Techno-economic analysis of alternative energy communities scenarios in small mountain localities in South Italy. A case study.

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1 Aim and case study

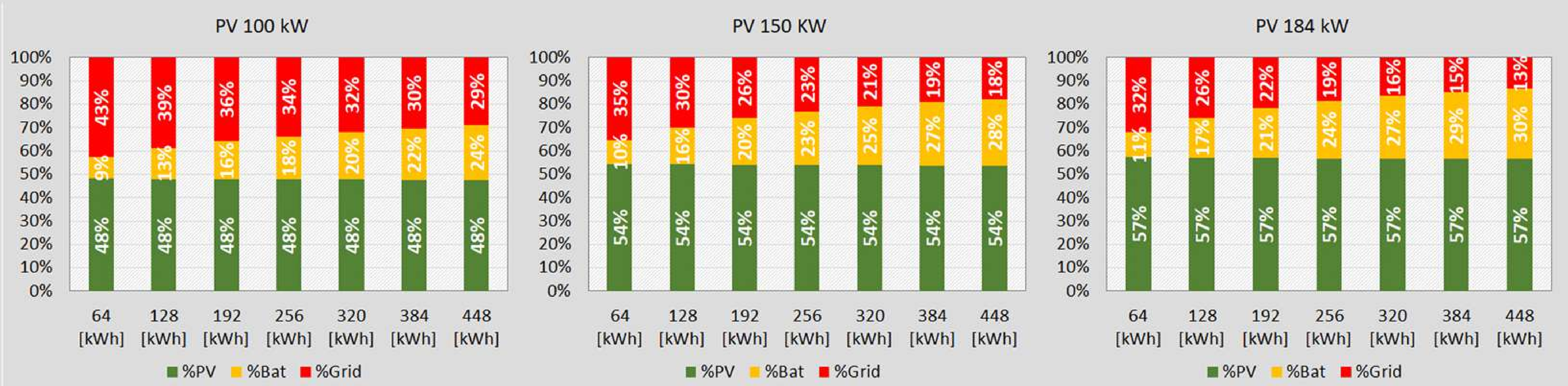
Energy communities can represent an interesting and necessary solution for businesses and citizens struggling with the climate crisis and the rising energy prices. In community energy systems, the energy demand of a group of households or public service is met by collectively generated electricity from renewable energy sources and this issue is particularly felt in small towns where the establishment of energy communities can bring social benefits and environmental advantages to the one side, and avoiding the dissipation of energy through grid losses on the other one. In this work, possible scenarios for the energy community in the small mountain municipality of Soveria Mannelli are proposed and analysed.

Location
Soveria Mannelli, CZ, South Italy,
Lat 39°05'N; Long 16°22'E
Altitude 800 a.s.l, area 20.5 km2
Climatic zone
E, 2374 degree-day
D.P.R 26 Agosto 1993 n° 412
Köppen classification
type Csa Hot-summer Mediterranean climate

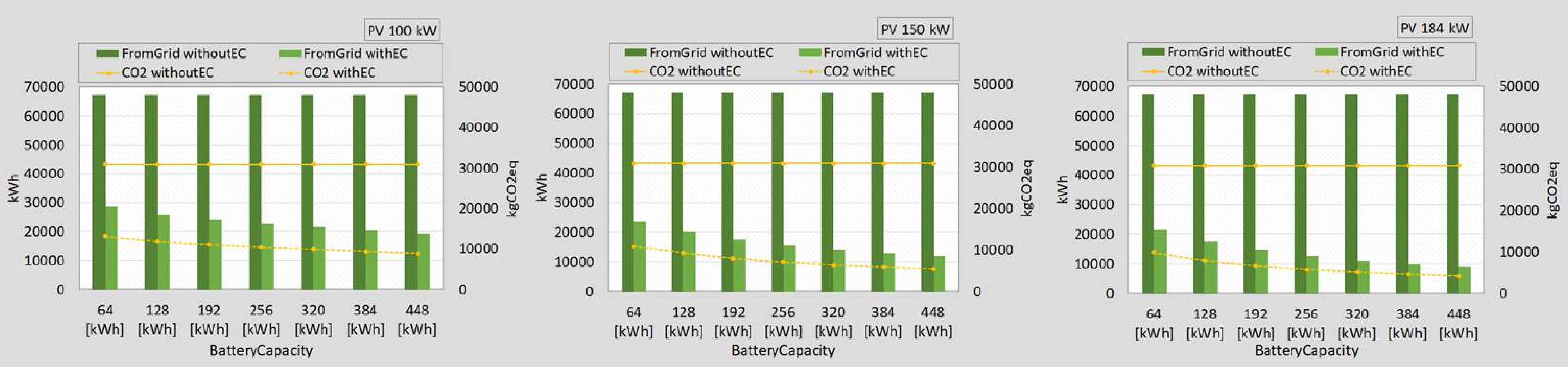
The buildings selected for analysis consists of five multy-story public buildings: the primary school, the secondary school and its branch, the city hall and the technical office. All buildings analysed have been subject to energy efficiency measures in recent years. A survey was made of the activities and habits in the buildings and the generators of the air conditioning systems are ideally replaced with air-water heat pump generators.

3 Results and conclusion

The percentages of self-consumed electricity from PV production, absorbed from the storage or from the grid for three different sizes of PV plants and different battery capacities. Considering the case of a 100 kW PV plant, for any battery capacity, the electricity directly consumed from the photovoltaic modules amounts to 48 %, whereas the energy provided from the same battery moves from 9% to 24%. The remaining energy is taken from the grid and it amounts in the worst case to 29%. When the maximum peak power of PV systems is installed on the roofs of the municipal buildings (184 kW), a higher reduction can be appreciated in the share taken from the grid that drops to 13 % for the greatest battery size. Storage capacity that 448 kWh was set as the maximum capacity both from a technical and economic point of view.

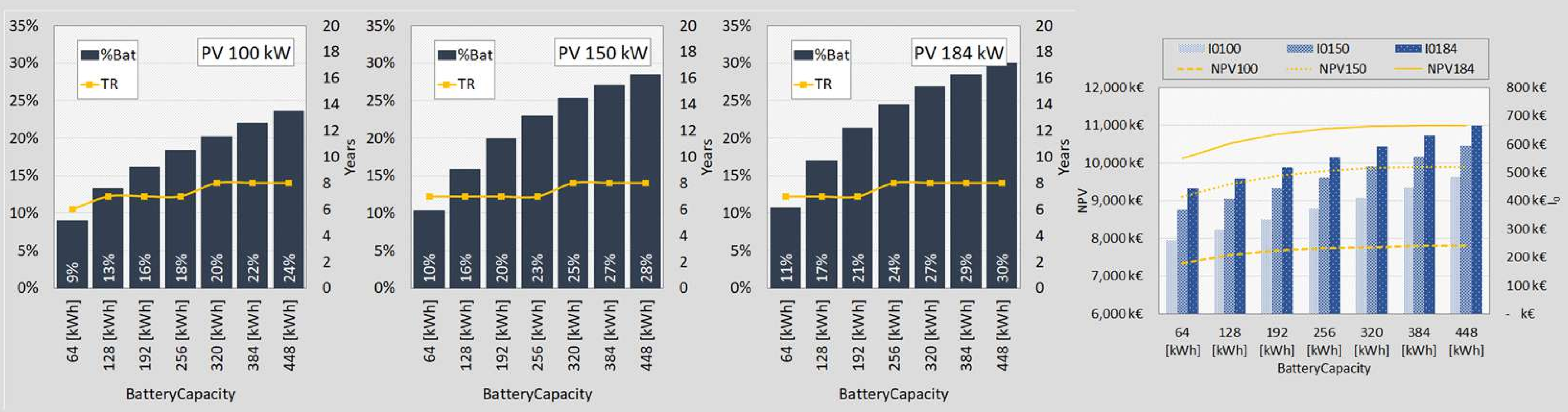


The trend of equivalent CO2 production in the current configuration of the municipality (without PV systems) and after the implementation of the energy community. Because of the drastic reduction of the energy withdrawn from the grid, the CO2 emissions are also considerably reduced and, furthermore, the reduction increases with the size of the batteries. In all the considered cases, it is worth noting to observe a drastic decrease in CO2 emissions. In the current configuration, the Municipality of Soveria Mannelli contributes to approximately 30,919.6 kgeq per year. Such value drops considerably after the implementation of the energy community, reaching the minimum in correspondence of the greatest battery capacity with emission amounting to 8 896.91 kgeq for the 100kW PV peak power and 4170.4 kgeq for the most favorable case of 184 kW. The highest achievable CO2 saving amounts to 26,749.3 kgeq with a reduction of 86.5 %.



The economic analysis evaluated the profitability of each scenario. The discounted payback is reported and for any PV and storage size is included in the period of 6-8 years. It is also interesting to observe how for any PV size, the greater battery sizes produce the same result, so the employment of batteries with a capacity over 320 kWh.

The NPV for each case was considered. NPV curve tends to become flatter move toward higher battery capacities.

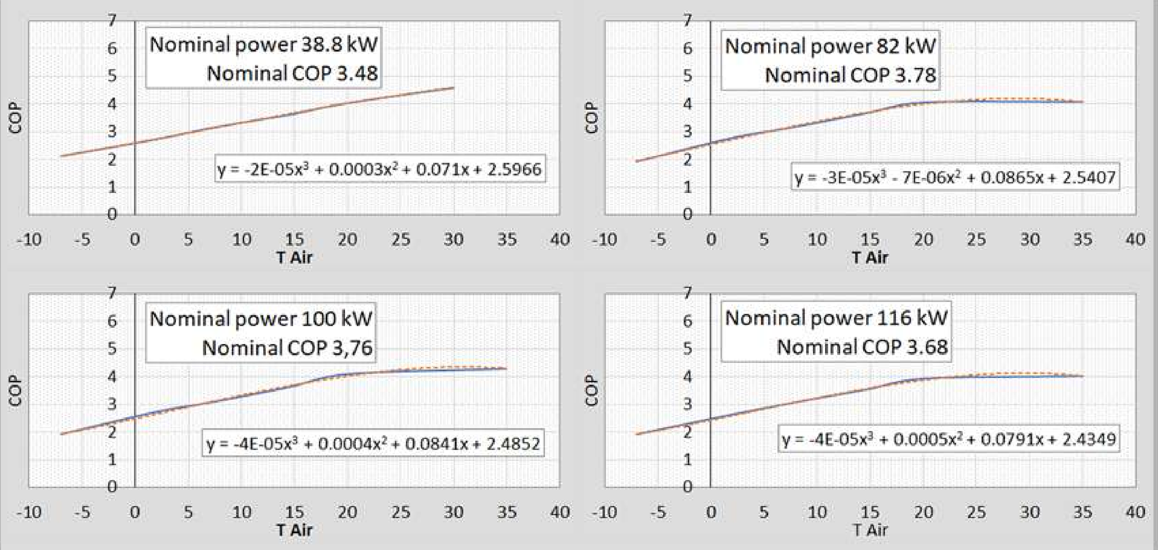


This research work examines and analyzes a real case study of a renewable energy community planned in a small town in the south of Italy. For this study, it was assumed that the generators of the air conditioning systems of the buildings considered are ideally replaced with electric air-water heat pump combined with a PV generator and an electric storage system.

The aim is to optimize the use of the energy produced and shared within the energy community. Future research work will include the extension of this study and consider replacing or adding additional renewable sources. It will also be useful to evaluate the interaction of families within the energy community.

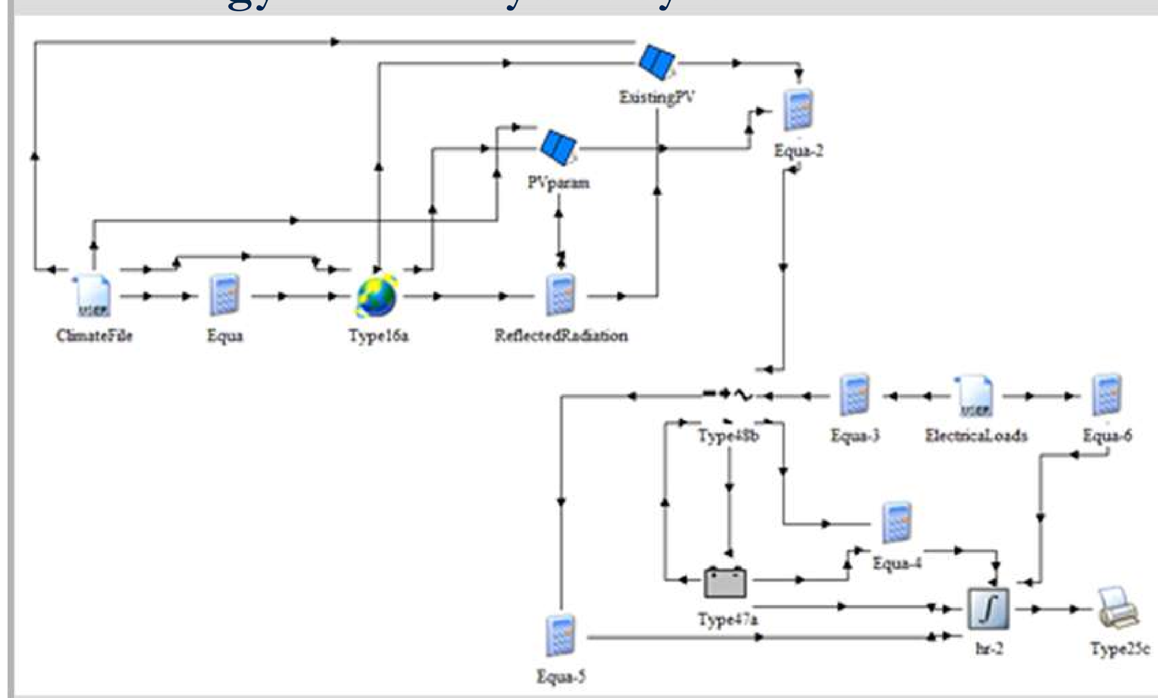
2 Methodology

Thermal energy demand and dynamic simulation.



The analysis of heating requirements was evaluated for each of the buildings using hourly dynamic simulations carried out by the commercial tool Termolog. After the evaluation of the thermal requirements as previously described, commercial heat pumps were chosen for each building analysed. The size of the heat pump has been chosen based on the design thermal load.
The heat pump characteristic curve was plotted for a flow temperature of 45 °C and its trend line was identified. Through the equation of the trend line, the COP was then calculated about the outside air temperature hour by hour. Finally having the COP and the thermal requirement, the hour-by-hour electricity requirement has been evaluated.

Energy community and dynamic simulation.



For the energy simulation an integrated approach in TRNSYS software was developed. This software does not include urban modelling and for this reason, Type9c was used, a data reader that considers the previously evaluated electrical loads. The simulations were carried out with a time step of 1 minute, but with the Quantity Integrator the results were printed directly with a monthly step to allow easier evaluations.

Parametric study and Tecno-economic analysis.

After the electric needs assessment, 21 parametric studies to be carried out were identified. The parameters chosen for the parametric study are the size of the photovoltaic generator and the capacity of the batteries.

PV modules	Battery capacity							Inverter
[kW]	[kWh]							[kW]
100	64	128	192	256	320	384	448	103
150	64	128	192	256	320	384	448	153
184	64	128	192	256	320	384	448	186

The economic analysis of investments is carried out using discounting methods. The discounting method used is the NPV (Net Present Value)the NPV discounted with the effective discount rates is equal to:

$$-I_0 + \sum_{k=1}^{n} R_k \left(\frac{1+e}{1+d}\right)^k - \sum_{k=1}^{n} (C_k + I_k) \left(\frac{1+g}{1+d}\right)^k$$

Financial indices		
Rate of inflation of the cost of energy	e	0.27
Customer's discount rate	d	0.04
The general rate of inflation	g	0.08
Initial cost	I_0	
Revenues	R_k	
Costs	C_k	

The values reported in the national price lists were used to evaluate the costs considering all the services necessary for the installation and their average cost. The revenues considered were the premium tariffs envisaged for shared energy and revenues from energy fed into the grid fixed by the national body in charge for 20 years.

Cost				Proceeds		
	PV modules	1190	€/kW	Electric energy	0.4	€/kWh
I_0	Inverter	1000	€/kW	Energy community	119	€/MWh
	Storage	586	€/kWh	PowerToGrid	0.07	€/kWh
	Maintenace	2.5% of I_0				

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