Economic Assessment and Business Models for Shared Use of Photovoltaic Systems in Multi-Apartment-Buildings - Case Studies for Austria and Germany

Introduction

Until recently in Austria, the usage of self-generated PV electricity was allowed in single-family homes only. Legislative amendements, come into force in July 2017, now authorize the shared use of PV systems in multi-apartment buildings too.

- This work aimes at assessing the economic viability of shared PV systems in Austria, considering different consumer objectives ranging from minimizing annual electricity costs to maximizing the self consumption rate.
- Therefore we assume a fictitious multi-apartment building with ten residential apartments (allocation of ten real household load profiles).
- An optimization model (MILP) is developed in Matlab using a multi-objective optimization (MOO) approach to combine conflicting consumer objectives.
- Optimizations are conducted for two scenarios:
  - Separate consideration of individual apartments (i)
  - Multi-apartment building considered as a total load (ii)
- Based on optimal-sized PV systems, profitability analyses are conducted. Further, we developed applicable business models for Austria.

Methodology

Problem (1)

Minimization of annual electricity costs:

$$EC_{min} = \min_{P_{peak}, e_{grid}, e_{pv2load}, e_{pv2grid}, b_{pv}} \sum_t (C_{var}(t)) + C_{pv\_peak} + C_{pv\_b} + c_{fix\_elec} \cdot X$$

$$C_{var}(t) = c_{var\_elec} \cdot e_{grid}(t) - e_{pv2grid}(t) \cdot p_{feed\_in}$$
$$C_{pv\_peak} = (i_{0pv} \cdot \alpha_{pv} + c_{clean}) \cdot P_{peak}$$
$$C_{pv\_b} = b_{pv} \cdot (c_{op} + c_{ins} + \alpha_{pv} \cdot c_{fix\_pv})$$

Problem (2)

Maximization of self-consumption (Minimization of annual grid consumption):

$$SC_{max} = GC_{min} = \min_{P_{peak}, e_{grid}, e_{pv2load}, e_{pv2grid}, b_{pv}} \sum_t e_{grid}(t)$$

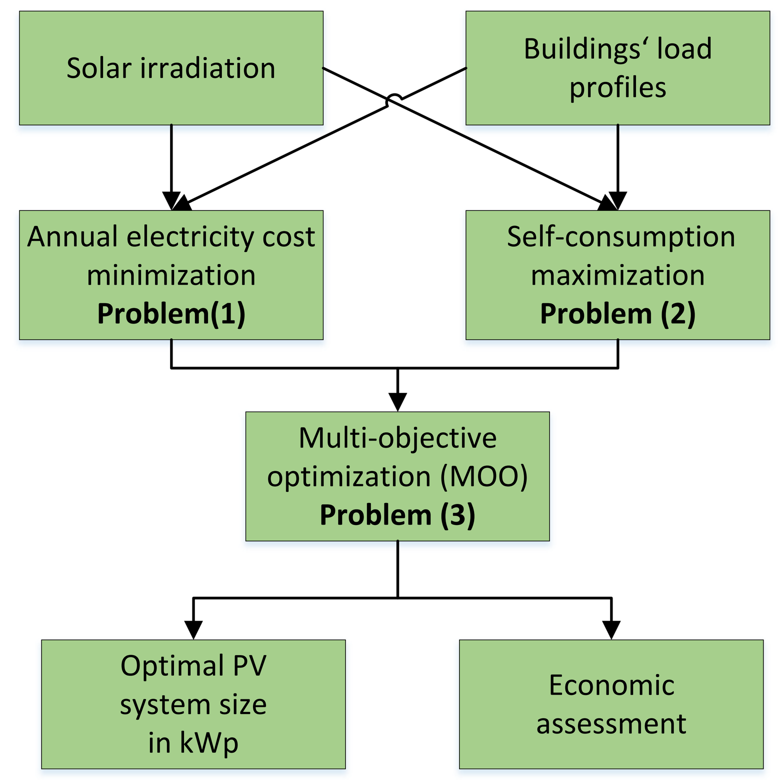
Problem (3)

Multi-objective optimization for conflicting objectives:

$$MO_{min} = \min_{P_{peak}, e_{grid}, e_{pv2load}, e_{pv2grid}, b_{pv}} \left(\gamma \cdot \frac{EC_{min}}{Result_{EC_{min}}(1)} + (1-\gamma) \cdot \frac{SC_{max}}{Result_{SC_{max}}(2)} \right)$$

Subject to:

$$e_{load}(t) == e_{pv2load}(t) + e_{grid}(t)$$
$$E(t) \cdot P_{peak} == e_{pv2load}(t) + e_{pv2grid}(t)$$
$$0 \leq P_{peak} \leq P_{peak\_max} \cdot b_{pv}$$
$$e_{grid}(t) \geq 0, \ e_{pv2grid}(t) \geq 0, \ e_{pv2load}(t) \geq 0$$



Nomenclature:

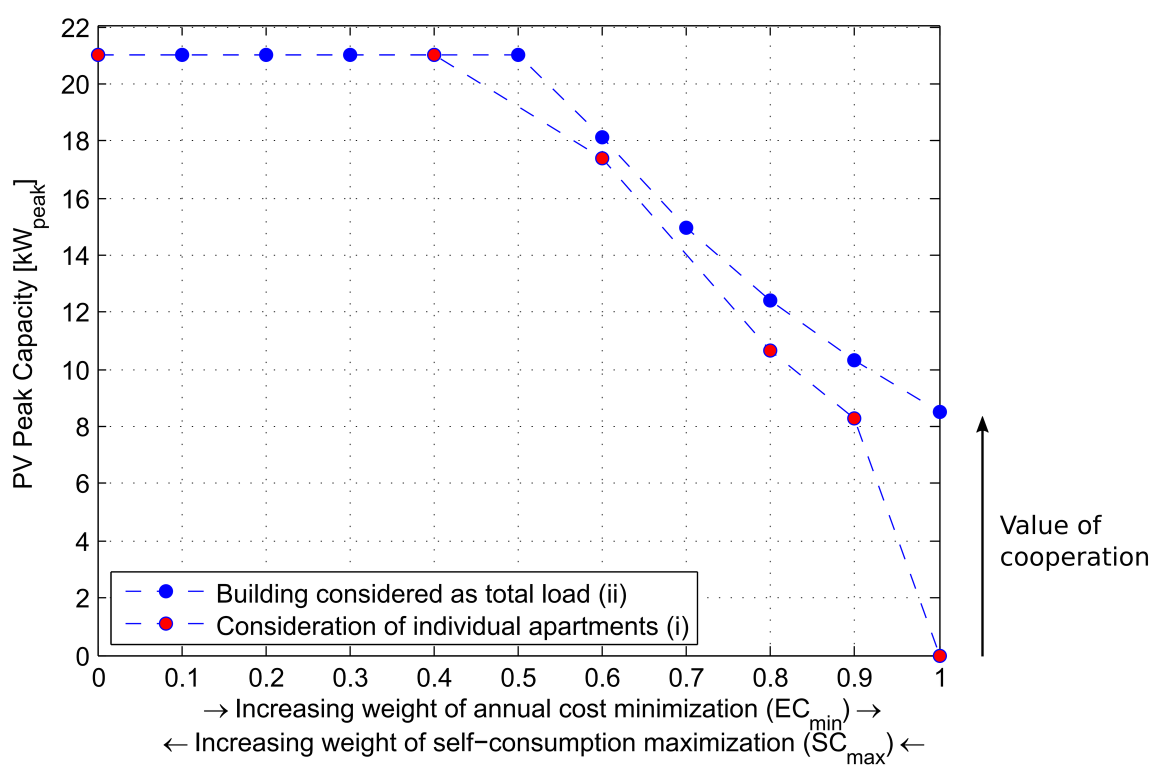
C_{pv_b}	Costs when PV installed [EUR/yr]
C_{pv_peak}	PV peak power dependent costs [EUR/yr]
C_{var}	Quantity dependent costs [EUR]
E	Electricity generated by PV system [kWh/kW$_{peak}$]
EC_{min}	Annual electricity costs minimization [EUR/yr]
GC_{min}	Annual grid consumption minimization [kWh/yr]
SC_{max}	Annual self-consumption maximization [kWh/yr]
MO_{min}	Multi-objective target function
P_{peak}	PV peak power [kW$_{peak}$]
P_{peak_max}	Maximum PV peak power [kW$_{peak}$]
$Result_{ECmin}$	Result of annual electricity cost minimization [EUR/yr]
$Result_{SCmax}$	Result of self-consumption maximization [kWh/yr]
X	Number of apartments
b_{pv}	Binary variable whether PV system is implemented

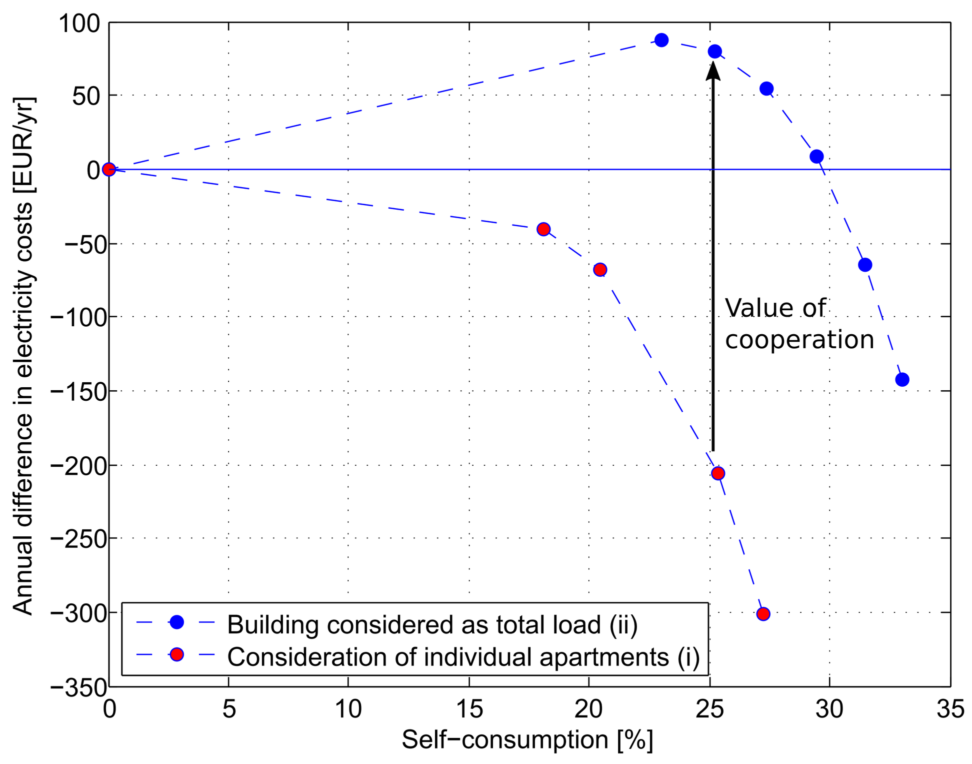
α_{pv}	PV system's annuity factor [1/yr]
c_{clean}	PV system cleaning costs [EUR/kW/yr]
c_{fix_elec}	Fixed costs of electricity [EUR/yr]
c_{fix_pv}	Fixed costs for installing a PV system [EUR]
c_{ins}	Annual insurance costs of PV system [EUR/yr]
c_{op}	Operating costs of PV system [EUR/yr]
c_{var_elec}	Variable component of retail electricity price [EUR/kWh]
γ	Weighting factor
e_{grid}	Electricity purchased from the grid [kWh]
e_{load}	Load [kWh]
$e_{pv2grid}$	Amount of PV electricity fed into grid [kWh]
$e_{pv2load}$	Electricity from PV system used to cover the load [kWh]
i_{0pv}	Specific investment costs of PV system [EUR/kW$_{peak}$]
p_{feed_in}	Price for electricity-feed into the grid [EUR/kWh]
t	time $\in \{0...35040\}$

Results

Case study Austria

- Retail electricity price: $c_{fix\_elec} = 65\,\text{EUR/yr}$, $c_{var\_elec} = 0.148\,\text{EUR/kWh}$
- Taking into account synergy effects by considering the building as a total load (ii) has a positive impact on the results leading to larger optimal PV system sizes and therefore to a higher cost saving potential.
- PV system sizes aiming at 100 % cost minimization show that by taking into account synergy effects (ii) marginal profitability can be achieved. For consideration of individual apartments (i), no PV system is built, as there doesn't exist any cost saving potential in this scenario.

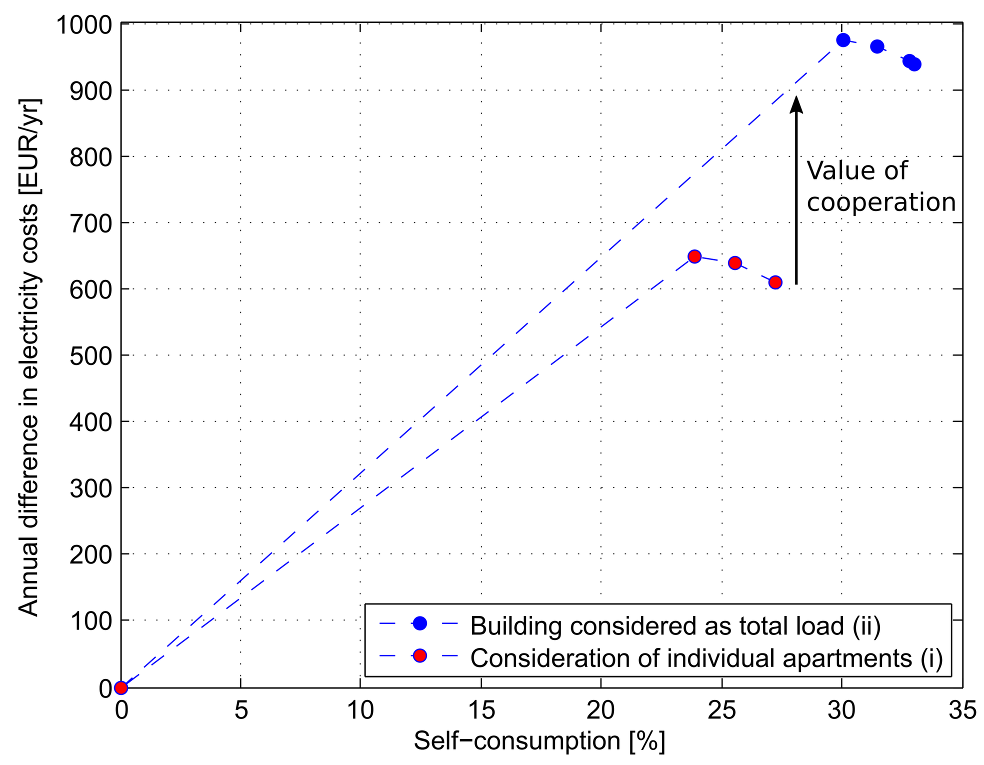




- The difference in annual electricity costs ($C_{diff} = C_{without\_PV} - C_{with\_PV}$) calculated for individual apartments (i) is clearly negative, meaning additional costs occur when installing a PV system.
- For the building considered as a total load (ii) costs can be saved to a moderate extent due to taking synergy effects into account.
- Profitability of shared use of PV systems is on the border. Additional occuring costs range - in the worst case - between 150 EUR/yr - 300 EUR/yr. These amounts have to be apportioned among ten consumers, leading in the worst case to marginal additional costs between 15 EUR/yr - 30 EUR/yr per household. → Need for cost/revenue allocation methods.

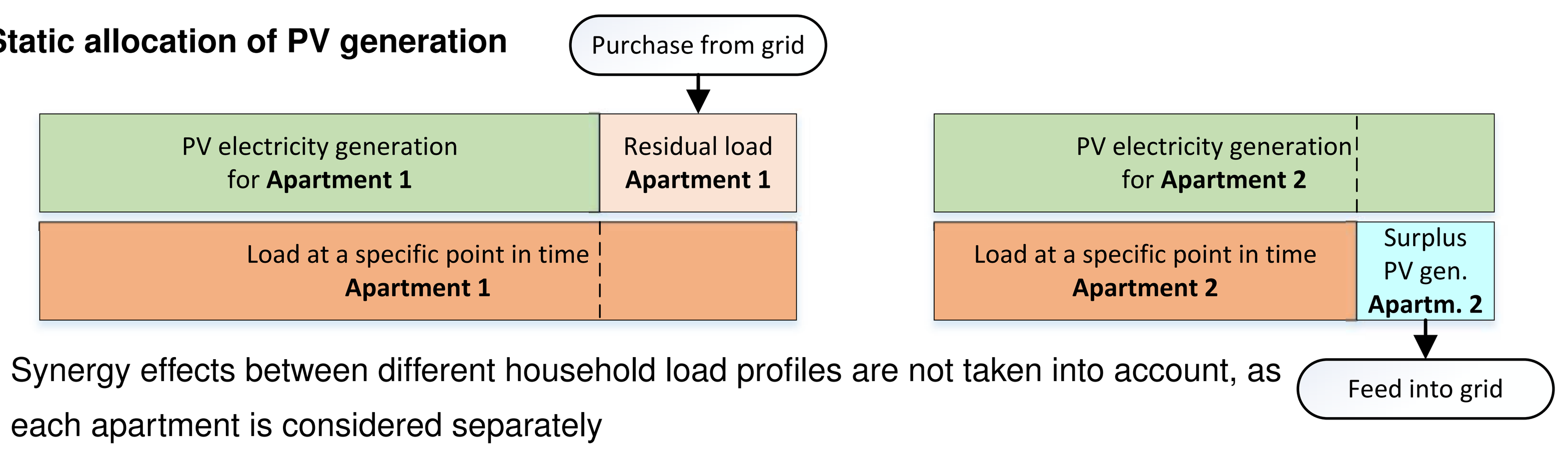
Case study Germany

- Retail electricity price: $c_{fix\_elec} = 50\,\text{EUR/yr}$, $c_{var\_elec} = 0.2732\,\text{EUR/kWh}$
- The difference in annual electricity costs ($C_{diff} = C_{without\_PV} - C_{with\_PV}$) is clearly positive for individual apartments (i) and even more for the building considered as a total load (ii).
- Shared use of PV systems is therefore highly profitable in the German case.
- The high cost saving potential is caused by the high variable component of the German retail electricity price, due to the high renewable energy surcharge, used to cover subsidy costs for different renewables.



Business Models for Austria

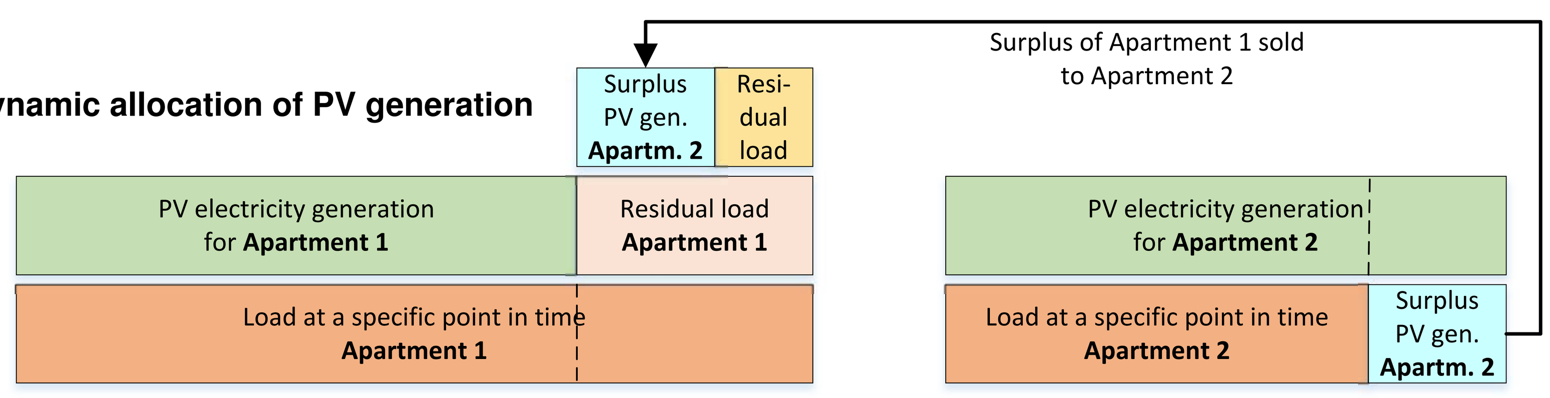
Static allocation of PV generation



Synergy effects between different household load profiles are not taken into account, as each apartment is considered separately

- PV electricity generation is allocated proportionately to each apartment
- Surplus PV electricity of one apartment can not be used by other parties and has to be fed into the grid
- No electricity trade between consumers of the same building possible

Dynamic allocation of PV generation



Synergy effects are taken into account as the building is considered as a total load (no consideration of individual apartments)

- Surplus PV electricity of apartments is not fed into the grid but rather used to cover the residual load of other parties
- Electricity trade between consumers of the same building possible
- Higher profitability and higher self-consumption rate compared to static allocation business model

Conclusions and Outlook

- The economic viability of shared PV systems strongly depends on the absolute value of the variable component of the retail electricity price, what is emphasised by comparison of the Austrian and German case study.
- Further adjustments of the legal framework will be necessary in the near future, in order to further expand existing business models.
- The development of profitable business models for all participants, as well as comprehensible accounting and billing methods will require special focus in future analyses.
- Solutions for consumers refusing participation in the shared PV concept have to be developed, as do regulations to deal with the consumers' freedom of choice.

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