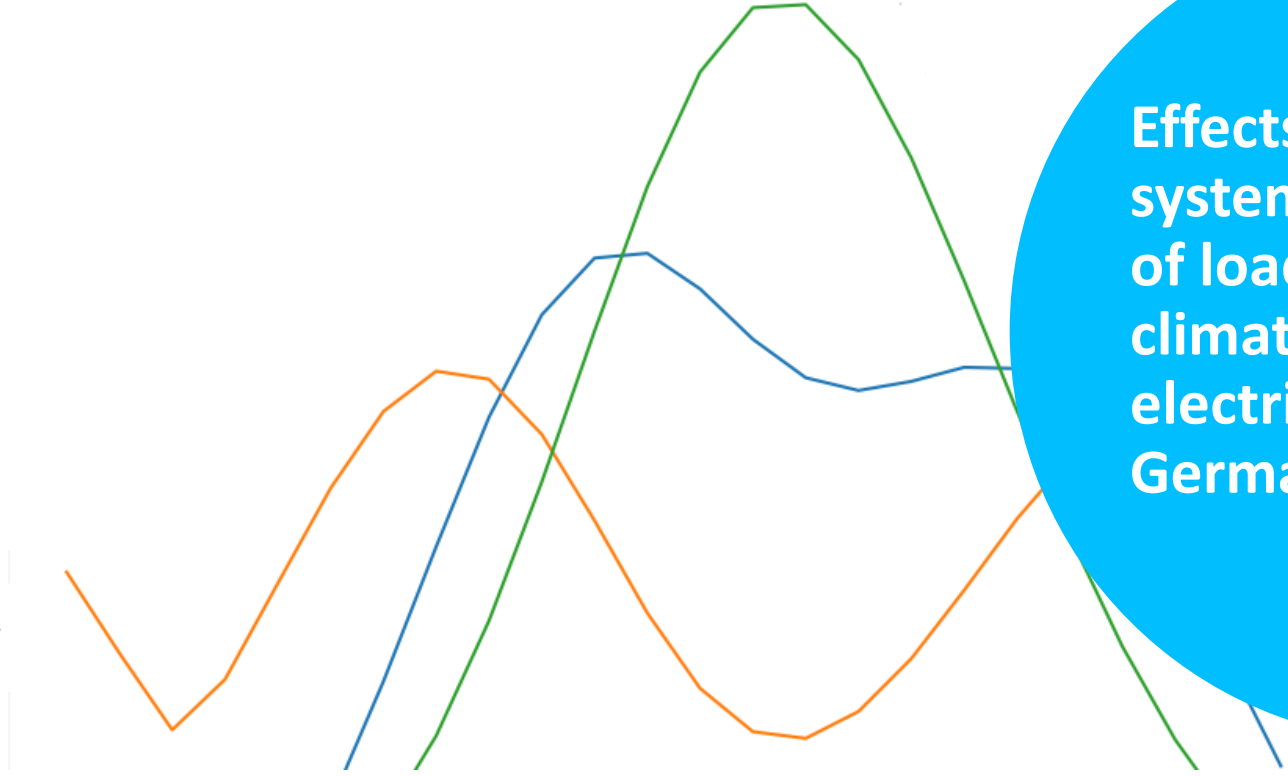
University of Stuttgart
IER Institute of Energy Economics
and Rational Energy Use



Effects of a systematic variation of load profiles on a climate neutral electricity system in Germany

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Agenda

1. Introduction
2. Methodology
   a. Load profile parametrization
   b. Systematic parameter variation
   c. Electricity Market Model
3. Results
4. Conclusion

Introduction

Introduction

- A climate neutral energy system has high shares of volatile renewable generation and low shares of controlling capacities

  → The difference between the renewable generation and the demand influences the system costs

    → The demand profile gains in importance

- Future demand profiles are shaped by new demands due to new technologies and changing demand patterns due to possible behavioural and societal changes (e.g.[1][2])

- How do changes in the demand profile shape affect the electricity system?

  → Systematic variation of load profile characteristics to explore the scope of possible effects

[1] Allison M, Akakabota E, Pillai G, 2018
[2] Burleyson C, Rahman A, Rice J et al., 2020

Methodology

Load profile parametrization

Load profile characterization

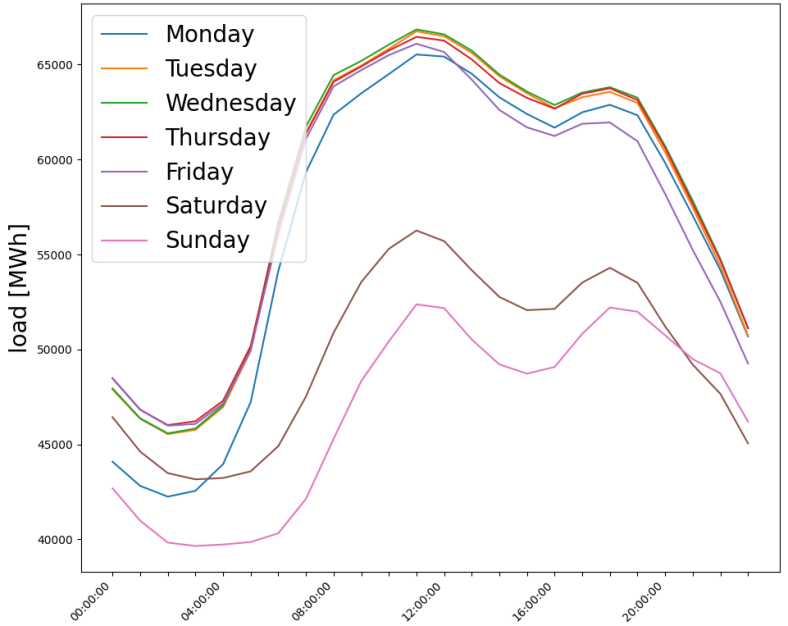
- Load profiles are often characterized via their maximal and minimal load
- The load peaks are often characterized via peak height, peak width and peak position (e.g.[3])
- These characteristics form the basis for the parametrization
- Peaks can be parameterized by height, width and position with a gaussian function
- Data: total electricity consumption for Germany 2021 in hourly resolution taken from [4]

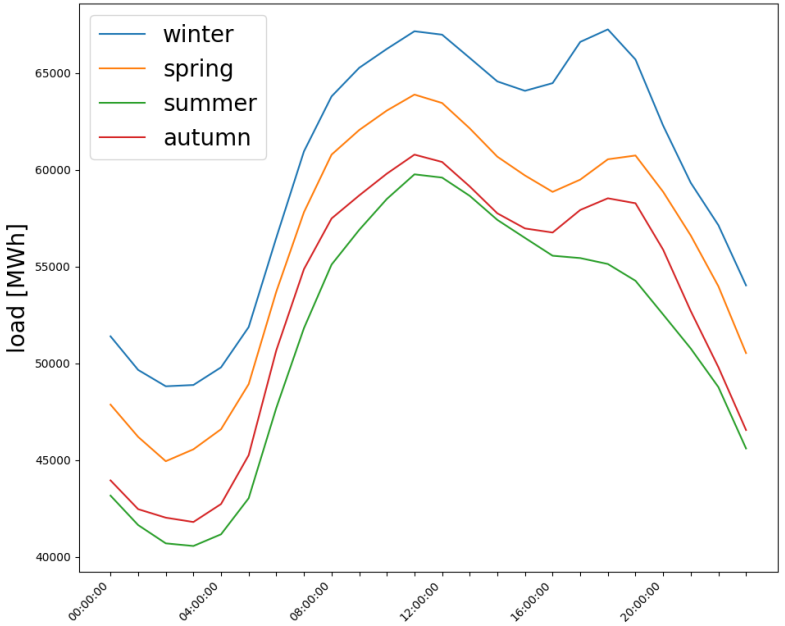
[3] Li H, Wang Z, Hong T et al., 2021
[4] Bundesnetzagentur | SMARD.de

Load profile parametrization

Load profile aggregation

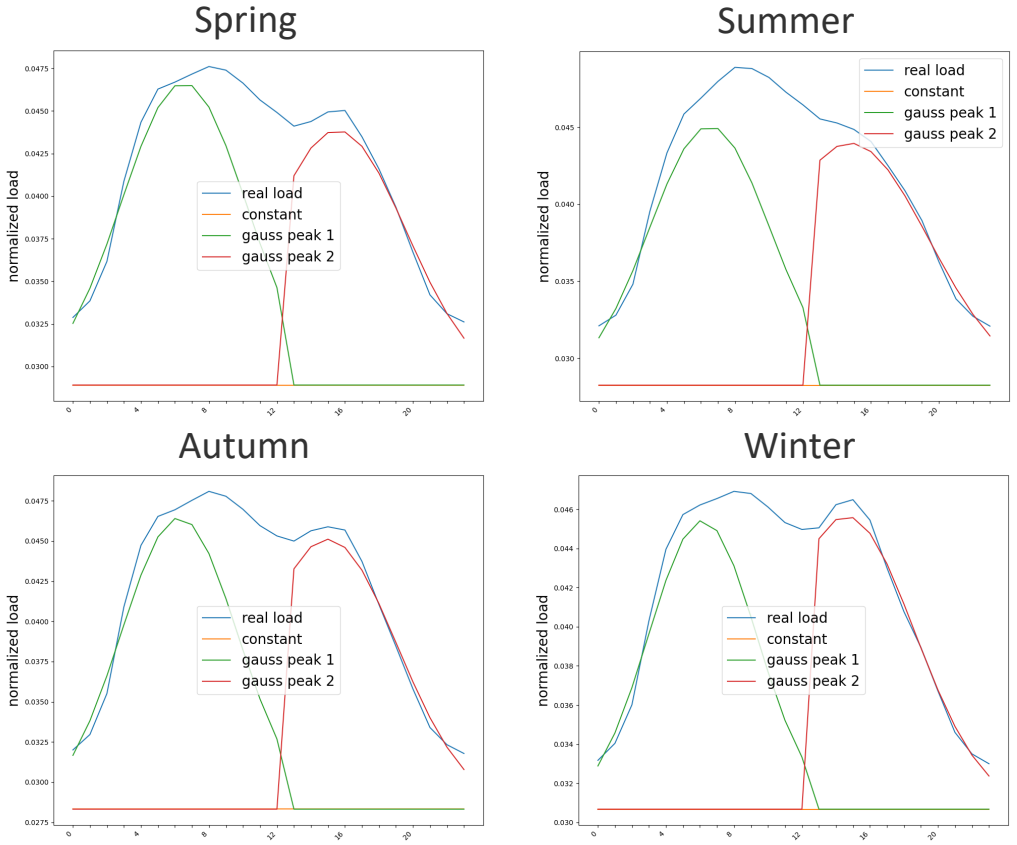
- Relevant time horizons: daily and annual
- Daily profile: simplification by aggregation into typical days for each season





Load profile parametrization

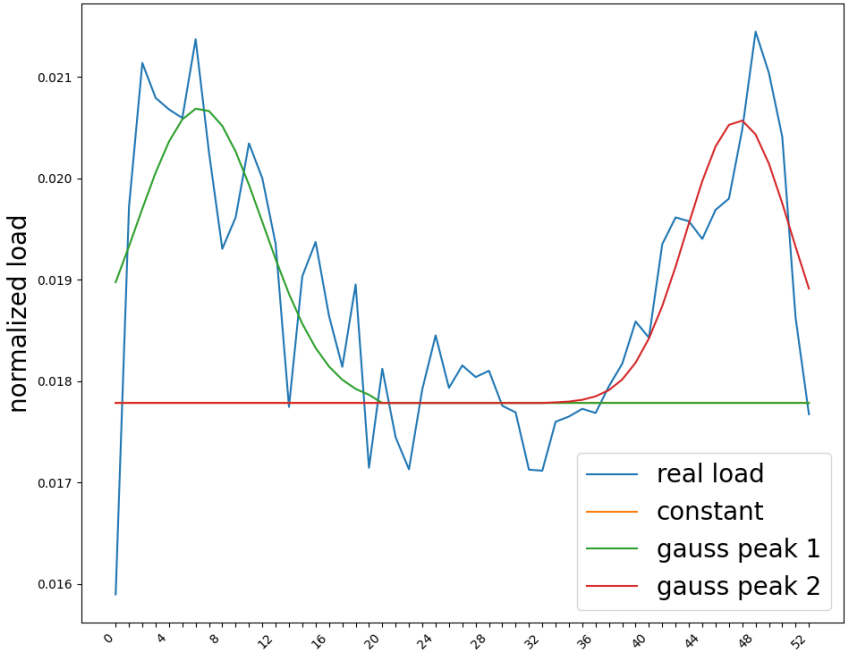
Parametrization daily profile



- The typical daily profiles are parameterized as a composition of two peaks and a constant base load
- The peaks are parameterized via peak height, peak width and peak position
- The initial parameters are determined via least squared fit to the data
- For the fit the start of the load curve is chosen at 3 am which corresponds to the hour closest to the load minimum for most daily profiles

Load profile parametrization

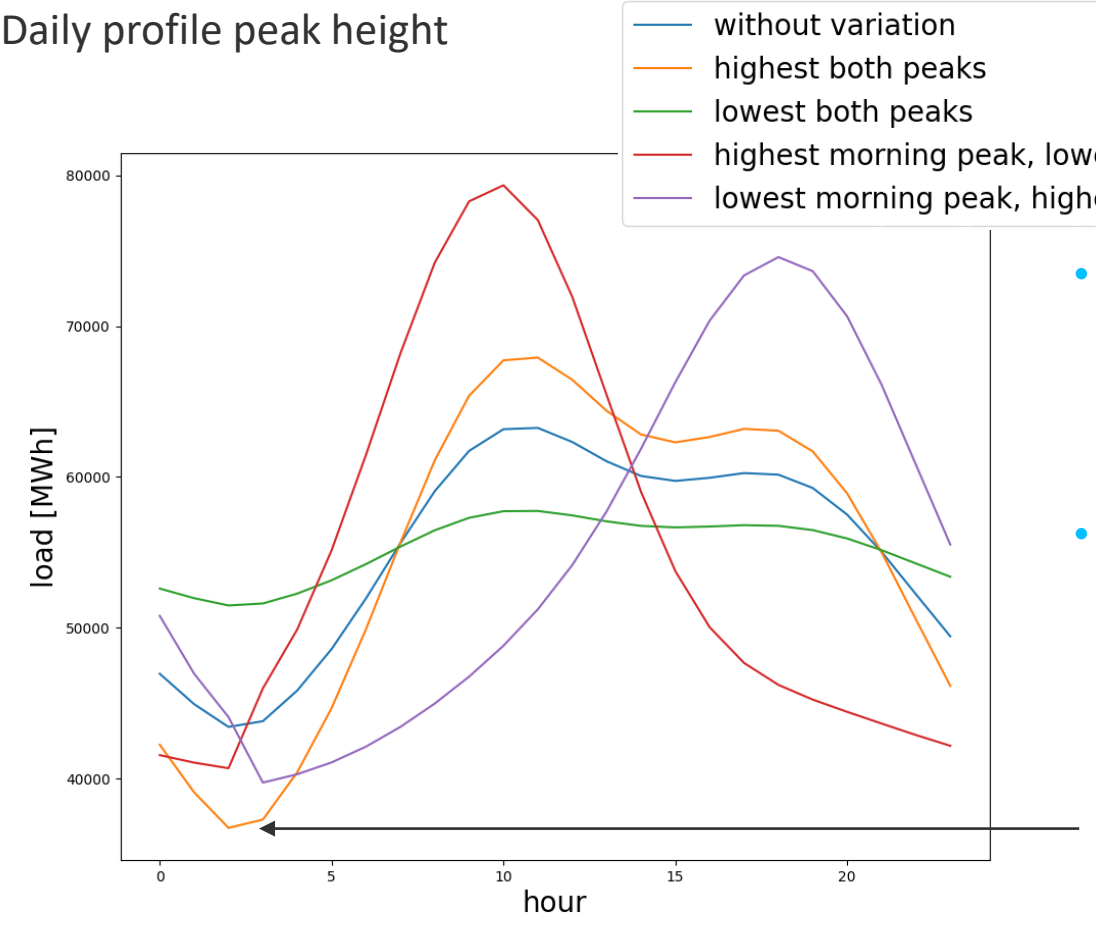
Parametrization annual profile



- The annual profile is parameterized as a composition of two peaks and a constant base load
- The peaks are parameterized via peak height, peak width and peak position
- The overall profile results as composition of the parameterized typical daily profiles scaled in accordance to the weekly profiles aggregated per season and the parameterized annual profile

Systematic parameter variation

Daily profile peak height



- Variation of daily peak heights by factors of

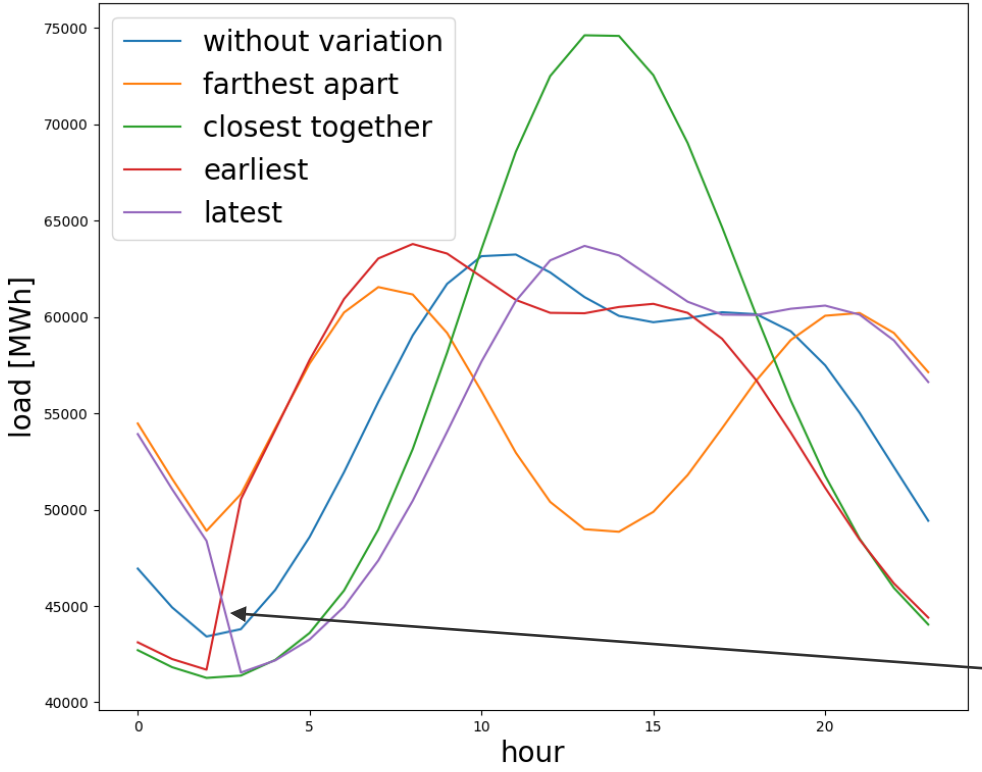
  0.25 0.5 0.75 1.0 1.25 1.5 1.75 2.0

- The total daily load is kept the same for all variations

Linear interpolation between 2 am (last hour of the day for parametrization) and 3 am (first hour for parametrization)

Systematic parameter variation

Daily profile peak position



- Variation of daily peak position by

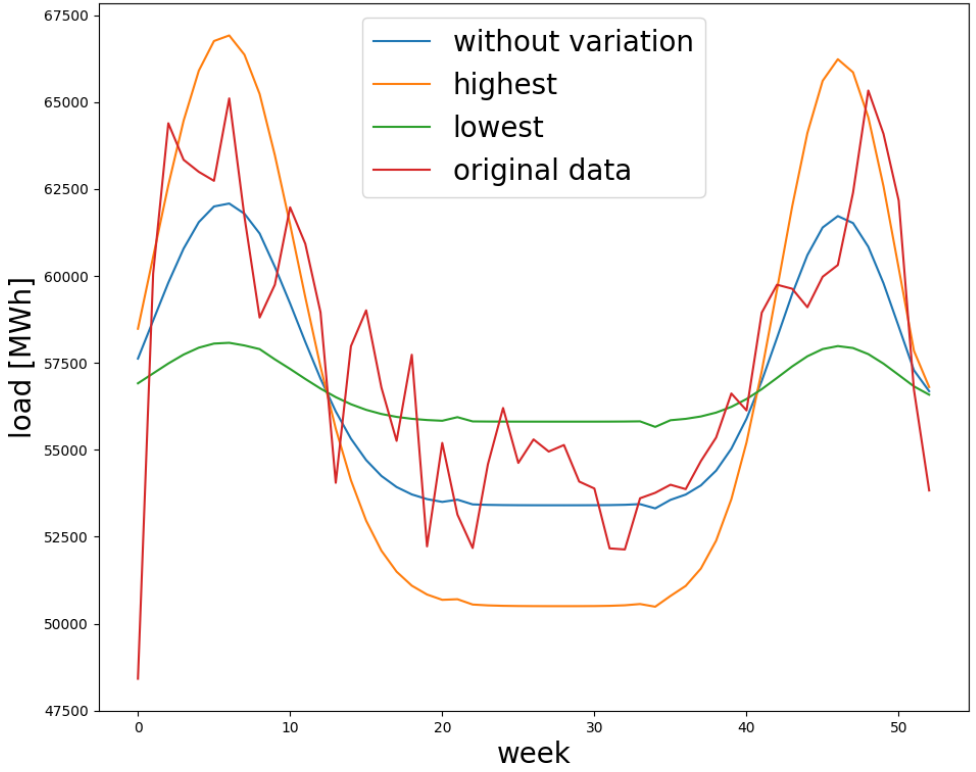
  ± 0.5h ± 1.0h ± 1.5h ± 2.0h ± 2.5h

- The total daily load is kept the same for all variations

Linear interpolation between 2 am (last hour of the day for parametrization) and 3 am (first hour for parametrization)

Systematic parameter variation

Annual profile



- Variation of annual peak heights by factors of:

  0.25 0.5 0.75 1.0 1.25 1.5 1.75 2.0

- The total annual load is kept the same for all variations

Electricity Market Model

European **E**lectricity **M**arket **M**odel – E2M2

Input

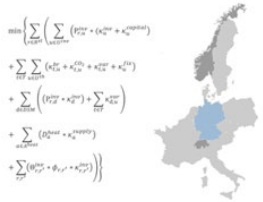
Dispatch
- Power plant data
- Existing power plants
- Renewable generation

Investments
- Options
- Costs

Restrictions
- Electricity demand
- Upper/Lower bounds

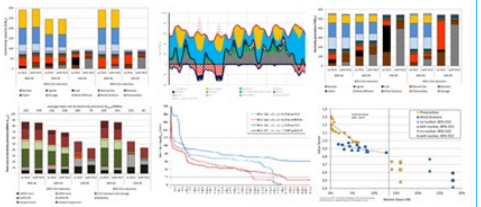
Model

- Linear optimization
- Minimization of system costs
- Restrictions must be met
- Investment decisions and dispatch optimized



Results

- Invested Capacities
- Dispatch
- System costs
- Electricity prices
- Power mix

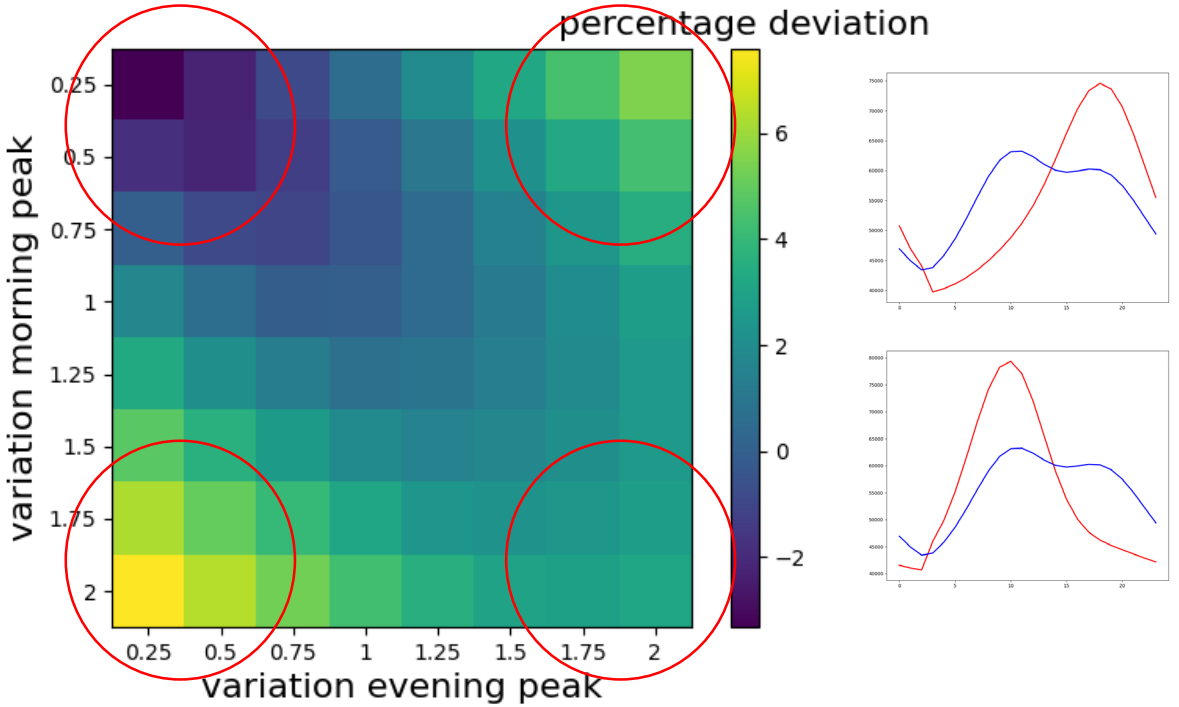


Without investment lower or upper bounds

Results

Results

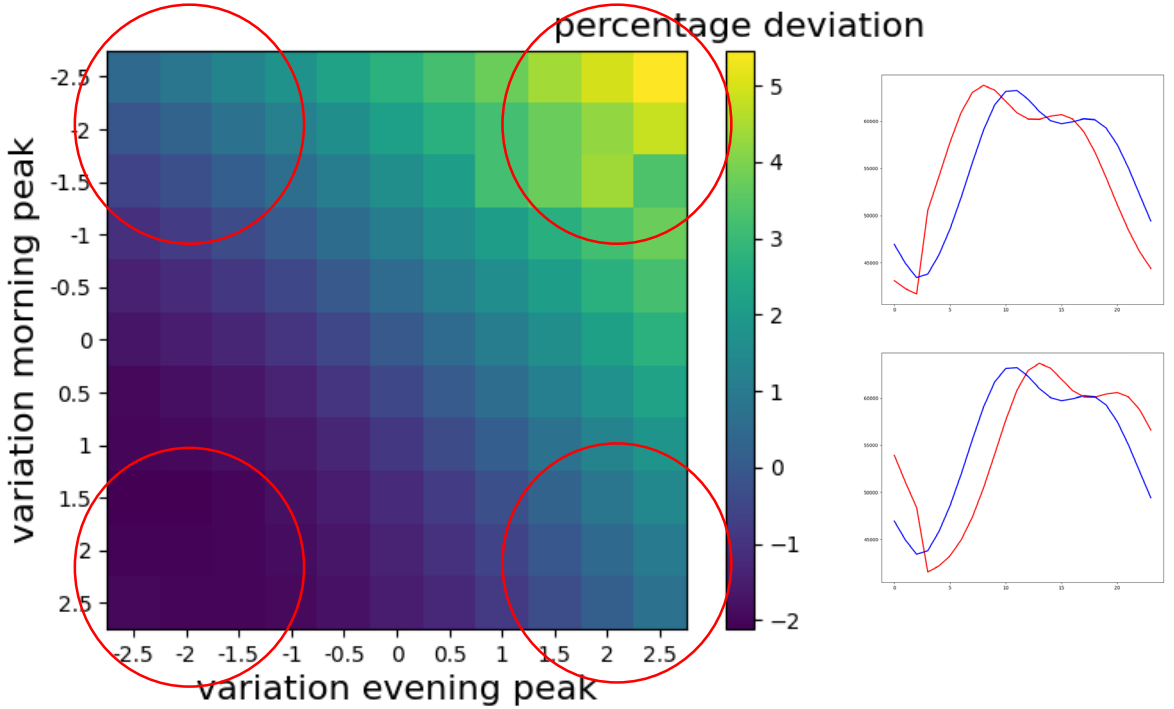
System costs daily profile peak height variation



- Flatter peaks lead to smaller system costs and higher peaks lead to higher system costs
- The biggest height difference between the two peaks leads to the biggest increase in system costs, this corresponds to the biggest overall peak height

Results

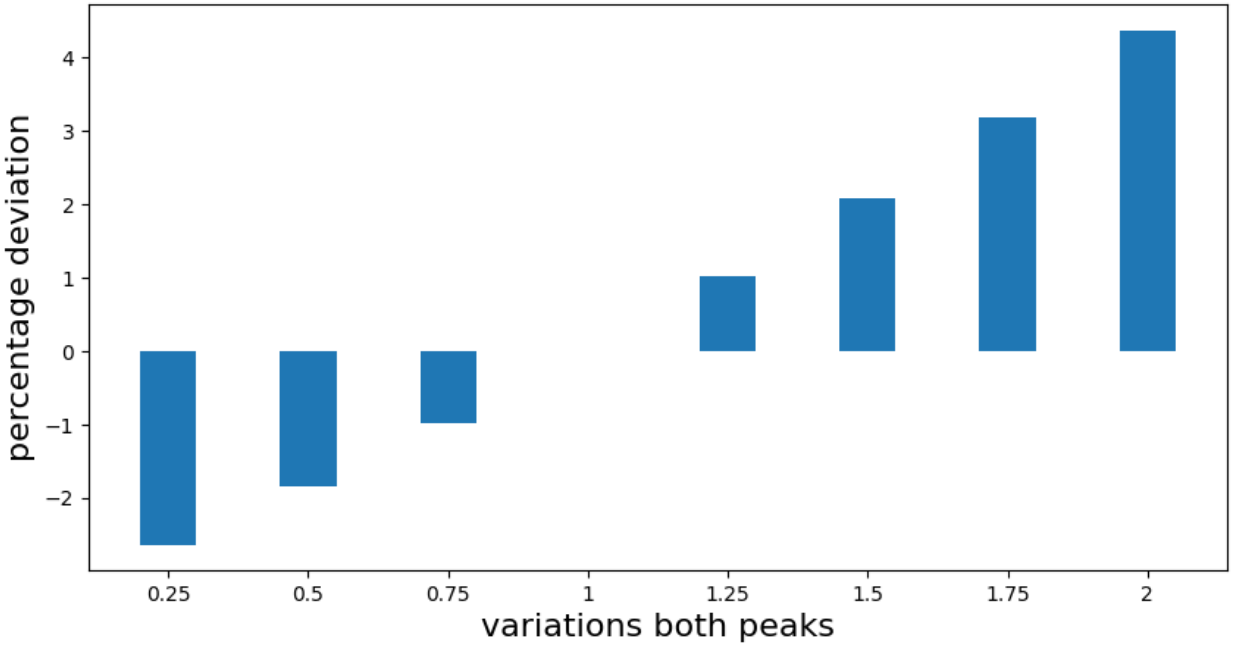
System costs daily profile peak position variation



- A greater difference between the position of the two peaks leads to higher system costs
- A smaller difference between the two peaks, resulting in a single peak created by the overlap, leads to a slight decrease in system costs
- An equal shift in position of both peaks leads to slightly higher system costs

Results

System costs annual profile peak height variation



- Flatter peaks lead to smaller system costs and higher peaks lead to higher system costs
- The range of the percentage deviation corresponds to the range of the daily profile variations

Conclusion

Conclusion

Summary

- The parametrization of load profiles via peak height, width and position leads to a synthetic profile with a deviation to the data of χ^2 between 1.06e-5 and 2.03e-06 for the aggregated daily profiles and χ^2 = 2.84e-05 for the aggregated annual profile
- The parametrization enables a systematic variation of load profile charateristics such as peak height and peak position
- The examined variations lead to deviations in the overall system costs from 2.76 Million € increase to 1.28 Million € decrease
- The variations of the daily profile point to more or less expansive times of the day

Conclusion

Outlook

Planned work:

- A detailed analysis of investments and dispatch for the different variations and the different technologies
- A smaller granularity of variations in regions of interest
- A combination of peak height and peak position variations for the daily and annual profile
- A sensitivity analysis with different weather years

Literature

[1] Allison, M., Akakabota, E., & Pillai, G. (n.d.). *Future Load Profiles Under Scenarios of Increasing Renewable Generation and Electric Transport*.

[2] Burleyson, C. D., Rahman, A., Rice, J. S., Smith, A. D., & Voisin, N. (n.d.). *Changes in Electricity Load Profiles Under COVID-19: Implications of "The New Normal" for Electricity Demand*.

[3] Li, H., Wang, Z., Hong, T., Parker, A., & Neukomm, M. (2021). Characterizing patterns and variability of building electric load profiles in time and frequency domains. *Applied Energy*, *291*. https://doi.org/10.1016/j.apenergy.2021.116721

[4] Bundesnetzagentur | SMARD.de

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Thank you!

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