Optimal design of a HESS for peak-shaving BEV fast charging demand at a highway rest stop

Semester Project

Sean Bone

Supervisor:
Christian Peter
Paul Scherrer Institut

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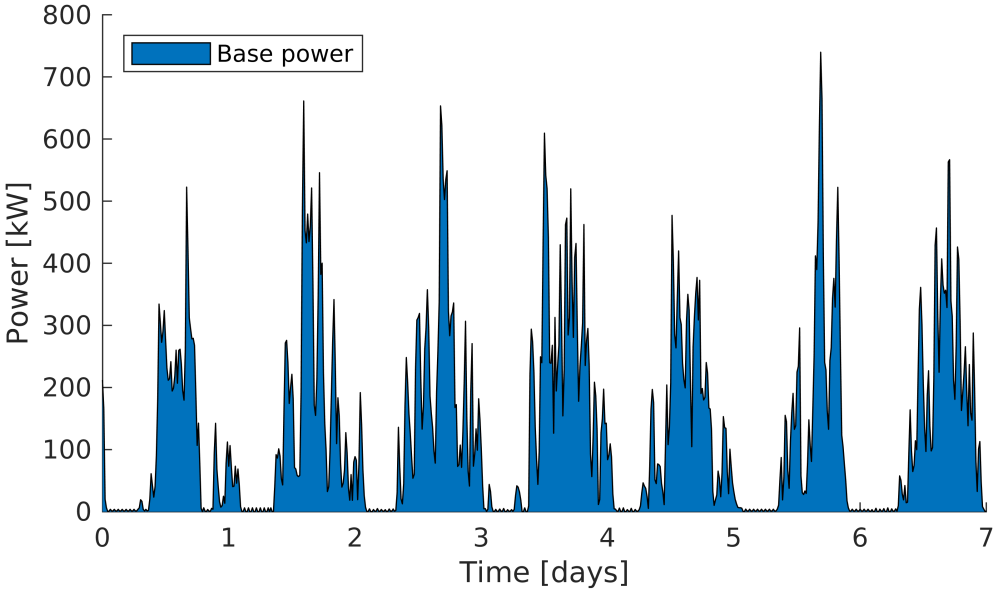
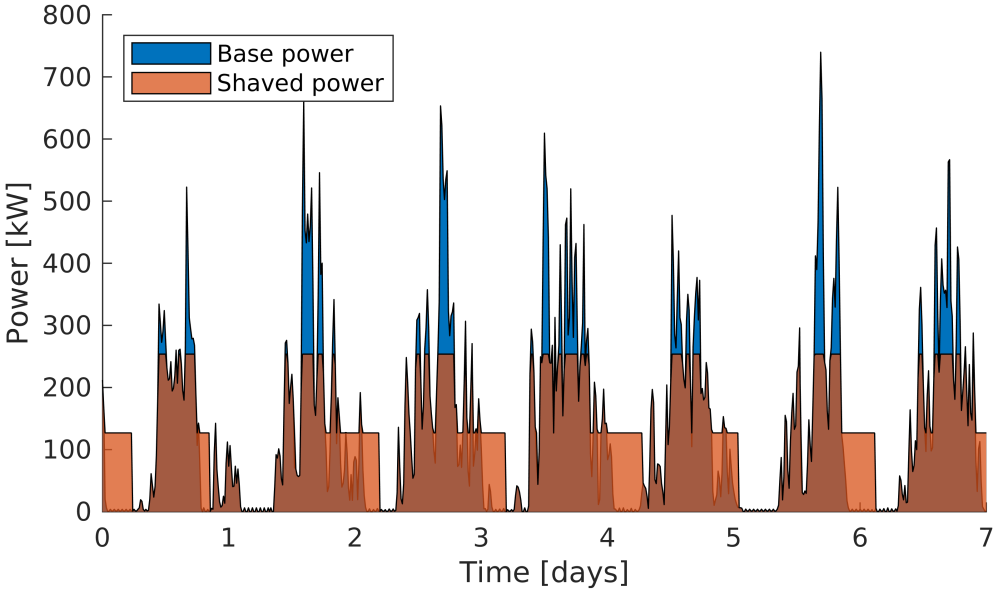
Setting: highway rest stop for battery-electric cars

Image source: carscoops.com

Example one-week power demand profile

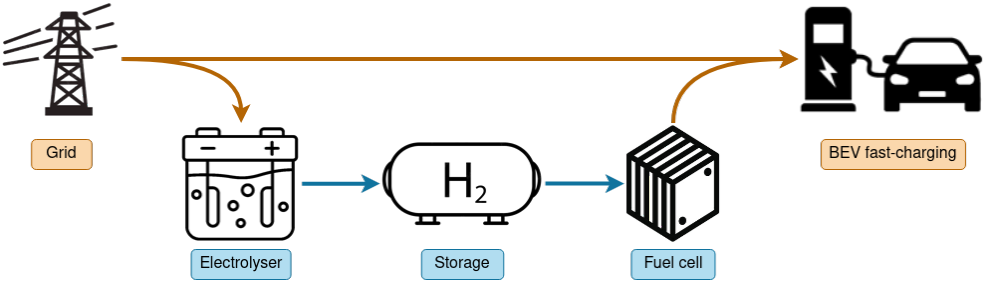


Example of peak-shaved power demand



Background
HESS

Hydrogen Energy Storage System



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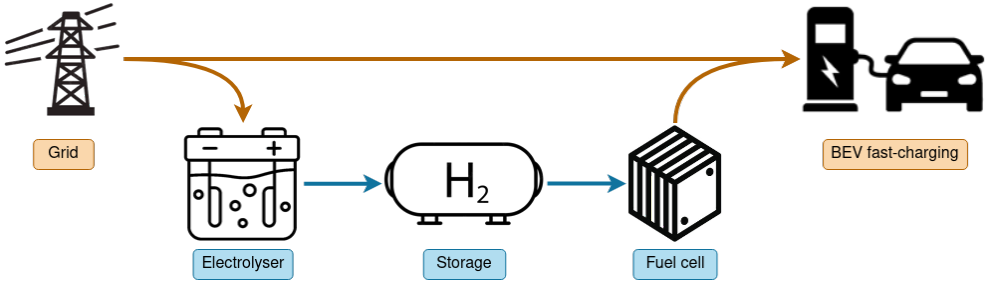

Trade-offs:

- CAPEX vs OPEX
- HESS vs BESS
- Sizing of components: ELY, H2 tank, FC, battery

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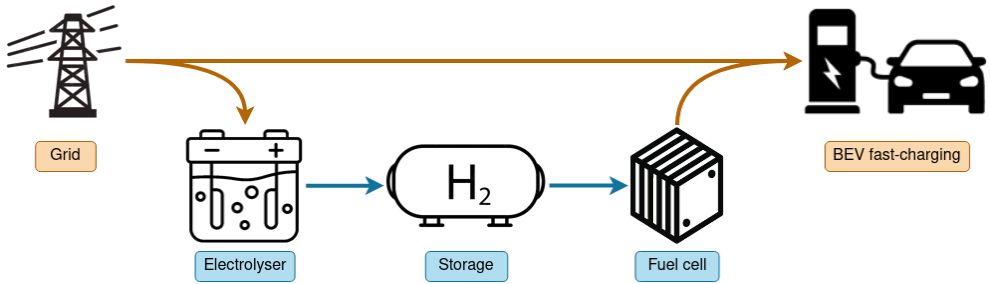

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- Sizing of components: ELY, H2 tank, FC, battery
- Present and future scenarios

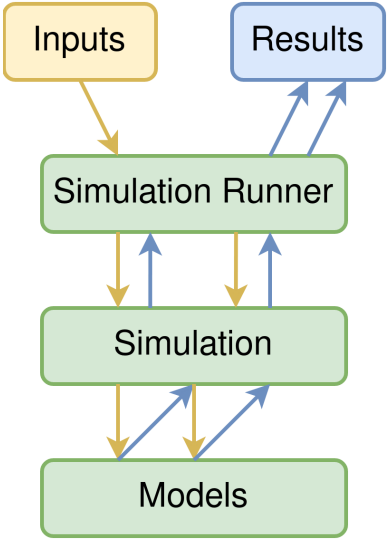
Illustration icons from stock.adobe.com (non-commercial license)

Background

HESS

Implementation

Implementation: framework structure



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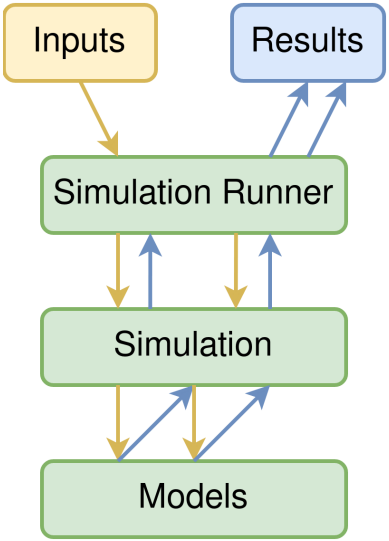
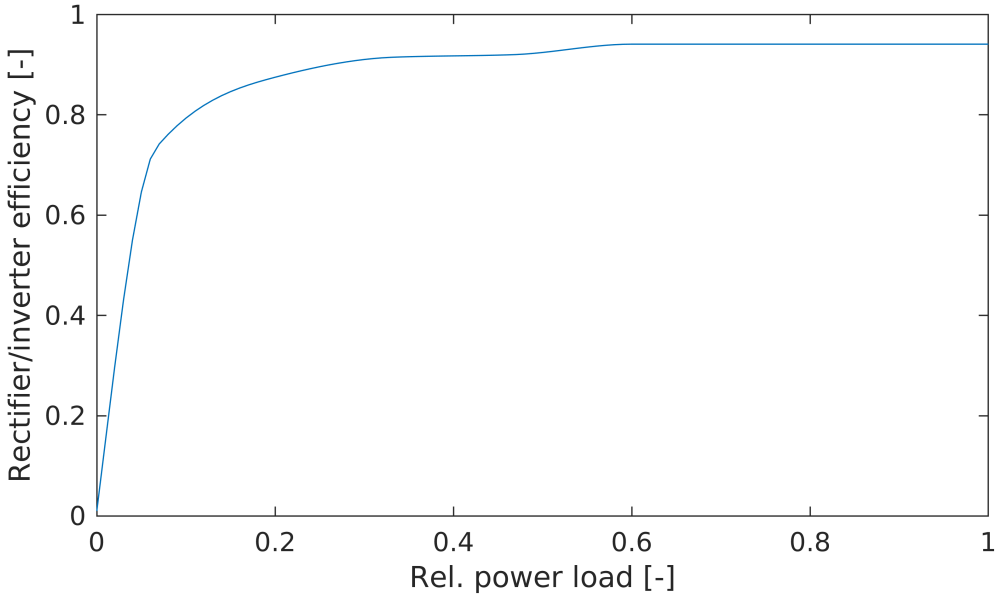
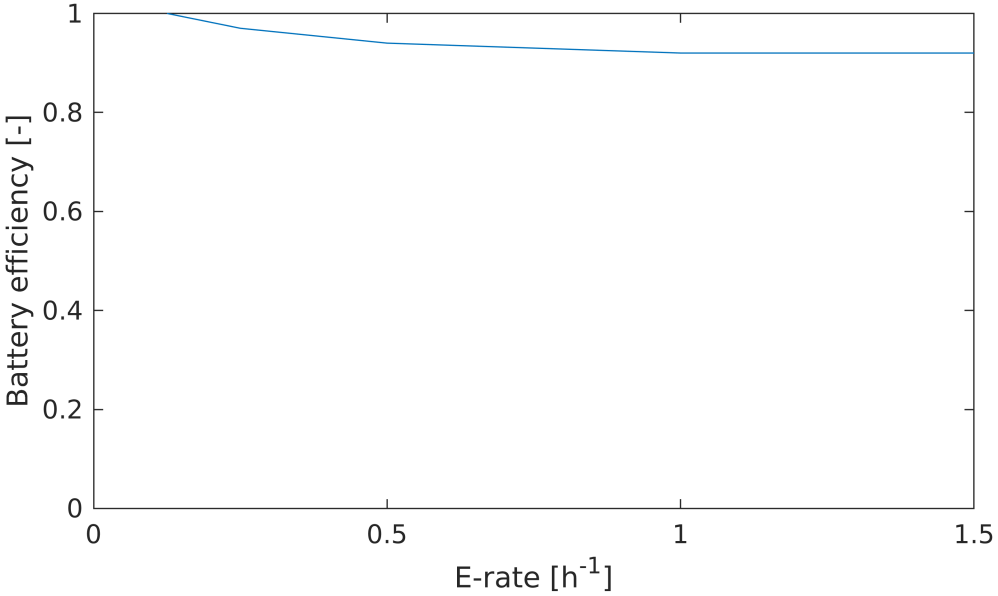


- Structured input/output format
- Each output contains all inputs for reproducibility
- Modular design allows adding or replacing of parts independently
- Allows for longer and larger simulations

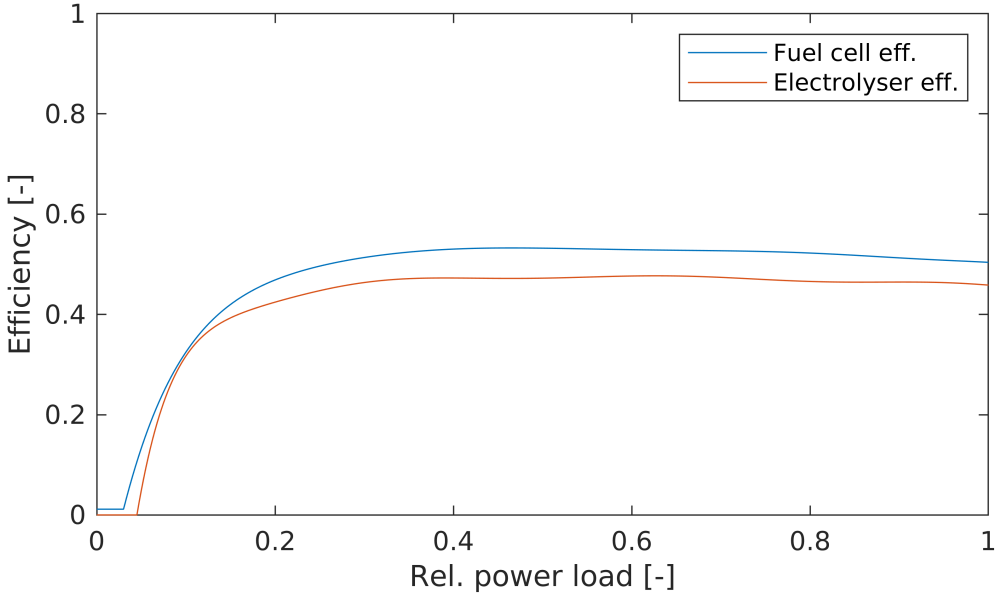
Implementation: BESS power conversion efficiency



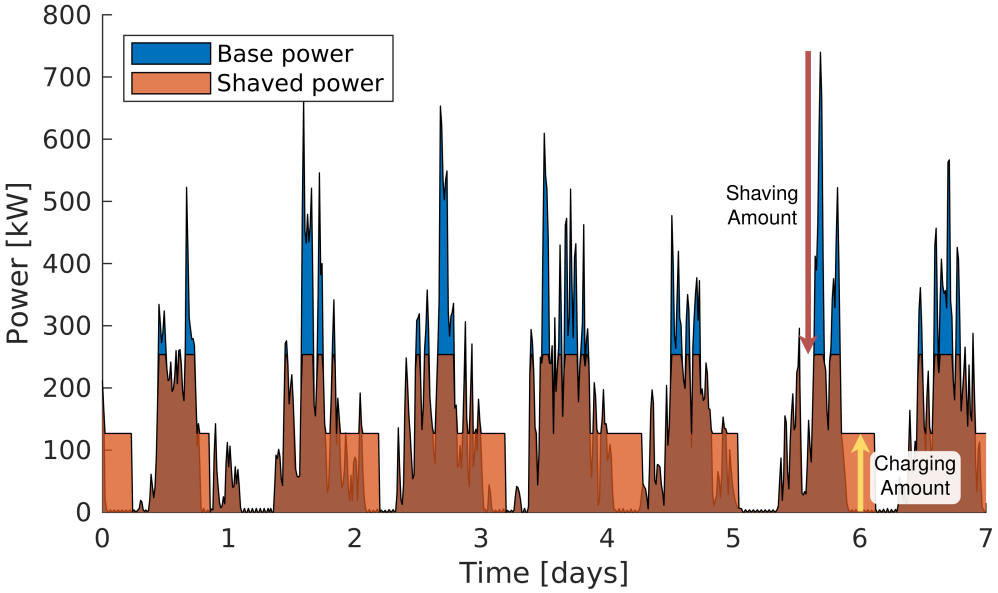
Implementation: BESS E-rate to efficiency



Implementation: HESS efficiency



Implementation: peak-shaving algorithm



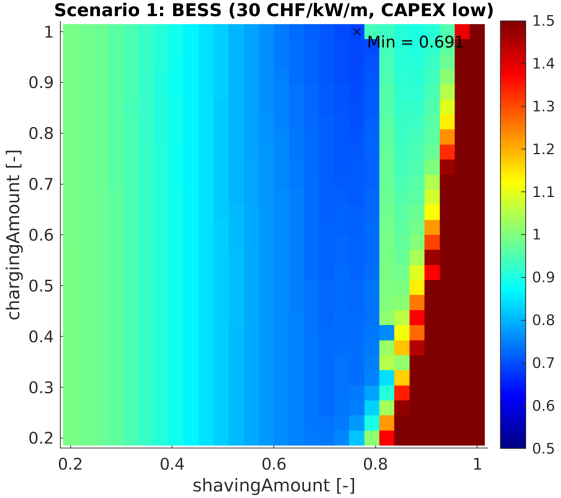
Background

HESS

Implementation

Results

Grid-search heatmaps



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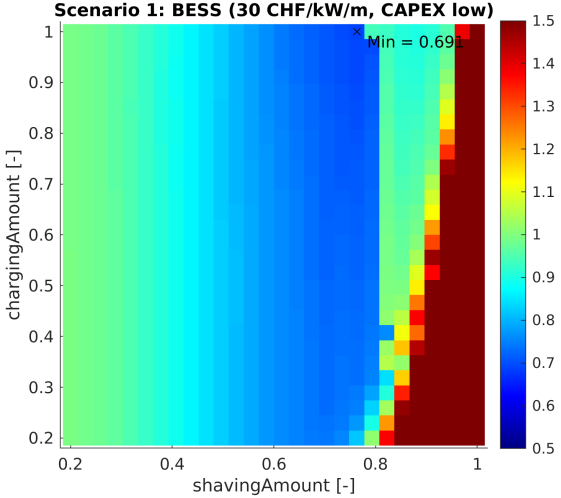

- Each cell in heatmap is a full simulation
- ~ 40 mins per sim x 784 cells ≈ 22 days of simulation time
- Ran in a weekend thanks to parallelisation of grid-search!

OPEX: Benutzungsdauer

Usage time (Benutzungsdauer):

$$\text{BD} = \frac{\text{Total energy [kWh]}}{\text{Avg. monthly peak [kW]}}$$

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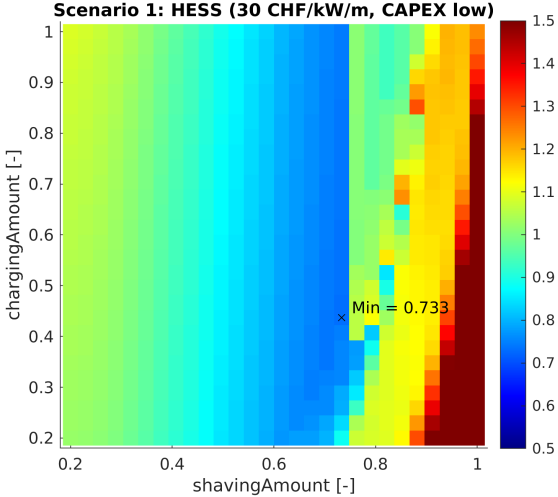
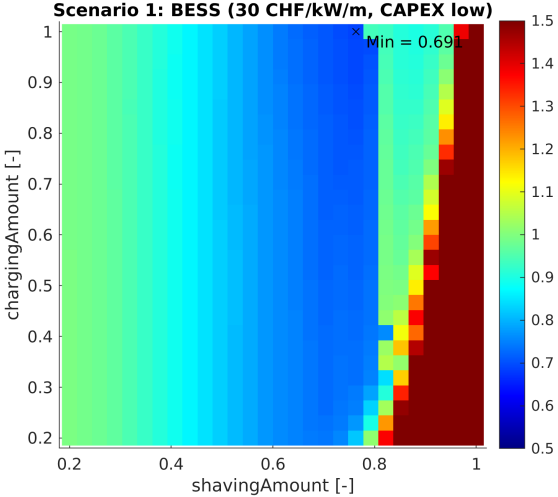
Rates change for BD > 3500 h:

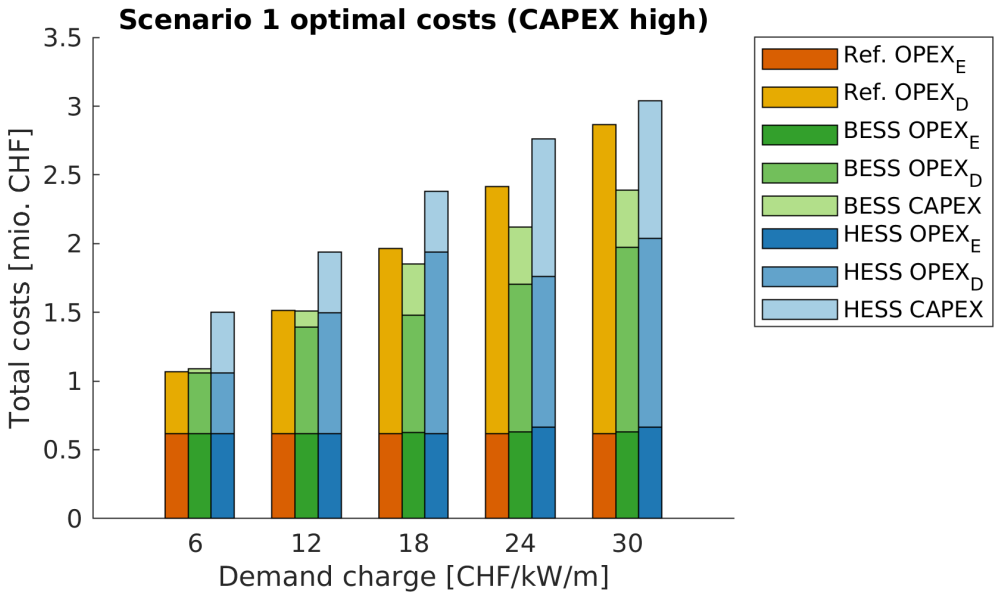
- Energy charges $\times \sim 0.5$
- Demand charges $\times \sim 2$

HESS vs BESS: impact of usage time (Benutzungsdauer)





Summary: 2019 data (all year)



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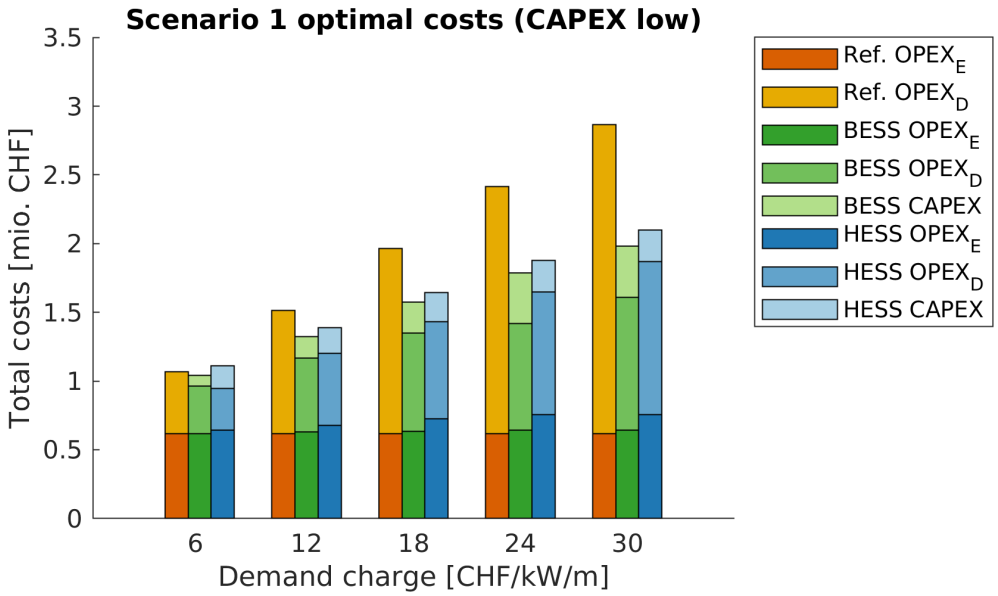
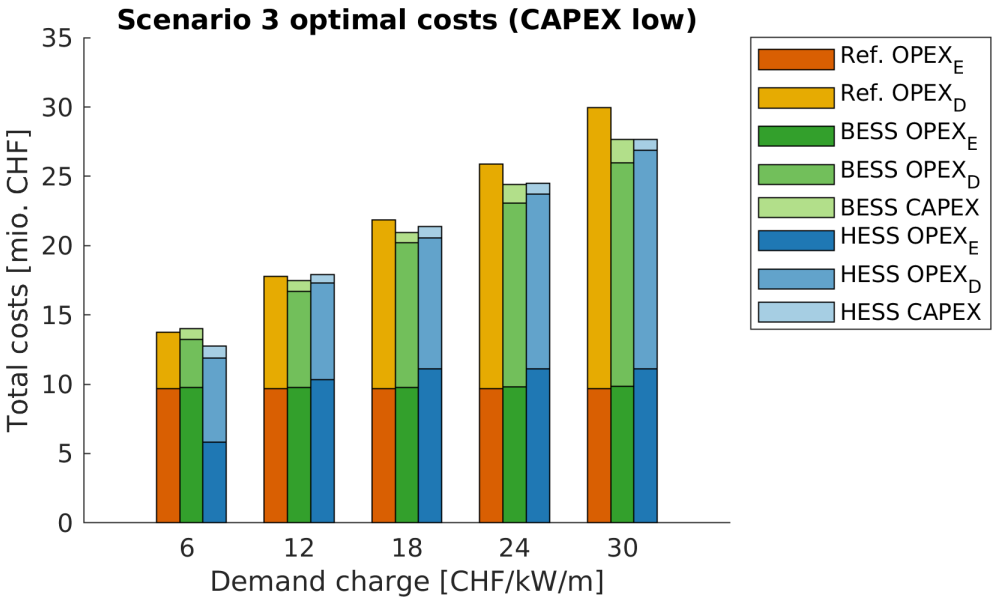


Summary: 30% BEV share (synthesised, one week)



Conclusions

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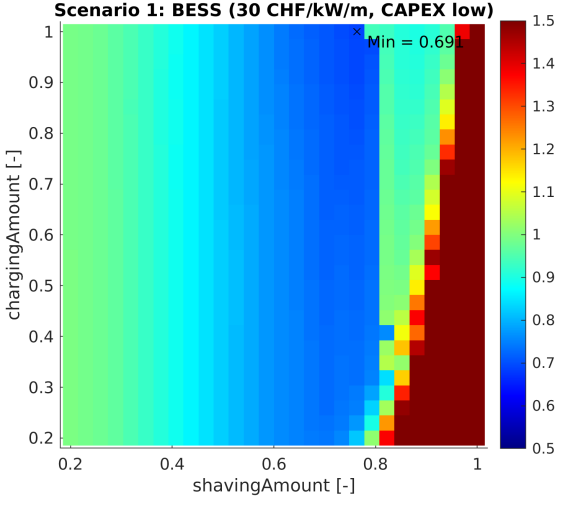
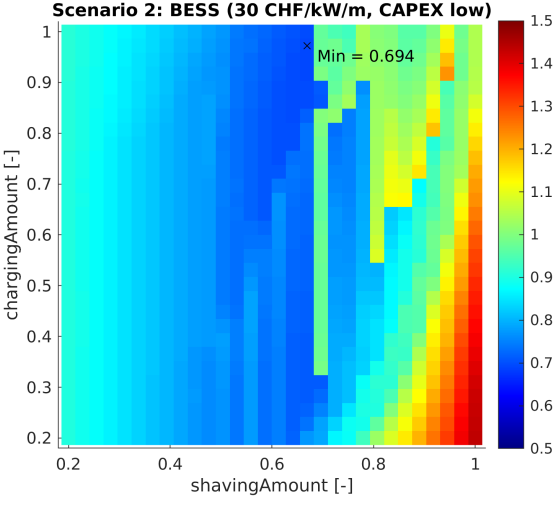
Code framework proof-of-concept:

- Grid-searches are easy to run and reproduce
- Parallelisation allows for larger simulations and grid-searches
- Structured outputs allow for simplified handling of results for plotting etc.

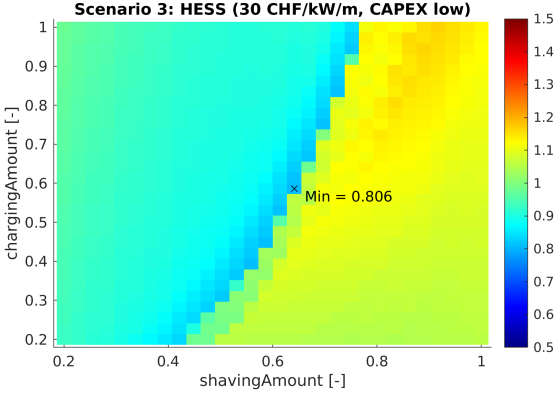
Thank You!
Questions?

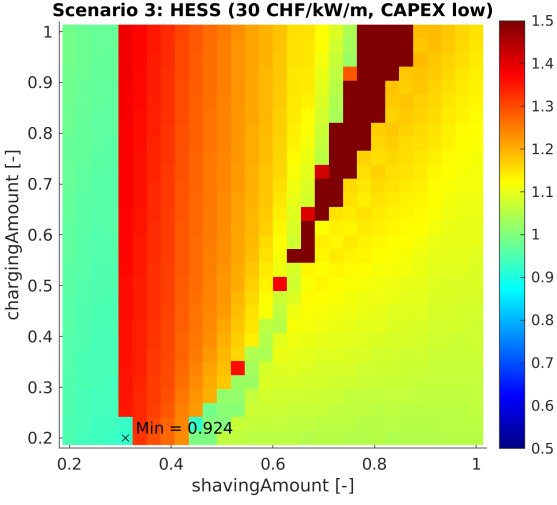
1-year data vs 1-week data



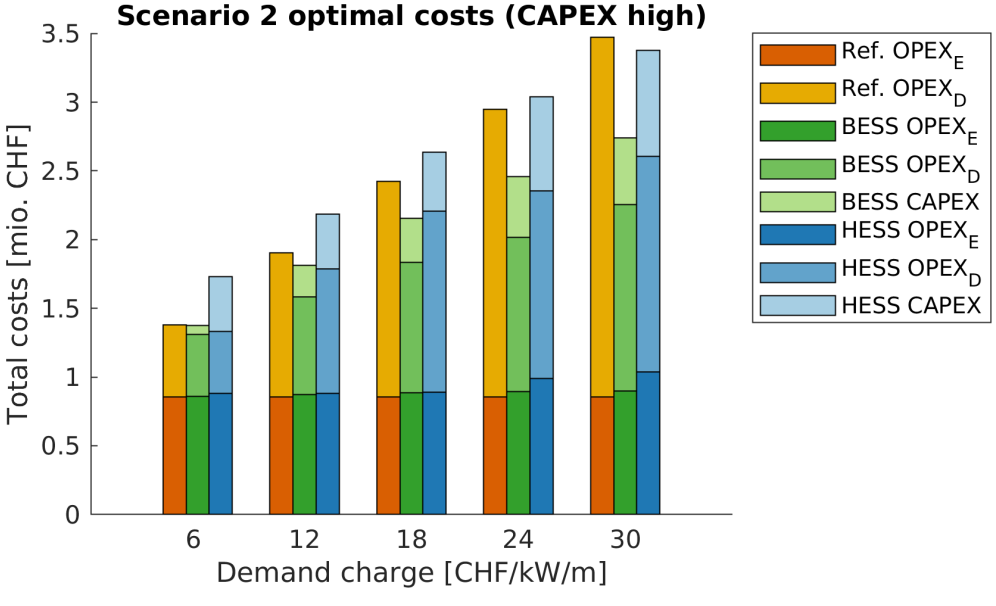


Impact of Benutzungsdauer: 30% BEV share (synthesised, one week)





Summary: most energy-intensive week of 2019



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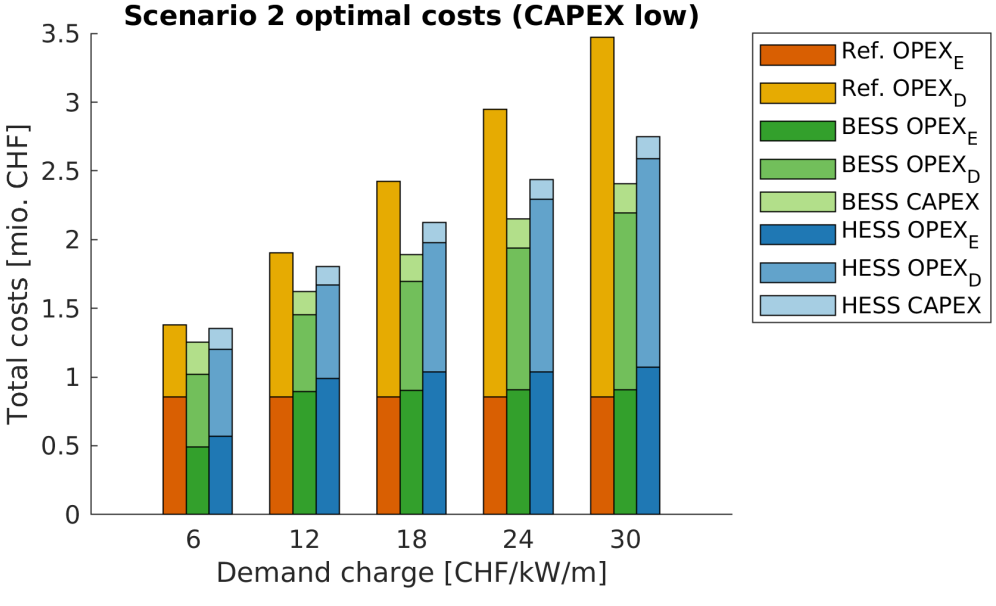

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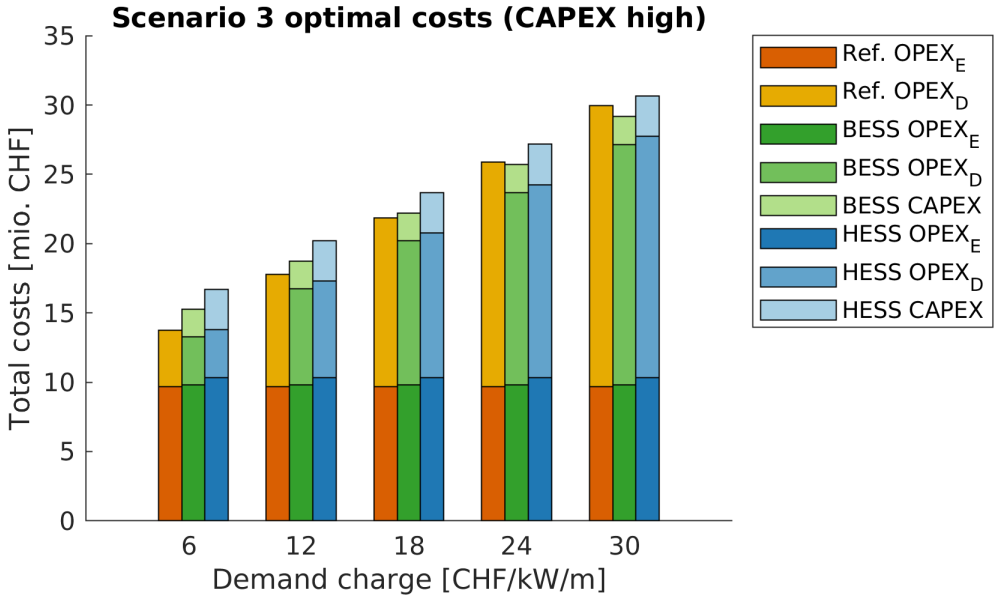

Minimum required capacity algorithm

Given a peak-shaving plan, how big does my H2 tank need to be?

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Given a peak-shaving plan, how big does my H2 tank need to be?

- Non-trivial question, as answer depends on actual power demand, ESS efficiencies, etc...
- Previously done by trial-and-error – hard to reproduce reliably!
- New algorithm computes a hard lower bound to capacity of any ESS
- Estimate can be refined based on efficiencies of specific ESS
- Proof of correctness in the full report