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PAPER TITLE

SMART PARKING OPTIMAL DESIGN FOR RENEWABLE ENERGY COMMUNITIES INTEGRATION IN POWER SYSTEM

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OUTLINE

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2. METHODOLOGY
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4. RESULTS
5. CONCLUSIONS

INTRODUCTION

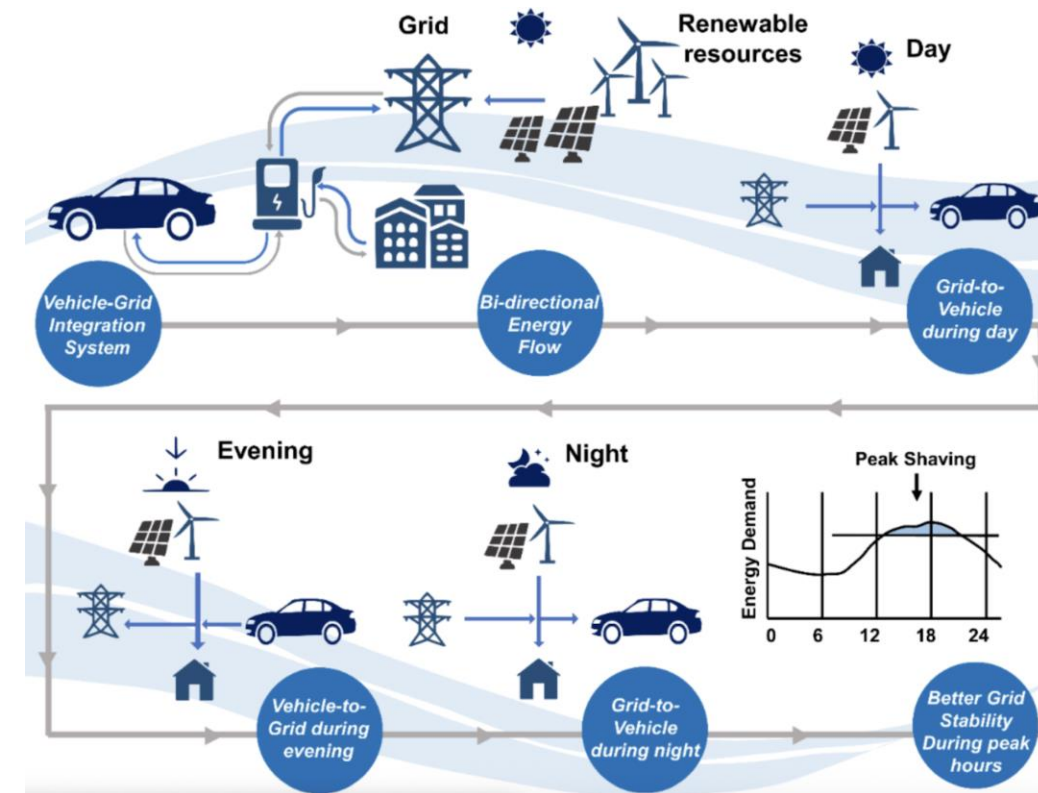
The electrification of mobility and the diffusion of Renewable Energy Communities (RECs) are redefining the paradigm of electric systems.

Vehicle-to-Grid (V2G) technologies enable electric vehicles to actively contribute to grid stability by acting as mobile storage units. However, the integration of these technologies requires advanced energy management solutions from both technical and regulatory perspectives.

This paper analyzes the optimal implementation of smart parking integrated into RECs, focusing on the combined role of photovoltaic systems, energy storage systems, and two-way charging stations.

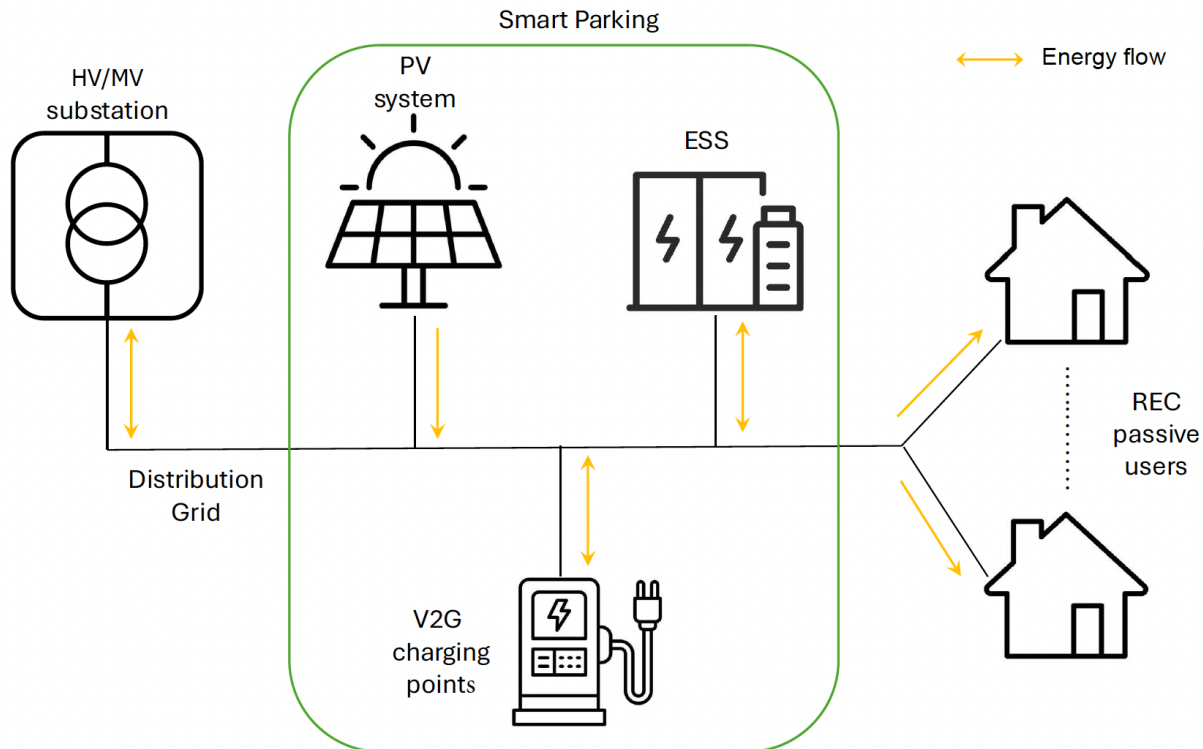
The bidirectional exchange of energy between vehicles or energy storage systems and the local grid can thus transform the parking belonging a REC lot into an active community player, capable of absorbing excess energy produced by renewable facilities during daylight hours and returning it to the grid or other community members at times of highest demand.

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METHODOLOGY

The proposed methodology aims to determine the optimal size of the PV system and storage unit to be integrated into a smart parking serving a REC.



The optimization criterion considers maximizing local self-consumption and minimizing total annual costs (C_0), taking into account Italian regulatory conditions.

$$C_0 = c_{ess} \cdot Q + c_{pv} \cdot P + \sum_{h=1}^{8760} (P_{buy,h} \cdot q_{g2l,h} - P_{sell,h} \cdot q_{l2g,h} - P_{inc,h} \cdot q_{sh,h})$$

The optimization problem is to find the pair (P, Q) that minimizes C_0 , subject to technical constraints such as maximum installable PV power, ESS charge state limits (20%-90%), and a single daily charge/discharge cycle.

The analysis also considers economic indicators such as payback time, Net Present Value, and Profitability Index.

CASE STUDY

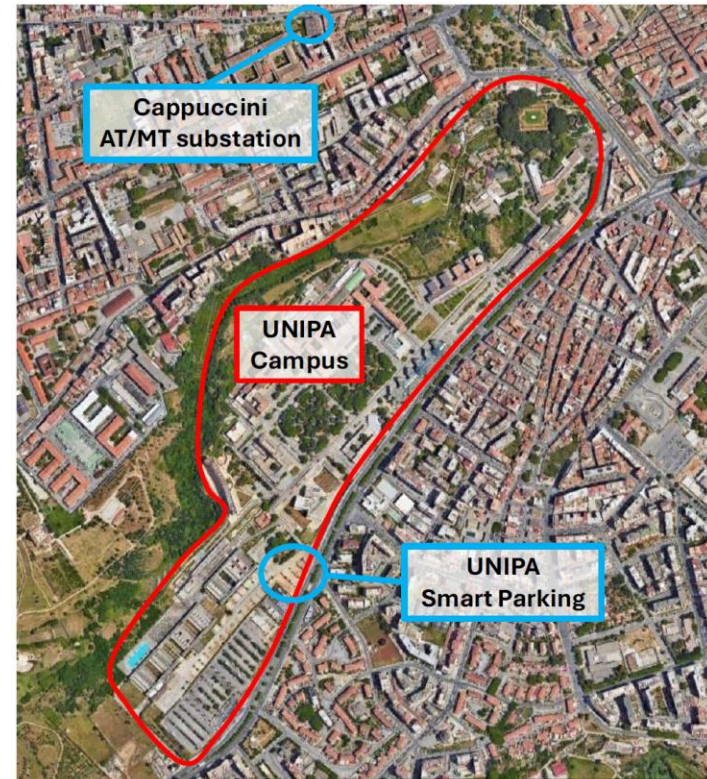
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The case study is set within the Palermo University campus, specifically in the area of the Faculty of Architecture, powered by the “Carrubba University” secondary substation.

The REC under study includes a smart parking with charging stations, a photovoltaic system, a storage system, and the adjacent buildings.

Two scenarios were considered:

1. V1G mode, where the vehicles act as loads only;
2. V2G mode, where energy is returned to the grid during evening or peak hours.



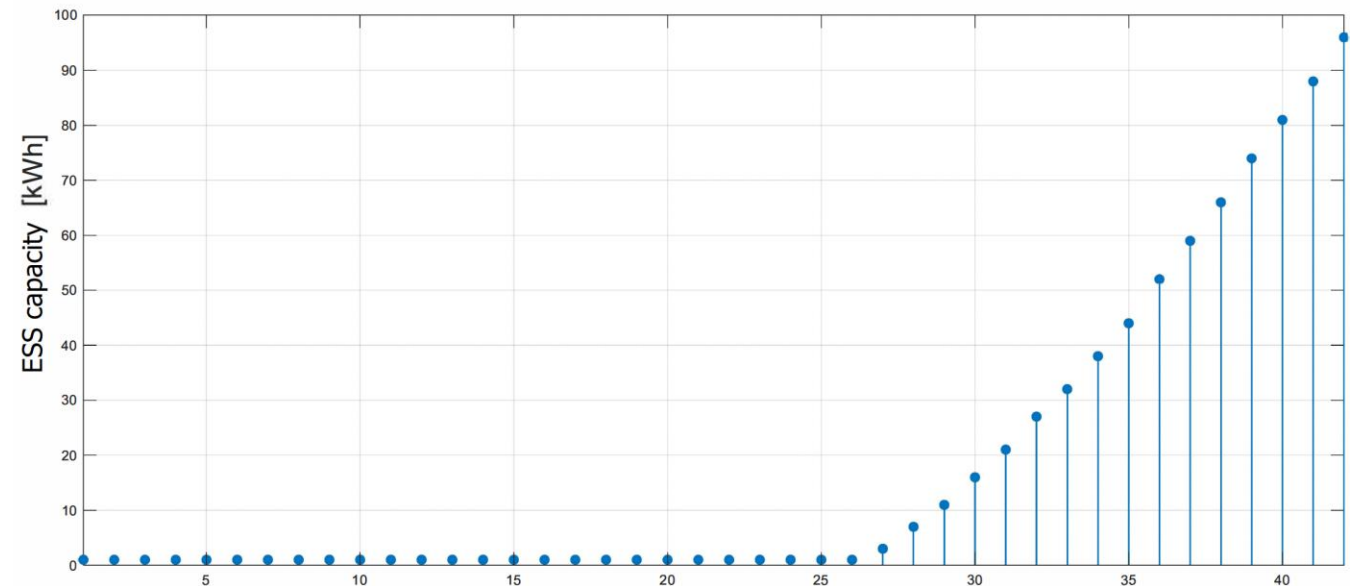
RESULTS: scenario 1

In the first scenario analyzed, electric vehicles are considered exclusively as passive loads (V1G). Energy is stored during daylight hours exclusively in the stationary storage system.

The optimized system involves the installation of a 42 kW photovoltaic system and a 97 kWh storage system.

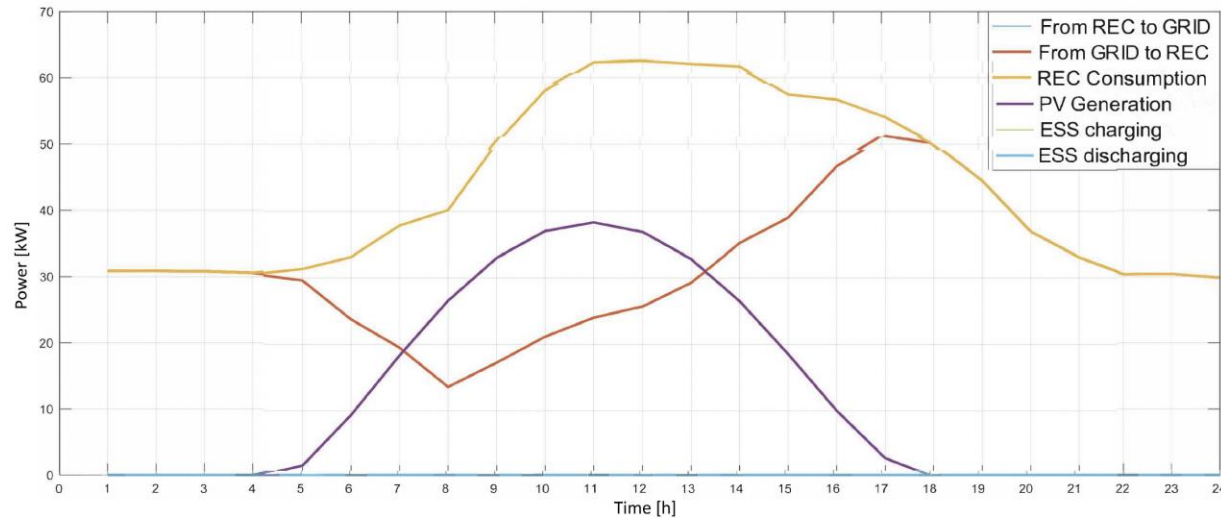
All the energy produced annually, amounting to about 86,715 kWh, is self-consumed within the community, with no feed-in to the grid.

As shown in Figure, the optimal capacity of the ESS increases as the installed PV power increases, reaching a maximum at 42 kW.



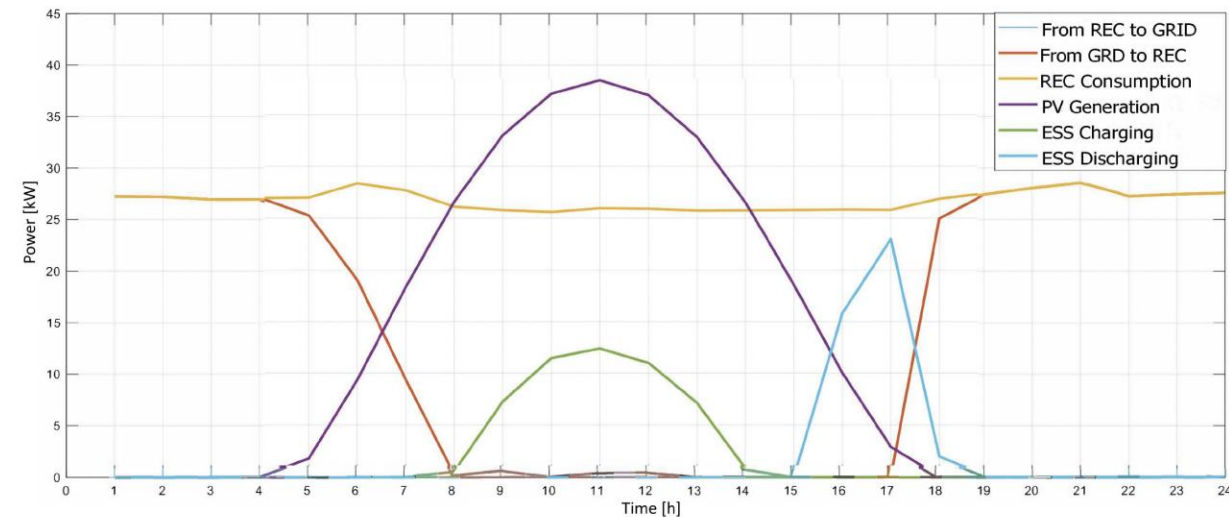
RESULTS: scenario 1

The figure shows energy flows during a weekday in June, highlighting the absence of energy surplus and the direct use of solar energy produced.



The investment payback time is estimated to be 5 years and 1 month, with a profitability index above 15. In environmental terms, there is an estimated reduction of over 479 tons of CO₂ in 20 years.

This figure shows the situation on weekends, when some of the surplus energy is stored in the ESS to cover evening loads.



RESULTS: scenario 2

In the second scenario, V2G functionality is introduced, allowing electric vehicles to return energy to the grid or community.

Five vehicles with 30 kWh batteries are considered, with 30% availability for community use.

This results in an additional energy availability of 45 kWh.

Due to the contribution of the vehicle batteries, the required capacity for the stationary storage system is reduced from 97 to 52 kWh.

This provides a significant reduction in investment cost, estimated at about €60,000, and a decrease in payback time to 3 years and 5 months.

In addition to the economic benefits, V2G introduces additional operational flexibility, improving the resilience of the energy community. However, its implementation requires advanced planning, especially with regard to the variability of vehicle availability and the need to develop dedicated control and compensation systems.

To mitigate these critical issues, a viable strategy could be to employ University service vehicles, dedicated in part or in full to community needs.

CONCLUSIONS

The study proposed in this paper demonstrated the benefits of integrating smart parking, photovoltaics, and storage systems within Renewable Energy Communities.

In particular, the proposed strategy enables reduced energy costs, improved self-consumption, and lower CO₂ emissions.

The adoption of V2G further strengthens the economic sustainability and resilience of the local grid. However, its implementation requires careful operational management, establishment of compensation mechanisms for users, and adoption of advanced control systems.

Future goals include the development of intelligent algorithms for real-time management and the testing of models based on vehicles with predictable usage profiles.



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THANK YOU!

