oemof user & developer meeting –
session on the model POMMES

Introducing POMMES - a European dispatch and invest power market model using oemof

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POMMES - Overview

Inputs

- Load (peak and timeseries)
- Installed RES capacity, timeseries (wheather data)
- Techno-economic power plant data for Germany
- Techno-economic power plant data for the EU
- Interconnector capacities (maximum and timeseries)
- Techno-economic data for water plants (reservoir)
- Techno-economical data for storages
- Fuel costs, CO2 prices
- operation costs
- Demand response data
- Techno-economic data for investment alternatives

Models

- RES simulation (external / not integrated yet) for determining RES feed-in timeseries
- **Dispatch optimization**
- **Invest optimization**

Outputs

- **(Hourly) day-ahead price**
- **Cost-optimal dispatch of capacities**
- **Cost optimal capacity Expansion strategy**
- **Overall power system costs**

dispatch model only

Investment model only

The ER Fundamental power market model in a nutshell: model target and brief categorization

- **Model targets**
  - Determining a **cost minimal capacity** (power plant) **dispatch (**and **wholesale (day-ahead) power prices)** for Germany
  - Determining a **cost minimal capacity** (power plant) **expansion** strategy and overall system costs for Germany (until at most 2050)

- **Brief categorization** (based on Hall and Buckley 2016)

criterion	manifestation
purpose	general: **scenario analysis** (**forecasting**) specific: capacity dispatch & power prices, capacity expansion
structure	**exogeneous** parameters: demand (except for DR), RES capacity and infeed, cost parameters, technical parameters **endogeneous** variables: power plant production, power plant investments
geographic coverage	**Germany** + electric neighbours (AT, BE, CH, CZ, DK1, DK2, FR, NL, NO1-5, PL, SE1-4)
sectoral coverage	**power market** (effectively day-ahead) from a macroeconomic point of view (no bidding simulation)
time horizon	**short** (<= 1 year) to **long term** (up to 2050), dependent on basic model used and model configuration
time step	hourly (4hourly, 8hourly, 24hourly); quarter-hourly possible

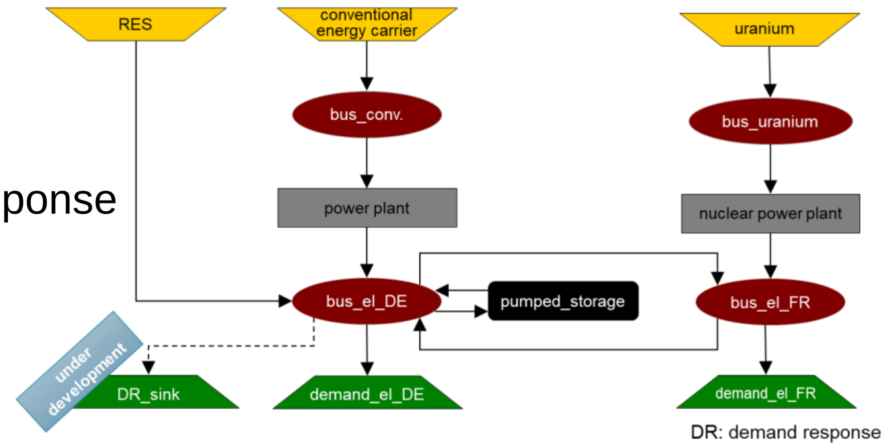
Target and basic approach

- **Target(s)**
  - investment cost minimization
  - dispatch cost minimization

- **Modelling goals**
  1. Determine a cost minimal invest strategy
  2. Determine a cost minimal dispatch strategy given these investments
  3. Determine wholesale (day-ahead) power prices for the dispatch strategy

- **Focus**
  - regional: Germany + EU (dispatch only)
  - technological: power plants + demand response

- **Architecture / concept** → quite flexible



Input data

Parameter	Source
Conventional power plants DE	OPSD, NEP
Renewable power plants DE	ÜNBs, BNetzA
Power plants EU	Powerplantmatching (OPSD, GPPD and others)
Renewable power plants EU	OPSD, IRENA
Technology and efficiencies	OPSD, own data and assumptions
Interconnectors	ENTSO-E, TYNDP
Hydro reservoir storages	Powerplantmatching, ENTSO-E
Costs data (invest, variable, fuel, emissions)	combined from various different sources (Schröder et al. 2013, Kost et al. 2018 and many others …)

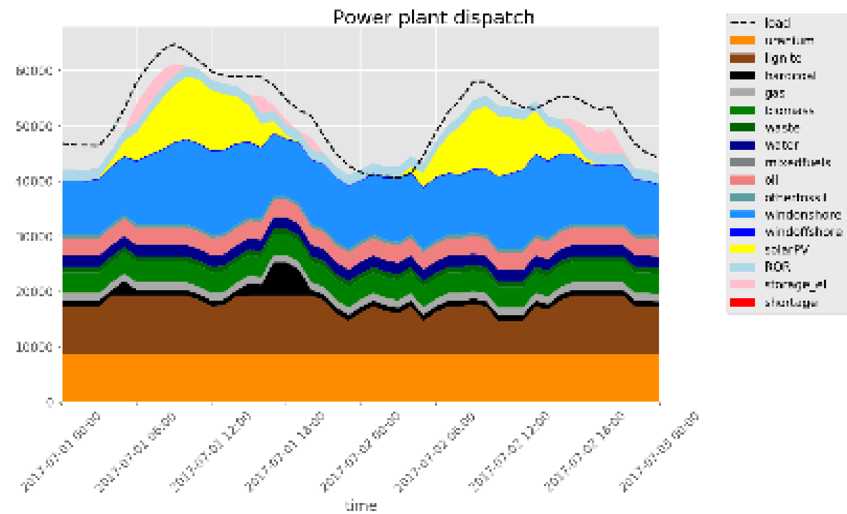
OPSD (2018), ÜNBs (2018), BNetzA (2019a), BNetzA (2019b), Gotzens et al. (2019), IRENA (2020), Ghosh et al. (2019), ENTSO-E (2018), UBA (2019); Schröder et al. (2013); Kost et al. (2018)

The dispatch model

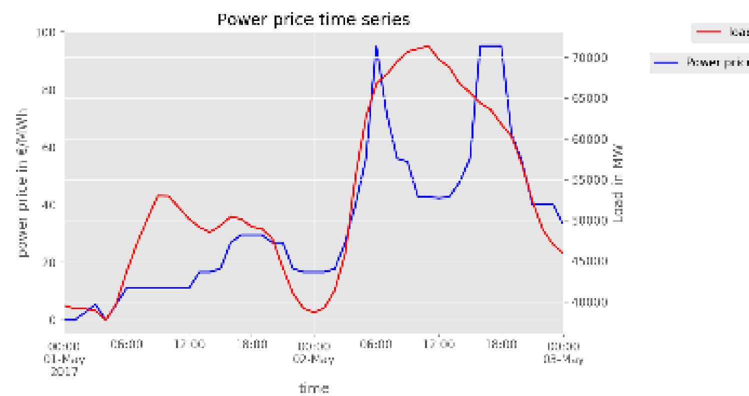
- **Forecast**

Perfect foresight, for one year (2016-2050), rolling horizon (optional)

- **Resolution**
  - Hourly
  - Block-sharp or plant clusters
  - DE as unified market area**
  - Europe: DE + electrical neighbours
  - Cost coverage: (variable) marginal costs, no fixed costs (yet)



- **Special features**
  - RES cost modelling enables negative prices*
  - power prices obtained from duals of electr. bus
  - Links and hourly NTC values for exchanges



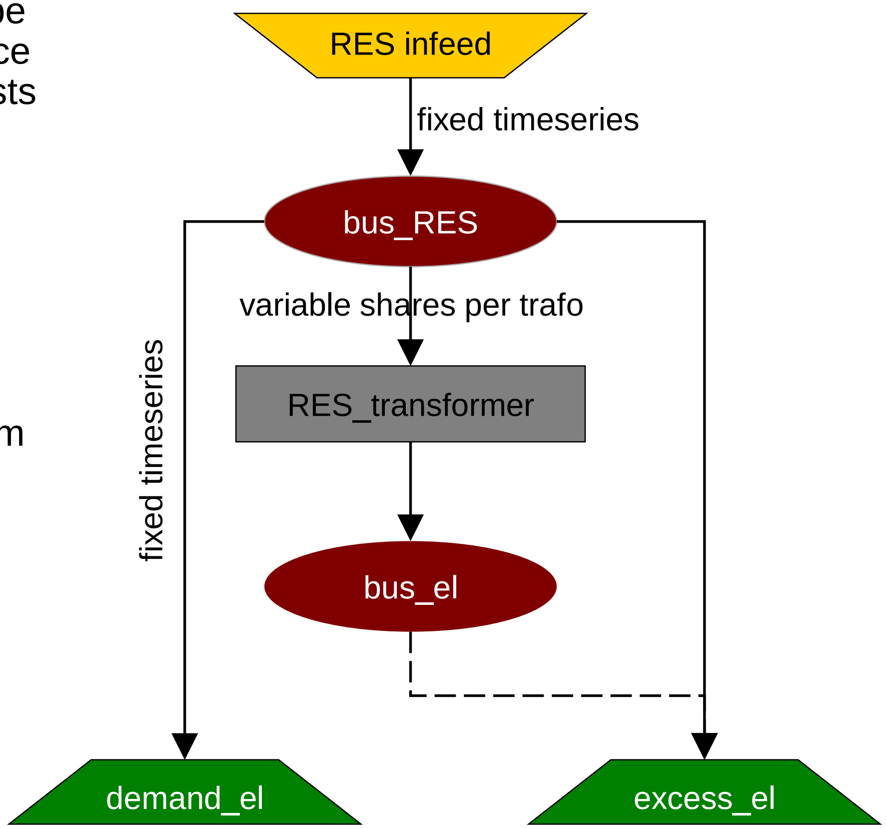
- **Complexity reduction**
  - Rolling horizon
  - Unit clustering

The dispatch model – RES modelling approach

- Background:
  - Modelling RES at 0 costs is not sufficient
  - Consequence: no negative prices can be modelled since other plants bid / produce at their (positive) short-run marginal costs

- Approach:
  - Empirical evaluation of RES values applicable using the „EEG-Bewegungsdaten“ from the German TSOs
  - Assumption: RES in the market premium model bid at (opportunity) costs* of $-AW + E[MP]$
  - Clustering RES by AW and type to reduce complexity and model negative price steps
  - One residual cluster for all RES in FIT

RES: PV, Wind onshore / offshore



* E[MP] = MP for historical simulation

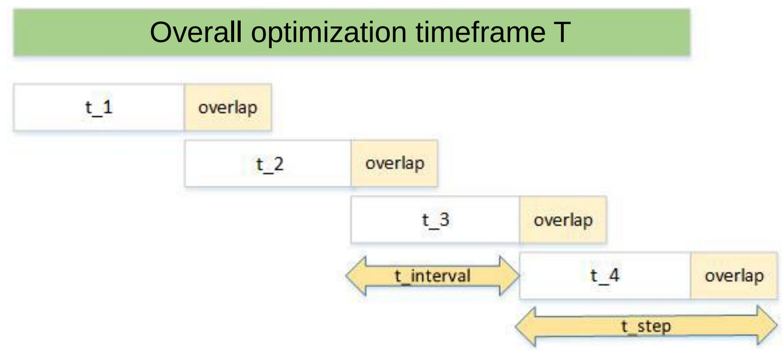
Complexity reduction measures

label
transformer_natgas_1
transformer_natgas_2
transformer_natgas_3
transformer_harcoal_5
transformer_harcoal_6
transformer_harcoal_7

label
transformer_cluster_natgas_1
transformer_cluster_natgas_2
transformer_cluster_hardcoal_1

- **Transformer data aggregation**
  - K means clustering by power plant efficiency
  - Separate groups per energy carrier and CHP status (CHP plants vs. non CHP)
    - 9 (energy carriers) x 2 (CHP status values) = 18 (groups)
    - Some of the groups are not practically relevant
    - Cluster number can be flexibly adjusted

- **Rolling horizon** approach
  - Slice overall optimization timeframe into (equal length) smaller timesteps
  - Pass results for the last timestep simulated to new timeslice
  - Optimize for smaller timesteps and concatenate results
  - Optionally include some overlaps (esp. for depicting storage behaviour)



- **Myopic optimization**
  - Basically a rolling horizon variant on an annually basis and without overlap
  - Can be used to simulate multiple investment rounds and to depict limited foresight

- **Timeseries aggregation**
  - Basic: reduction of granularity using downsampling and mean values
  - Advanced: typical periods, type years → integration ongoing

Image source: Büllesbach (2018), p. 62, based on Marquant et al. (2015), p. 2141; modified

Basic steps for a model run - Highly simplified and <u>excluding</u> previous data preparation

0. create input data

- Alternative 1: use *existing data*
- Alternative 2: Run some *jupyter notebooks* upfront
  for creating new input data (see previous section for details)

1. configure

- Determine **model configuration**, mostly using boolean control parameters
- Optionally: adapt input file names / model configuration

```
92 # 11.05.2019, JK: Determine
93 RollingHorizon = False
94 AggregateInput = True
```

2. read in input data

- Read in **input files from Excel** and **csv sheets**

3. model run

- Create an **oemof representation** of the model: nodes and edges
- Create a **mathematical problem** instance and solve it

4. process results

- Create **plots** (console output / saved)
- Create **results files** (.csv)

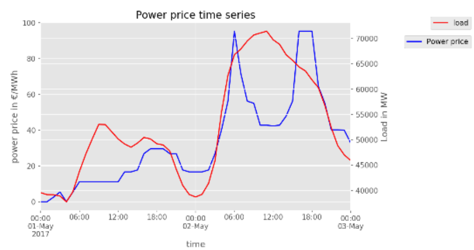


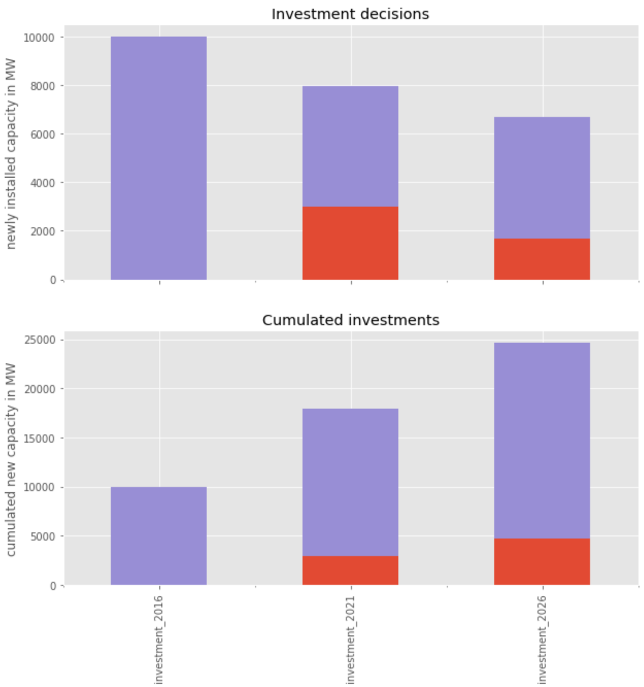
Image sources: www.python.org; https://github.com/jupyter/jupyter.github.io/blob/master/assets/main-logo.svg; https://de.wikipedia.org/wiki/Datei:Microsoft_Excel_Logo.svg; https://www.gurobi.com/wp-content/plugins/hd_documentations/documentation/8.1/ampl-gurobi/logo.png; all links accessed 05.11.2019

The investment model

- **Forecast**

Perfect foresight with one investment point, multiple years (2016-2050) flexibly chosen, overall or myopic optimization

- **Resolution**
  - 24h, 12h, 8h, 4h or h
  - power plant clusters, new built units as power plant fleets
  - DE only
  - Cost coverage: (variable) marginal costs, investment annuities, no fixed costs (yet)



- **Special features**
  - Commissioning / Decommissioning
    workaround for exogenously determined decisions resp. shutdown when lifetime limit is reached
  - Exogeneous commissioning / decommissioning decisions integrated → e. g. different coal-exit paths integrated

- **Complexity reduction:**
  - Myopic optimization
  - Unit clustering
  - Time series aggregation (integration ongoing)

The investment model – Modelling exogeneous capacity development

- Background:
  - There is only **one investment timestep** resp. few if myopic approach is chosen
  - There are some **new-built projects** though which will likely be installed soon
  - There are some **political plans for shutting down** uranium and coal; from an operators point of view, old units will go offline soon
  - *Problem: But once up and running a plant „stays in the model"*

individual unit

label	year	min_load_factor	max_load_factor
old_coal_plant_1	**2020**	0.4	1.0
old_coal_plant_1	**2025**	0.4	1.0
old_coal_plant_1	**2030**	0	0

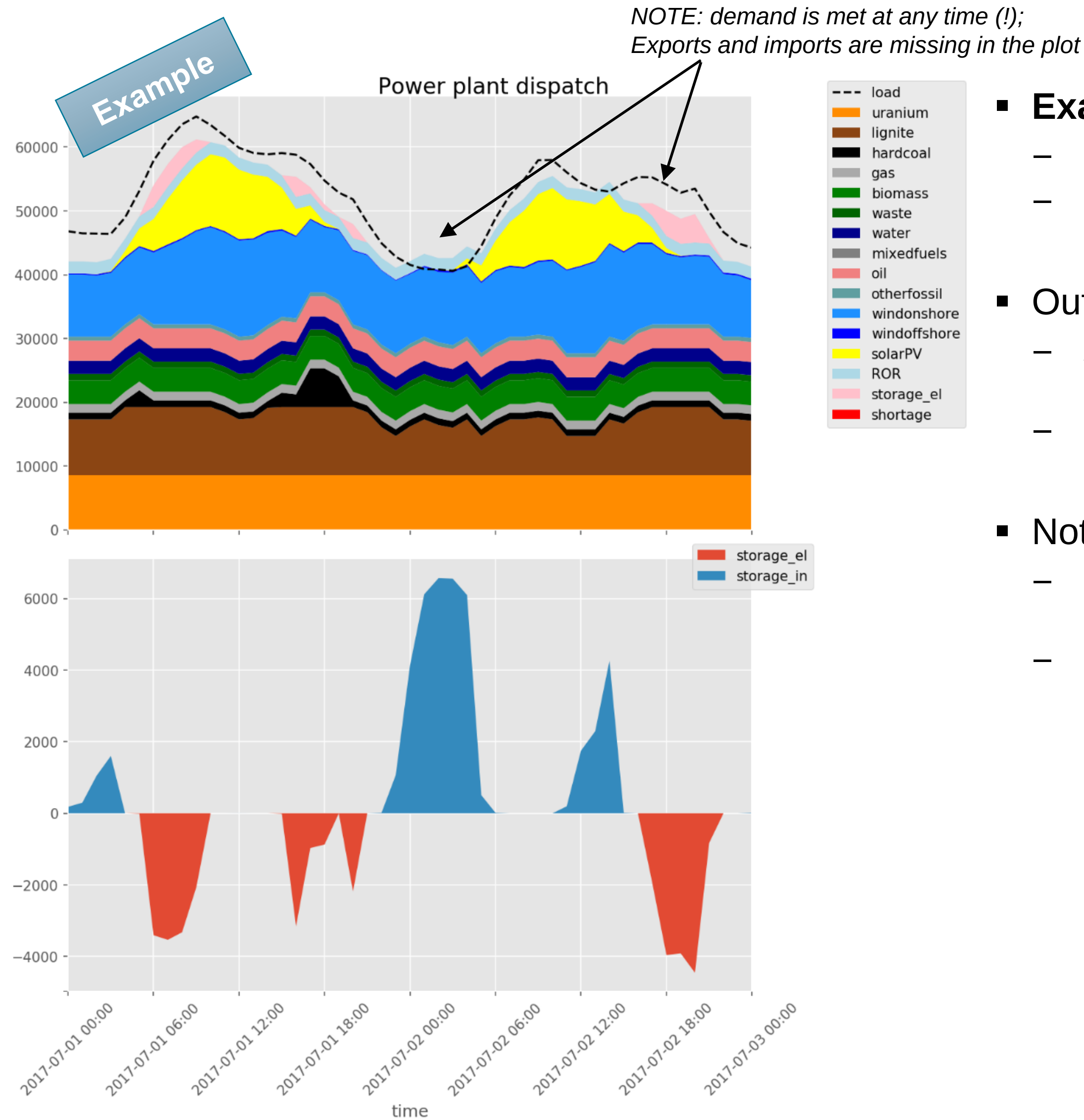
power plant cluster

label	year	min_load_factor	max_load_factor
old_coal_cluster_1	**2020**	0.1	1.0
old_coal_cluster_1	**2025**	0.1	1.0
old_coal_cluster_1	**2030**	0.1	0.9

plant going offline accounted for 10% of overall cluster capacity

- Approach:
  - **Determine likely commission / decommission date**
  - Decommissionings: Force min and max output of plant to zero if it will be decommissioned; **decrease min / max output** of cluster
  - **Commissionings**: **Increase capacity max** parameter of cluster; add investment costs to the target function as fixed cost term

Production results (example)

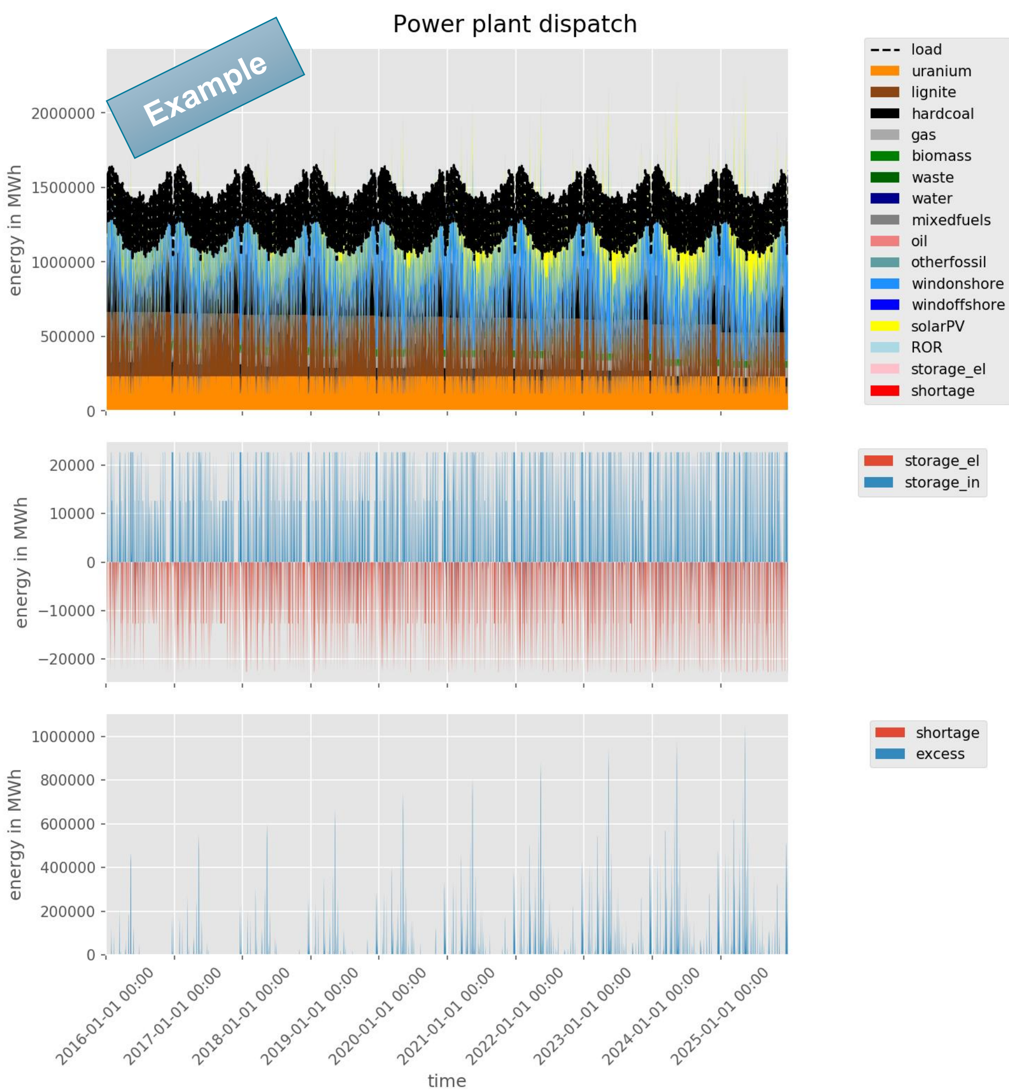


- **Example: European dispatch model run**
  - **aggregated** power plant portfolio
  - **hourly resolution for 2 days**

- Outputs depicted
  - Aggregated production per energy carrier (Germany)
  - storage balance (Germany)

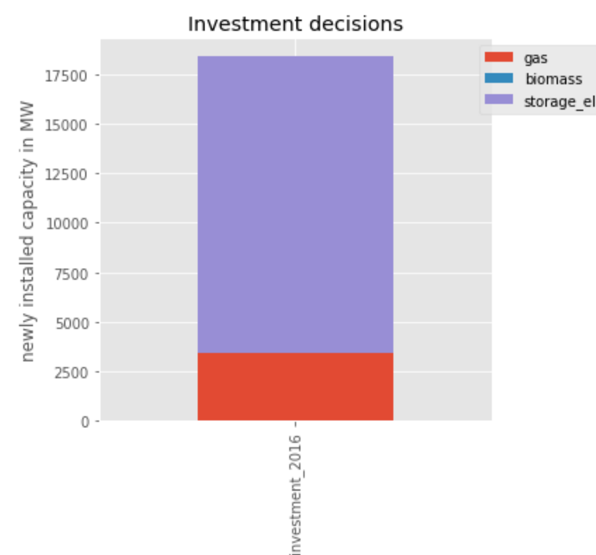
- Not depicted
  - excess / shortage balance
    → no occurence in simulated timeframe
  - Imports / exports → plot yet to follow

Investment results (example)

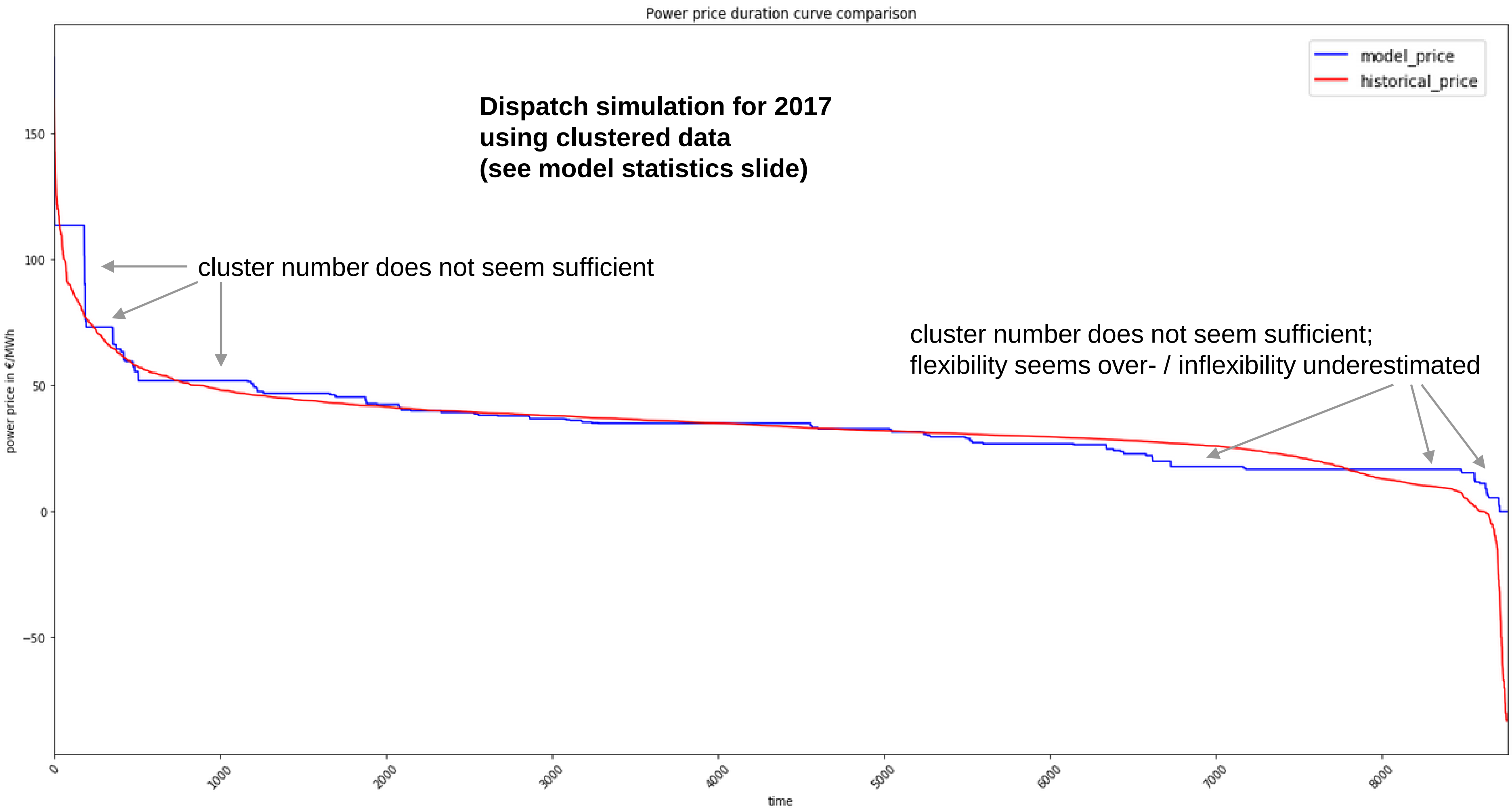


- **Example: German invest model run**
  - **aggregated** power plant portfolio
  - **24hourly resolution for 10 years**

- Outputs depicted
  - Aggregated production per energy carrier (Germany)
  - storage balance (Germany)
  - excess / shortage balance
    → high excesses since no exports / imports are modelled
  - Investment decisions taken



A first quick‘n‘dirty model validation analysis – „The price is right“ …or is it?!



Data source: EPEX spot (2019)

Critical discussion and outlook

Critical discussion

- Advantages
  - Open source / open data approach used*
  - RES modelling / modelling negative prices
  - Different complexity measures integrated → enables to do a benchmark
- Parameterization
  - Update ongoing
- Features
  - Some pretty „standard“ ones are lacking: e. g. multi-period invest, balancing power markets, fixed costs → integration planned

Outlook

- Dispatch modelling
  - Mostly data updates
  - min / max modelling for industrial and CHP power plants
  - maybe further inflexibility modelling
- Investment modelling
  - Decision: myopic workaround vs. multi-period investment
- General
  - nicer plots
  - speed up / tidy up parts of the implementation
  - Release first version (probably within this year)

*model is not yet open source, but will be made available as soon as first publications are published (and major bugs fixed ;-))

Literature (1/2)

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Literature (2/2)

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