Masterthesis

„Validation of pv battery systems as a basis for further simulation of electric vehicles."

sonnen

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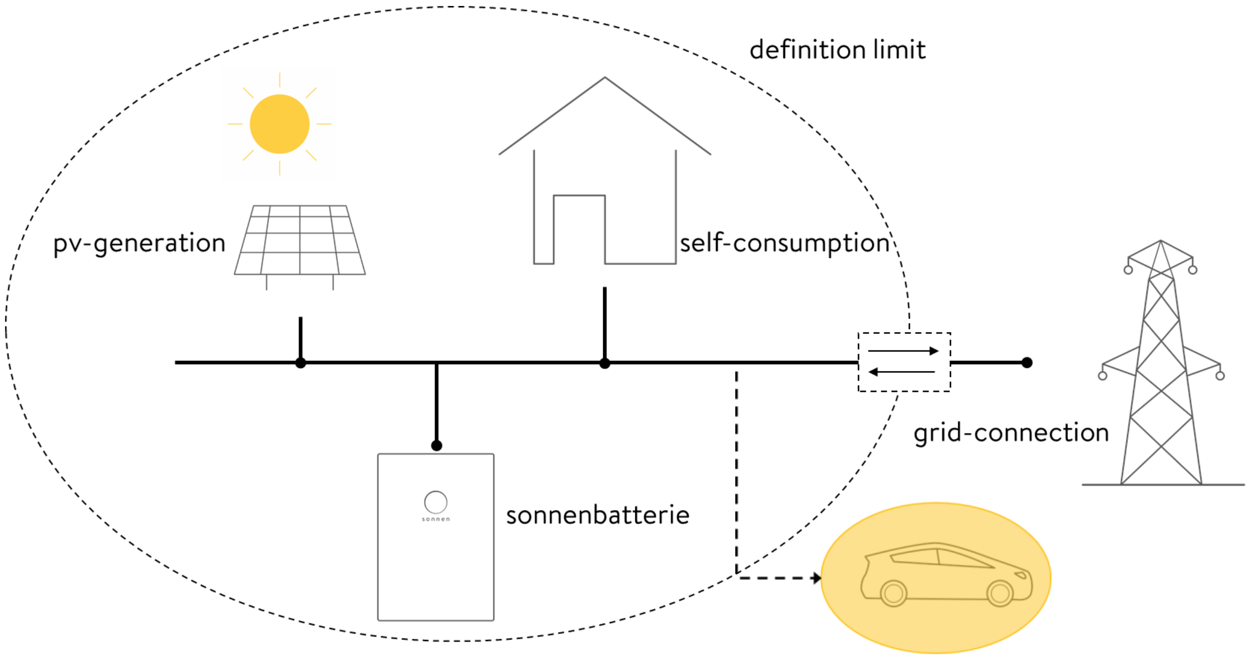
What is the global goal of the masterthesis?

→ A rational statement about the optimal integration of electromobility into a decentralized energy system.

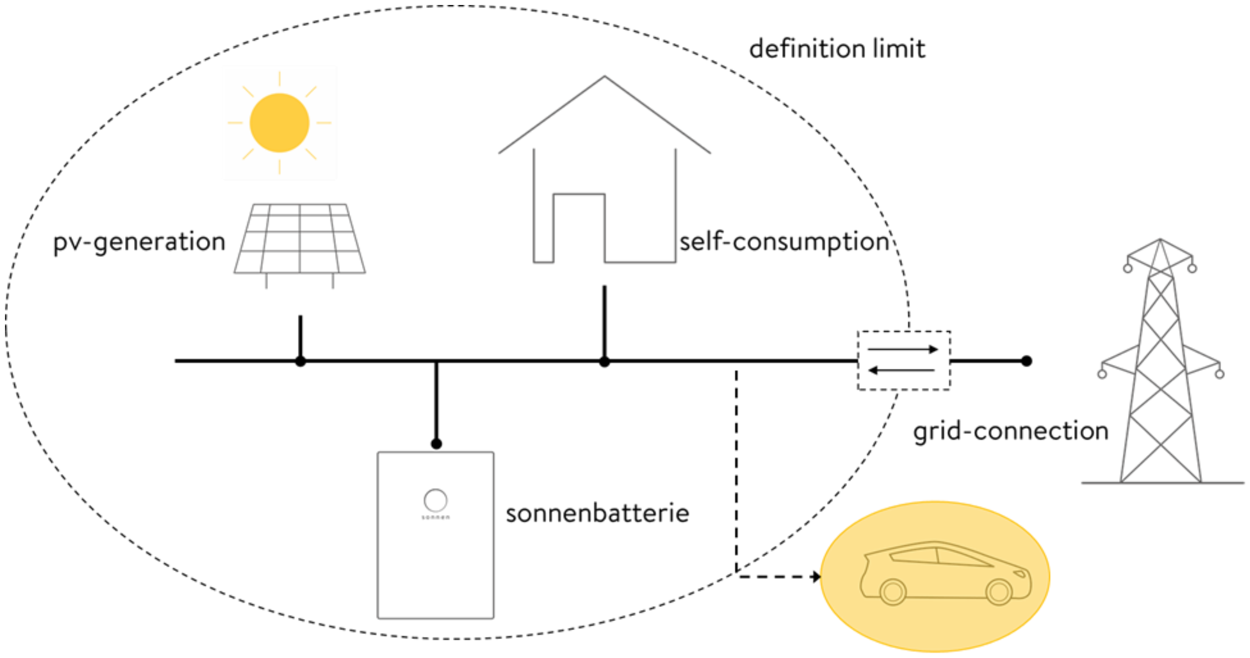
This leads to the central research question:

„How can an electric vehicle (EV) be optimally integrated into a PV battery system?“

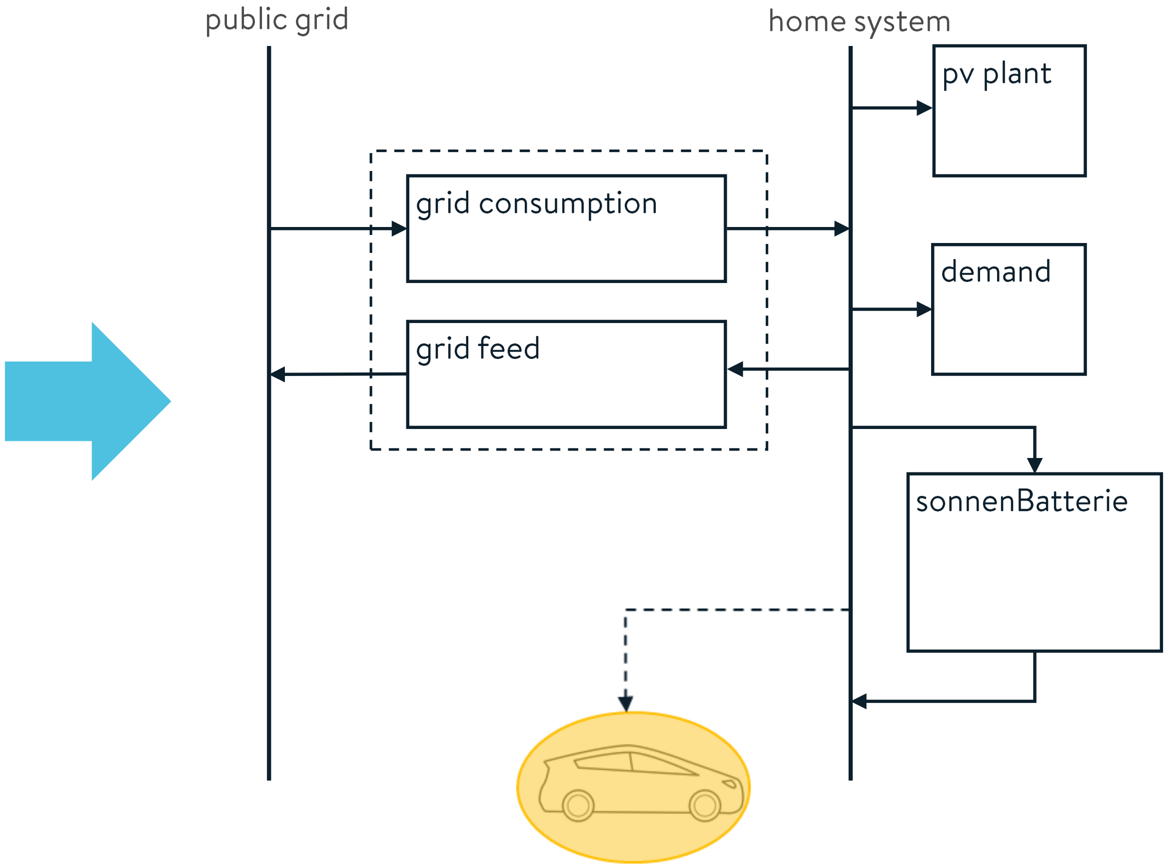


How can this question be answered?

- Modelling of a self-consumption optimized PV battery system



EV simulation



But what is exactly optimized?

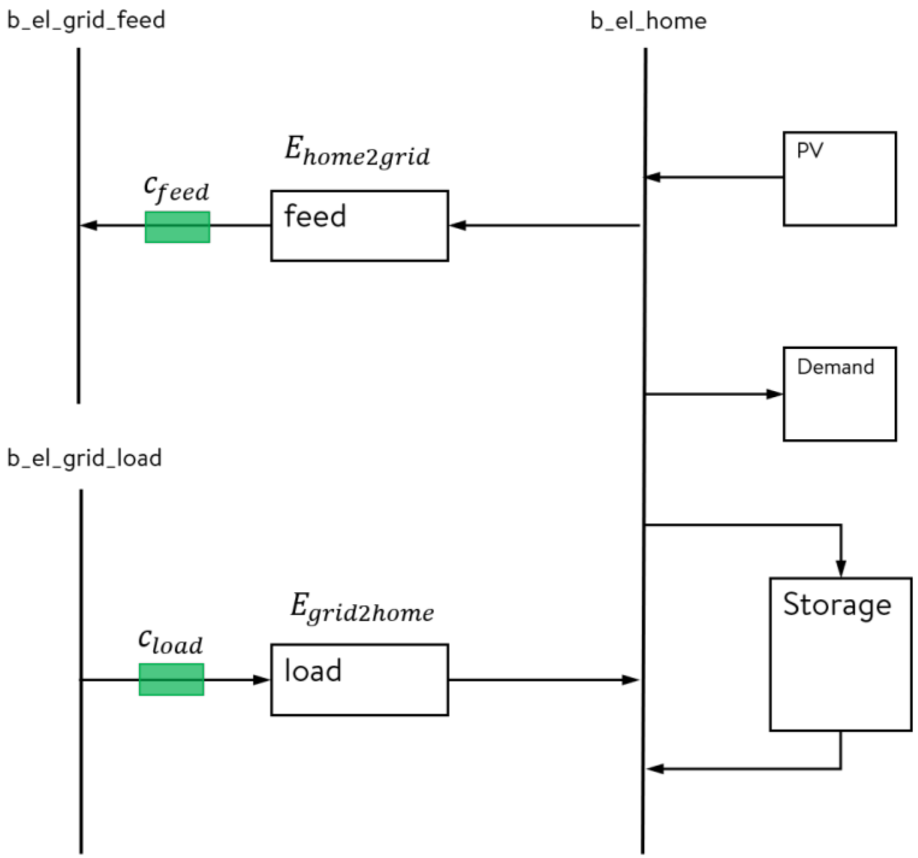
The optimal solution to a problem is equivalent to the minimum/maximum of an objective function.

OEMOF

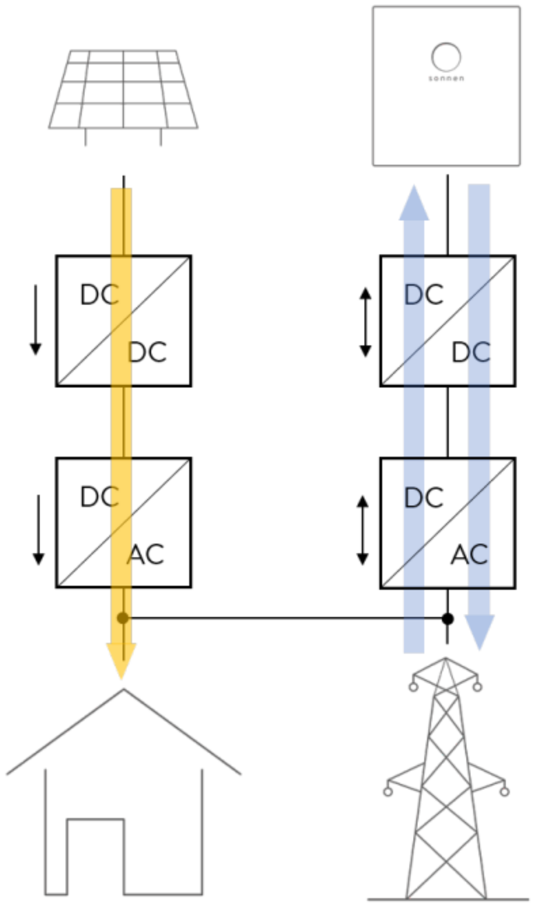
„Open Energy **M**odeling Framework"

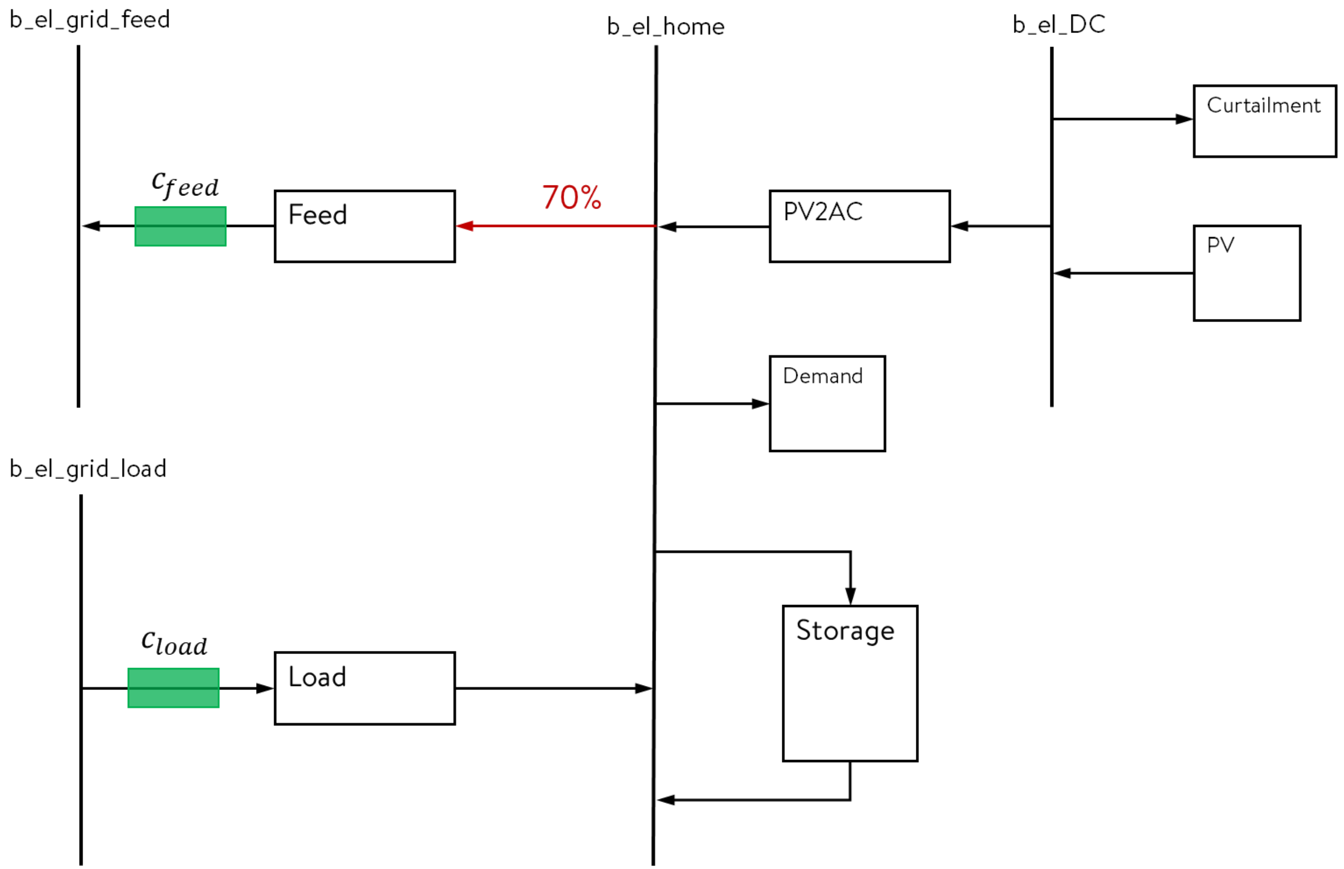
provides the following objective function in respect to the defined problem

$$K = min(\sum_{n=0}^{N} \underbrace{c_{\text{feed}} \cdot E_{\text{home2grid}}}_{-K_{\text{feed}}} + \underbrace{c_{\text{load}} \cdot E_{\text{grid2home}}}_{K_{\text{load}}})$$

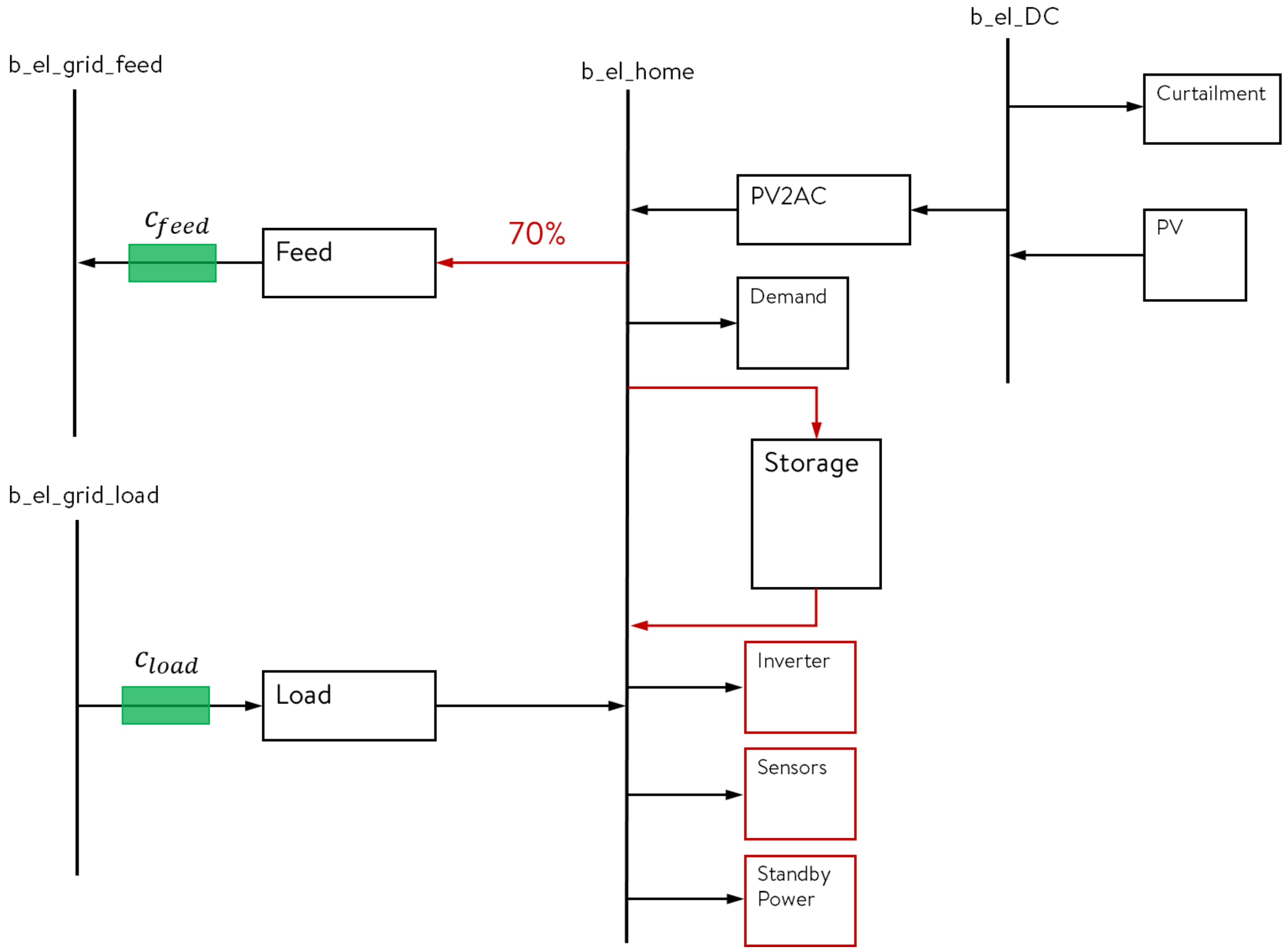


The ideal modeling according to the AC topology:





… and the modeling of losses according to the efficiency guideline.

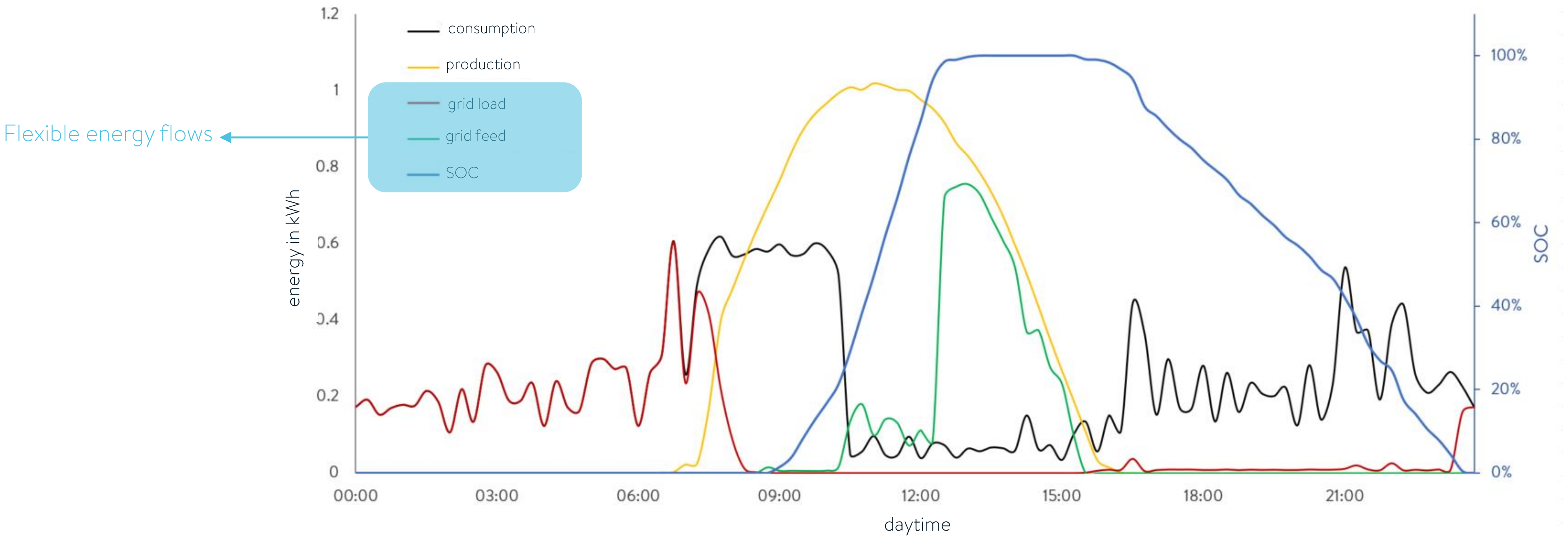


Synergy: Reality vs. Modeling

- Can the modeling be used to simulate the behavior of a real self-consumption optimized pv battery system?

A daily control:

Real behaviour time series of a pv sonnenBatterie system



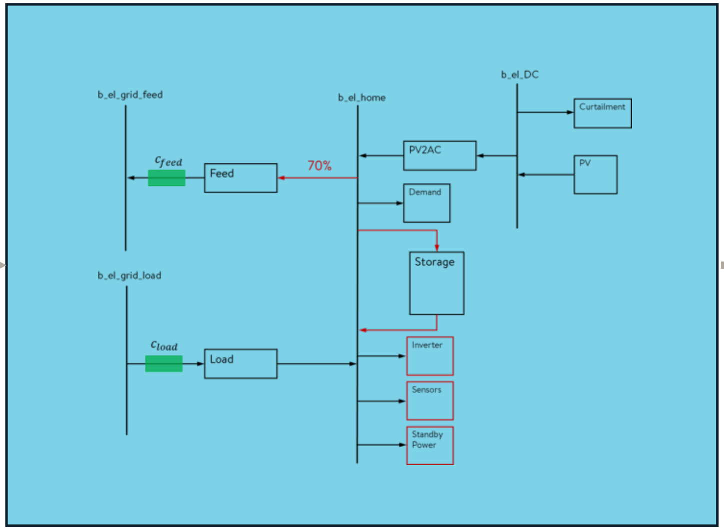
To simulate the daily control:

- Reproduction of the flexible energy flows
- Time discretization: 15-minute intervals

INPUT

- Timeseries pv-generation
- Timeseries demand

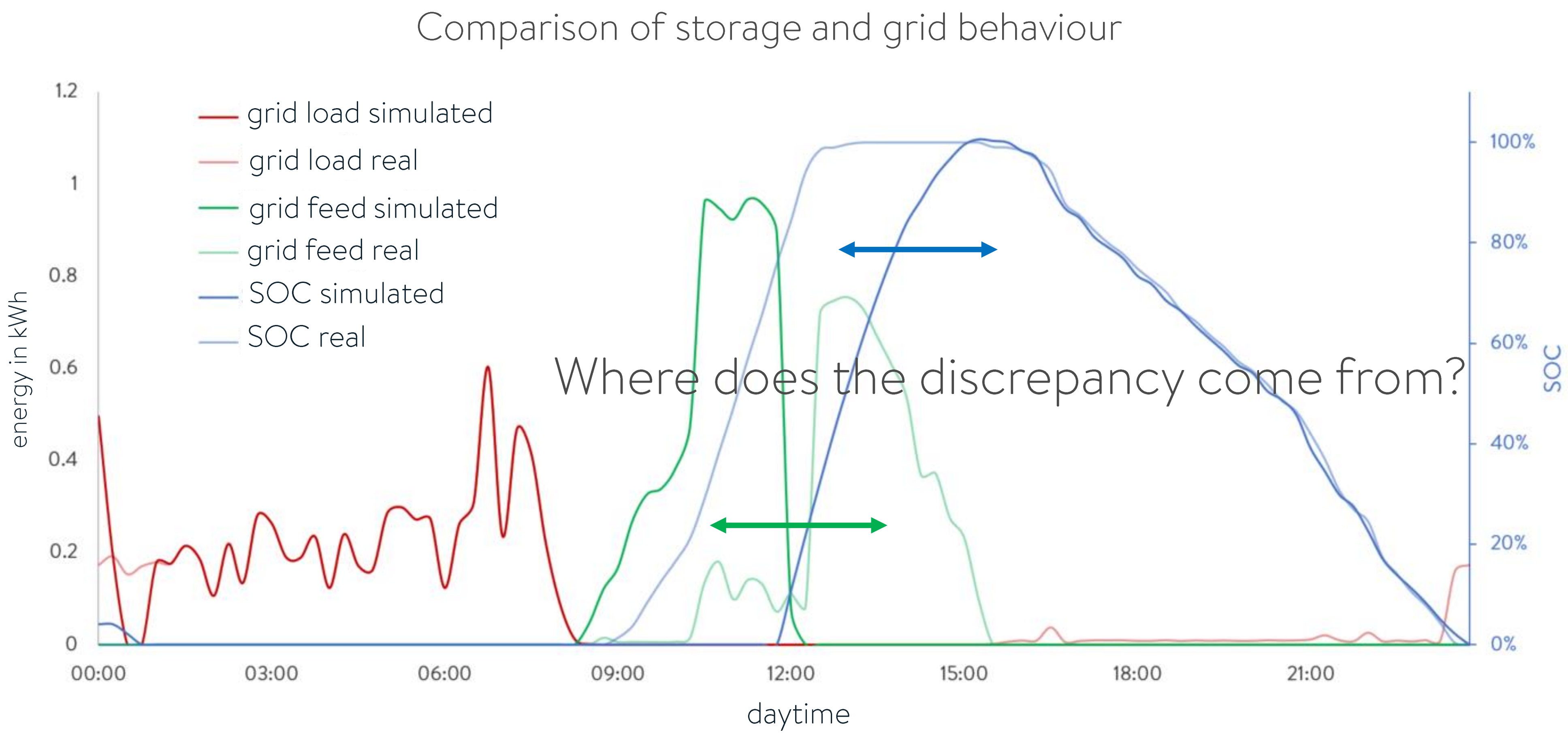
SIMULATION MODEL



OUTPUT

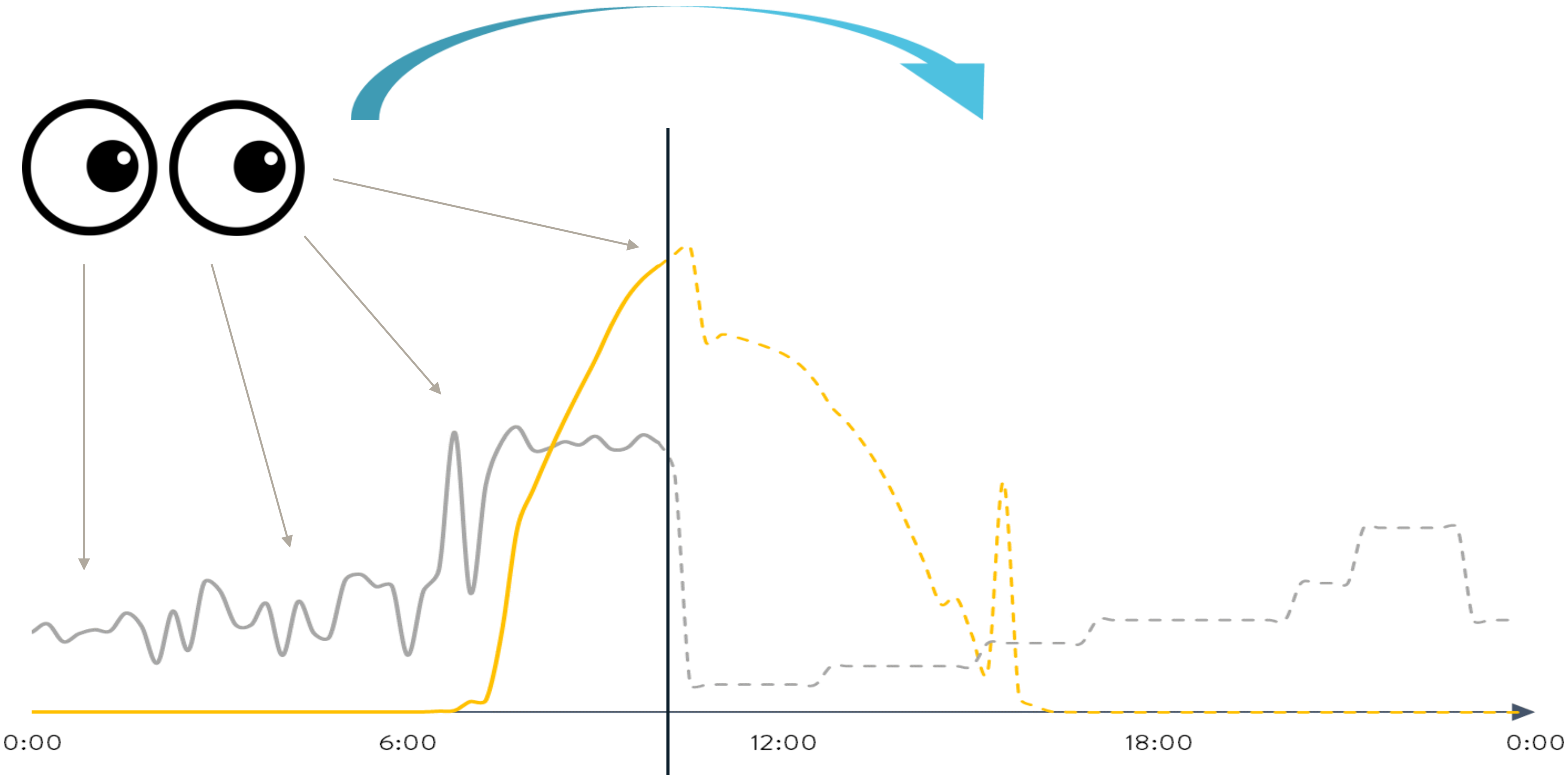
- Storage behaviour
- Energy exchange with the grid

Synergy: Reality vs. Modeling

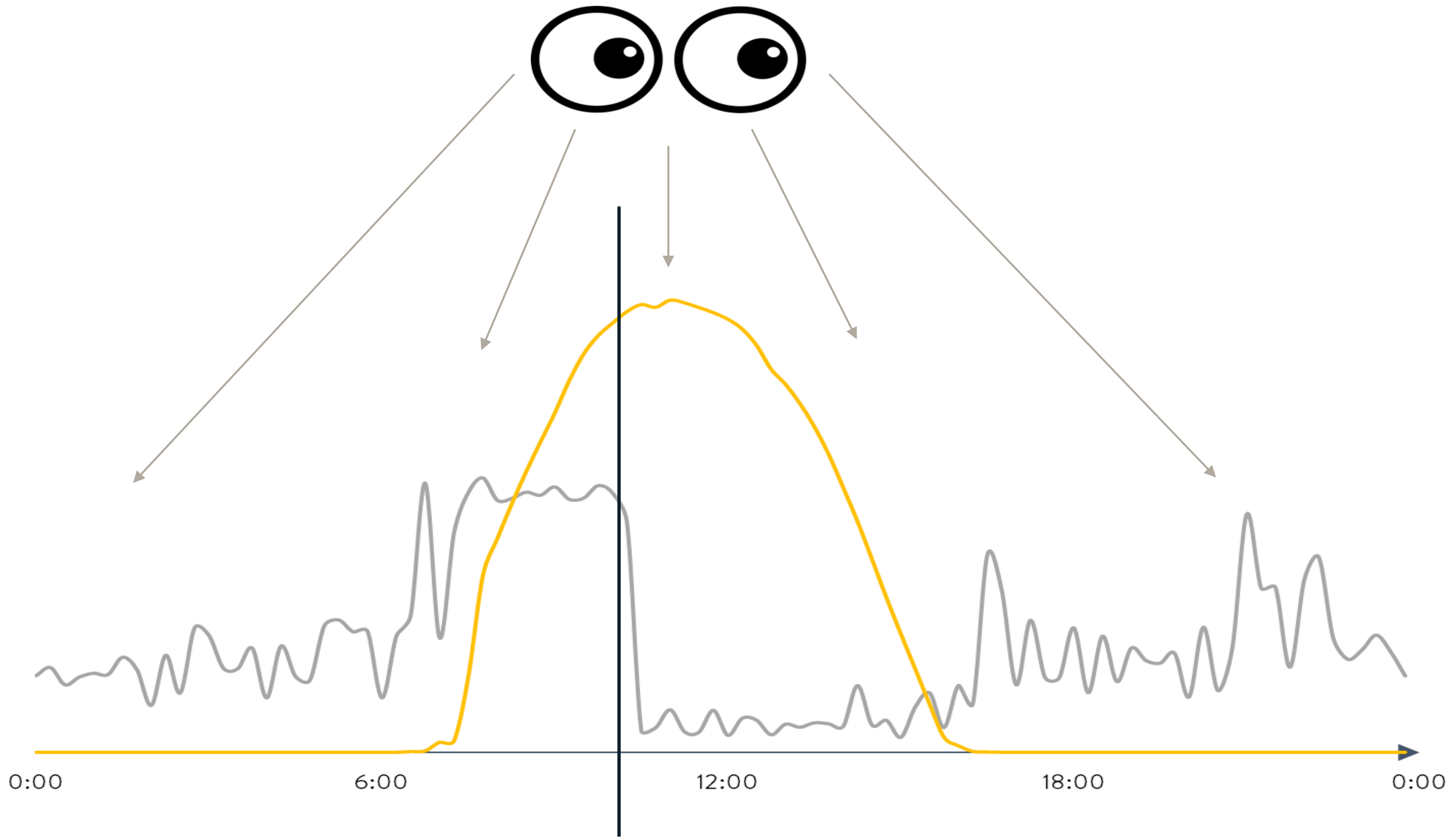


Where does the discrepancy come from?

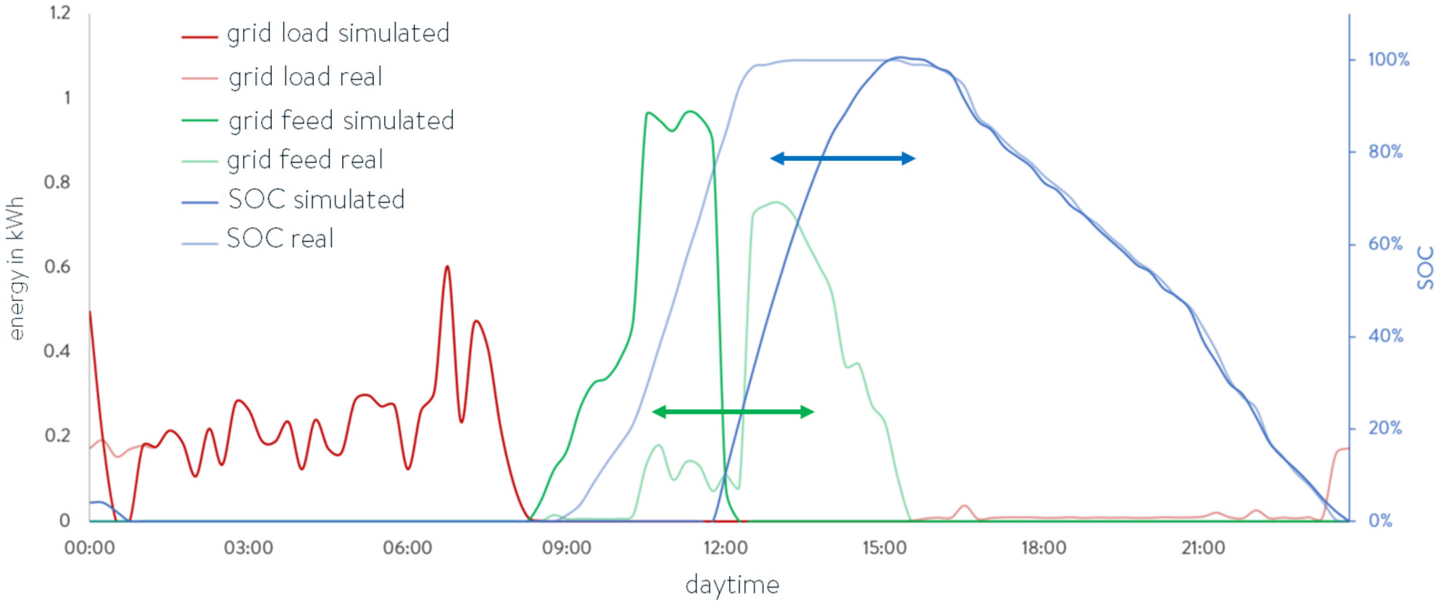
Prediction of the sonnenBatterie

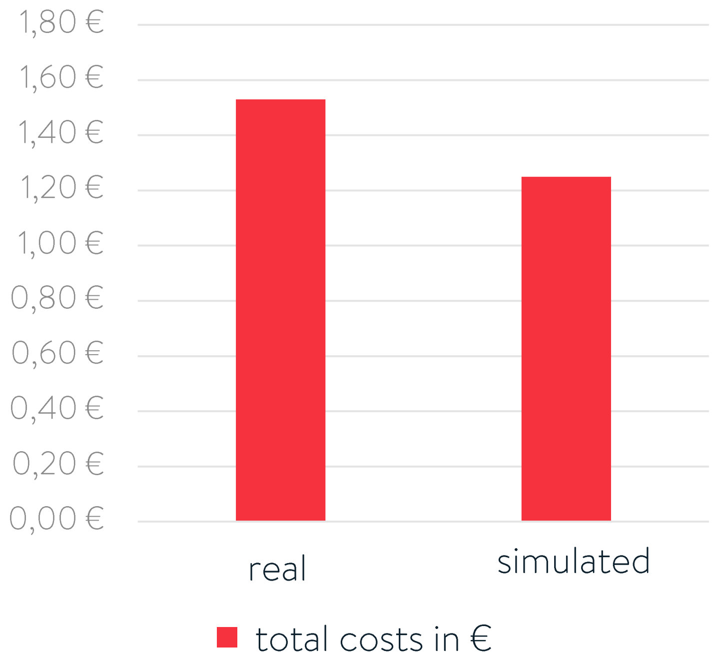


The perfect foresight of the optimizer



What does that mean?





- discrepancy as a result of the perfect foresight
- sonnenBatterie uses defensive load strategy due to prediction faults
- the optimizer knows at any timestep the future demand/generation
- the simulations results should be interpreted as the optimal solution, which causes the lowes cost
- in reality, this solution can only be approximated

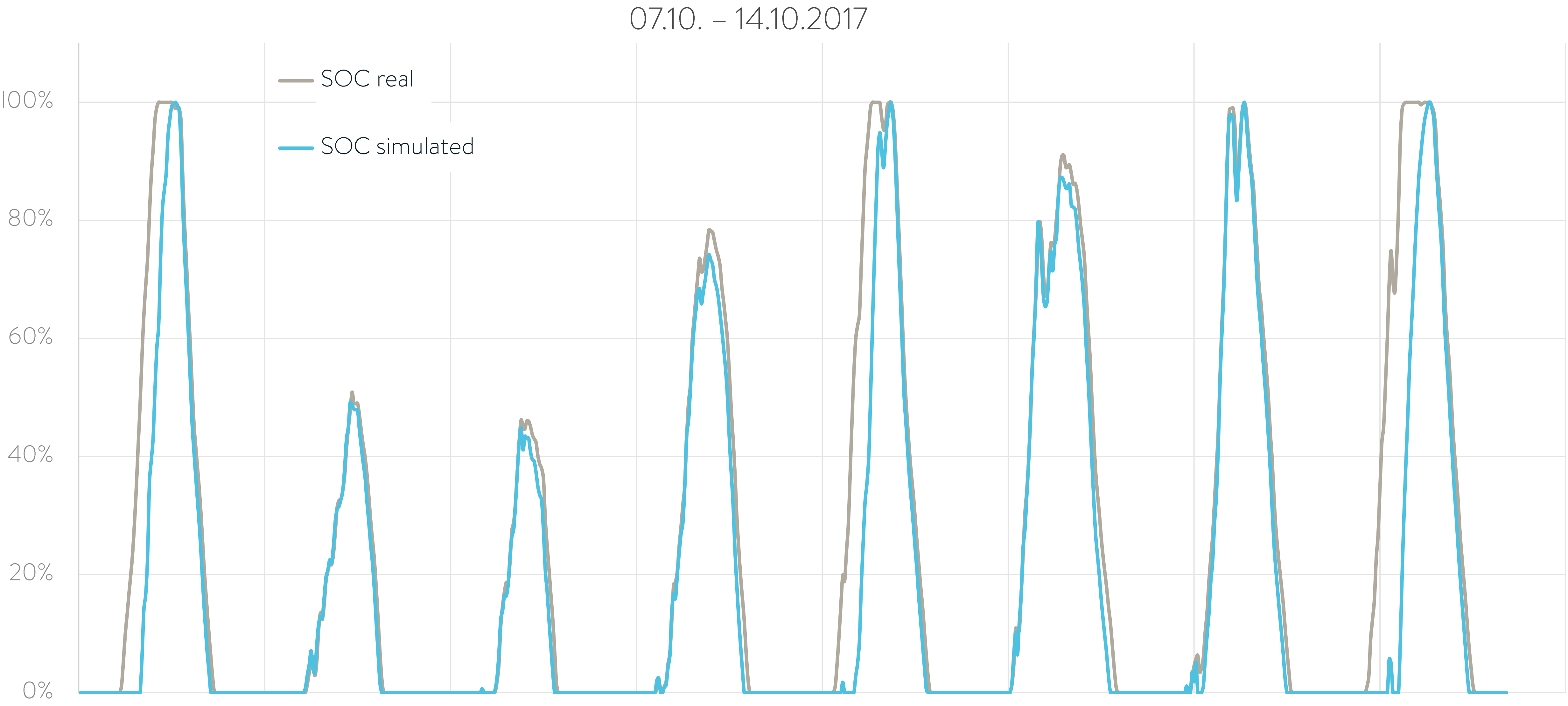
A short summary:

- The modeling reproduces the behaviour of a self-consumption optimized pv battery system
- There are temporal discrepancys to reality due to the perfect foresight problem

→ To integrate electric vehicles in the simulation of pv battery systems a detailed validation makes the results more reliable

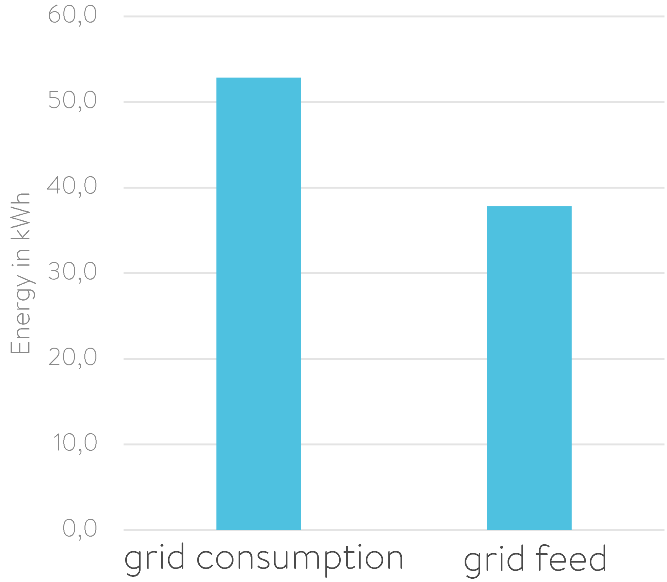
A weekly control of the storage behaviour…

storage behaviour

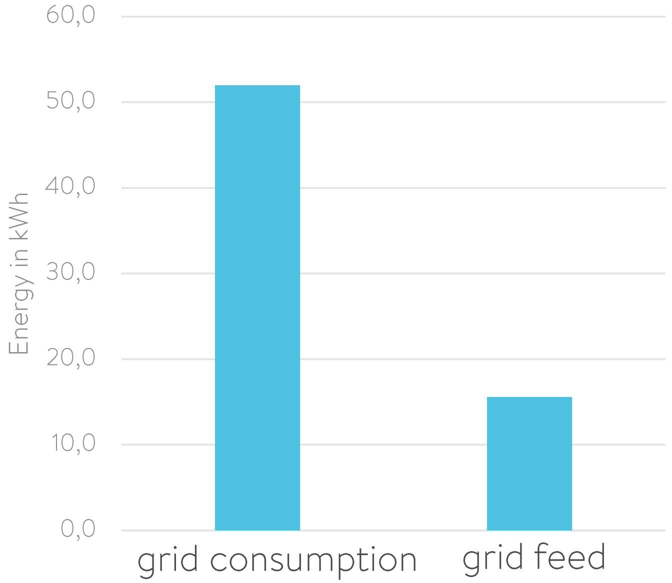


07.10. – 14.10.2017

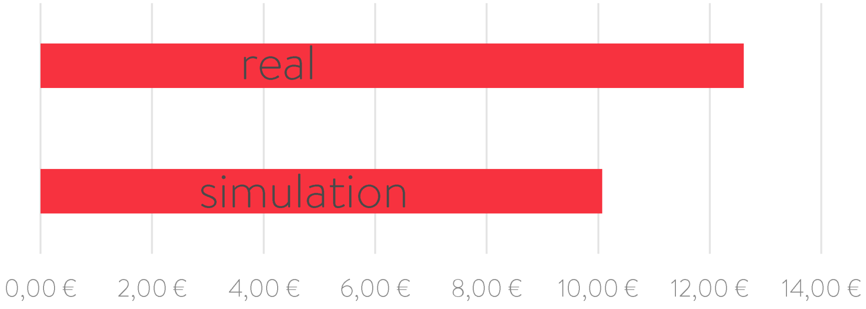
simulation



real



total costs



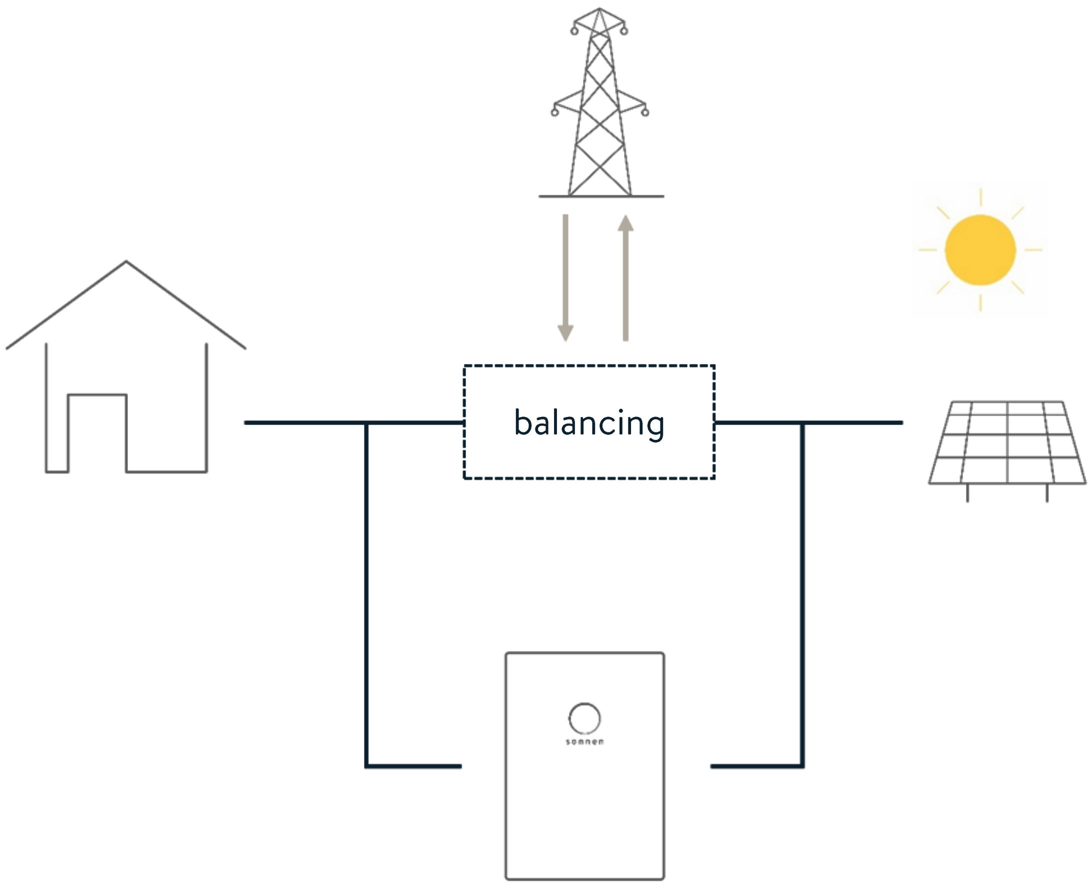
An annual control of the system behaviour…

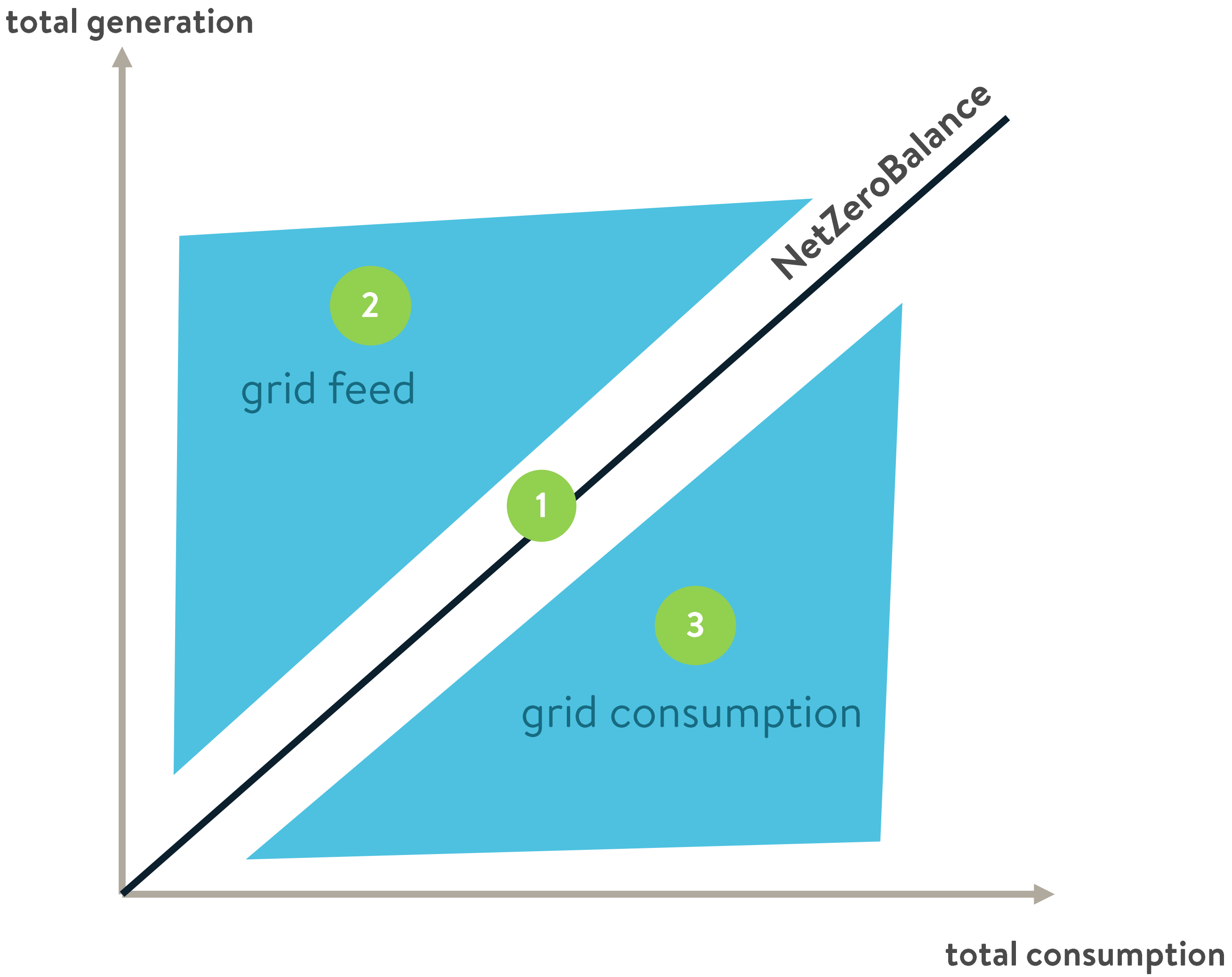
- An annual timeseries analysis becomes to confusing

→ another visualisation is necessary

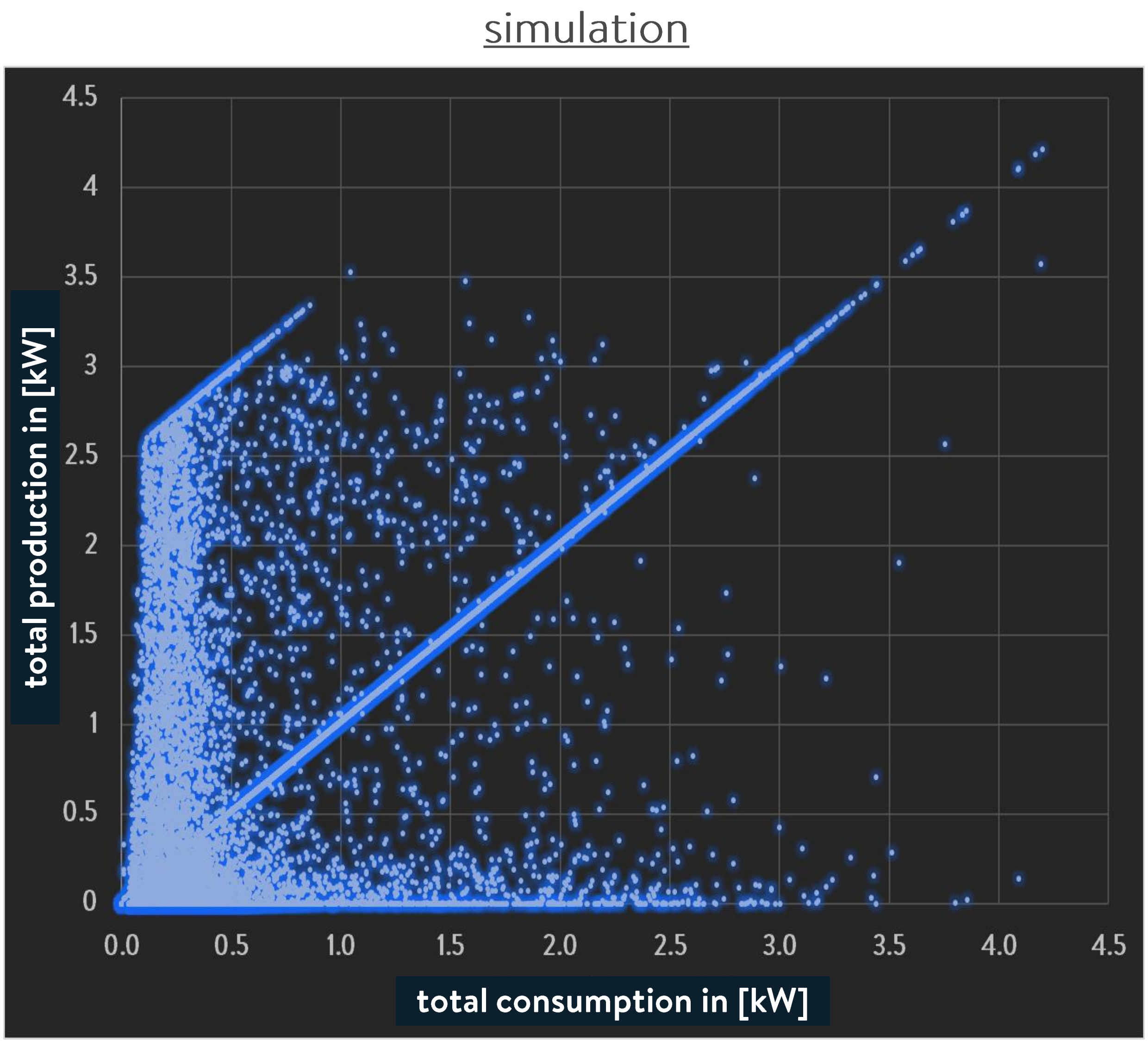
Visualisation using the NetZeroBalance [2]

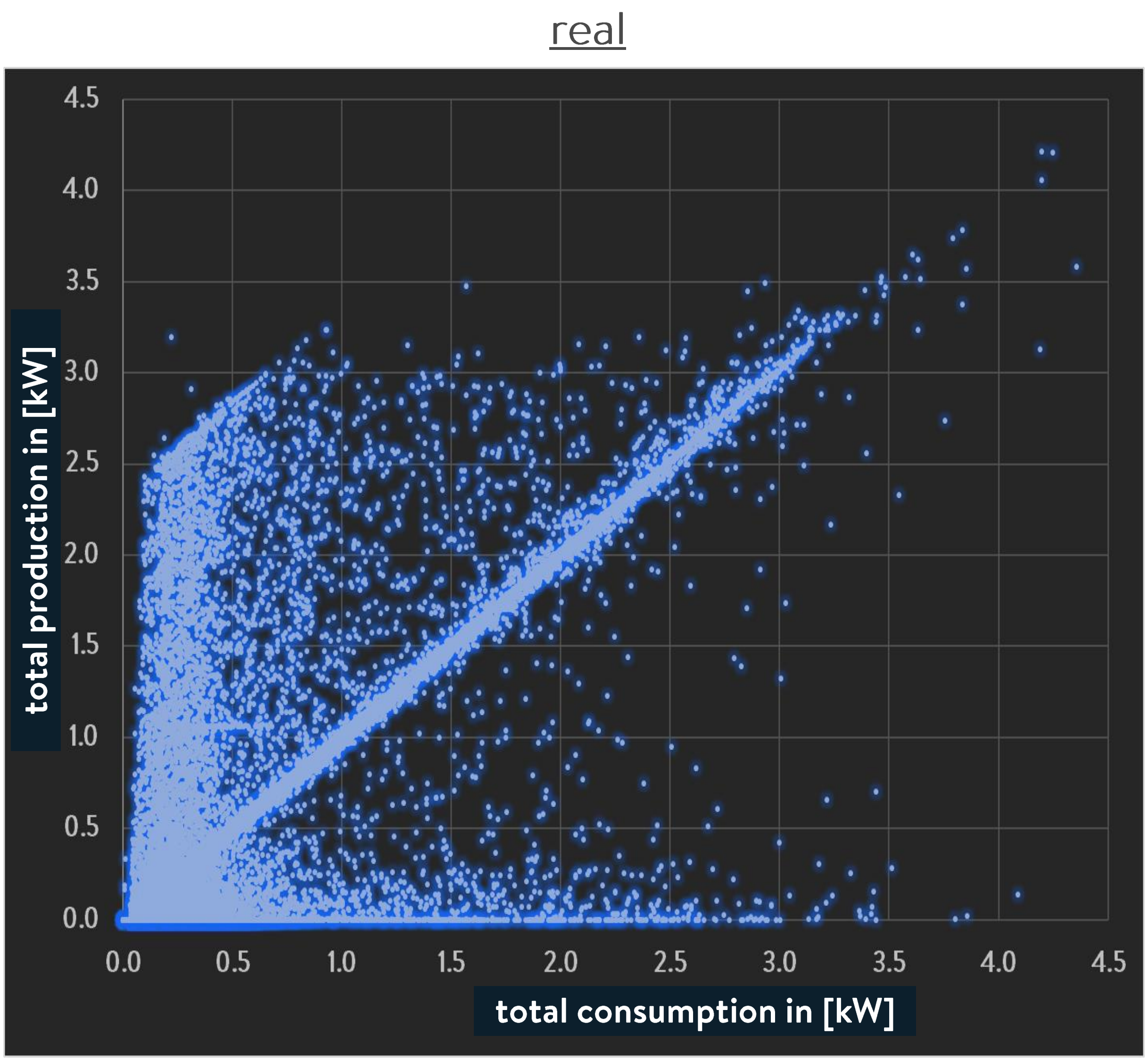
- Illustration of every 15-minute energy flow situation with one data point





NetZeroBalance





A short summary

Adequate reproduction of the system behaviour of a pv battery system over 1 year

BUT: No validation method to compare different dimensioned pv battery systems

→ coefficient searched!

technical coefficients

- technical coefficients only balancing a part of the systems losses
- grade of autharky **not suitable** - depends on battery size
- grade of own consumption **not suitable** – depends on size of pv plant

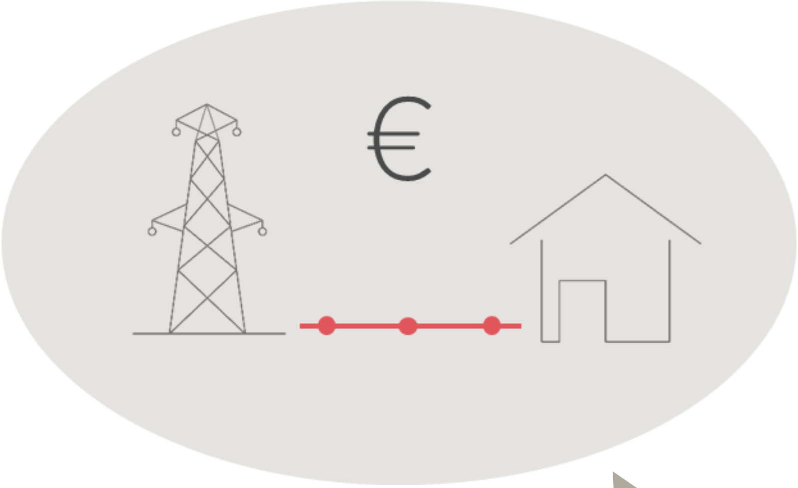
economic coefficients

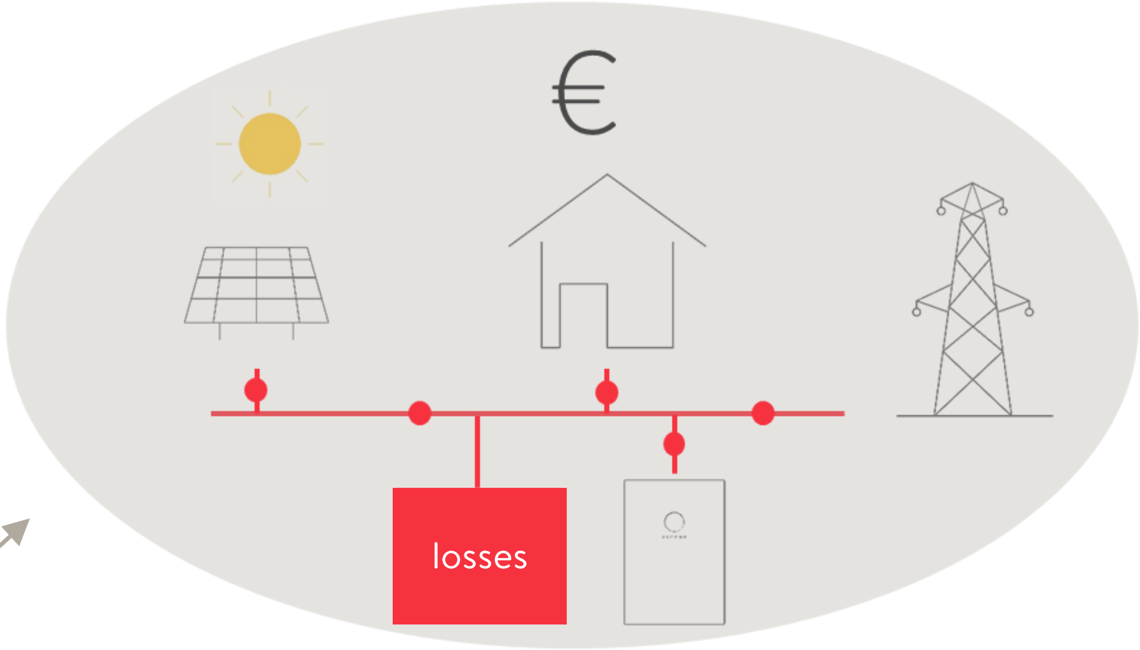
- evaluate energy flows monetary in terms of costs
- independent of dimensioning
- with the correct choice of the definition limit, all losses are taken into account

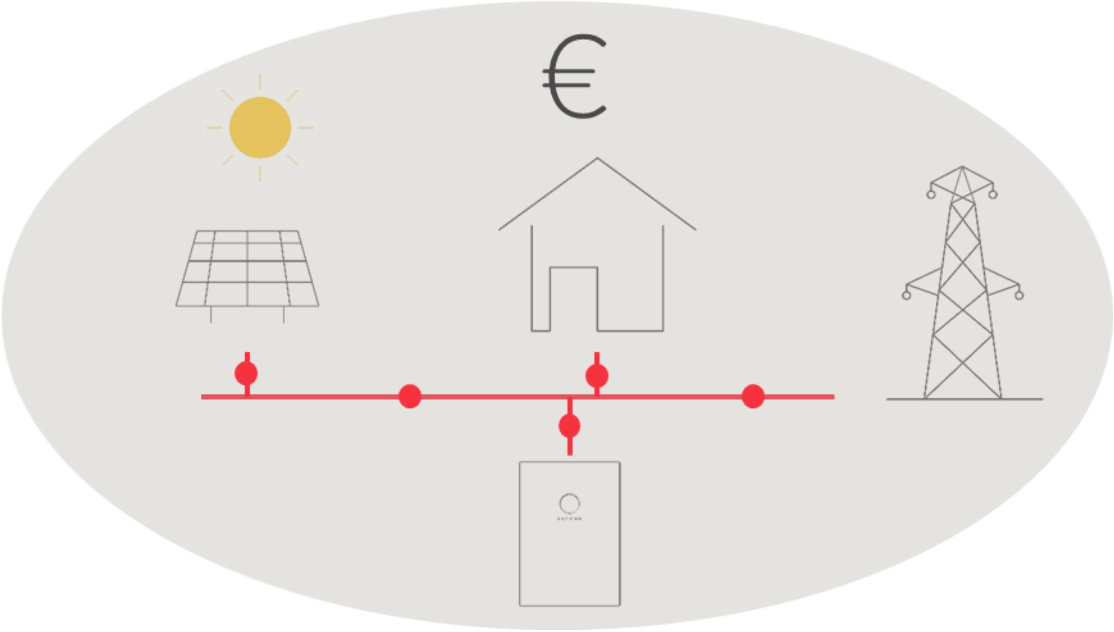
$$€ = kWh \cdot \frac{€}{kWh}$$

→ the standardized economic coefficient for pv battery systems of the HTW-Berlin: SPI (System Performance Index)

SPI – System Performance Index ? [1]







$$SPI = \frac{\Delta C_{REAL}}{\Delta C_{IDEAL}} = \frac{C_{REF} - C_{REAL}}{C_{REF} - C_{IDEAL}}$$

ideal savings

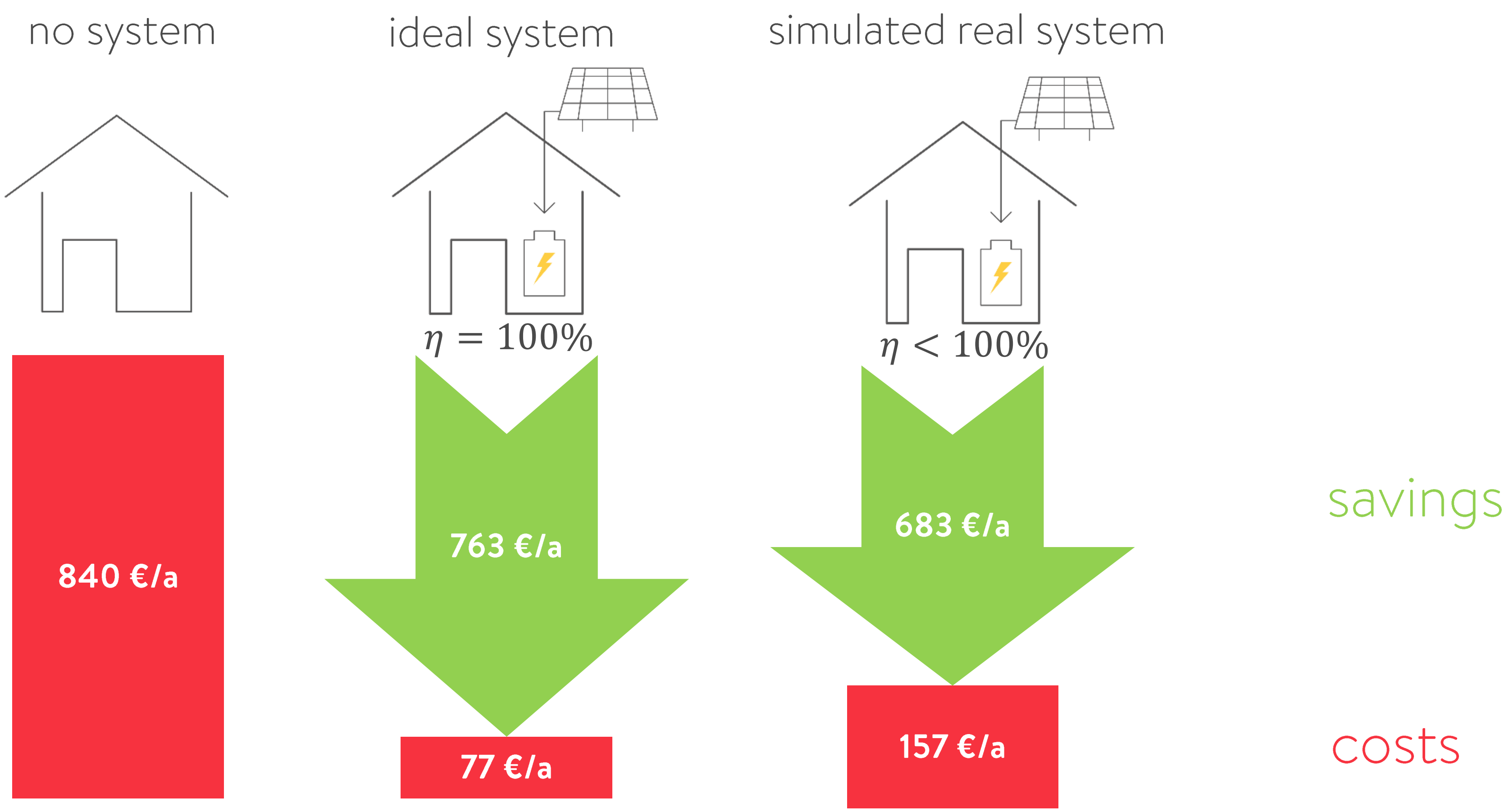
real savings

Interpretation of the SPI

- the SPI states in a quantitative way how much the real pv battery system approaches the cost savings of an ideal pv battery system
- thus, it is a rate of efficiency related to an ideal pv battery system
- evaluates economic benefits of a pv battery system

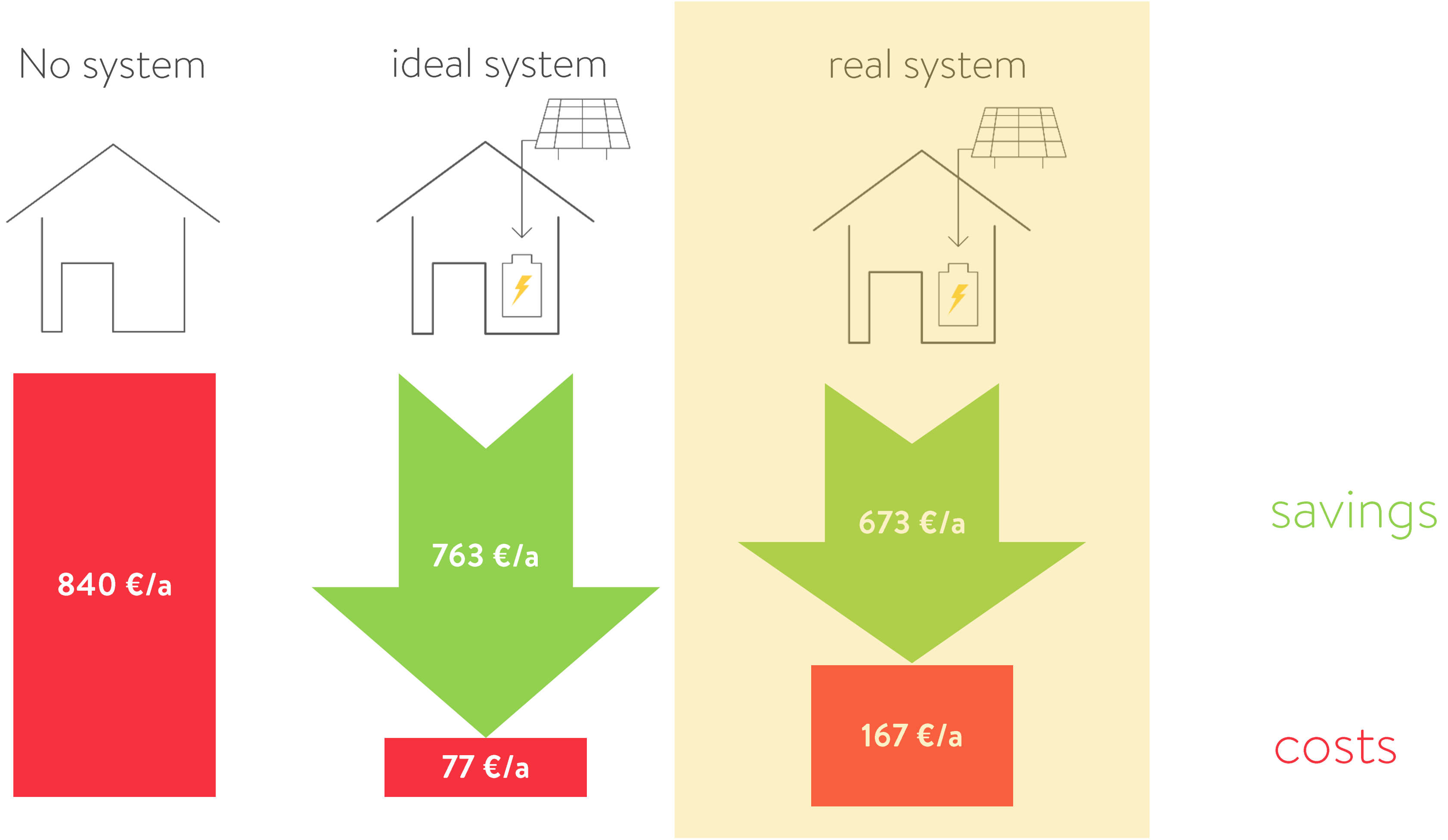
→ with the SPI an annual validation of variable dimensioned pv battery systems is possible

simulated SPI



$$SPI = \frac{simulated\ real\ savings}{ideal\ savings} = \frac{683\ €/a}{763\ €/a} = 89{,}5\%$$

real SPI



$$SPI = \frac{real\ savings}{ideal\ savings} = \frac{673\ €/a}{763\ €/a} = 88{,}0\%$$

validation of one pv battery system

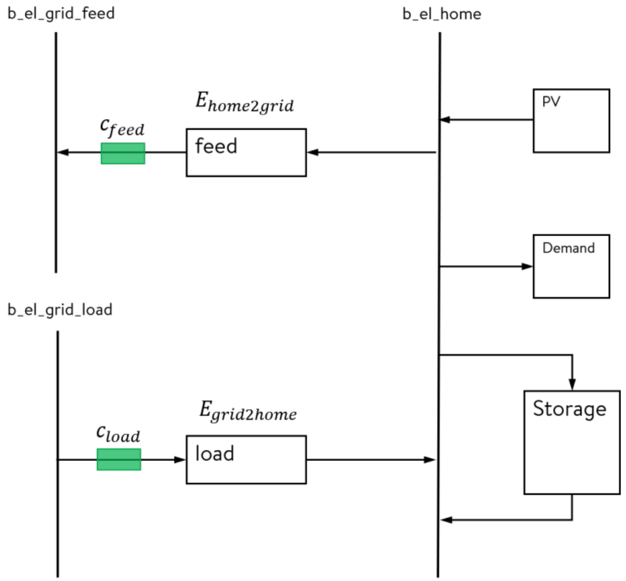
$$\% \text{ accordance} = \frac{SPI_{DATA}}{SPI_{SIM}} = \frac{88{,}0\%}{89{,}5\%} = 98{,}3\ \%$$

validation of n – pv battery systems

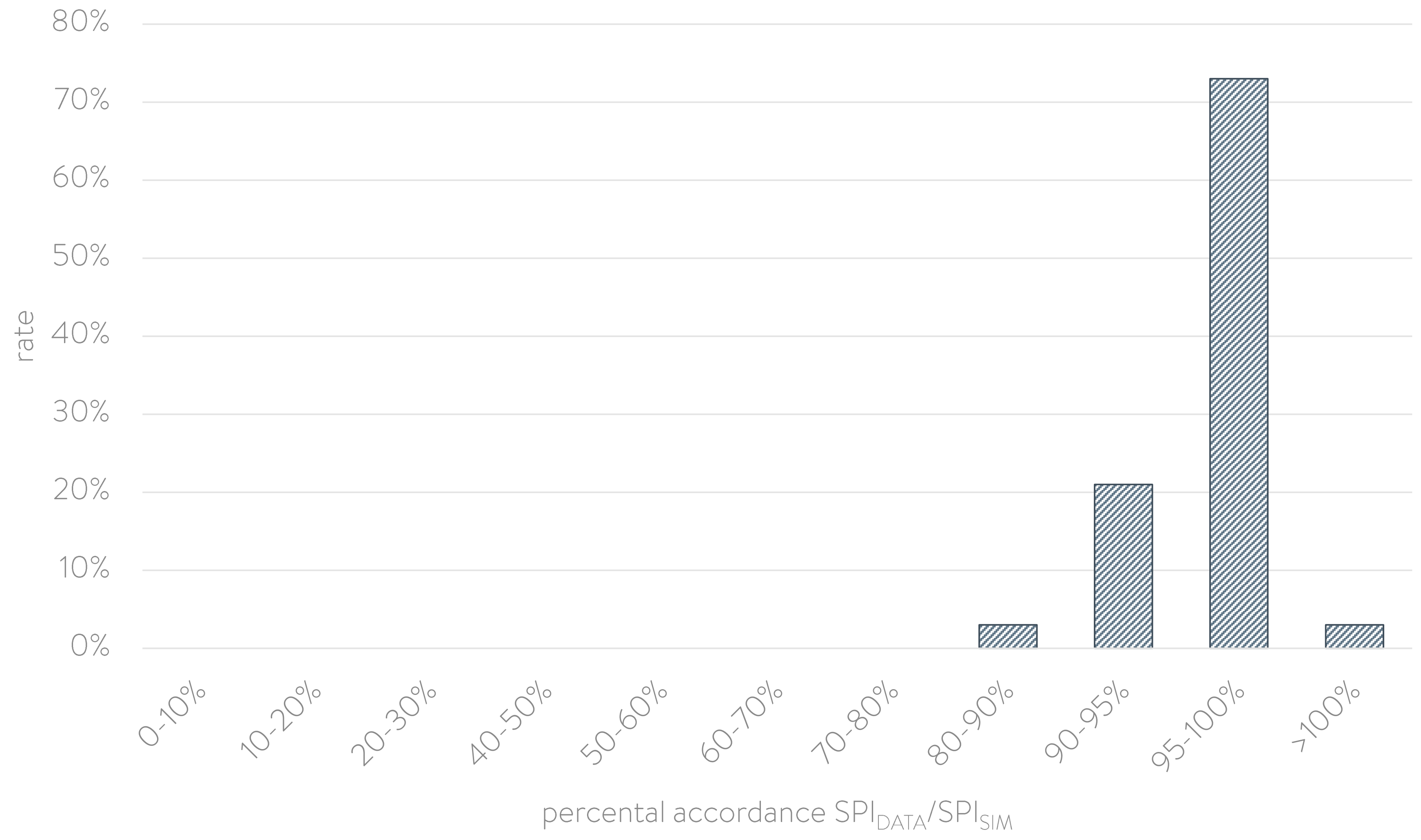
sonnenDatabase

$$\% \text{ accordance} = \sum_{n=1}^{100} \frac{SPI_{DATA}}{SPI_{SIM}}$$

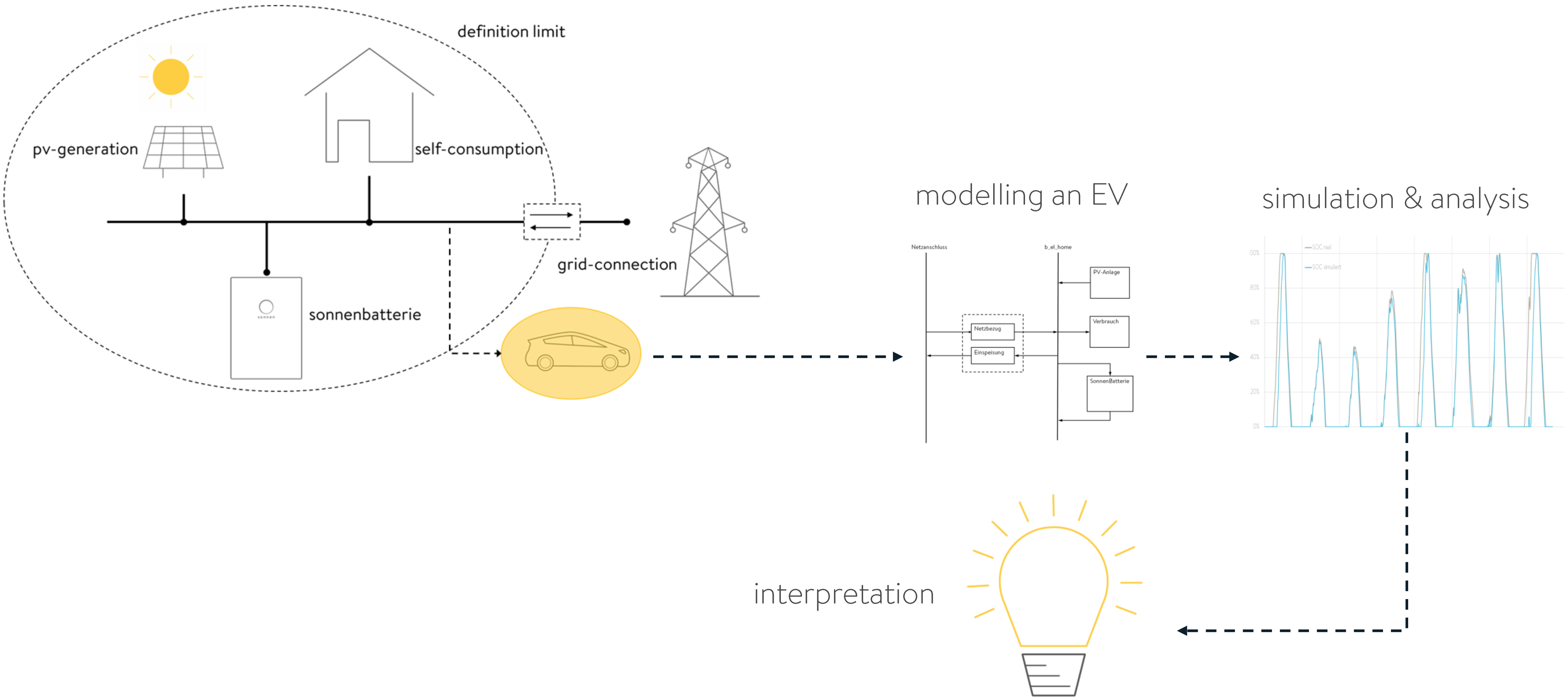
simulation



validation result of 100 simulated pv battery systems



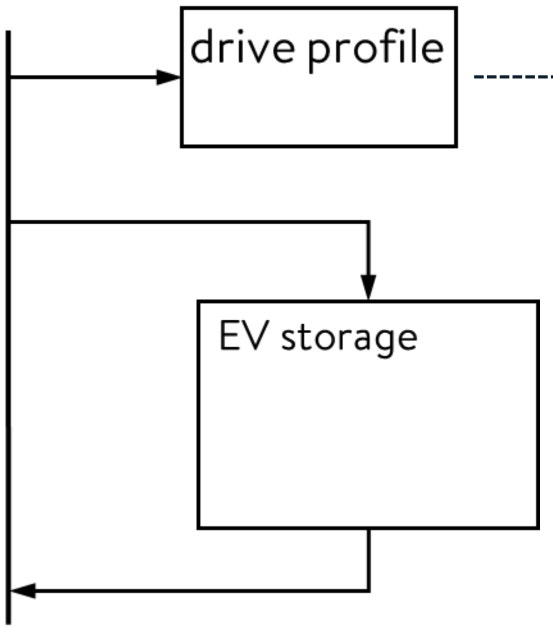
Next thing to do...



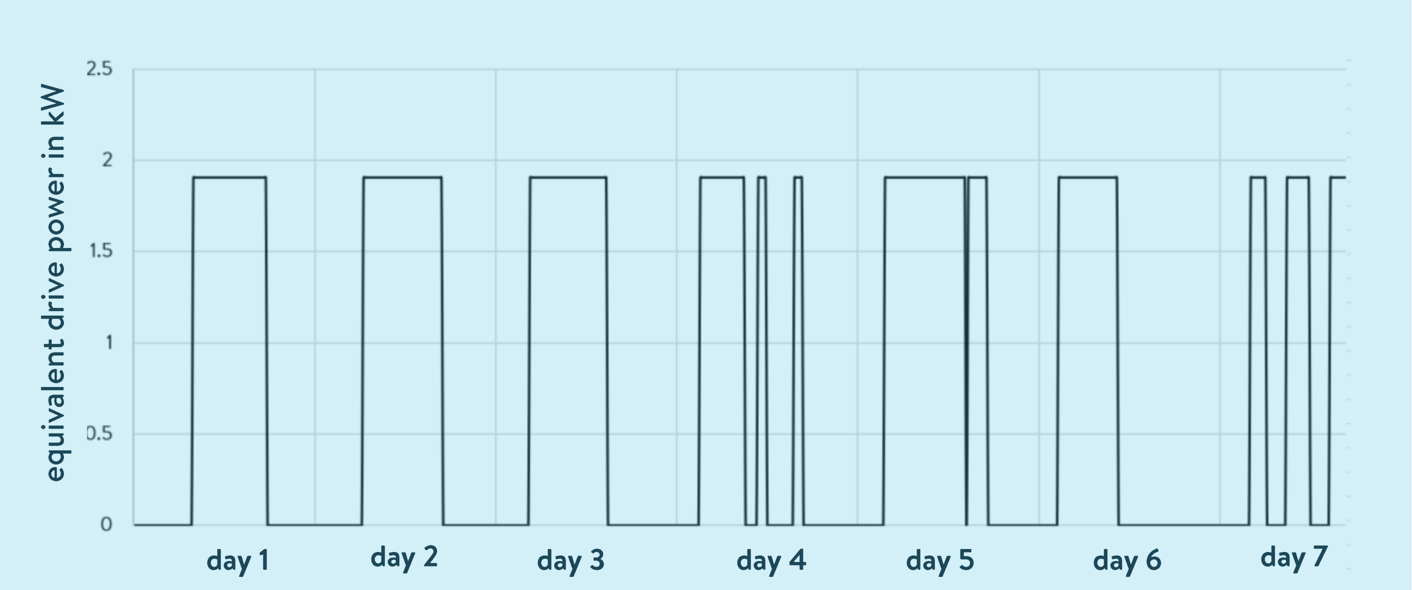
modeling an EV

An EV consists of a

- electrical storage and
- the way it is discharged



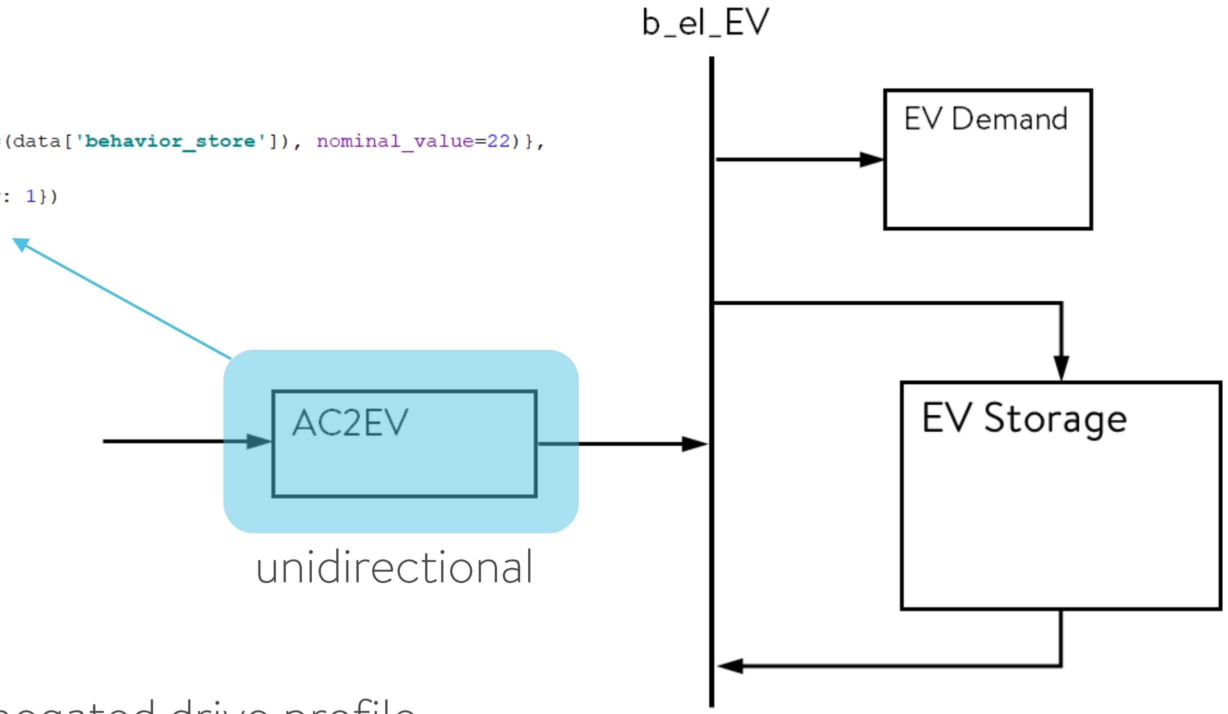
weekly drive profile



modeling an EV

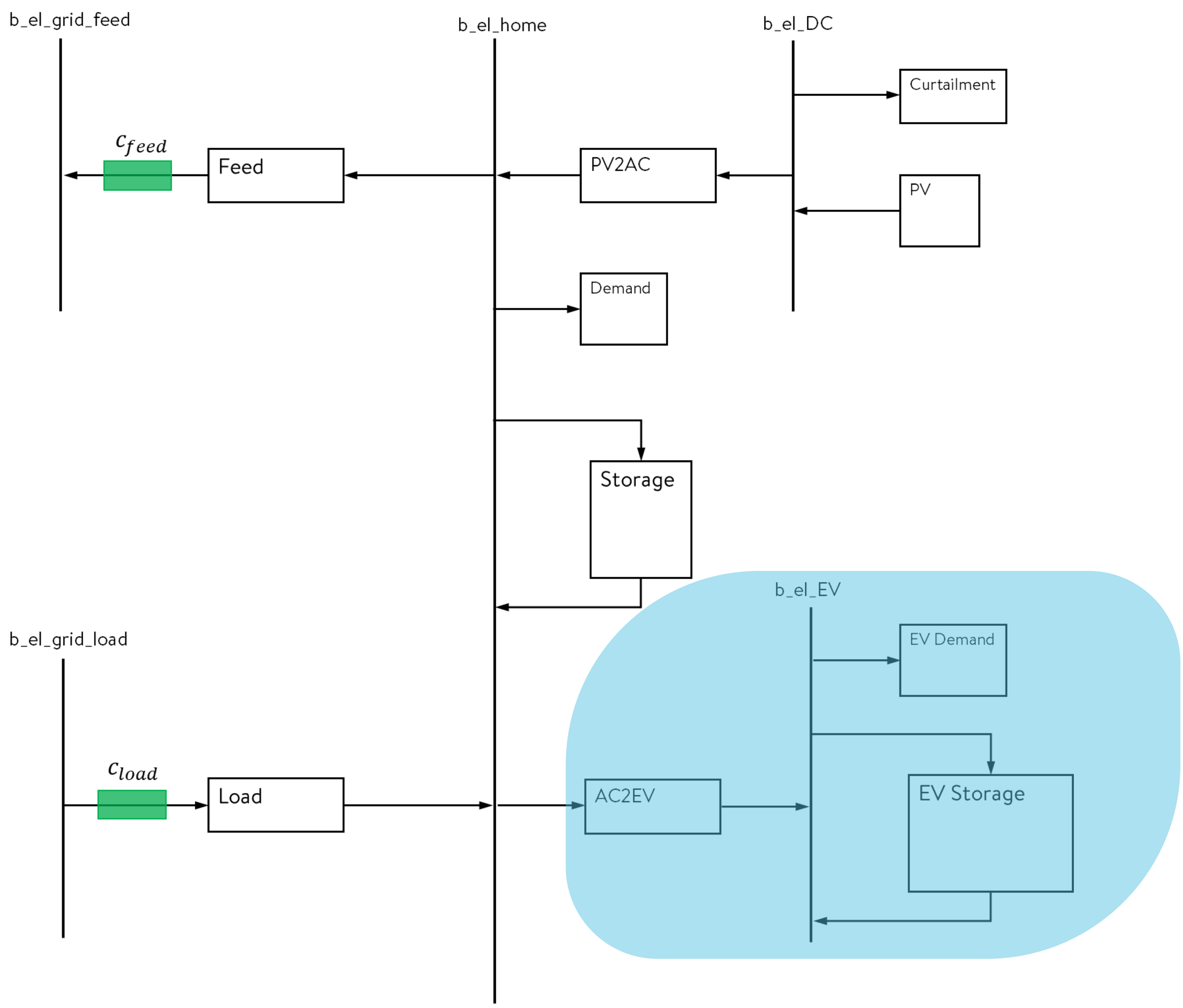
The EV gets integrated in the pv battery system in an unidirectional way

```
AC2EV = LinearTransformer(label='AC2EV',
                          inputs={b_el_home:Flow(max=(data['behavior_store']), nominal_value=22)},
                          outputs={b_el_ev:Flow()},
                          conversion_factors={b_el_ev: 1})
```



`(max=(data['behavior_store'])` = negated drive profile

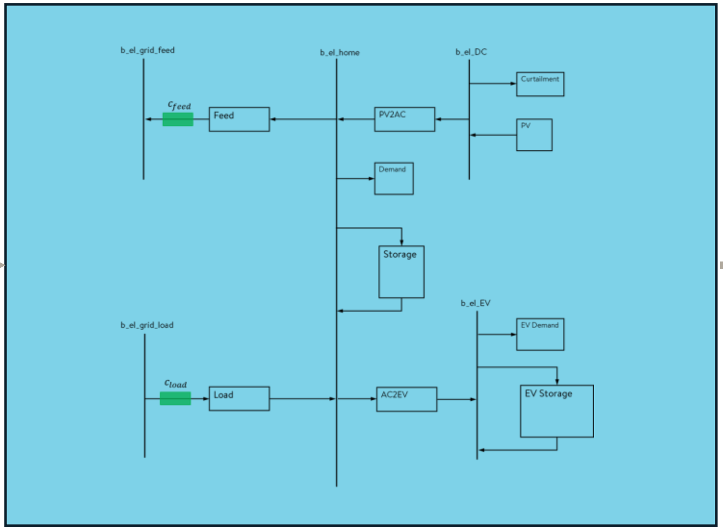
modeling an EV



Simulation of the EV integrated pv battery system:

- A weekly analysis

SIMULATION MODEL



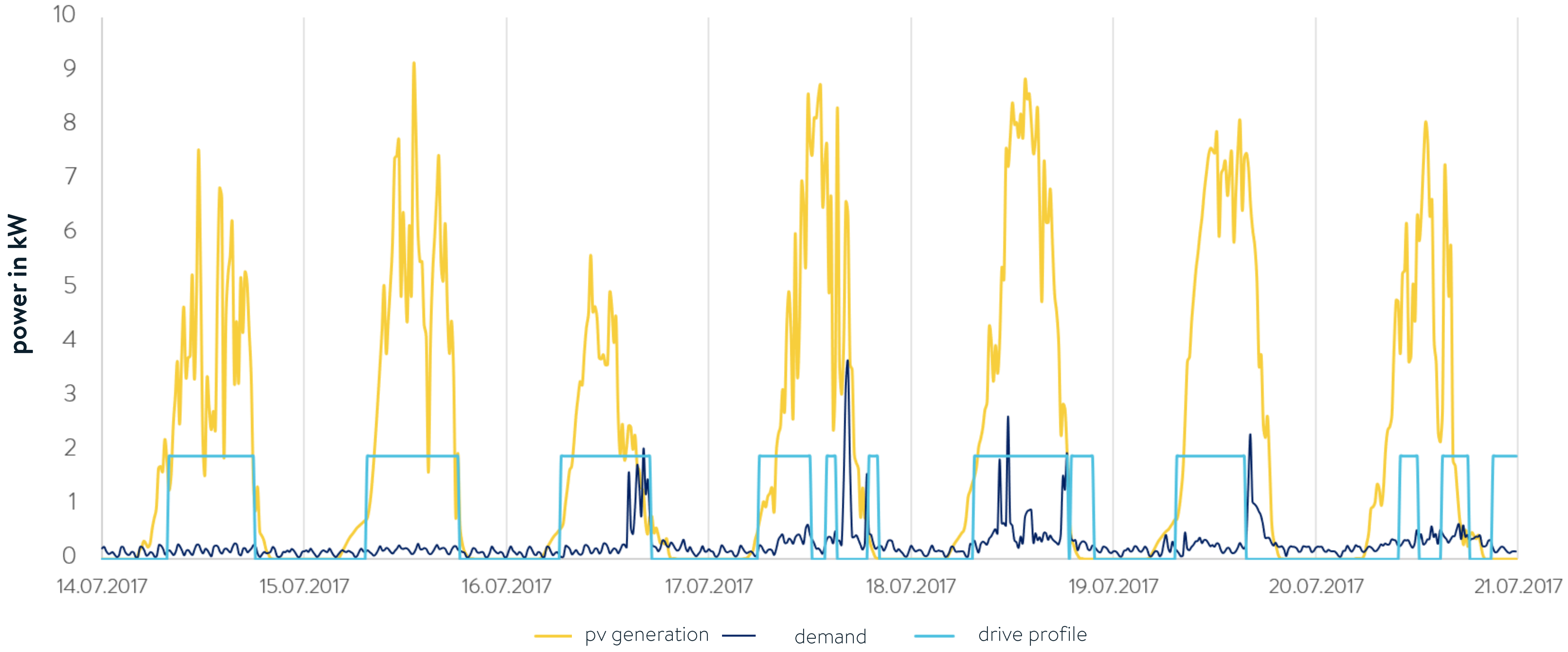
INPUT

- Timeseries pv-generation
- Timeseries demand
- Timeseries drive profile

OUTPUT

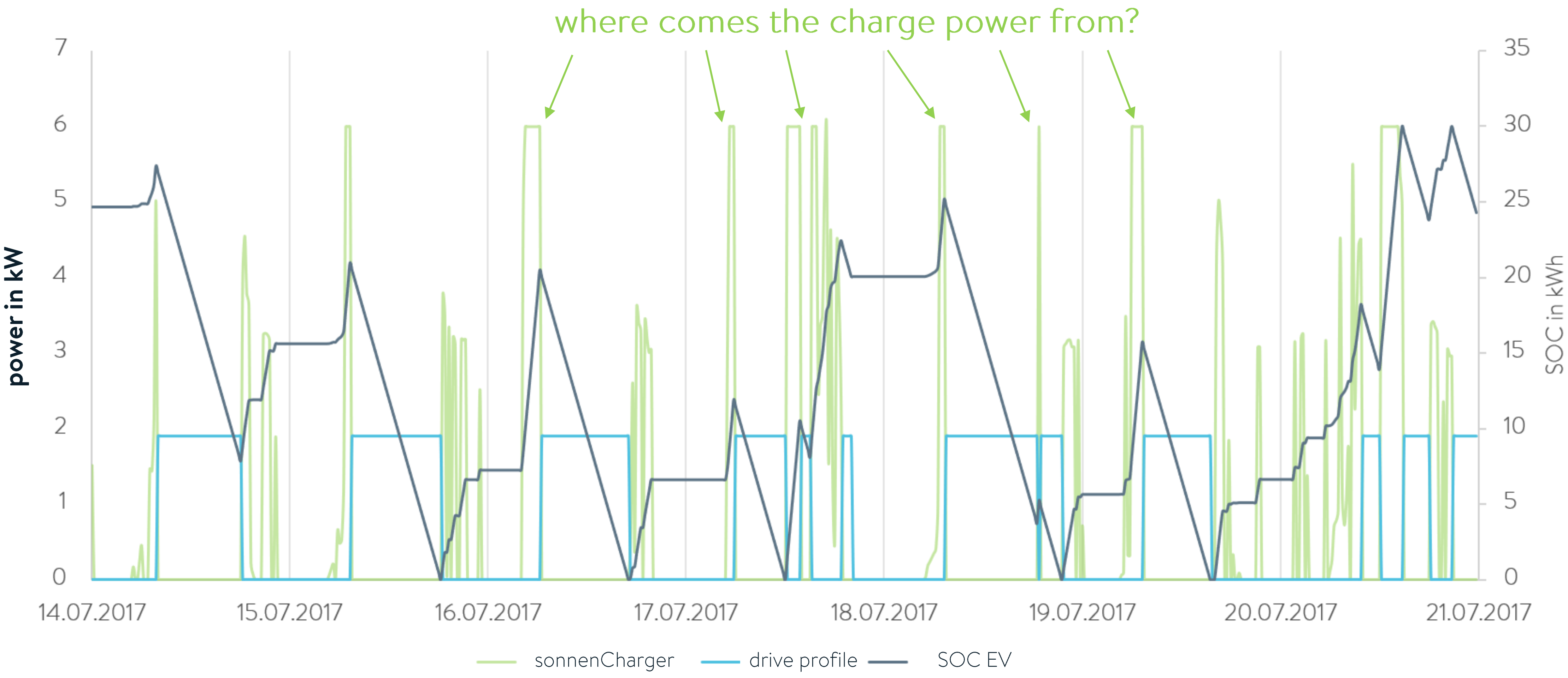
- sonnenBatterie behaviour
- EV battery behaviour
- systemtransparency

Input data



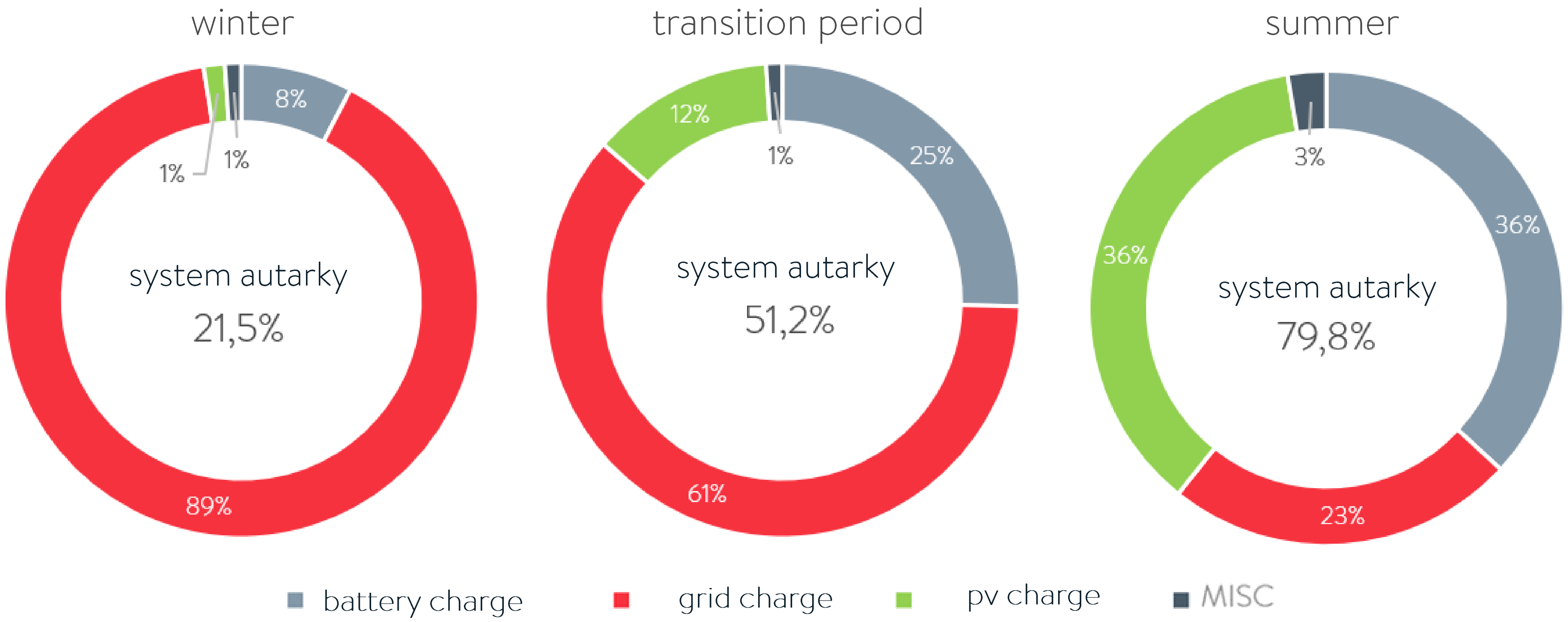
power in kW
10
9
8
7
6
5
4
3
2
1
0
14.07.2017
15.07.2017
16.07.2017
17.07.2017
18.07.2017
19.07.2017
20.07.2017
21.07.2017
pv generation
demand
drive profile

Analysis EV charging

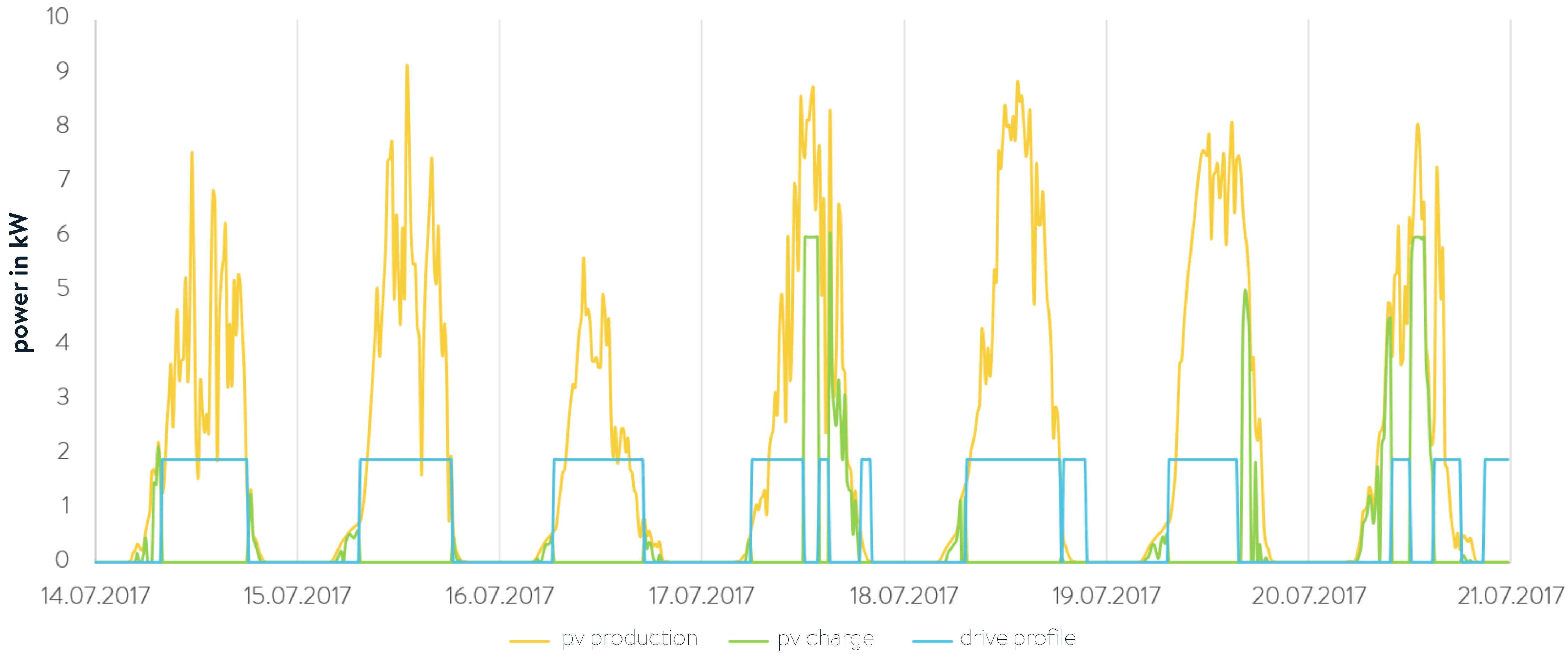


Transparency analysis

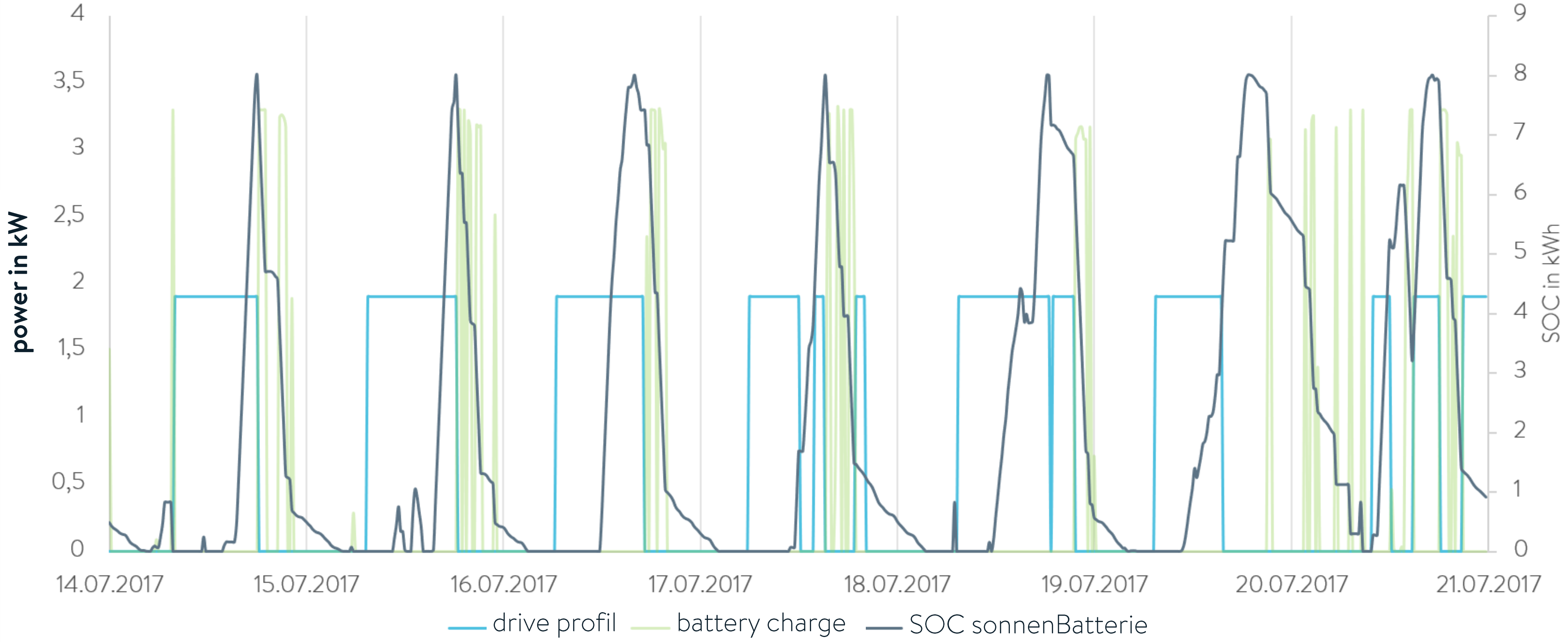
pv plant:	10,5	kWp
weekly demand:	68,8	kWh
sonnenBatterie:	8	kWh
EV battery:	30	kWh



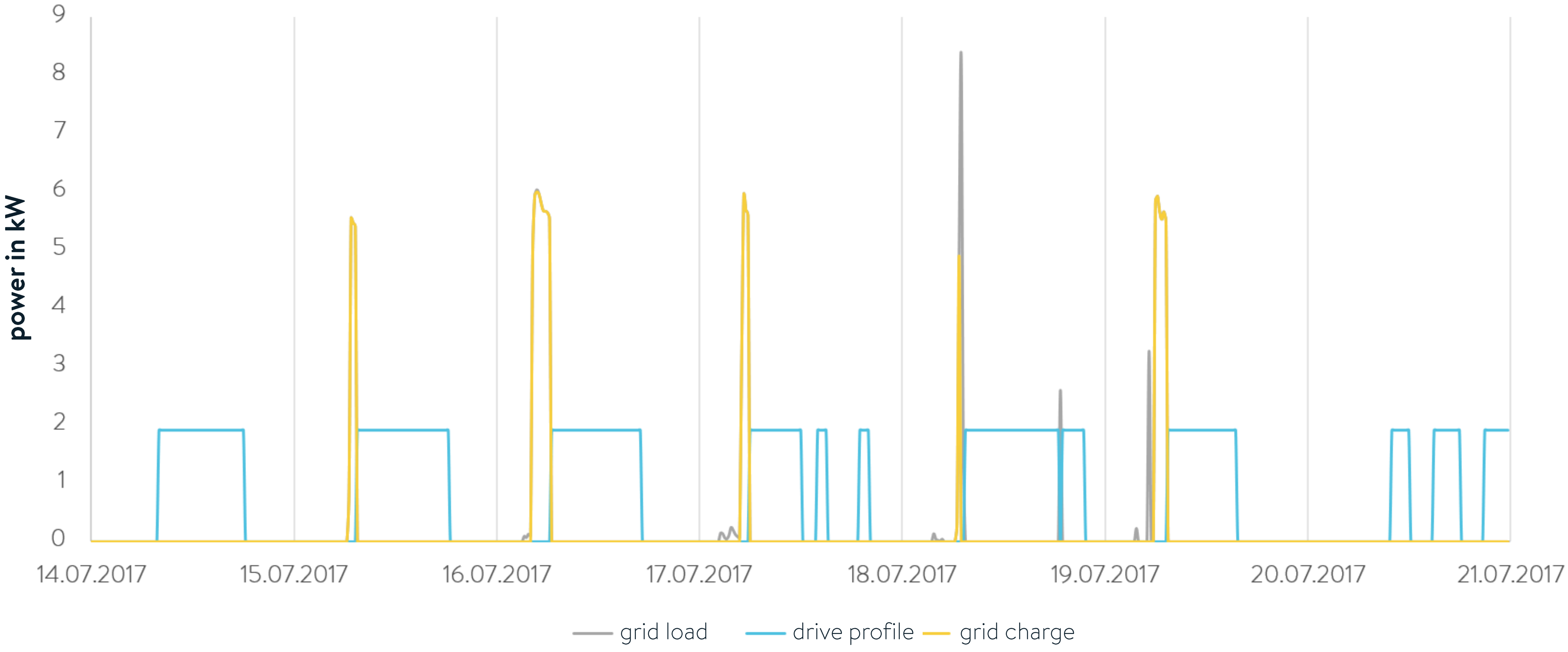
charging: pv → EV battery



charging: sonnenBatterie → EV battery



charging: grid → EV battery



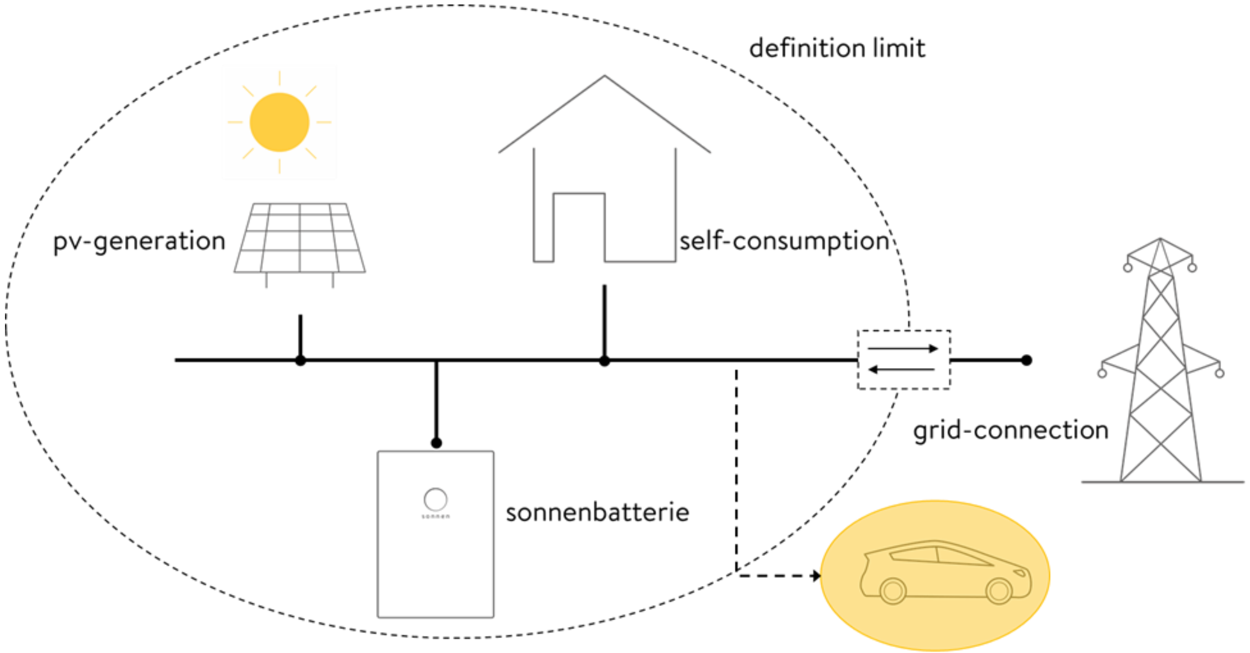
Interpretation of simulations results

The charging priority of an electric vehicle connected to a self-consumption optimised pv battery sytem consists as followed:

1. PV – charging
2. sonnenBatterie – charging
3. grid - charging

...this could be the basis for algorithm development...

Thank you for your attention!



Sources

[1] Weniger, J. ; Tjaden, T. ; Quaschning, V. : Vergleich verschiedener Kennzahlen zur Bewertung der energetischen Performance von PV-Batteriesystemen. In: *32. Symposium Photovoltaische Solarenergie* (2017)

[2] Apperly, M. ; Monigatti, P. ; Suppers, J. : Grid-Lite: A network integrated semi-autonomous local area electricity system. In: *Proceedings of the 4th international conference on green IT solutions* (2015)