Economic Optimization of PV Systems with Storage

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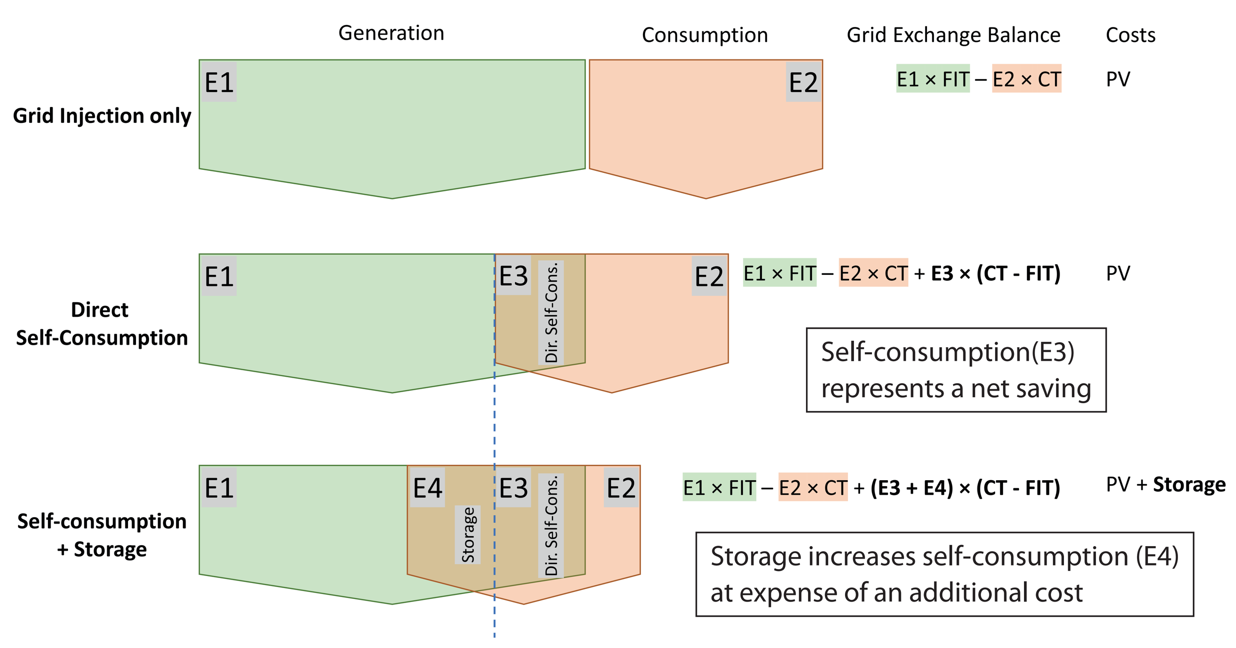
Abstract

Financial profitability analysis is a substantial preliminary study topic and a key decision criterion when designing and building a PV system, both for small residential use and for commercial purpose. In this context, energy storage has increased the capability for maximizing the energy self-consumption and the profitability of PV systems, but it has also complexified the optimization strategies. Battery storage in a PV system allows to displace the usage of the solar generated power to times where consumption is needed. However, the sizing of the optimal system depends on many factors, such as meteorological data, load profile, battery size and price, feed-in tariffs, etc. PVsyst is a simulation software used to model PV systems, from small residential size up to large utilities. The new economic evaluation tool included in the software allows to perform a detailed analysis, producing key financial indicators such as the CAPEX (Capital Cost of the Investment), LCOE (Levelized Cost of Energy), payback time and return on investment (ROI). The aim of this study is to establish a methodology for the optimization of PV systems with self-consumption and storage. The optimization of several economic variables, based on parametric simulations, will be presented. We will analyze the impact of the PV array and battery capacity on the profitability of the system, for different external conditions like the selling/buying tariffs, the load profile and the geographical location.

Financial Impact of self-consumption

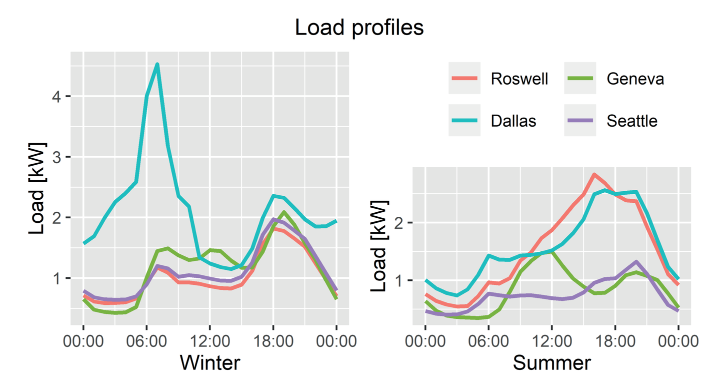


Values in this study

Parameter	Value
PV System costs	1250 Euro/kWp
Storage costs	250 Euro/kWh
Overhead costs	6000 Euro (5-25 kWp)
Feed-in tariff (FIT)	0.025 Euro/kWh
Consumption tariff (CT)	0.23 Euro/kWh
System lifetime	20 years

Other values lead to different limits for profitability
General approach does not change

Location and load profiles



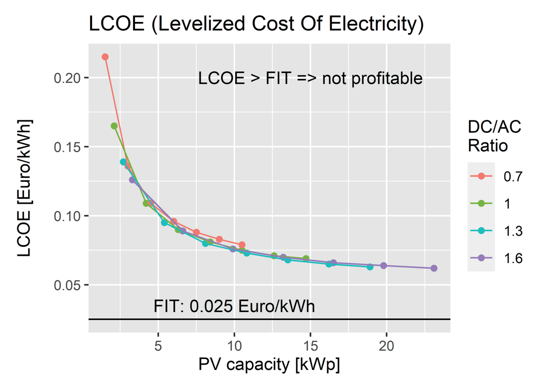
The shape of the Load profiles drives the rates of self-consumption E3 and E4

Peaks during day: Air conditioning
Peaks at early morning: electrical heating

Site	GHI	Load	Climate	AC
	kWh/m2/y	MWh/y		
Roswell	2095	9.7	Semi-arid	x
Geneva	1293	9	Temperate	
Dallas	1846	16.5	Humid subtropical	x
Seattle	1220	7.8	Temperate	

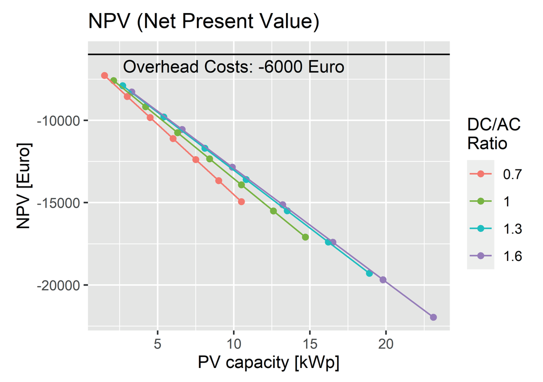
Sources of load profiles:
Geneva: BDEW, German Federal Association of Energy and Water
US: Office of Energy Efficiency & Renewable Energy (EERE)

Grid injection only



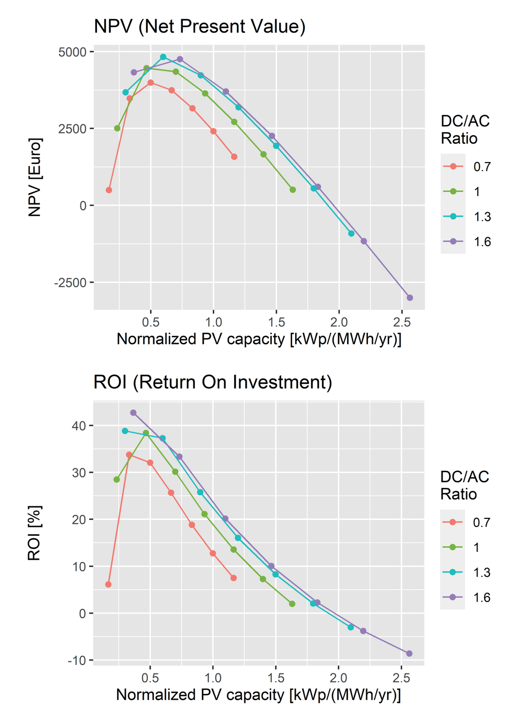
LCOE will not change with self-consumption
LCOE increases with battery capacity

NPV and ROI always calculated for system lifetime (20 years)



Direct Self-Consumption

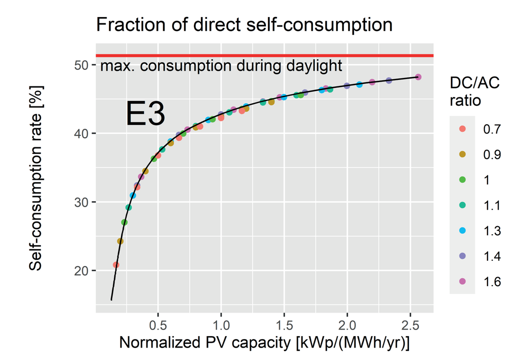
Optimization from individual simulations

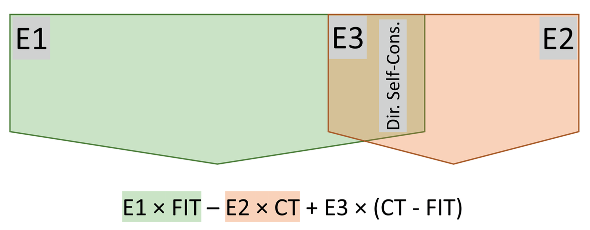


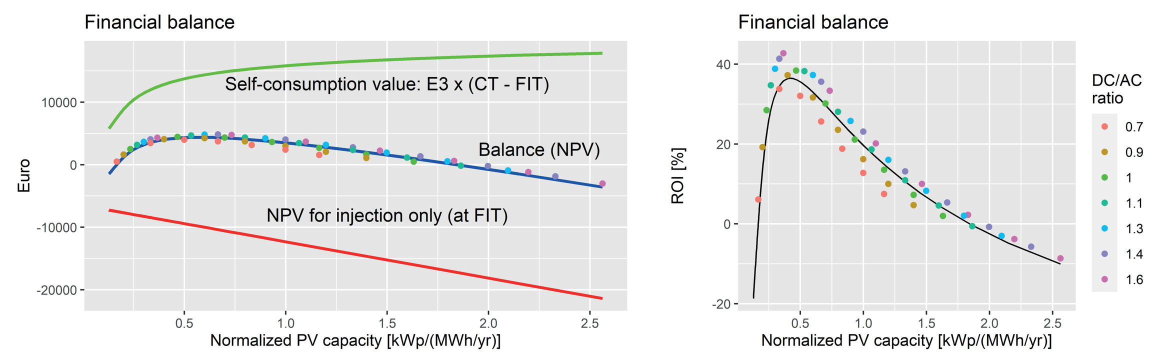
Optimal sizing similar

PV capacity normalized to total yearly consumption

Estimation from single simulation

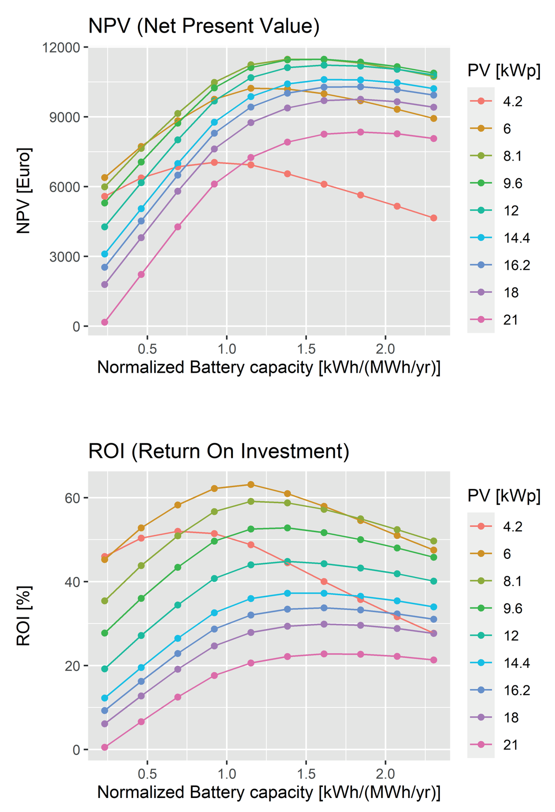






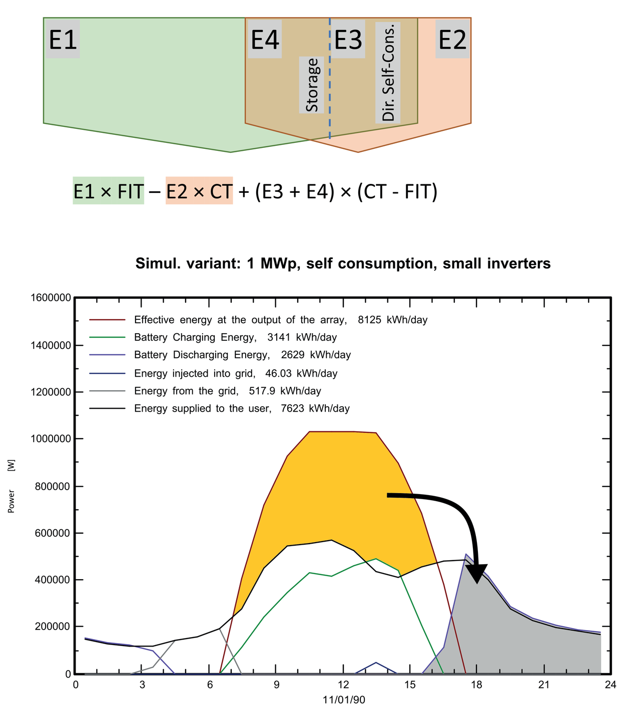
Self-consumption and Storage

Optimization from individual simulations



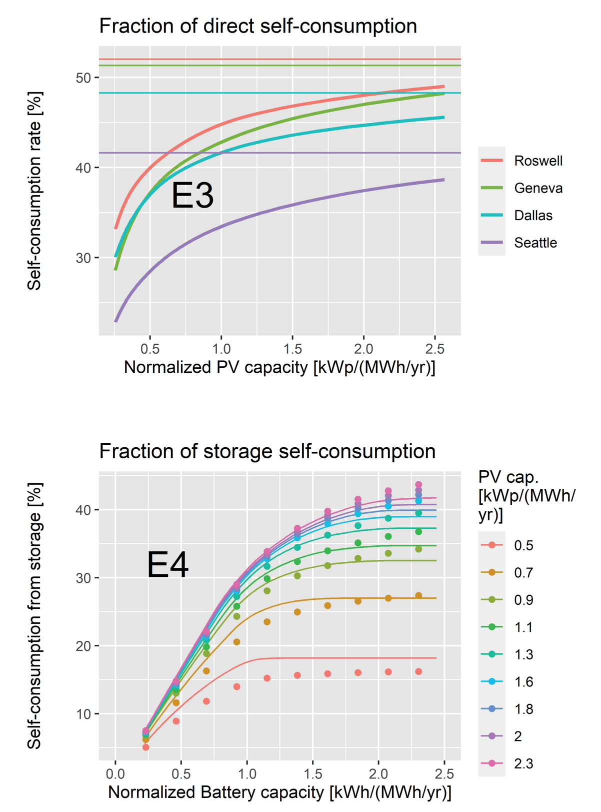
Battery capacity normalized to total yearly consumption

Estimation from single simulation

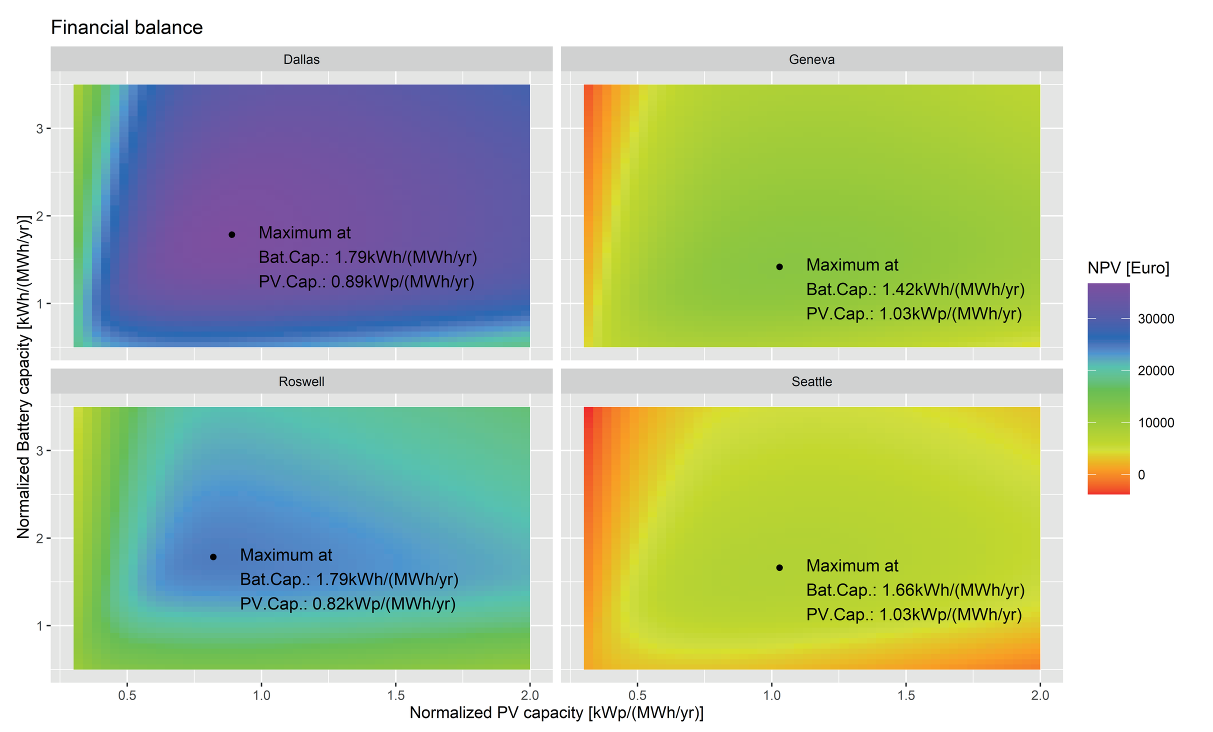


Self-consumption

Depends on load profile
Battery effectively extends PV generation into evening



Simple battery model:
Use daily overproduction to supply daily missing load



Comparison for different load profiles and climates:
When normalized to the total yearly consumption the optimal sizes are similar:
PV capacity: 0.8 – 1.0 kWp/(MWh/yr)
Battery capacity: 1.4 – 1.8 kWh/(MWh/yr)
This will change with different costs and tariffs!

Summary and Outlook

We presented a general way to optimize the sizing of a PV system with storage and self-consumption. The criteria for optimization were the maximization of either the net present value (NPV) or the return of investment (ROI). To understand the impact that self-consumption and storage have on the economic variables, we broke down the analysis into three steps. First, we considered the bare generation and selling of energy to the grid, to which we added the contribution of direct self-consumption. After this, we examined how adding storage to the system influences the economic variables.

The key to understanding these economics, are the curves describing the amount of self-consumption as function of the PV and battery capacity. We then showed, that for a given yearly load profile, these curves can be estimated from a single simulation. The optimal sizing obtained from this approximation corresponds to the detailed search of the optimum by performing many individual simulations.

The insights obtained in this study will be used to implement tools in the PVsyst software that will guide the user efficiently when optimizing a PV system with storage.