Optimization Tool for Technoeconomic Assessment of Redox Flow Battery and Supercapacitor based Hybrid Storage Systems

Mattia Duranti [1,*], Marcin Buchajczyk [1], Saman Korjani [1], Edoardo Gino Macchi [1]

[1] Center for Sustainable Energy, Fondazione Bruno Kessler, Via Sommarive 18, 38123 Trento

Context & Research Objectives

Context

- A real-world academic facility has a 5÷10 kW load, which is partially met with a 40 kWp co-located PV plant. The remainder is purchased from the grid.
- Power is purchased at dynamic spot prices and surplus PV is sold at a fixed feed in tariff of 6.90 €/MWh.

Objective

- Use a HESS to reduce the annual cost of the energy and increase PV self-consumption, avoiding curtailment.

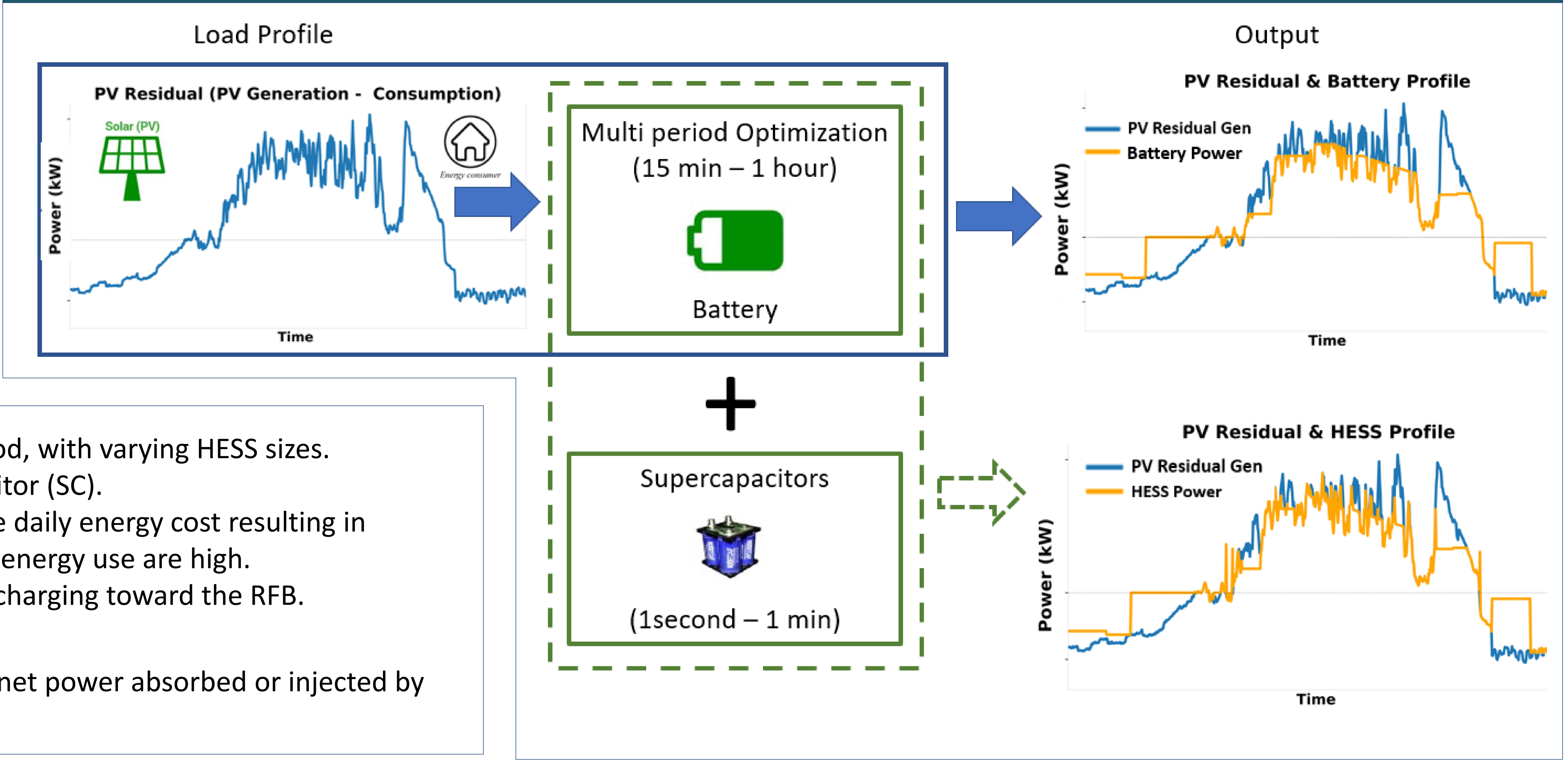
Method

- HESS interaction with the facility was simulated over a 1-year period, with varying HESS sizes.
- HESS was comprised of a redox flow battery (RFB) and supercapacitor (SC).
- RFB use was optimized with a genetic algorithm (GA) to reduce the daily energy cost resulting in charging when power price is low and discharging when price and energy use are high.
- SC operates on a rule-based logic, charging with excess PV and discharging toward the RFB.

Constraints

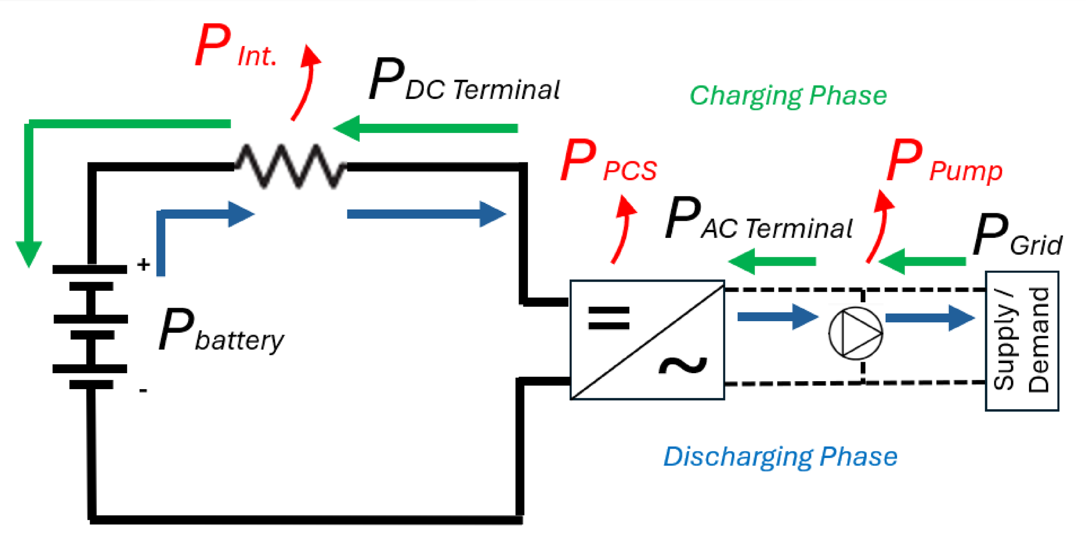
- The grid power connection point is limited to 30 kW, therefore the net power absorbed or injected by the HESS + PV plant + Facility cannot exceed this amount.

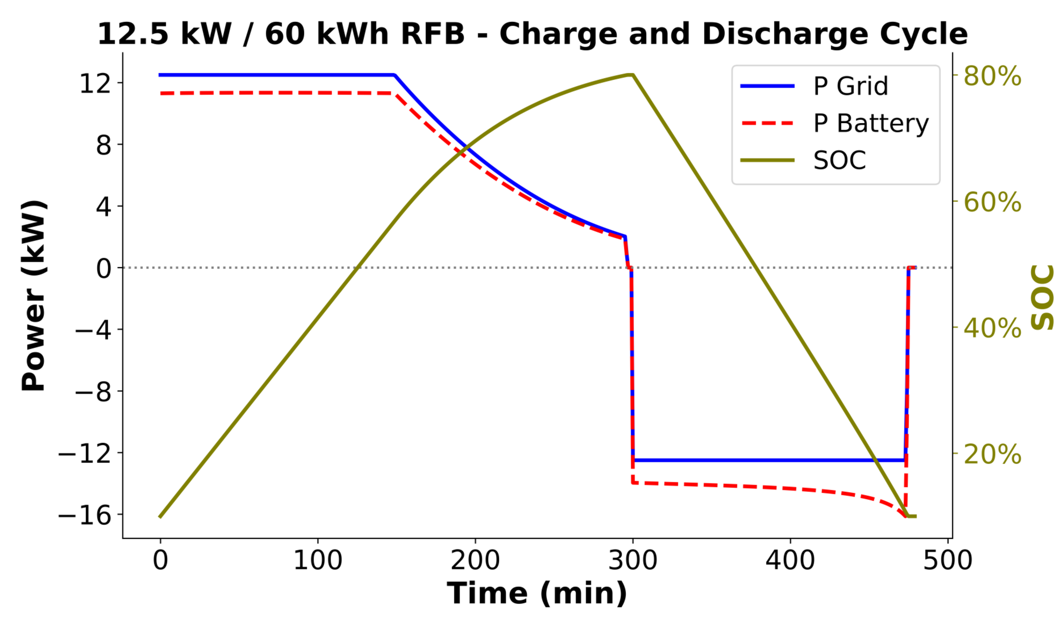
HESS Interaction Scheme



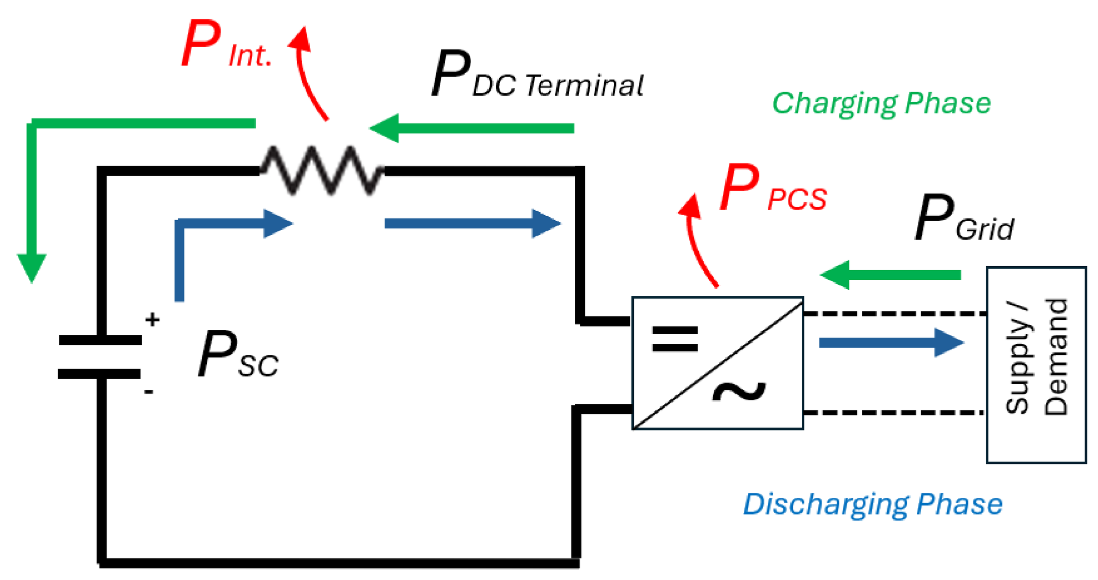
RFB and SC Models

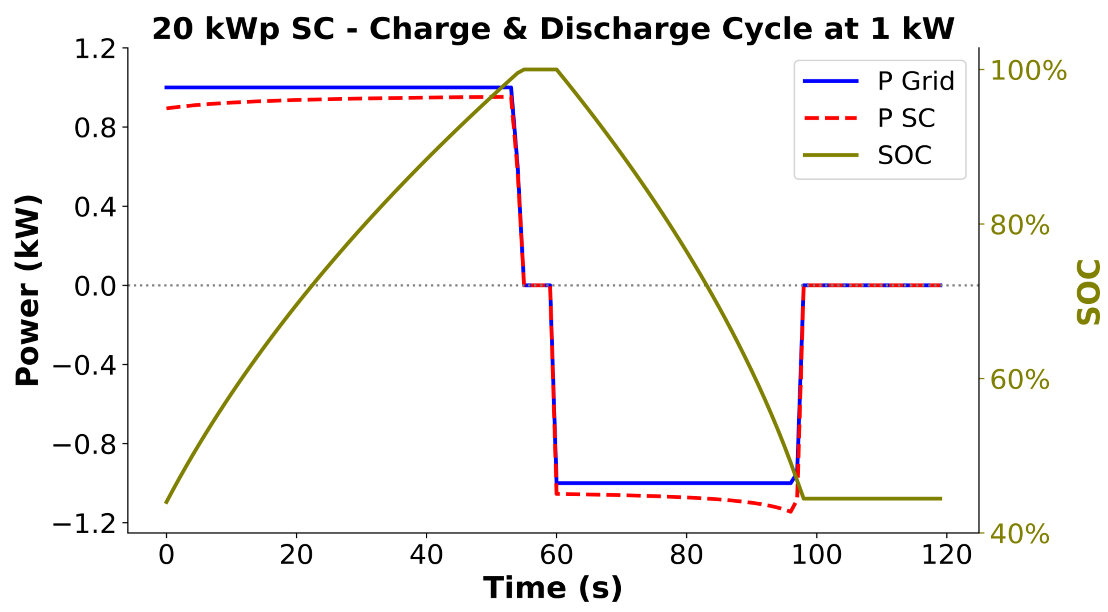
RFB Model



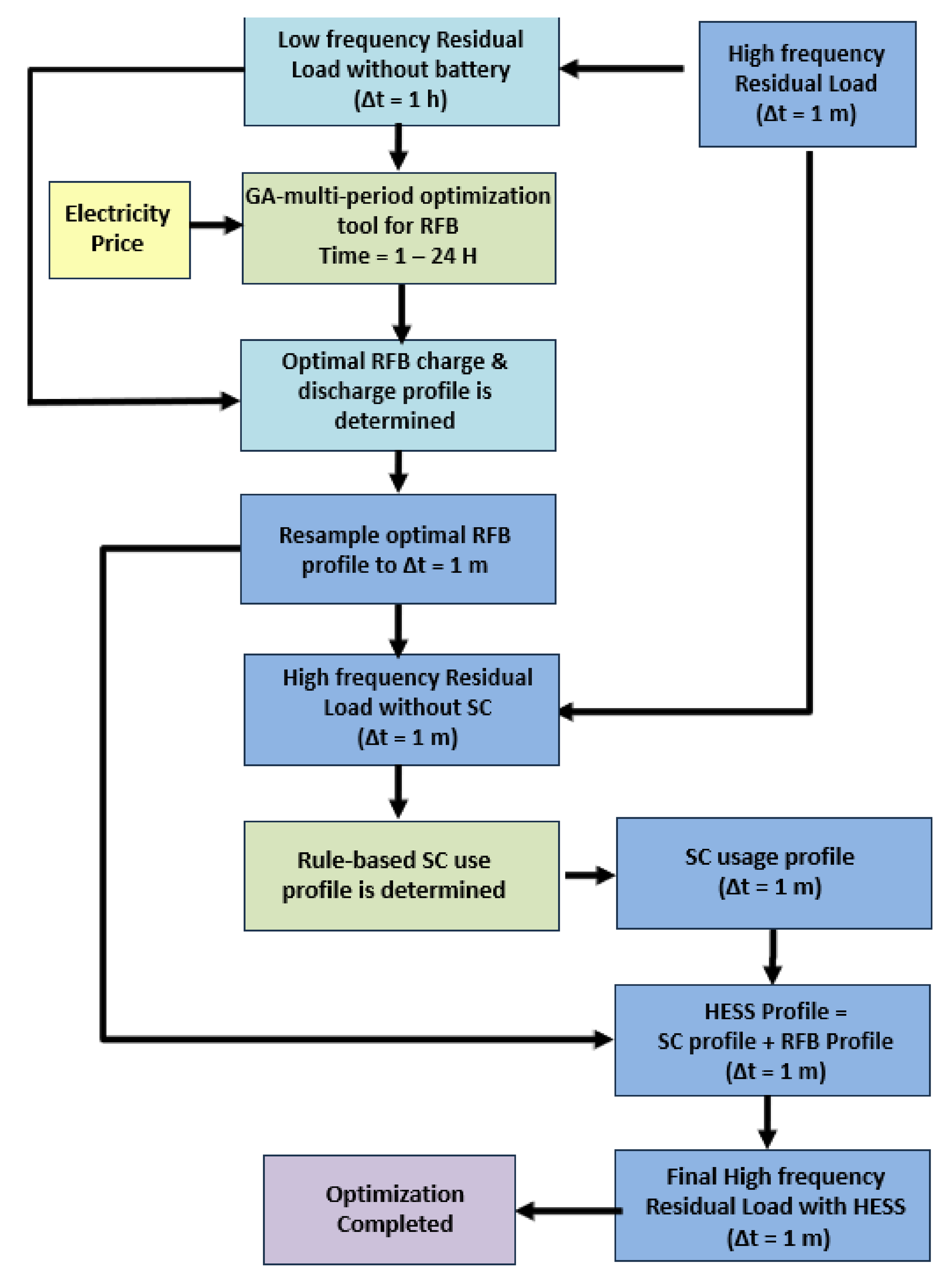


SC Model





Optimization Scheme



Model Constraints & Parameters

RFB Parameters

Electrolyte	Vanadium
Electrolyte Conc.	1.6 mol / L
SOC Limits	10 - 80 %
Max. Cell Voltage	1.5 V
Cell area	1628 cm²
Internal Resistance	1.6 Ωcm²
Decay Rate due to Oxid.	0.055% / Cycle
Overall Decay Rate	0.217% / Cycle
CAPEX	300 – 700 €/kWh

RFB Sizes

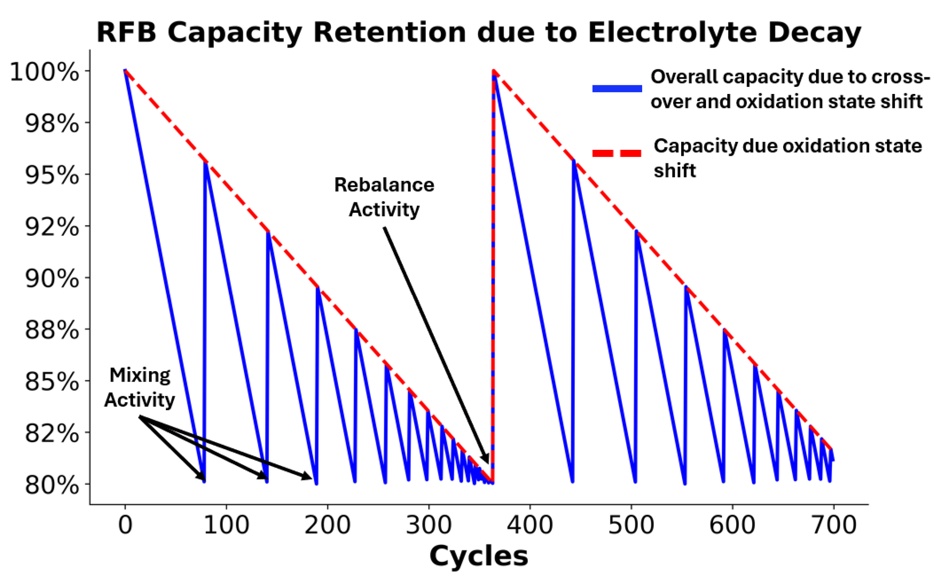
Storage Size	60 - 180 kWh
Rated Power	12.5 – 25 kW

SC Sub-Module Parameters

Peak Power	20 kWp
Min. / Max. Voltage	12 / 27 V
Useable Energy	58.5 kJ
Internal Resistance	8 mΩ
Capacitance Decay	$2x10^{-5}$ % / Cycle
Resistance Increase	$1x10^{-4}$ % / Cycle
CAPEX	25-40 €/kWs

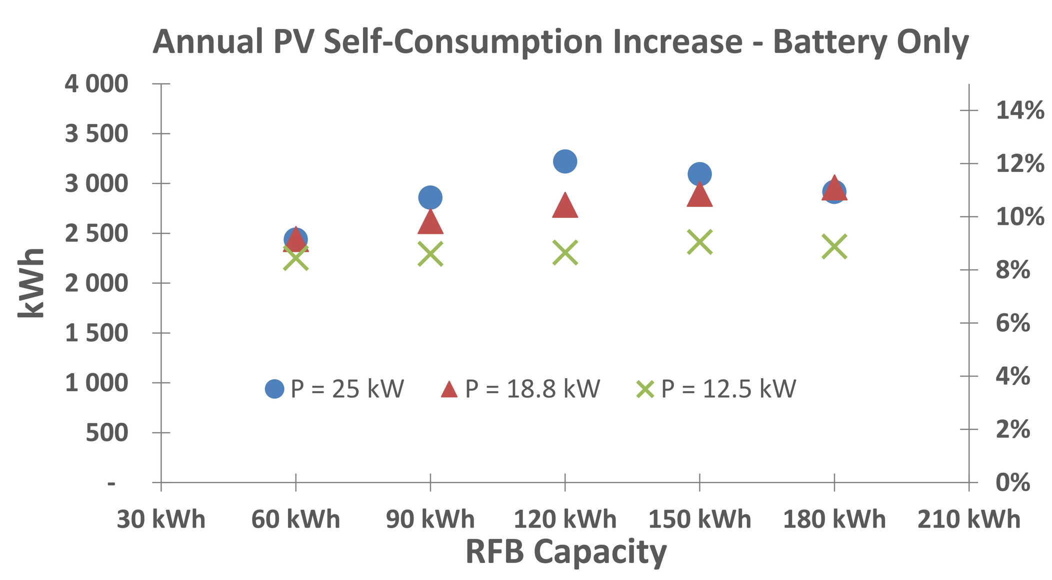
SC Sizes

Sub-Mod. in Series	1 – 5
Sub-Mod. in Parallel	1
Peak Power	20 – 100 kWp

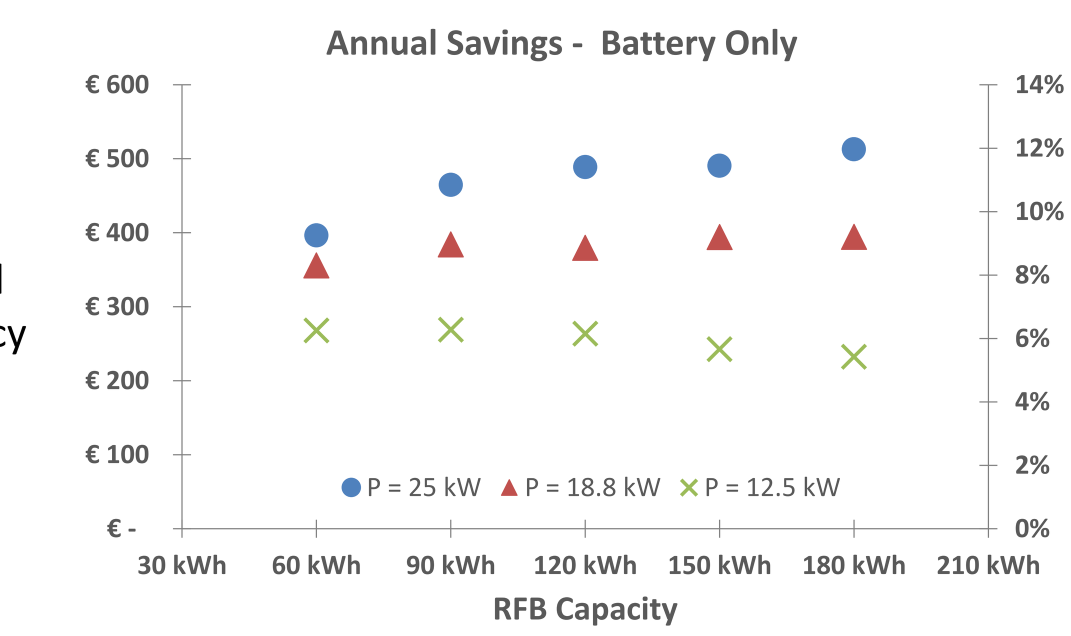


Results

Battery Size	Results	25 kW	18. 8 kW	12.5 kW
60 kWh	Battery Cycles	490	412	310
90 kWh		372	299	214
120 kWh		289	230	157
60 kWh	No. of Mixing Activities	11	10	8
90 kWh		9	7	3
120 kWh		6	4	2
60 kWh	No. of Rebalance Activities	1	1	0.12
90 kWh		1	0.15	0.39
120 kWh		0.18	0.34	0.55



Annual savings in battery only case are € 219 to € 513, corresponding to 5.2 to 12.2 % for an original annual energy cost of € 4,214.
Annual PV self-consumption increased by 8 – 12%.
SC contribution to annual savings is < 0.2 %, hence SC is not deemed as useful for this use case. A better use would be via ancillary services like grid frequency regulation, which would likely be more profitable.
Financial analysis deemed that RFBs and HESSs are economically unviable for this use case, as the NPV <0 for up to a 20-year project period. RFB and SC CAPEX is too high, and discounted revenues are unable to pay off the initial investment.



* Presenting and corresponding author.
Contact mail: duranti@fbk.eu

This work is co-funded by the European Union, through the granting authority CINEA under the Horizon Europe (project SMHYLES grant No. 101138029) and by the Italian Ministry of Enterprises and Made in Italy in the framework of the Important Project of Common European Interest (IPCEI) European Battery Innovation (project IPCEI Batterie 2 - CUP: B62C22000010001).