Modelling of imports and exports for the German electricity system

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April 12, 2019 | ENERDAY Dresden

Agenda

1. Motivation and objective
2. Systematization of modelling approaches
3. Description of implemented model
4. Preliminary results and outlook

Modelling of imports and exports for the German electricity system

Motivation

Electricity system is undergoing rapid change: Liberalization, growing share of fluctuating renewable energies and increasing European integration

→ International electricity exchange is gaining importance

→ Adequate depiction of imports and exports within power market models is useful and necessary.

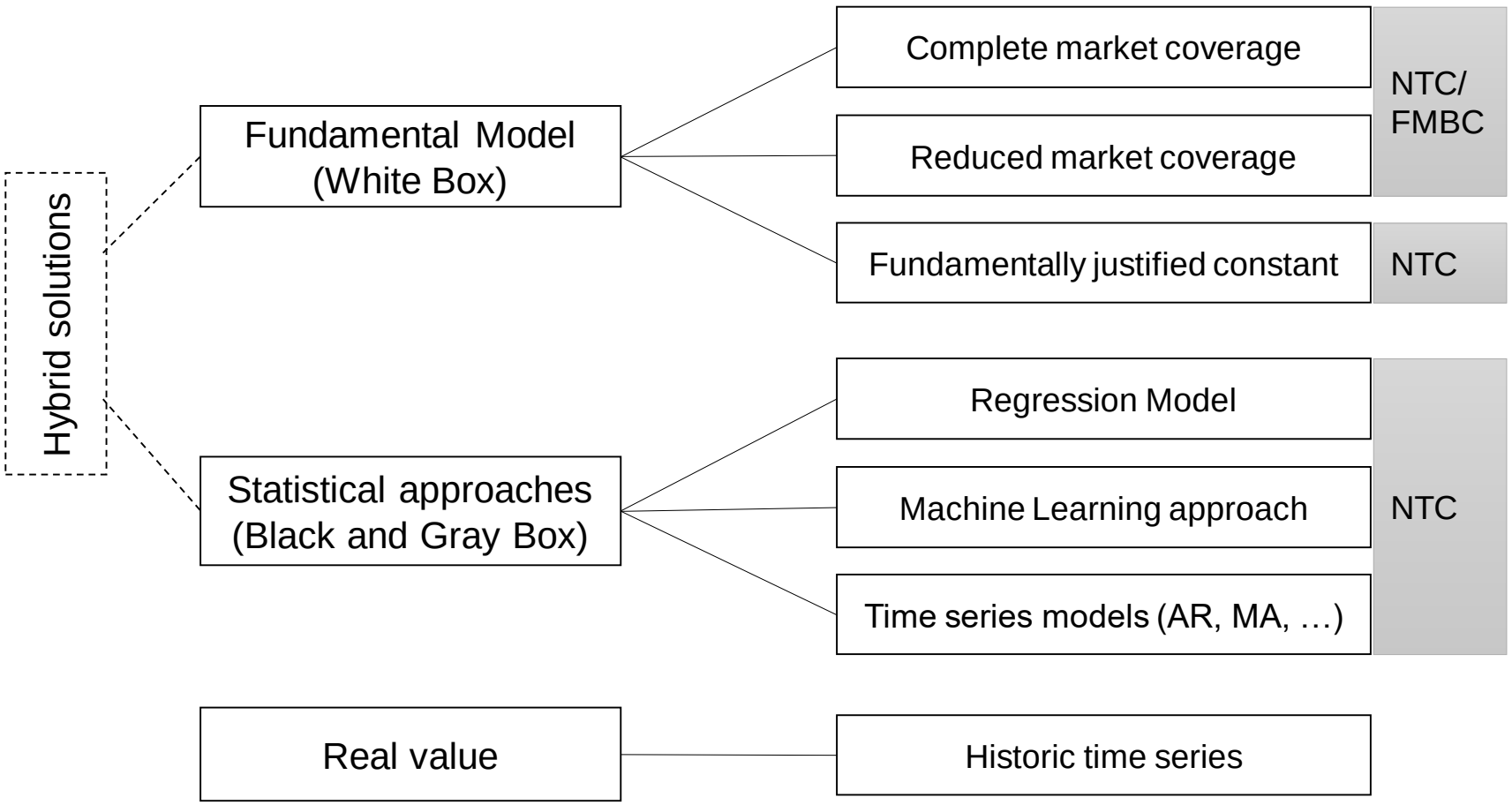
Objective

Integration of electricity import and export into a German power market model

Boundary conditions

- Time period: 2015 to 2030
- Time resolution: (quarter-)hourly
- Considered countries: Germany and its electrical neighbors (AT, BE, CH, CZ, DK1, DK2, FR, NL, NO, PL, SE4)
- Assumption: All electricity is sold on day-ahead market

Systematization of existing approaches for modelling imports and exports



Source: Own categorization based on twelve expert interviews and literature research

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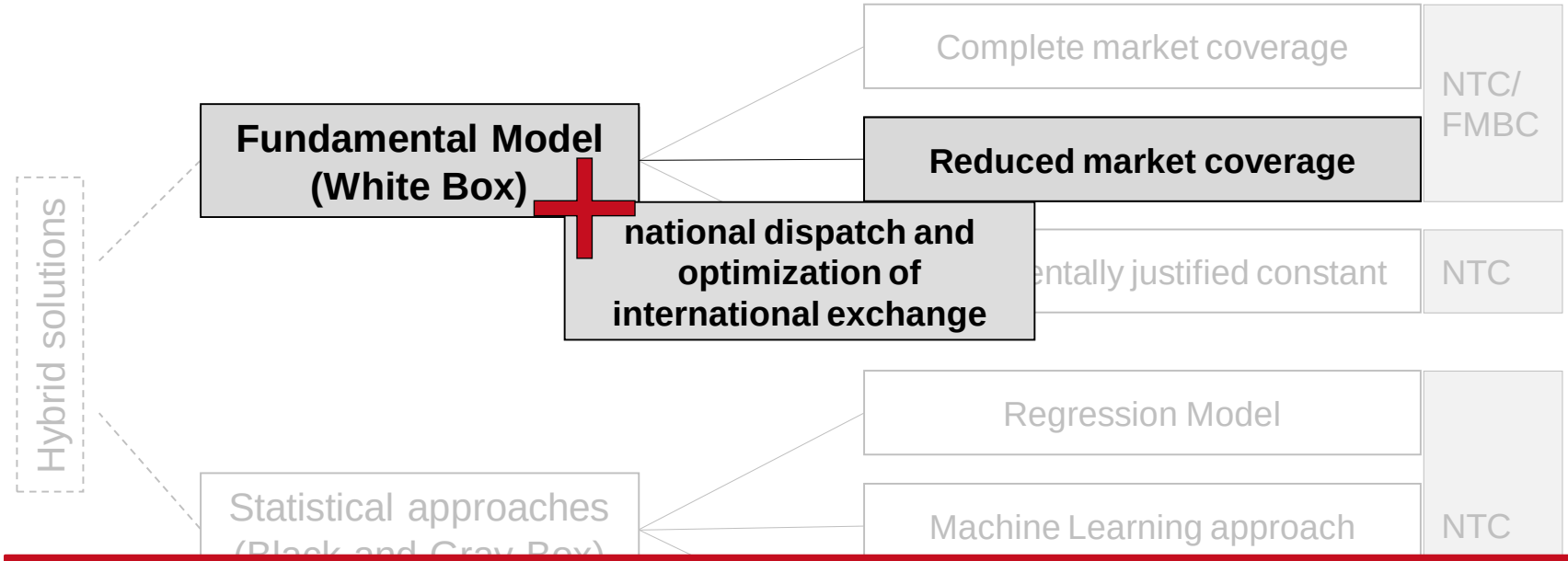


Elements of fundamental model

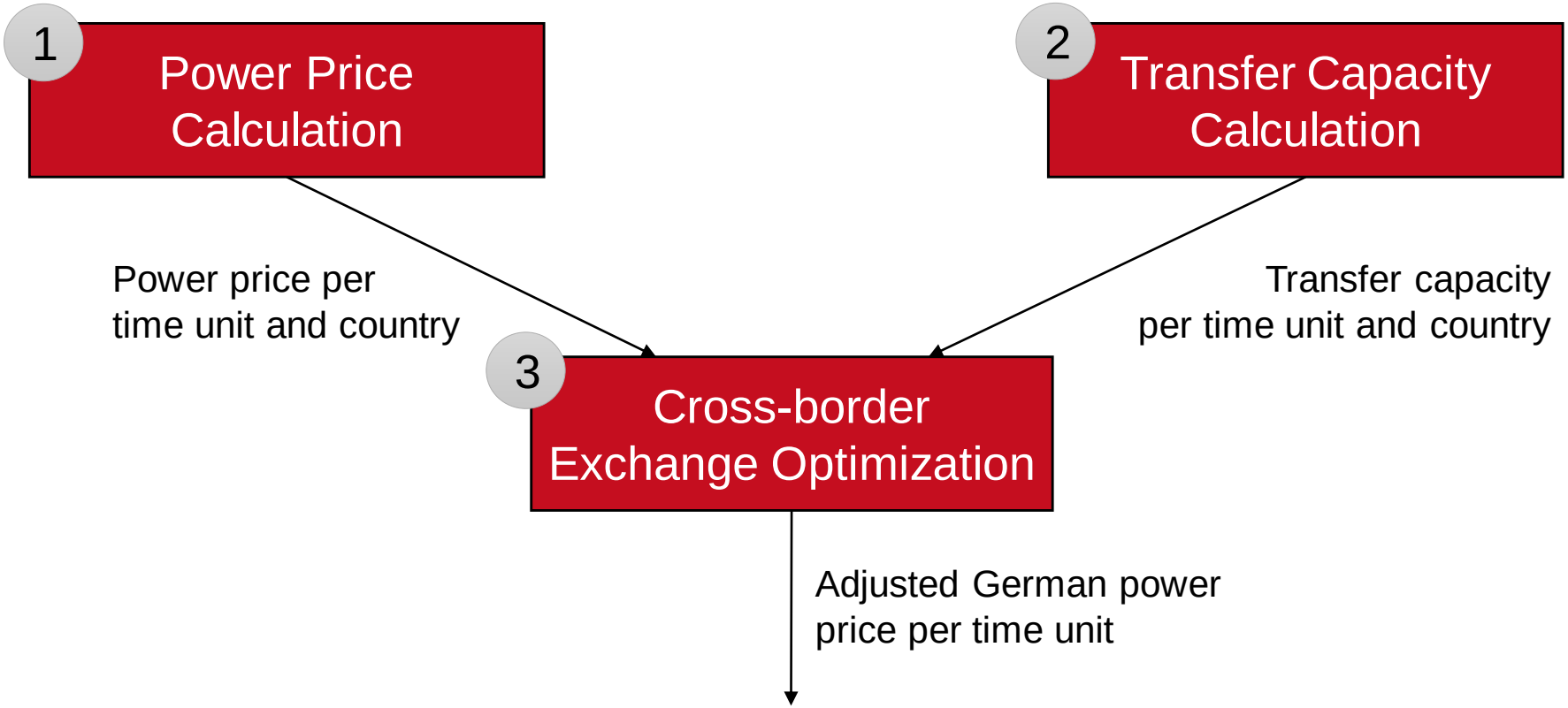
1) Calculation of power prices of a country not taking into account import and export
2) Calculation of time-variable transfer capacities of interconnectors
   → Detailed analysis of every border to determine a calculation method
3) Calculation of adjusted German power price taking into account import and export optimization
   → Methodology of „level of detail“ developed to handle computational power

Source: Own categorization based on twelve expert interviews and literature research

Overall structure of implemented model

Input data:
- Power plant fleet
- Renewable power production
- Demand

Input data:
- Maximum NTC
- Technical profile (incl. forecasts of wind and demand)

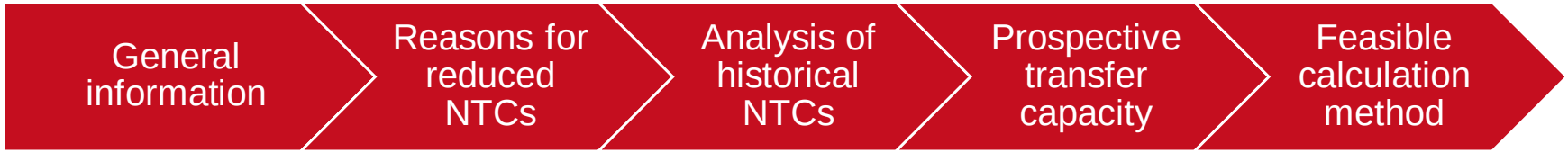


1 Upfront power price calculations

- Simple linear dispatch model
  - according to the merit order rationale
  - aim: cost minimization for a given load level
- Isolated model runs for every country
- Main data sources:
  - OPSD
  - ENTSO-E Transparency

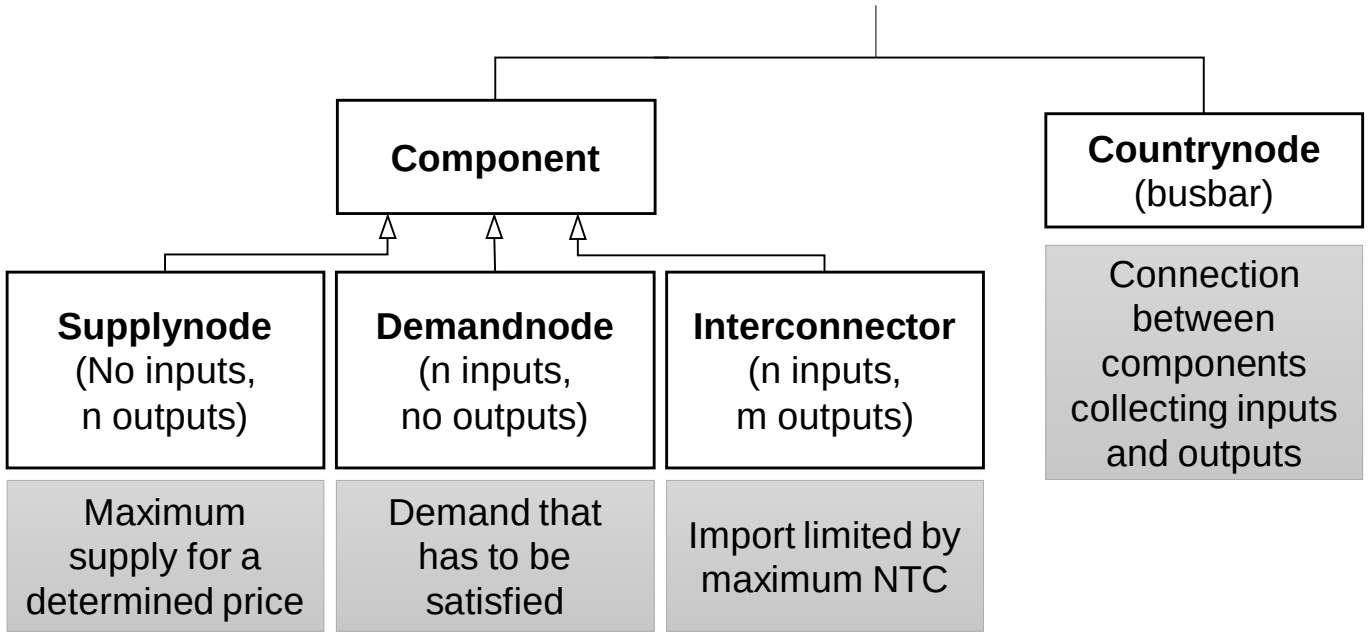
2 Upfront transfer capacitiy calculations

- Net Transfer Capacity (NTC) as measure for available transfer capacity
- Determination of maximum and time-dependent NTC per market area and year
  → Technical profiles (formerly) used for scheduling commercial exchange show dependency to other factors



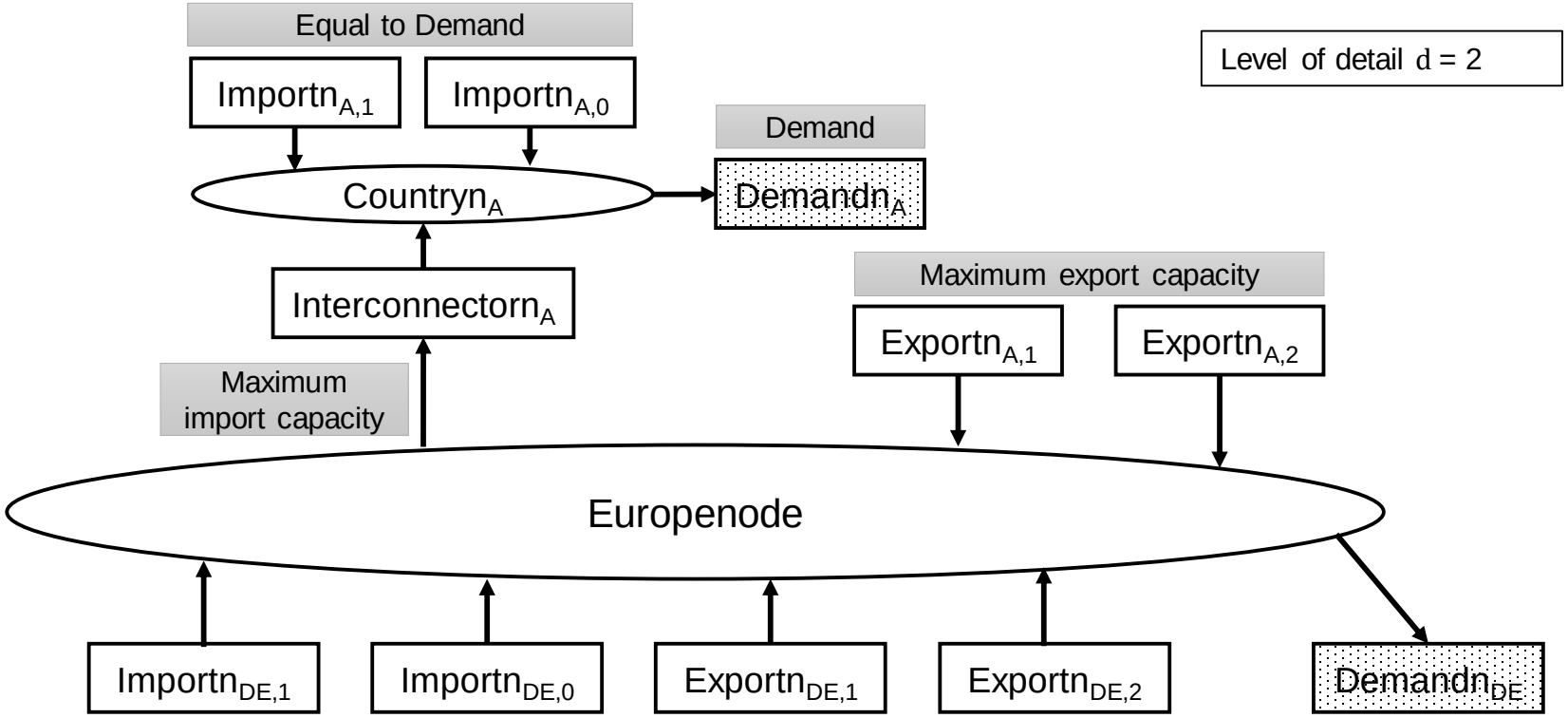
- Main data sources
  - ACER and CEER
  - BNetzA
  - ENTSO-E Transparency
  - TSOs
  - TYNDP
  - Interviews with TSOs and experts from research
- Preliminary conclusion
  → Limited transparency with large differences in regard to quality and quantity of data between the market areas

3 Cross-border Exchange Optimization module



Source: Own illustration based on Hilpert et al. (2017)

3 Cross-border Exchange Optimization module



Determination of level of detail, resolution and year → Setting up exchange optimization model using a framework → Calculation of optimal power flows → Recalculation of German power prices

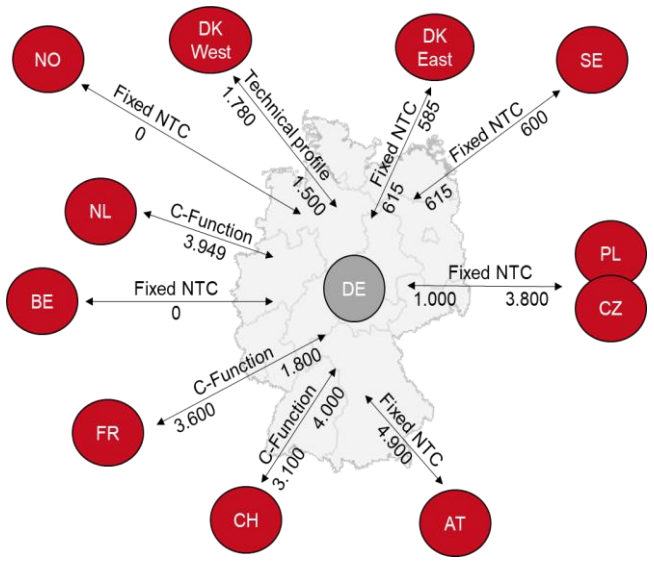
Source: Own illustration

Preliminary results of NTC analyses and model

Analyses of available transfer capacity

In general good approximation of available transfer capacity; however quality between neighboring countries varies

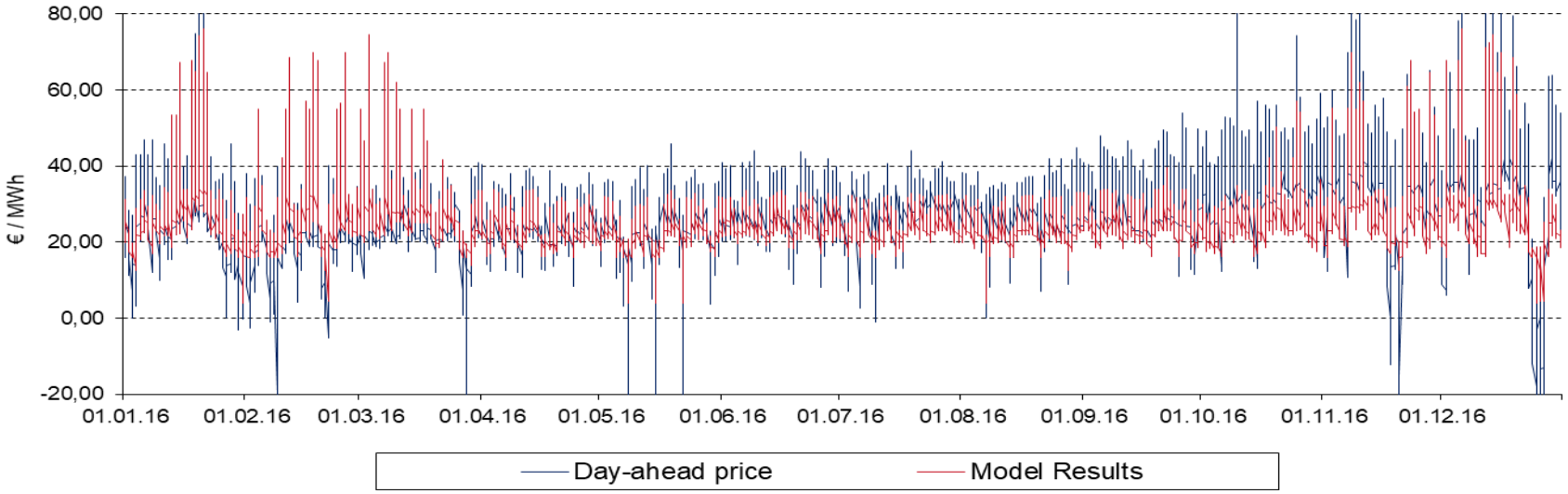
→ Mean Absolute Error (MAE) between 0 MW and 383 MW



Preliminary results of calculation of German power prices

- First results show good approximation of power prices with MAE of 6.93 €/MWh and an average electricity price of 25.97 €/MWh for 2016 (level of detail d = 2)
- Closes gap between simple modelling approaches with fixed NTCs and extreme computation-intense ones based on load flow calculations
  → Adequate tradeoff between model complexity and computation time

Outlook - Modelling of imports and exports for the German electricity system



Outlook

- Detailed testing with qualitative and comprehensive data set necessary
- Extension of model with additional technologies and dynamic behavior of power plants
- Evaluate combination of fundamental model with statistical approach
- Crucial basis and starting point for further considerations
  → In the long-term implementation of flow-based market coupling is reasonable

 Source: ENTSO-E (2018)

Thank you for your attention!

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BACK UP

Energie und Ressourcen

Model formulation (import & export optimization only)

- Minimization of costs (1): $Min \sum_{(i,o)} \sum_t \boldsymbol{Flow}_{(\boldsymbol{i},\boldsymbol{o},\boldsymbol{t})} * VariableCost_{(i,o,t)}$

$\forall (i,o) \in FLOWS\ , \forall t \in TIMESTEPS$

s.t.

- Energy balance for countrynodes (2): $\sum_{i \in Inputs(n)} \boldsymbol{Flow}_{(\boldsymbol{i},\boldsymbol{n},\boldsymbol{t})} = \sum_{o \in Outputs(n)} \boldsymbol{Flow}_{(\boldsymbol{n},\boldsymbol{o},\boldsymbol{t})}$

$\forall n \in BUSES, \forall t \in TIMESTEPS$

- Flow limit for exports (3) $\boldsymbol{Flow}_{(\boldsymbol{B},\boldsymbol{C},\boldsymbol{t})} \leq \boldsymbol{max.NTC}_{\boldsymbol{export}(\boldsymbol{C})}$

$\forall C \in COUNTRY_{BUSES} = BUSES \backslash \{BUS_{Europe}\}, \forall t \in TIMESTEPS$

- Flow limit for imports(4) $\sum_{i \in Inputs(B)\ \boldsymbol{from\ c}} \boldsymbol{Flow}_{(\boldsymbol{i},\boldsymbol{B},\boldsymbol{t})} \leq \boldsymbol{max.NTC}_{\boldsymbol{import}}$

$\forall c \in countries, \forall t \in TIMESTEPS, B = BUS_{Europe}$

Power Price Calculation Module