Aggregation methods for renewable infeed profiles in energy system models

Project Workshop

WeatherAggReOpt: Entwicklung von Aggregations- und Reduktionsmethoden zur Implementierung disaggregierter Einspeiseprofile erneuerbarer Energien in Energiesystemmodellen

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

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Project goal and overview

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Overview

- Developing **methods** for (partial) **aggregation of renewable infeed profiles** in energy system models while **minimizing the influence on the overall results** of such models

- Consideration of **temporal, spatial and technological aggregation**

- Main **tasks**
  - **Theoretical work** regarding optimal (dis-)aggregation
  - Dedicated workpackages on **spatial, technological and temporal aggregation**
  - **Evaluation and testing of developed methods** in pre-existing energy system models

Methods and approaches

Project WeatherAggReOpt

Temporal aggregation

- Analytical approach using stylized optimization models
- Statistical analyses regarding effects of temporal aggregation

Spatial aggregation

- Analysis of weather data
- Impact of spatial aggregation

Technolog. aggregation

- Aggregation of investment choices based on value components
- Aggregation of PV units

Testing

- Construction of a reference test model
- Implementation and testing of methods in large-scale electricity market models

Analytical approach for temporal aggregation

- Highlights
  - Inspired by problems of scenario aggregation in the field of stochastic programming
  - Solution quality of the model based on aggregated time series compared to the solution of the original problem
  - Analytical results derived for a simplified version (peak-load-pricing)

- Methodology
  - Original (non-aggregated) problem → Corresponding reduced problem → Meta problem
  - Application (analytical, numerical) utilizing the peak-load-pricing model

Pöstges, A., Weber C., 2019. Time series aggregation – A new methodological approach using the "peak-load-pricing" model. Utilities Policy, 59. (https://doi.org/10.1016/j.jup.2019.05.003)

WP 5: Temporal aggregation and reduction of renewable infeed profiles aus EE-Anlagen

Analytical approach – key insights

Temporal aggregation (UDE)

Results

- With N technologies, **2 N + 1 time segments sufficient** to replicate capacities, energy quantities & prices
  - if appropriately selected and in a single node model without operational constraints (“peak-load-pricing model”
- **Separate** consideration of the **time step** with the **highest residual load**
  - much **higher shadow price** in this timestep has an **important impact on overall cost**
  - True also for models **with endogenous renewable generation capacities** as well as to **multi-region cases**

Further work on multi-region settings

- **Scarcity of transmission capacities** impacts possible aggregation
  - Case distinction: **non-binding vs. binding transmission** constraints: one common or multiple supply stacks
- Description of the infeed distribution over **different residual load levels** required – with **storage** also relative position of time segments matters

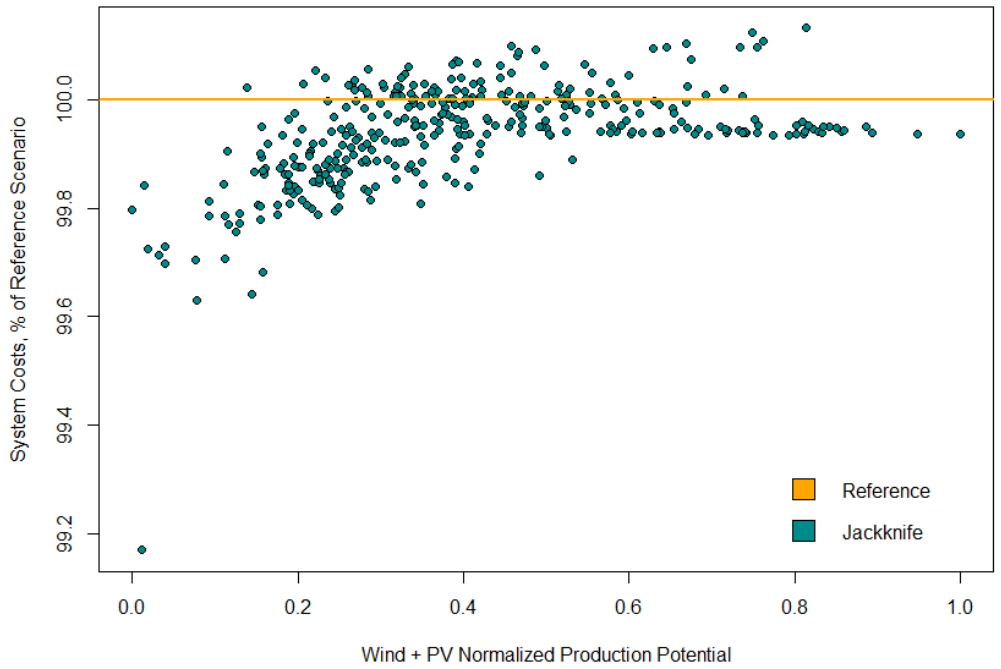
WP 5: Temporal aggregation and reduction of renewable infeed profiles aus EE-Anlagen

Effects of temporal aggregation - Statistical Analysis of serial dependance

- Using 2 statistical tests: **Randomization** and **Jackknife-method**
- Randomization of hours in days, hours in months, days in months, days in years, weeks in year
- Randomization of hours in months
  - **More short term storage** and the storage volume of the **long term storage decreases** by around 85 %, but is consistent over the model runs
  - **PV expansion decrease** by 50 % (PV more expensive than Wind in the scenario)
- Randomization of days in months
  - Storage volume of **long term storage decreases** by 25-40 %
  - **PV expansion decreases** by 25 %
  - Results are more spread than in other randomization
- Randomization of days in years
  - **PV expansion decreases by 80-90 %** due to the elimination of the seasonal structure

Effects of temporal aggregation – Impacts of extreme events based on statistical analysis

- **Jackknife-method**
  - systemically leave out observations
  - Remove a day from the dataset and calculate the results
  - Repeat for each day in the dataset
- **Results:**
  - The exclusion of **periods with low capacity factors for wind/PV** have the highest impact on the model results
  - The **impact** becomes greater when there is a **cluster of low generation days** or weeks
  - The observation with the lowest capacity factor has not necessarily the biggest impact



Analysis and Aggregation of weather data

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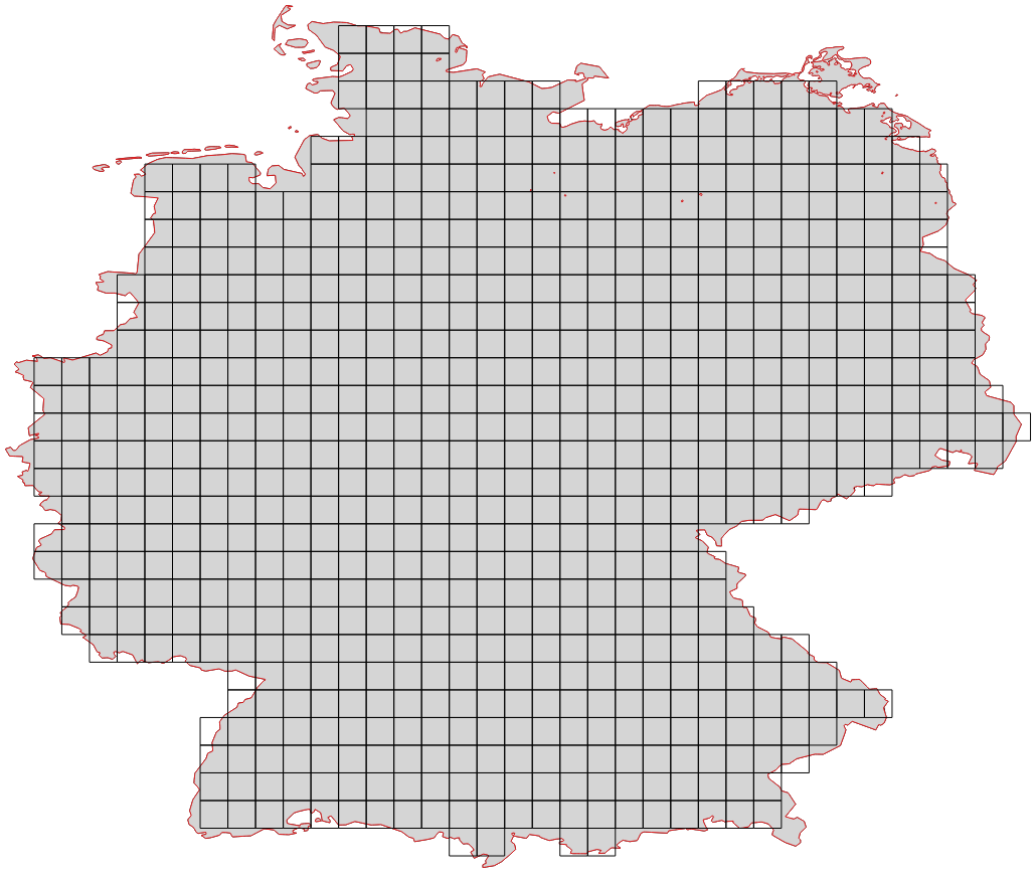
Spatial Aggregation (ISE)

- Selection of Weather Dataset:
  - Merra-2 (NASA)
  - CFSv2 (NCEP)
  - ERA5 (ECMWF)
- ERA5 Was selected based on the following criteria
  - Longest observation period
  - Windspeed on 100m as parameter
  - Higher resolution than the Merra V2 Dataset
  - Weather model of the newest generation



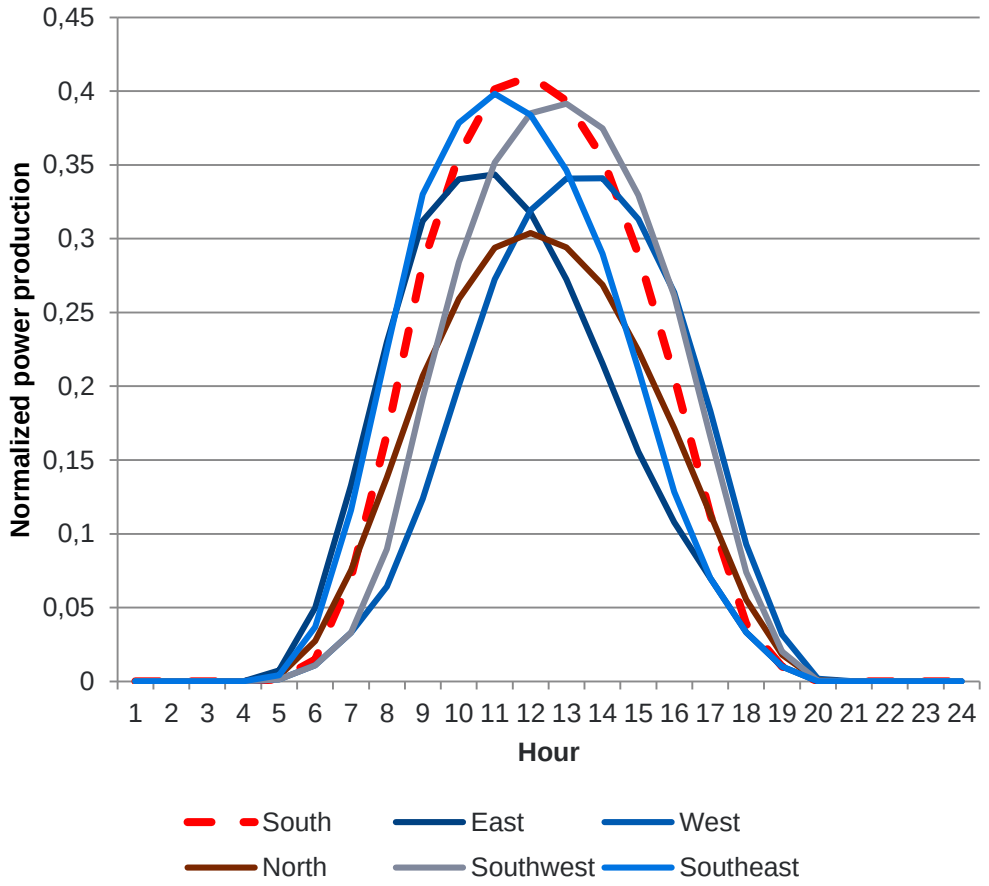
Technological aggregation for PV power plants

Problem formulation:

- **Differences** between various module types **small** regarding efficiencies, **especially with high irradiance**
- **Differences in module orientations** potentially more important

Analyses & results:

- 11 different module orientations calculated and tested in model runs
- Differences between profiles are too small to make up the discrepancies in full-load-hours



Spatial and technological aggregation based on value components

Problem formulation:

Multiple investment choices e.g. location and technology type for wind energy to be aggregated for large-scale system models

Approach:

I. **Definition of value components**

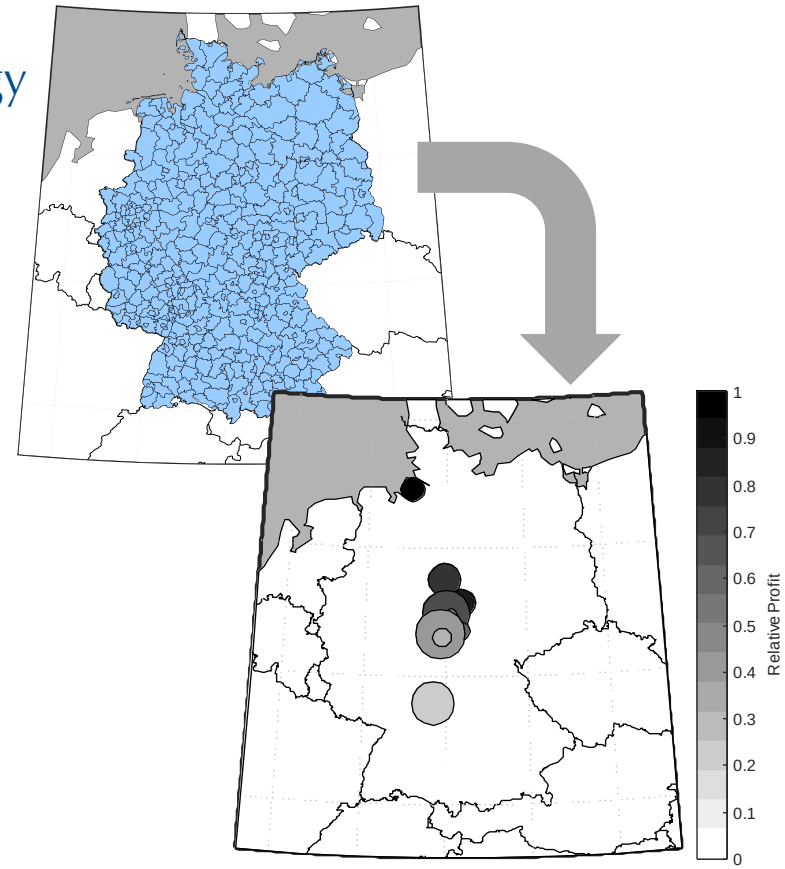
II. **Computation** of the **value components**

1. Choice of adequate scenarios
2. Define investment choices as objects for the clustering algorithm
3. Calculate value components for various scenarios

III. **Aggregation of investment choices** in limited number of clusters

4. Predefine cluster numbers using hierarchical clustering
5. Aggregation of investment choices

➢ cf. **presentation** by **Arne Pöstges**



WP 3: Spatial aggregation and reduction of renewable infeed profiles

WP 4: Technlogical aggregation and reduction of renewable infeed profiles

Outlook

- Three months until end of project

Some ongoing work, notably:

- Time series aggregation in a detailed electricity market model
  - chronological time-period clustering
  - adopted the large European electricity market model JMM (Joint Market Model)
  - test and compare different designs of chronological time period clustering
- Test of the developed methods in existing large-scale models

Outlook:

- Use of the developed approaches for system studies
- Adaptive disaggregation?

Thank you for your attention!

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