Impacts of a forecast-based operation strategy for grid-connected PV storage systems on profitability and the energy system

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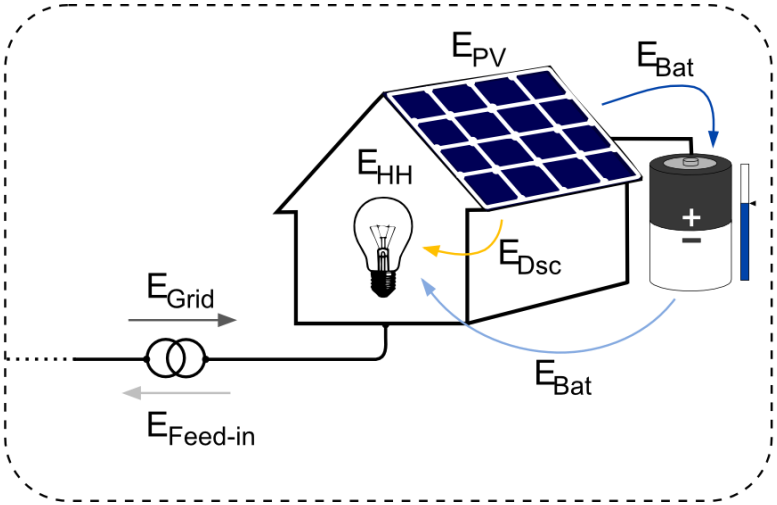
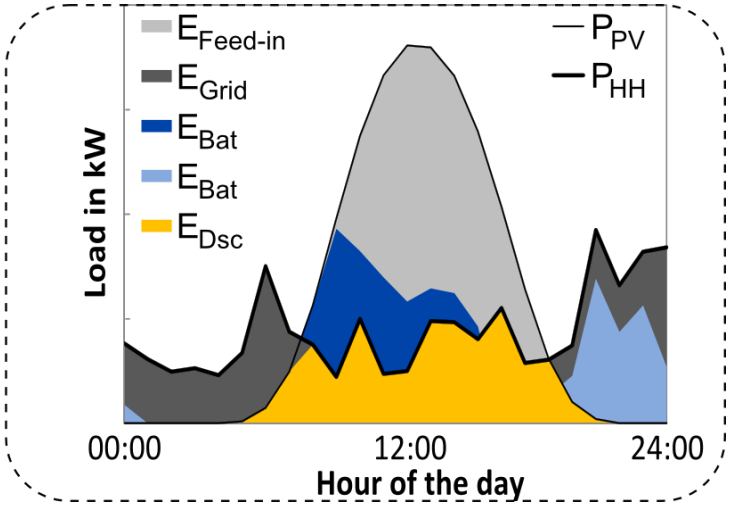
Agenda

- Battery enhanced self-consumption
- Model description
  - Battery operation
  - Load and Generation forecasting
- Results
  - Forecasting results
  - Battery operation
  - Economic implications
- Discussion and Conclusions

Battery enhanced self-consumption





- Electricity purchase price: **29.1 EUR-ct/kWh**
- Feed-in remuneration: **5.0 – 19.8 EUR-ct/kWh** (hourly, based on market premium tariff)

  Feed-in remuneration = Spot market price (hourly) + Market premium (monthly)

➔ Electricity purchase price > Feed-in remuneration → storage primarily for self-consumption

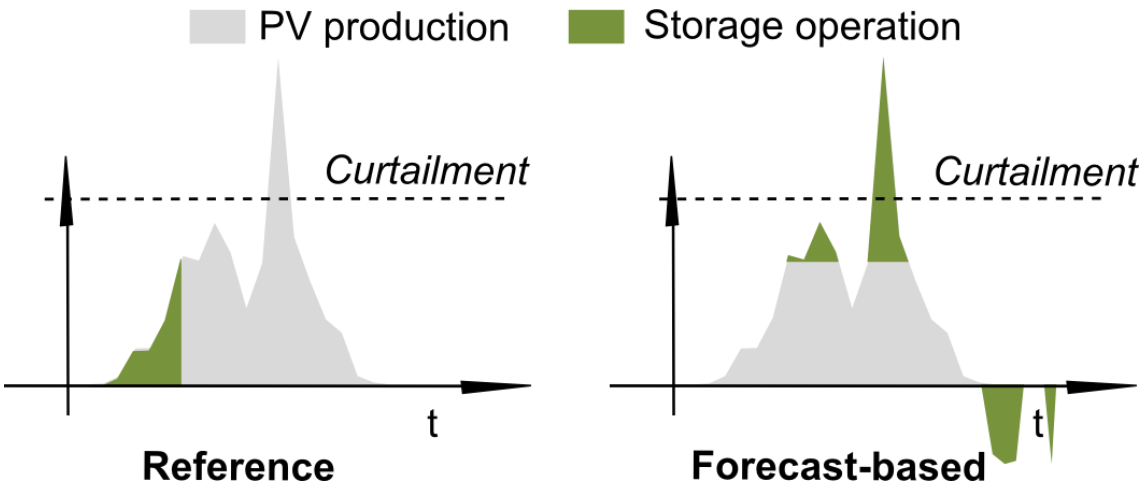
➔ Incentive to shift feed-in to hours with high remuneration

Battery operation

Comparing battery operation strategies:

- **Reference**: Simple relays-based storage controller as reference system
- **Forecast-based**: Control signal (forecasted) to reduce peak feed-in load and shift feed-in to hours with higher remuneration; no possibility of arbitrage

Constraint: Under current legislation in Germany: curtailment of feed-in >70% of peak power

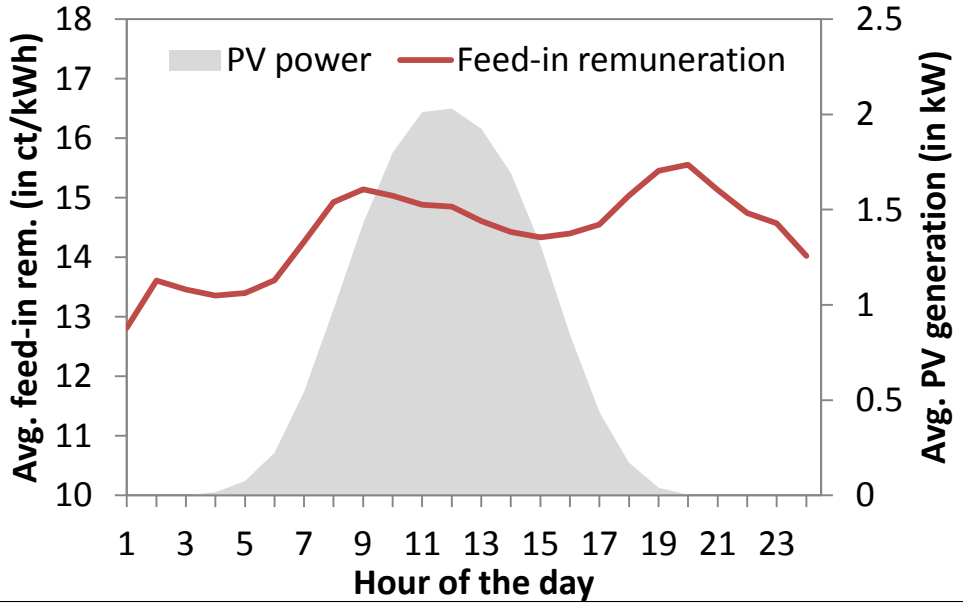


Battery operation

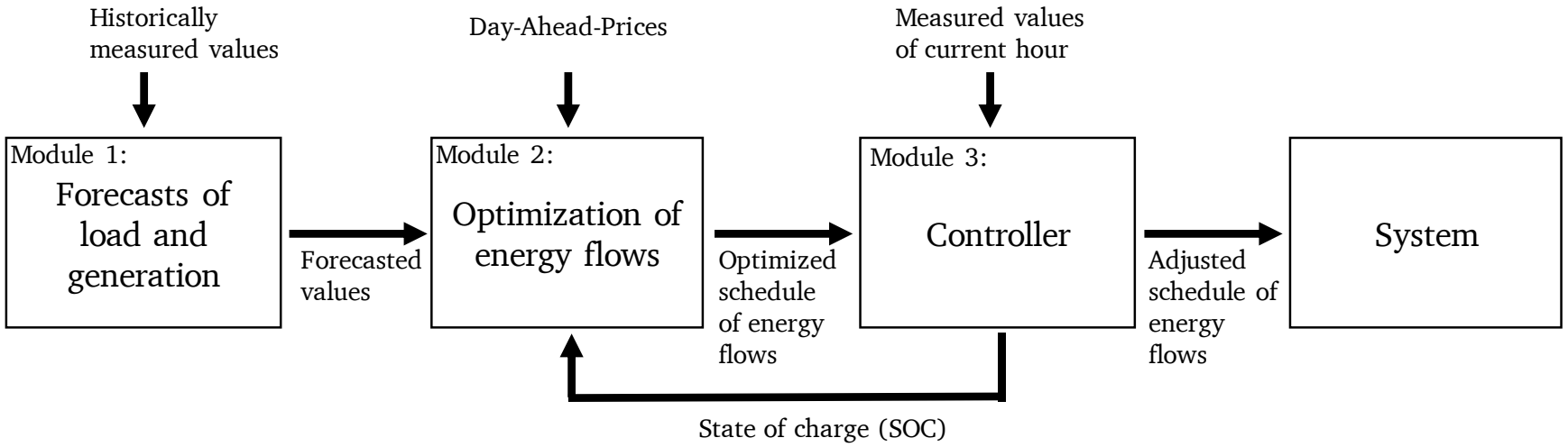
Comparing to cases for evaluation of forecast-based algorithm:

- **Reference**: Simple relays-based storage controller as reference system
- **Forecast-based**: Control signal (forecasted) to reduce peak feed-in load and shift feed-in to hours with higher remuneration; no possibility of arbitrage

Under current legislation in Germany: curtailment of feed-in >70% of peak power

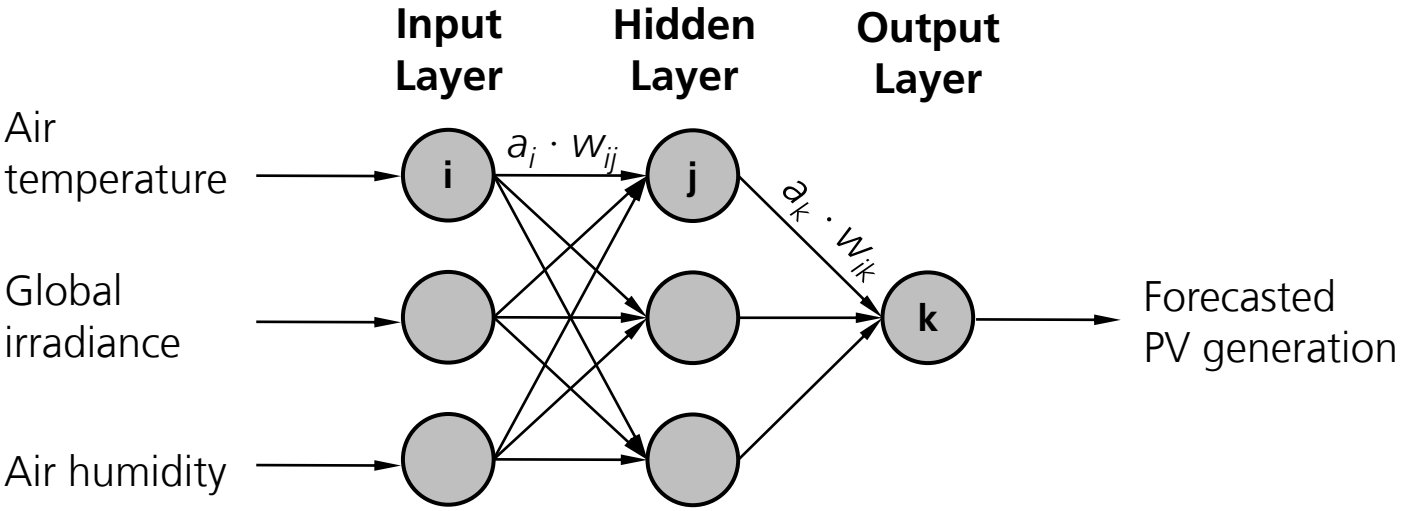


Overview forecast-based storage operation



- Self-consuming household with grid-connected PV + Battery system
- Optimization with rolling horizon, 24 h optimization interval, hourly basis

Load and generation forecast
Artificial neural network

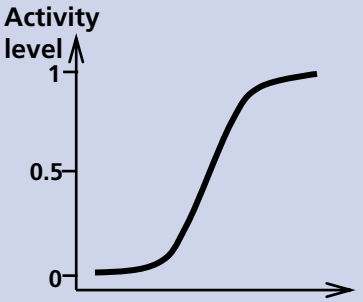


Number of neurons and layers based on Kern (2013)

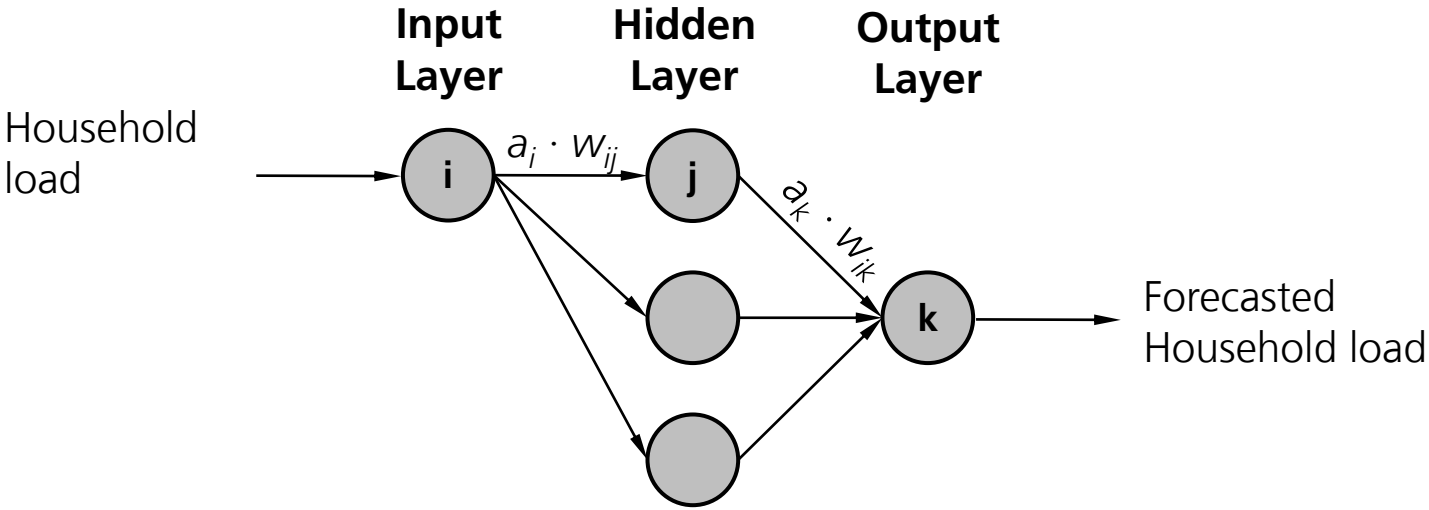
$Input_j = a_i \cdot w_{ij}$

a_i: activity level, the activity level is a function of the neuron *i*'s output

w_{ij}: weight between neurons *i* and *j*; the weight is modified based on the presented training data (*backpropagation*)



Load and generation forecast
Artificial neural network



$Input_i = a_i \cdot w_{ij}$

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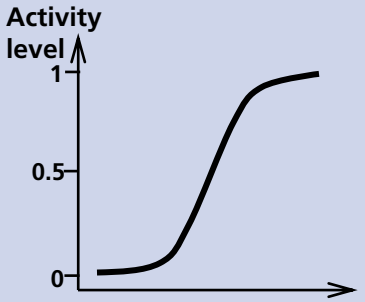
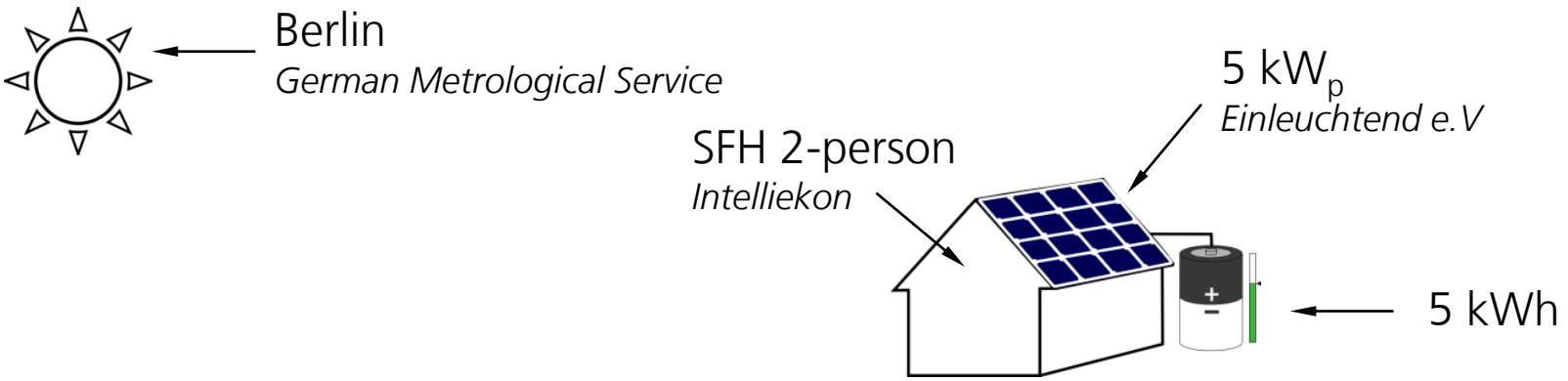


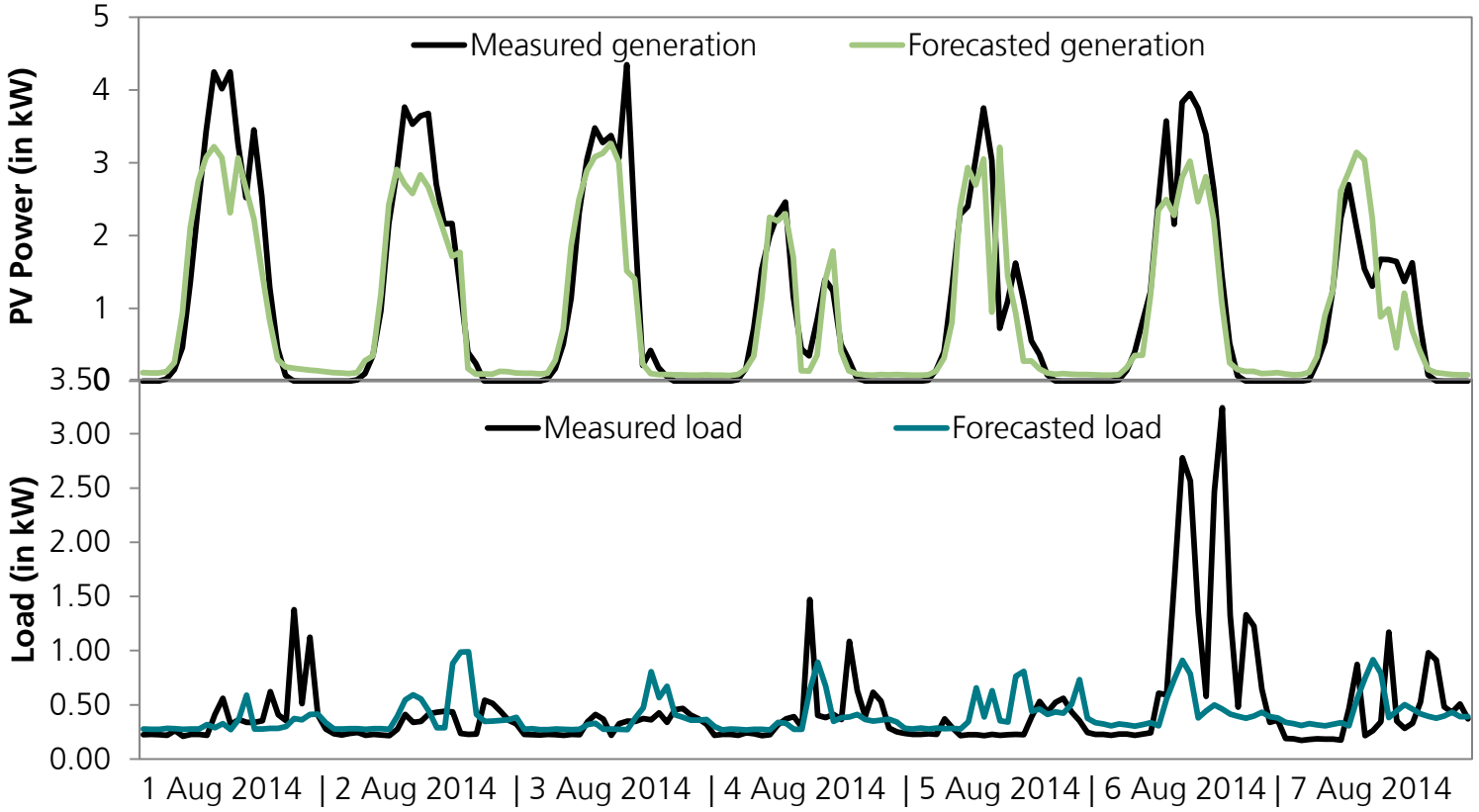
Case study

2-person single family home

- **Load**: Measured household profile from smart-meter survey (www.intelliekon.de)
  3311 kWh/yr
- **PV**: Measured PV power profile from "SonnJa" by Einleuchtend e.V.
  5671 kWh/yr
- **Weather data** (for ANN) from German Metrological Service (weather station Lindberg 18km distance from "SonnJa")
- **Battery**: 5 kWh, η = 95%, SOC_{min} = 80%, (dis-)charge rate 1C

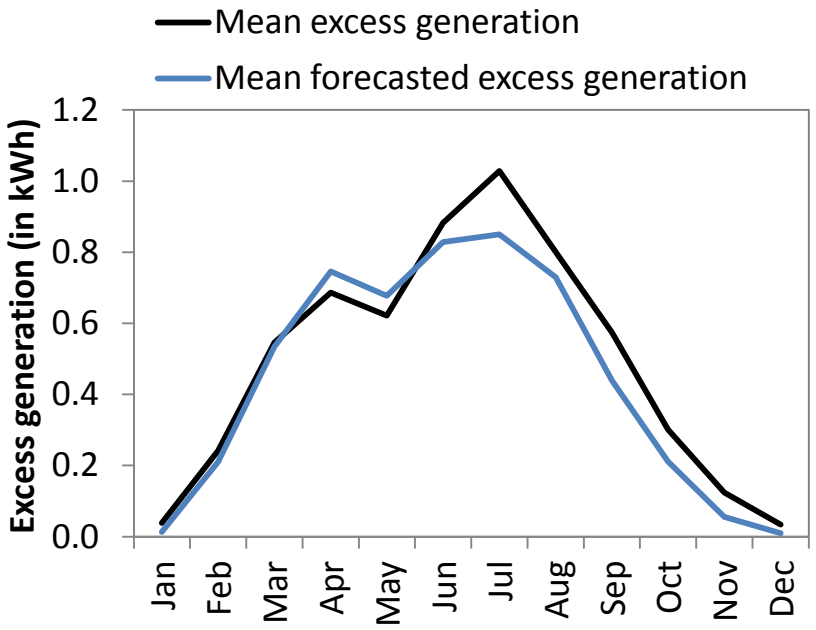


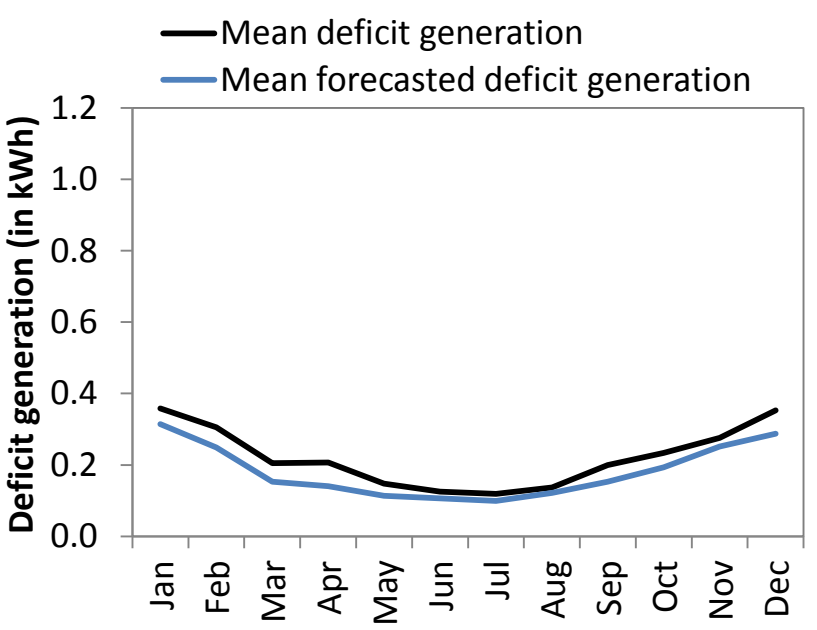
Results
Load and generation forecast



Results
Load and generation forecast II

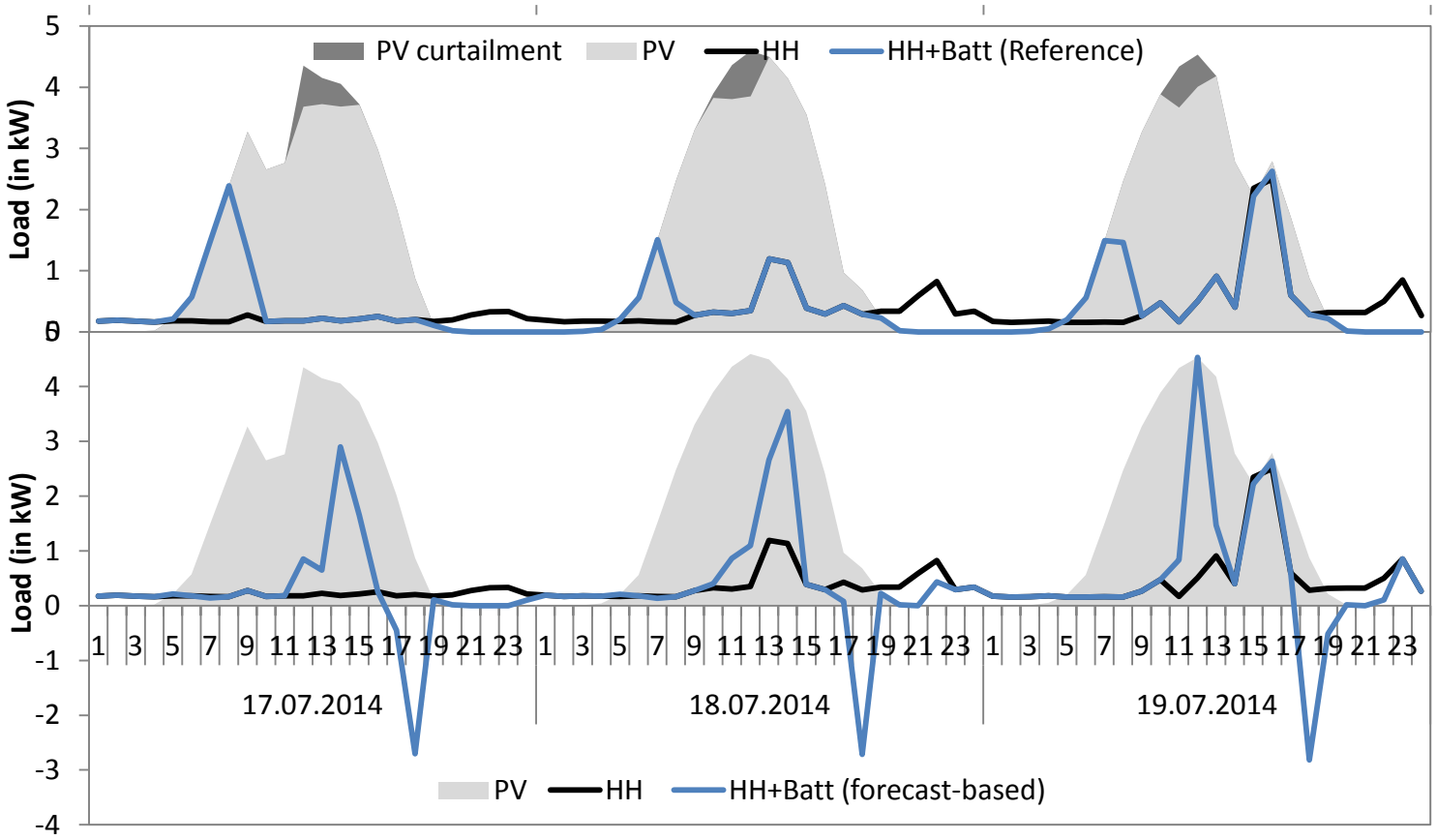
- Load and generation peaks are systematically underestimated
- Excess generation is underestimated by 354 kWh/yr (18%)
- Deficit generation is underestimated by 430 kWh/yr (10%)





Results

Battery operation



Results
Economic considerations

Performance forecast-based optimization vs. simple controller

- **Feed-in** + 34 EUR
  - curtailment is reduced from 56.2 kWh/yr to 13.2 kWh/yr
  - higher feed-in during hours of high prices
- **Self-consumption** - 43 EUR
  - self-consumption rate 38% (reference: 41%); reduced by 146 kWh/yr

Operating strategy	Savings from direct self-consumption	Savings from battery supply	Benefit Feed-in shift	Benefit Feed-in	Electricity bill
No PV System	-	-	-	-	**965 EUR**
Controller-based strategy	399 EUR	274 EUR	-	465 EUR	**-173 EUR**
Forecast-based strategy	399 EUR	231 EUR	56 EUR	443 EUR	**-165 EUR**

Discussion and Conclusions

Case study for **only individual household**: single load profile, PV and battery

➔ No universal conclusions

- **Forecast-based battery operation is system-friendly** (reduce of peak load, shift of feed-in to hours with high prices)
- Mainly due to forecasting errors, the forecast-based strategy **creates less financial benefits for the battery owner**

➔ System-friendly battery operation should be more incentivised

- **Future work**:
  - Influence of location of weather station on PV forecast?
  - Would arbitrage make a difference economically?
  - What prise-spread is necessary to make forecast-based battery operation feasible?

References

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Thank you for your attention!

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