Operation strategies of battery energy storage systems considering flexible loads

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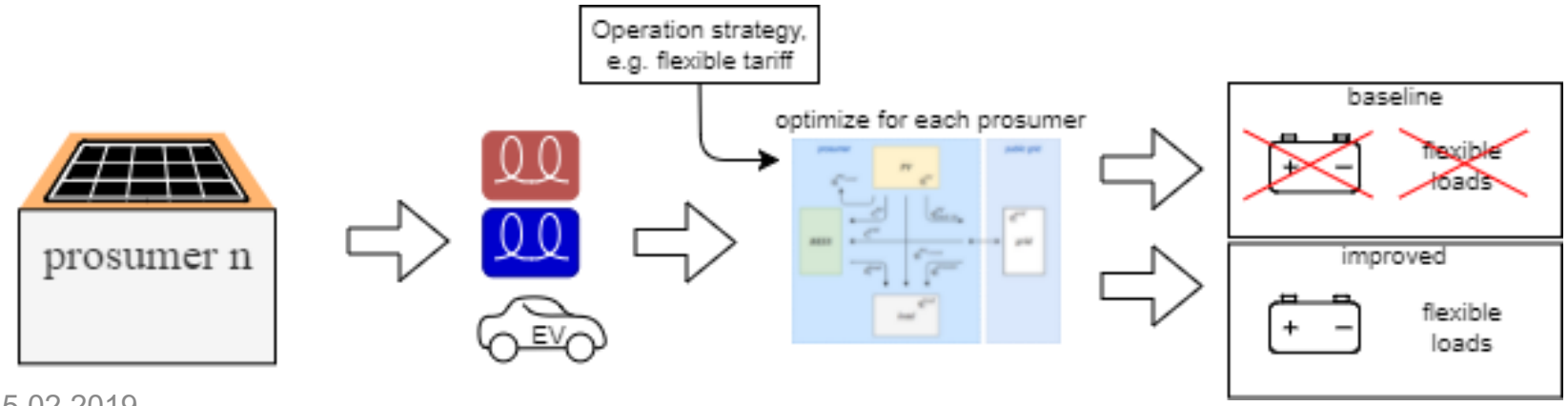
SHIFTING THE LIMITS

Agenda

- **Approach**
- Data basis
- Methodology
- Results

Approach

- Data basis: 103 consumer with PV production (prosumer)
- Extract flexible loads
- “Test” different strategies, e.g. flexible energy tariffs
- Optimize “prosumer-centric” for each prosumer
  - Baseload: no BESS, no flexibilities
  - Improved: BESS, flexibilities
- Analyze average impact on substation and prosumer



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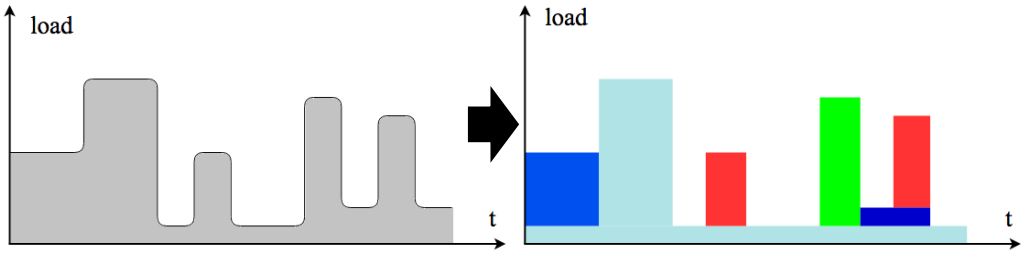
Data basis: Loads

- 103 measured load profiles
- Extract* recognised loads out of load profile for each prosumer



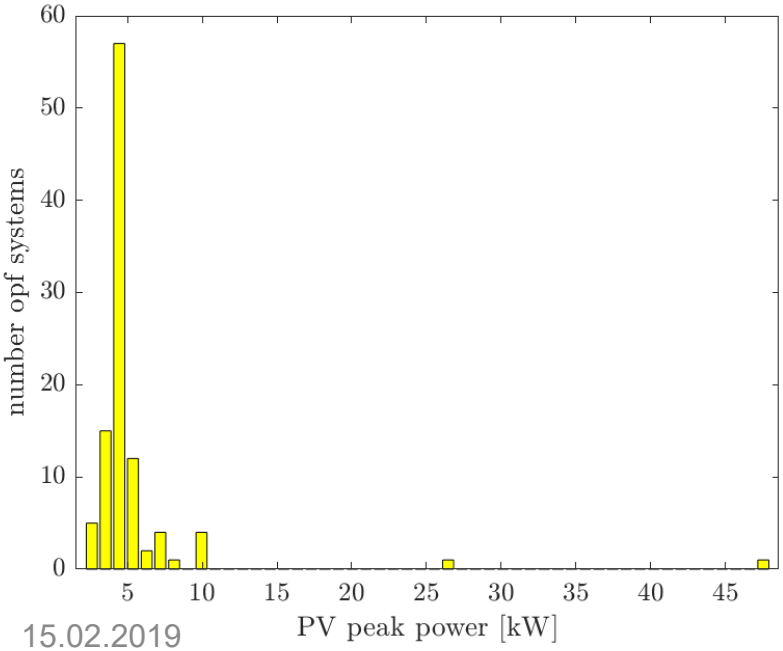
- Assign shifting potential** for each technology
  - Charging power of EVs may be optimized if plugged in

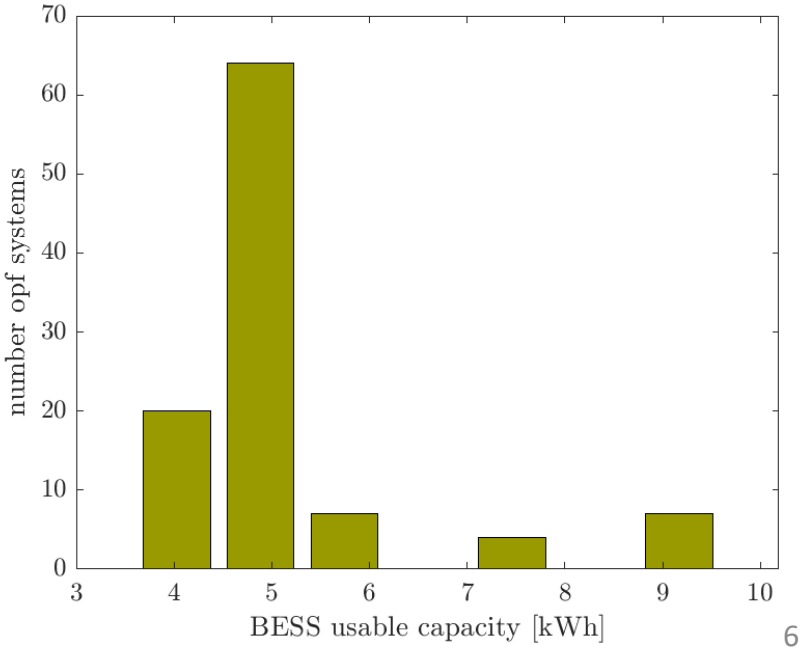
Flexible load	Shifting potential (h)
Refrigerator	1
Freezer	4
Hot water boiler	12
Electric radiator	1
Heat pump	1

Sources:
*Franz Zeilinger; Methodology for the automatic evaluation and comparison of distribution network management concepts (2019)
**Shifting Potential: de Bruyn et al.; Load shifts in household, industry, commerce and municipal infrastructure - potential analysis for smart grids (2014)

Data basis: PV and BESS

- 103 PV systems
- Simulate for every PV system a residential BESS according to their peak-power
- Average system
  - PV: 5 kWp, BESS: 5 kWh / 5 kW





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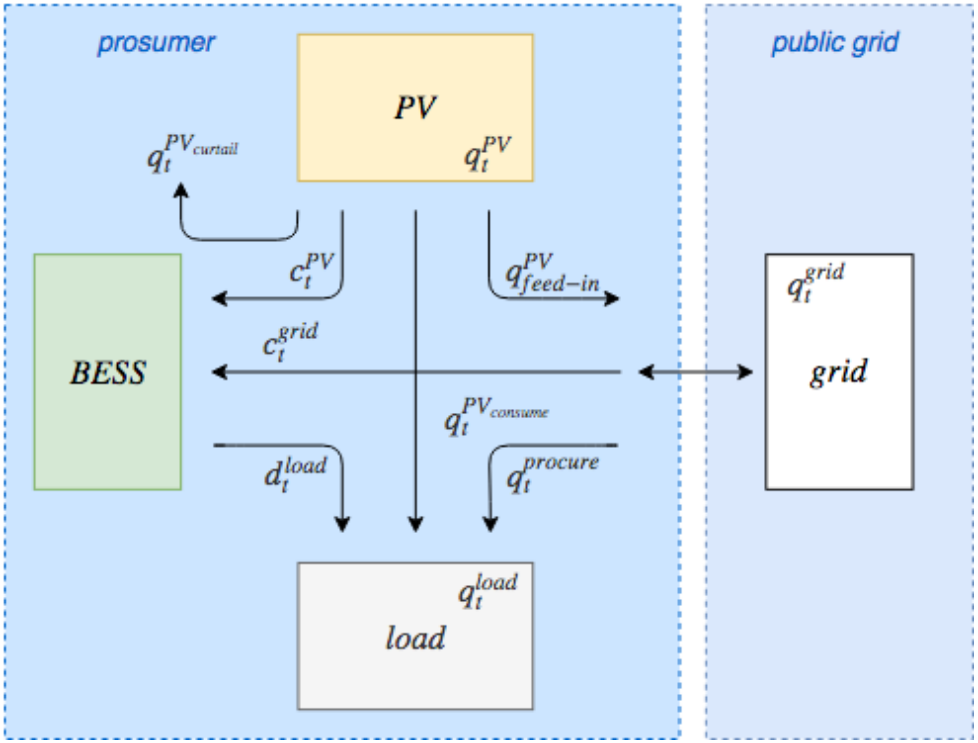
Methodology: Optimization for every prosumer

- Target function: Prosumer-centric optimization to minimize operational costs

$$\min\left(\sum_t\left[\underbrace{\left(q_t^{procure}+c_t^{grid}\right)\cdot p_t^{procure}-q_t^{feed-in}\cdot p^{PV}}_{\text{energy costs}}\right]+\underbrace{P_{\max}^{feed-in}\cdot p^{feed-in_{kW}}+P_{\max}^{procure}\cdot p^{grid_{kW}}}_{\text{power costs}}\right)$$



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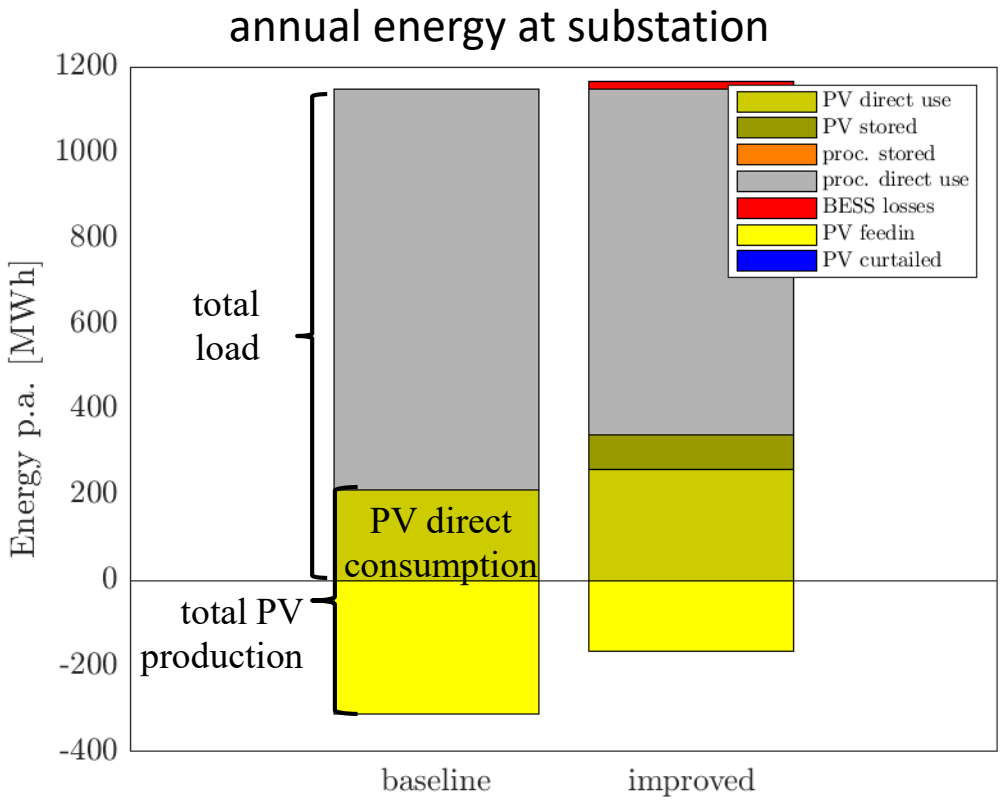
Operation strategy: maximize self-consumption

- Standard OS in storage systems
- Increased self-consumption due to BESS and flexible loads

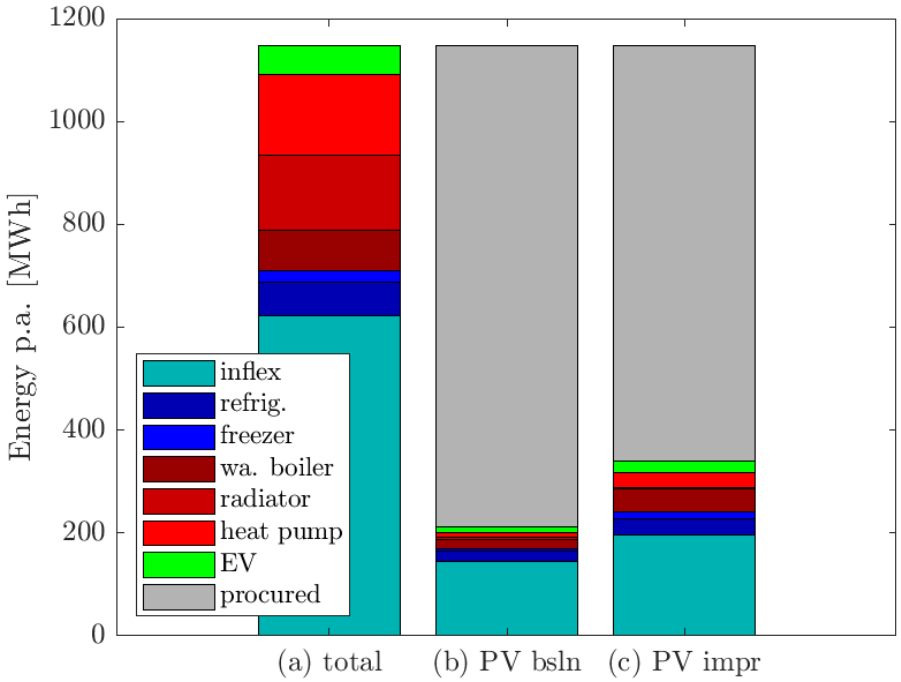
change baseline to improved	
self-consumption	From 40 % to 68 %
direct PV-consumption	22%

change of operational costs baseline to improved	
percentage	-16%
per prosumer	-180 EUR



Loads

- Individual loads have different behaviour
- Heat pump almost triples PV-consumption



Increase of PV energy consumption by load type, baseline to improved

inflex	35%
refrig.	77%
freezer	110%
wa. boiler	159%
radiator	2%
heat pump	187%
EV	95%

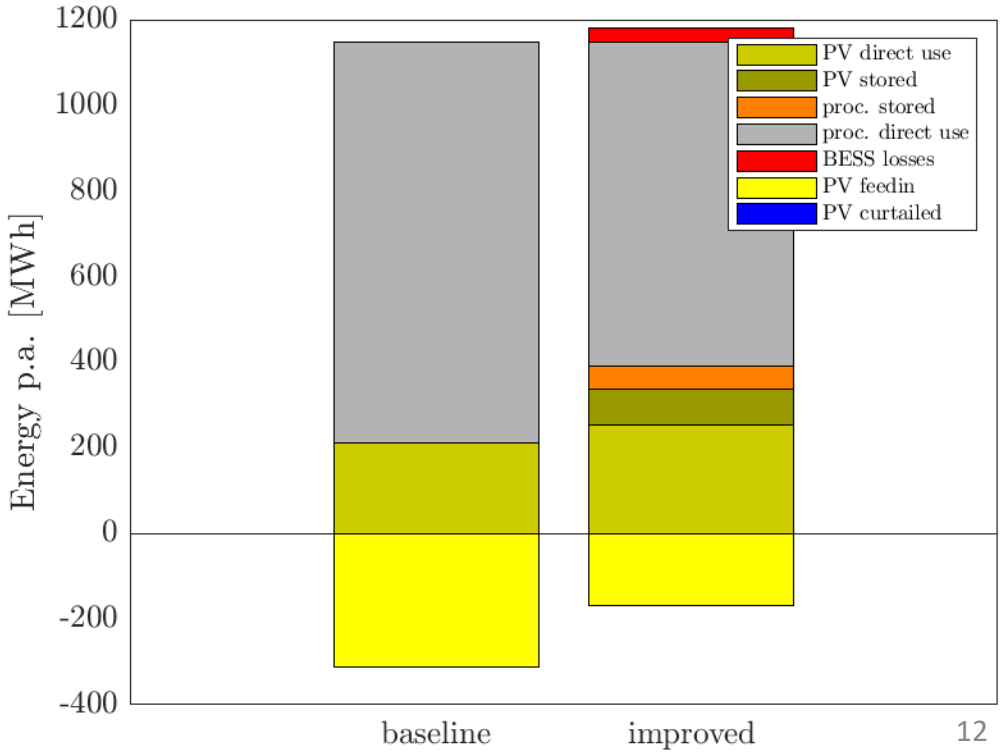
(a) Energy consumption of all loads
(b) Direct PV energy consumpton
(c) Direct and indirect PV energy consumption

Operation strategy: Flexible energy tariff

- Energy price: EPEX day-ahead of 2016
- Energy procured from grid and stored in BESS

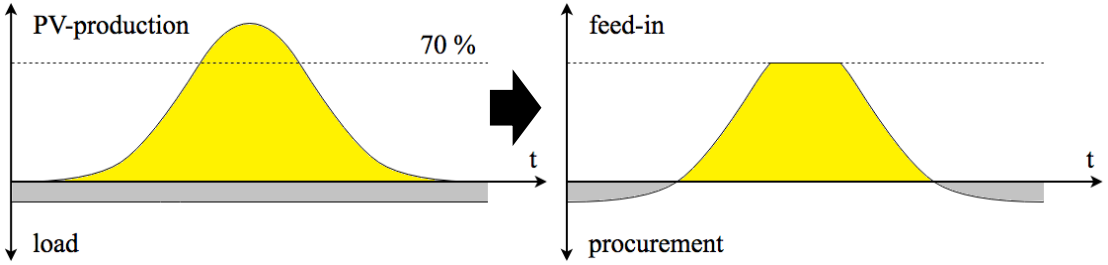
average procurement price [EUR / MWh]	
Baseline	33
Improved	26

change of operational costs baseline to improved	
percentage	-16%
per prosumer	-120 EUR

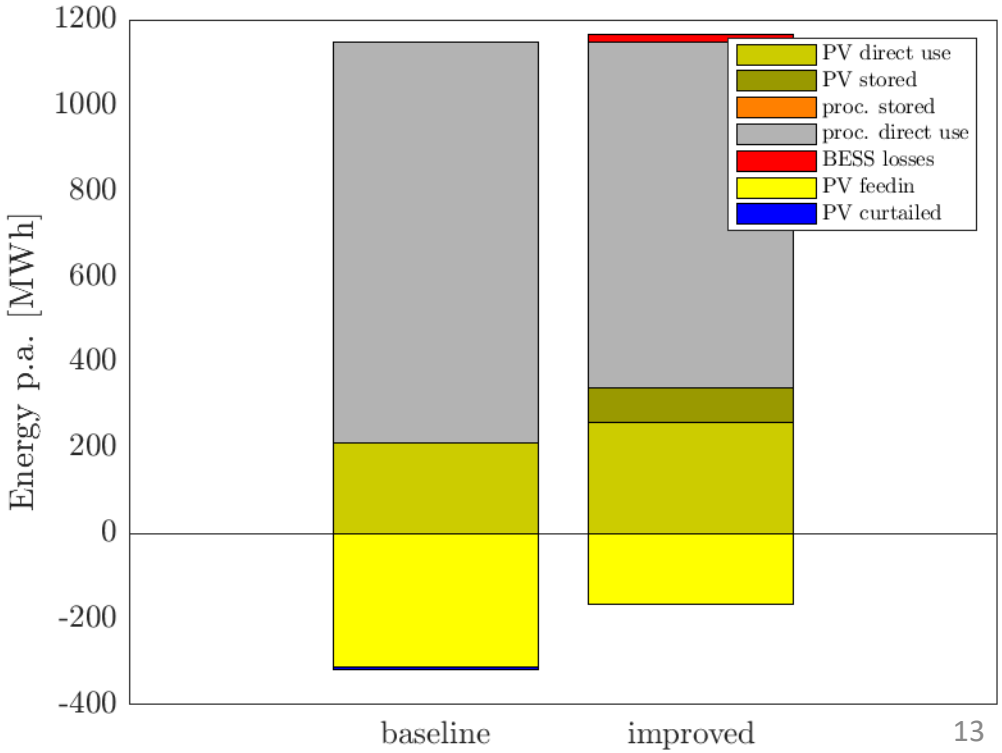


Operation strategy: 70 % curtailment

- Feed-in curtailment at 70 % of PV-peak power

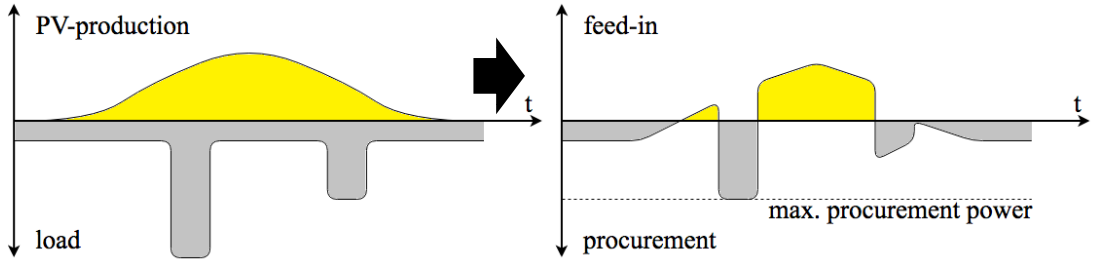


	baseline	improved
energy curtailed	0.76% (39 kWh per prosumer)	none



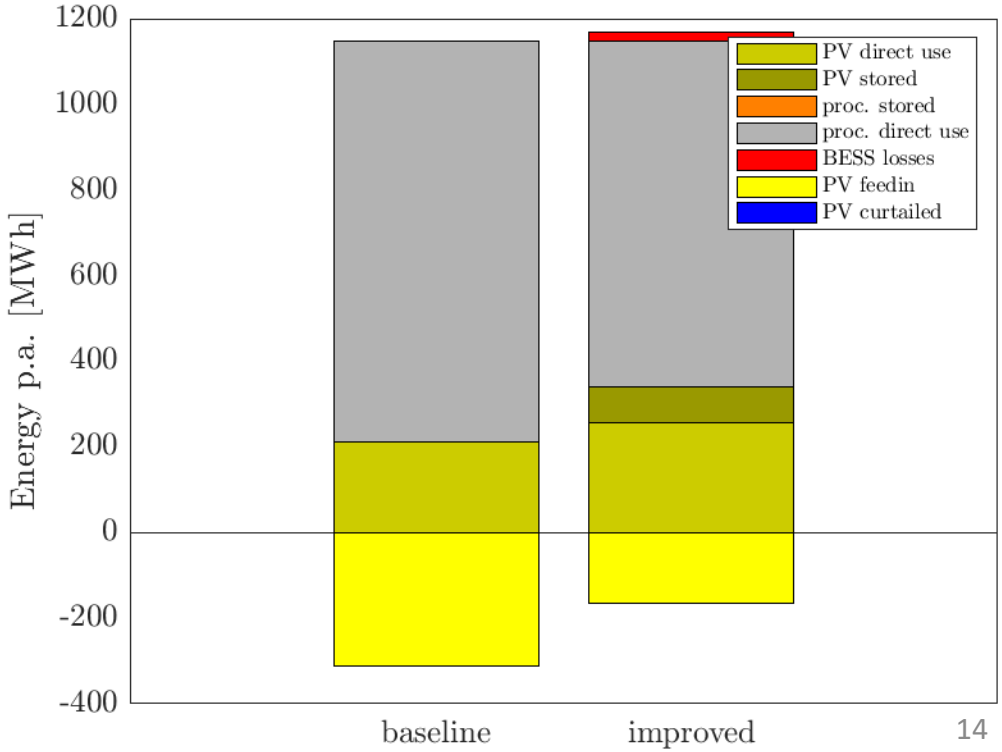
Operation strategy: Procurement power prizing

- power price for maximum annual procurement: 40 EUR / kW



Max. annual procurement power	
baseline	616 MW
impoved	578 MW

Change of operational costs baseline to improved	
percentage	-22%
per prosumer	-276 EUR



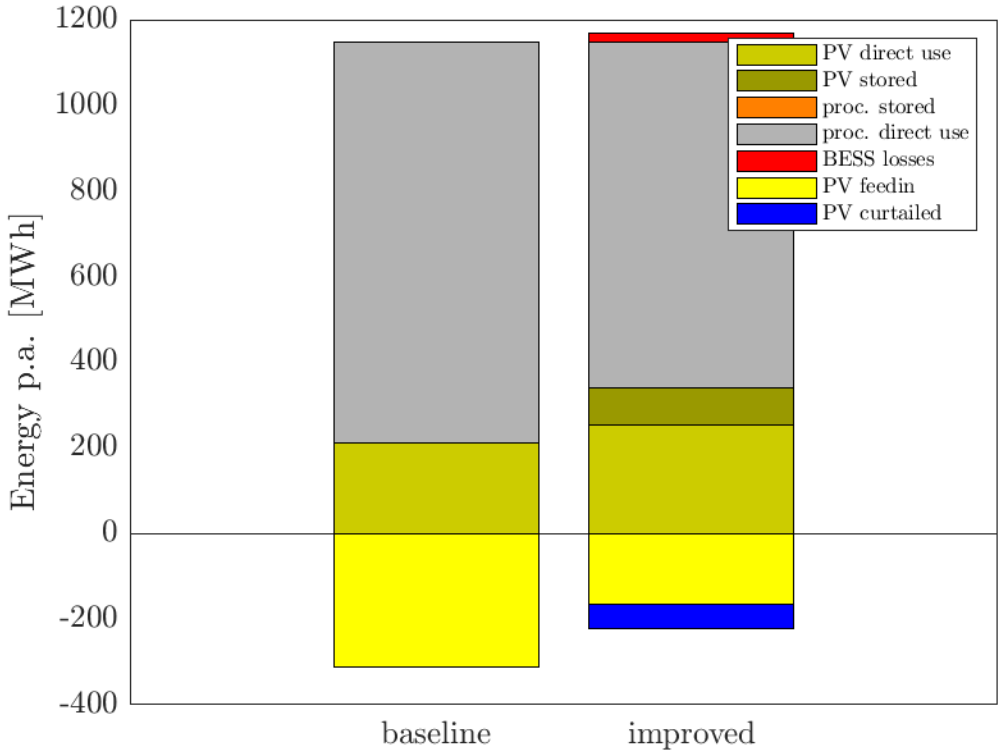
Operation strategy: Feed-in power prizing

- power price for maximum annual feed-in:
  40 EUR / kW

	baseline	improved
energy curtailed	none	10.7 % 276 kWh / prosumer

Max. annual feed-in power	
baseline	267 MW
impoved	23 MW

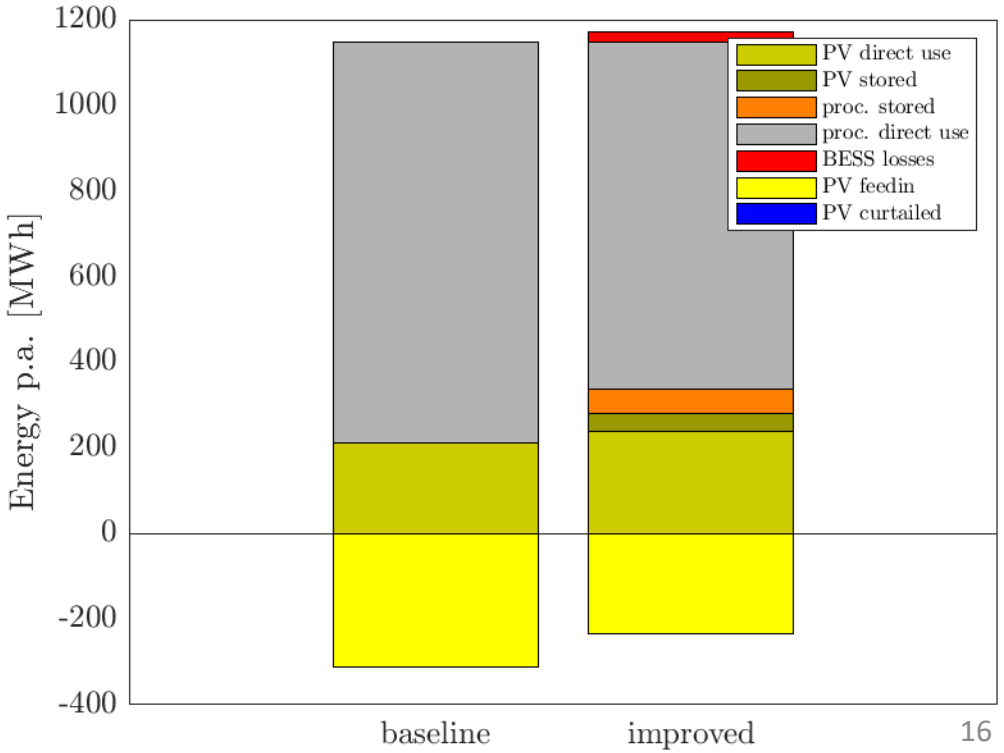
Change of operational costs baseline to improved	
percentage	-21%
per prosumer	-231 EUR



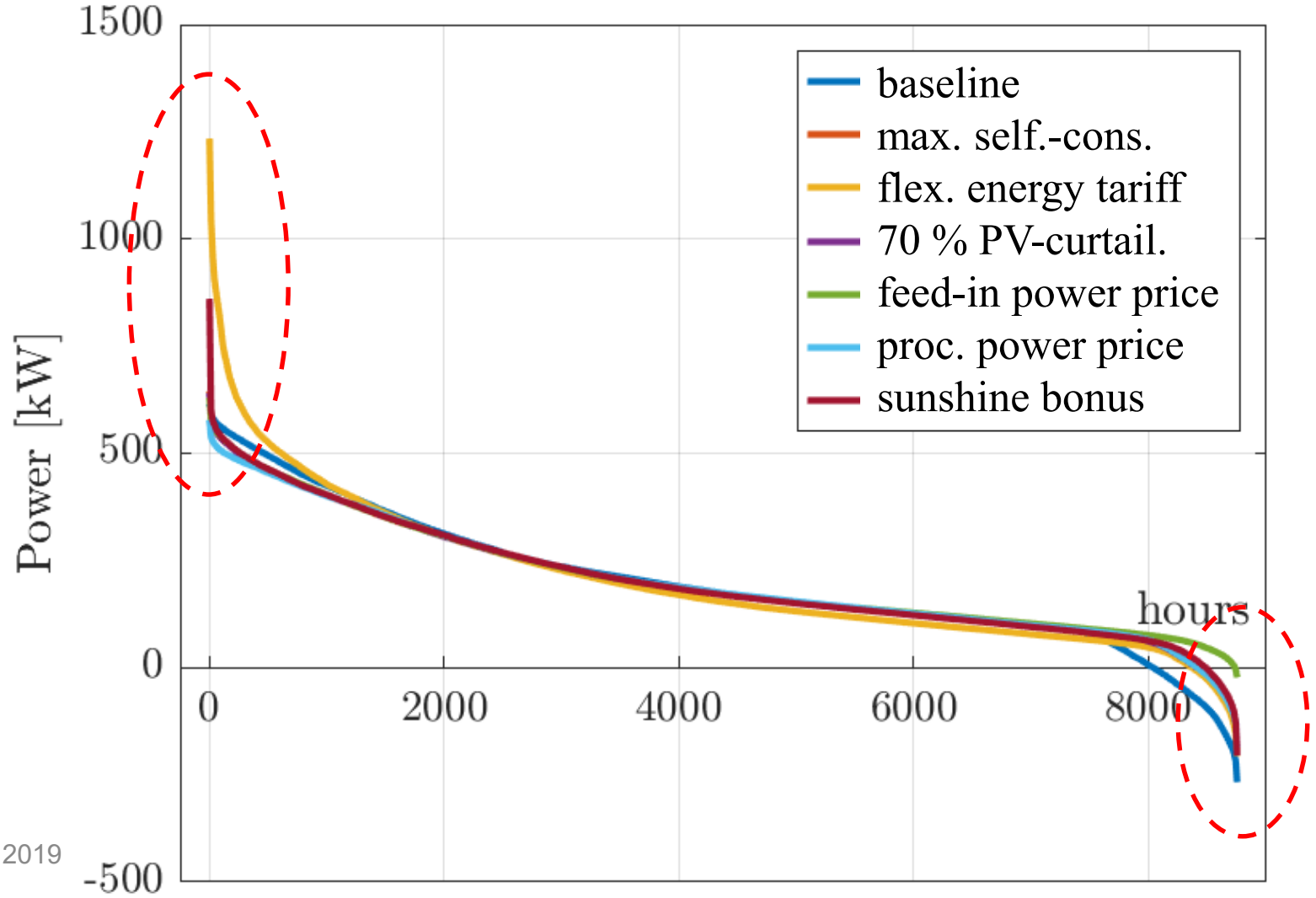
Operation strategy: Sunshine bonus

- Incentive for regional PV consumption
- applies if the total regional PV production exceeds 50 % of installed capacity
- bonus: 100 EUR / MWh

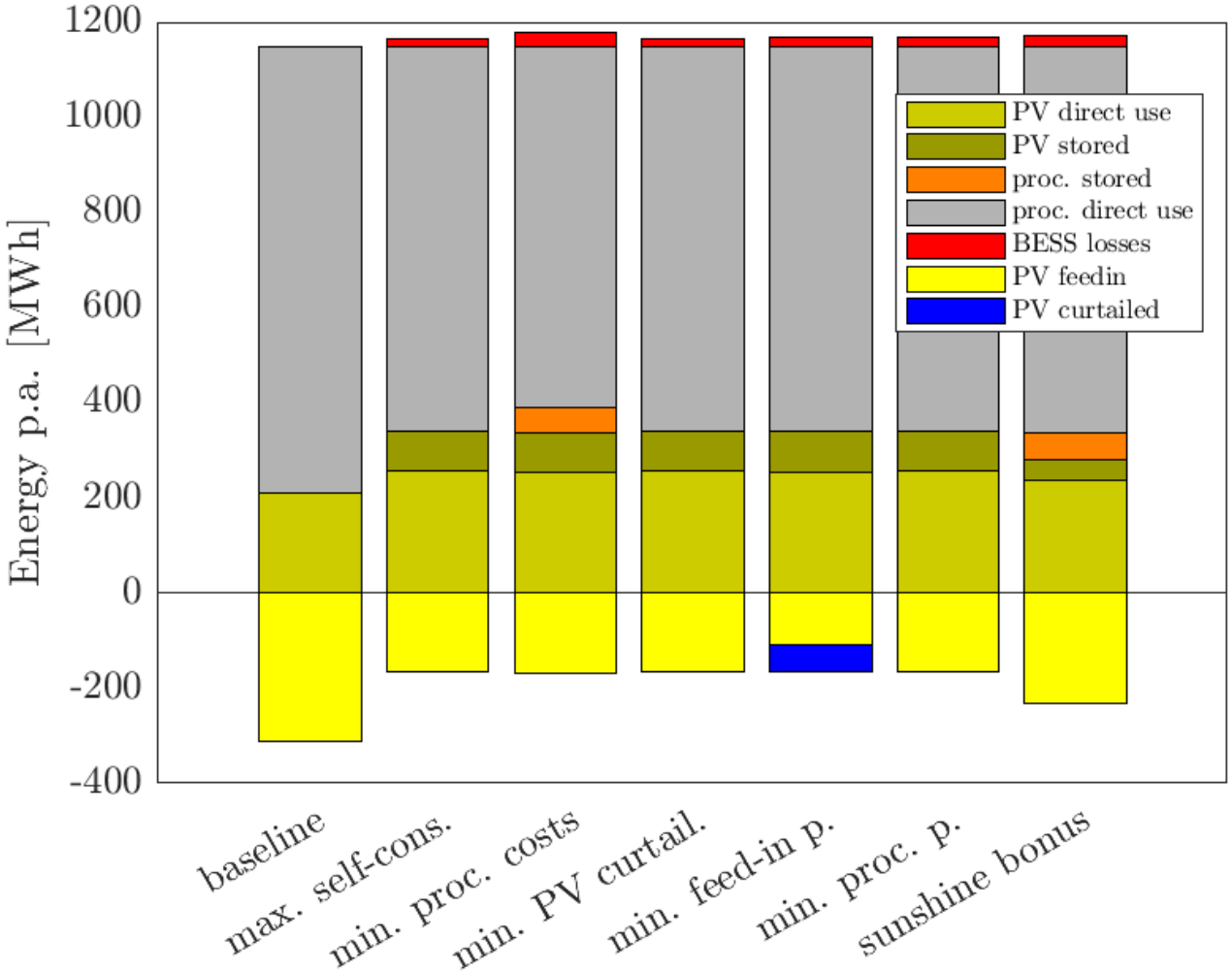
	baseline	improved
Sunshine bonus per prosumer	28 EUR	54 EUR
Self-consumption	40 %	62 %



Duration curve of power for all prosumer



Energy for each operation strategy



Summary and conclusions

- Flexibilities participated to increase self-consumption
- BESS and flexible loads reduce operational energy and grid costs (for prosumers) - about 200 EUR p.a.
- 70 % feed-in reduction has almost no influence (Baseline >1 % curtailment)
- Procurement power with BESS is not very sensitive to power pricing

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Integration of Loads and Electric Storage Systems into Advanced Flexibility Schemes for LV Networks

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