)	2,725.00 €	5,450.00 €	8,175.00 €	10,900.00 €	13,625.00 €
NPV					
NPV at 10 years	9,244.17 €	6,121.58 €	2,671.35 €	-1,069.62 €	-4,913.54 €
NPV at 20 years	14,006.97 €	7,334.33 €	113.80 €	-7,592.89 €	-15,471.75 €
NPV at 20 years (halving BEES costs)	15,847.88 €	11,016.15 €	5,636.54 €	-229.24 €	-6,267.19 €

The 10- and 20-years NPV results show that with current electricity tariffs, initial investment costs and extraordinary maintenance costs (in particular those related to the storage system substitution), the BESS investment is feasible in case of 5, 10 and 15 kWh battery sizes. However, the substitution of the batteries after 10-years lifetime greatly affects the profitability of the investment, especially for the 15

kWh battery size, that presents a NPV value equal to 2,671.35 € (16 % of the initial investment) after 10 years and equal to just 113.80 € (0.7 % of the initial investment) after 20 years. Considering the decreasing costs 2030 scenario of BESS described by IRENA [9], nonetheless, the NPV reach a value of 5,636.54 €, for the 15 kWh battery storage, also for the 20-years scenario. Moreover, it is worth mentioning that 50 % tax deductions have been taken into account only during the first 10 years of BESS lifetime (for all the three NPV scenarios) and not after its replacement, because this economic incentive will presumably end in 10-years time.

In conclusion, the NPV analysis for the 15 kWh storage system, identified as a good solution in relation to the results of the simulation made with Homer Pro, does represent an attractive investment only if BESS will undergo a substantial cost reduction as foreseen by IRENA [9]. Including different hourly energy tariffs in the analysis, might slightly improve the profit margins of the investment; however, it would not substantially change the results reported in Table 2.

5. Discussions

The monitoring campaign carried out for the Passivhaus residential building located in the Mediterranean climate, has provided meaningful information regarding its performance in terms of energy and grid interaction, as well as regarding the technical and economic feasibility of a BESS integration on the existing PV system. The energy analysis of the building has shown that the energy production by the PV system considerably overtake the total energy use for most of the year. Therefore, the grid interaction analysis, carried out with a hourly frequency, highlights that the installation of an electric energy storage system may lead the building to a higher level of independence from the grid.

Detailed analyses about grid interaction and energy simulations with operational data through Homer Pro software, have led to the definition of the optimal size for a storage system for the case study. Simulation results have shown that a 15 kWh Li-ion battery storage system represents a substantially good solution, since it allows to increase the energy self-consumption of about 85 % compared to the case without BESS. However, the economic analysis carried out using the NPV approach at 20 years (until the end of the existing PV system's lifetime), highlights that this solution does provide brilliant economic results, only if BESS will halve their investment costs by 2030.

6. Conclusions

The energy sector is undergoing a considerable and continuous transformation, the competitiveness of RES power generation is growing and evident, and policies and directives support and promote the increase of the share of energy production by RES. This implies an increasingly high share of energy produced from renewables, which by their nature are intermittent and difficult to forecast. The complexity of the power grid management is therefore destined to grow since it should take into account the potential of energy production from RES coming from systems installed on buildings that are the major end-users at the power demand side. In this context, it is necessary to identify solutions to manage the interaction between end-users and the power grid, and to achieve the power balance with a high rate of flexibility.

BESS are key elements to increase grid and demand flexibility, these systems can store energy when the energy production overcome the energy load of the buildings and contrast the imbalanced peak demands when required, increasing power grid reliability.

Operational data reported in this paper allowed to evaluate the possibility of integration of a BESS in a high performance building in the Mediterranean climate already equipped with a PV system, besides assessing the economic feasibility of the investment. Results shown that the attractiveness of the investment is still limited due to the short lifespan of the batteries and to the high costs of these systems; however falling costs of BESS can increase the feasibility of economic investments, unlocking new market opportunities.

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