



House of
Energy Markets
& Finance

Evaluation of risks for power plant operators through reconfiguration of price zones in extended Central Western Europe

Caroline Deilen, **Tim Felling***, Robin Leisen, Christoph Weber

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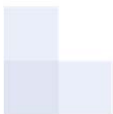
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DUISBURG
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*Presenting Author

Agenda

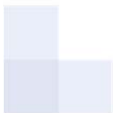
- Overview
- General approach
- Stepwise methodology
- Preliminary Results
- Conclusion and Outlook



Agenda

■ Overview

- General approach
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- Broad current discussion about future design of electricity markets in Europe
 - More infeed from renewable sources
 - Congestion management gets more important
 - Redispatch amounts and costs rise significantly
- New Price Zone Configuration (PZCs) might be a solution
 - ENTSO-E bidding zone study examines a new delimitation
 - Current EU guideline even envisages reviews of the price zone configuration (PZC) in regular intervals of three years
- Frequent change of PZCs (“Reconfiguration”) gives rise to additional regulatory risk for power plant operators
 - Their expected net present value (NPV) depends on the local prices
 - Corresponding zonal prices are directly influenced by PZC
 - Effects on investment and disinvestment

Two major streams in current research and discussions

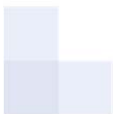
Overview

- Development of a new methodology to investigate the combination of the two major streams:
 - Price Zone Configurations
 - Investment Decisions and Risks

▶ First study that investigates the combination of both streams

- Methodology:
 - Description of risk factors using a partly meshed scenario tree
 - Consideration of different risk factors, e.g. uncertainties in grid development, changing coal and gas spread
 - Different reconfiguration schemes are compared, e.g.:
 - Existing zones remain unchanged
 - reconfigured price zones every five years
 - using different price zone configuration per scenario
 - using robust price zone configurations

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Five-step methodology for assessing the implications of different Reconfiguration Schemes

General Approach

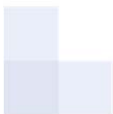
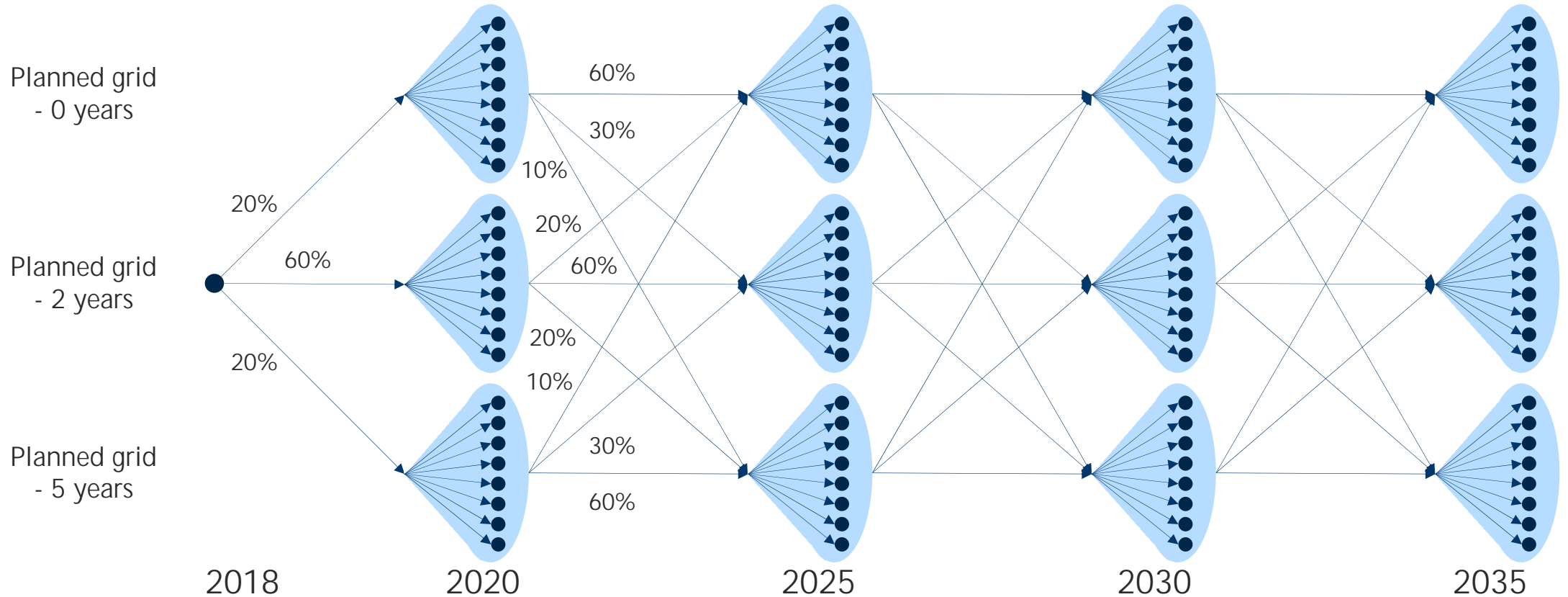
1. Construction of a partly meshed scenario tree
 - Considered risk factors:
 - Price spread (coal vs. gas fired generation)
 - (Delays in) Grid expansion
 - RES expansion & demand variation
2. Calculation of LMPs for every single scenario
3. Computation of PZC by cluster Algorithm
 - Different versions of robust PZCs
(e.g. robust against grid expansion uncertainties, robust against renewables expansion uncertainties)
4. Aggregation of nodal prices to zonal prices according to PZC
5. Assessment of contribution margin (CM) in each scenario and computation of NPV

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- **Stepwise methodology**
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 - (2) Calculation of LMPs
 - (3) Computation of (robust) price zone configurations (PZC)
 - (4) Re-Aggregation of nodal prices to zonal prices
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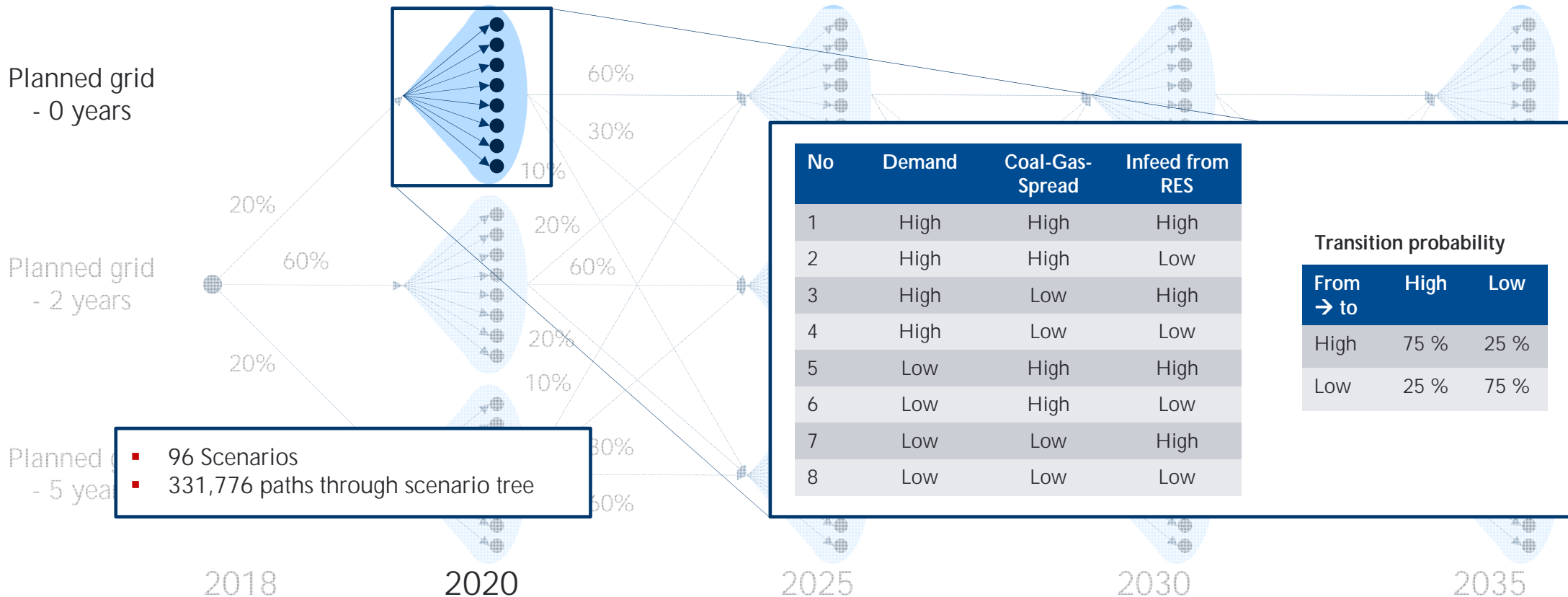
Example construction of scenario tree focus grid expansion uncertainty, three other risk factors

Constuction of partly meshed scenario tree



Example construction of scenario tree focus grid expansion uncertainty, three other risk factors

Step 1: Constuction of partly meshed scenario tree

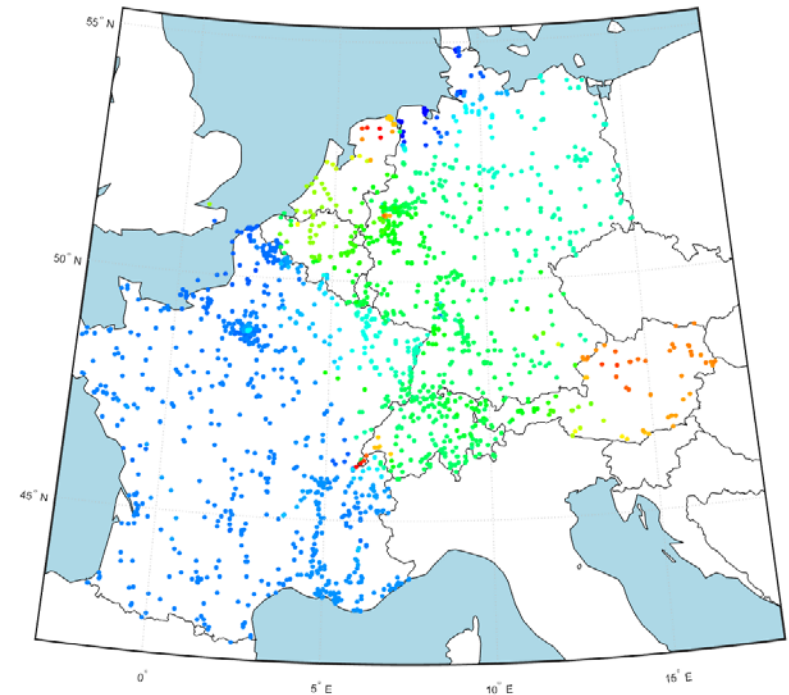


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Calculation of LMPs for every single scenario

Step 2: Calculation of LMPs

- Computation of LMPs by DC-OPF
- For every single scenario and for every hour
- Gridmodel includes:
 - Around 2300 nodes
 - Around 900 Generators



Exemplary LMPs for one hour

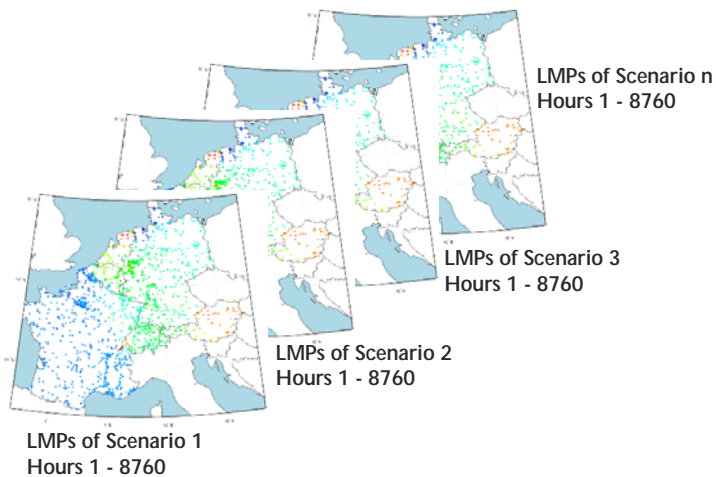
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Step (3) Computation of PZC by cluster Algorithm

Step 3: Computation of Price Zone Configurations (PZCs) by Cluster Algorithm

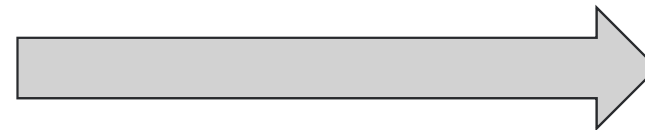
Input from Step (2): LMPs

LMPs of all selected scenarios
1 LMP for each node for each hour



Cluster Algorithm

Minimization of within-zone price variation
Hierarchical Algorithm



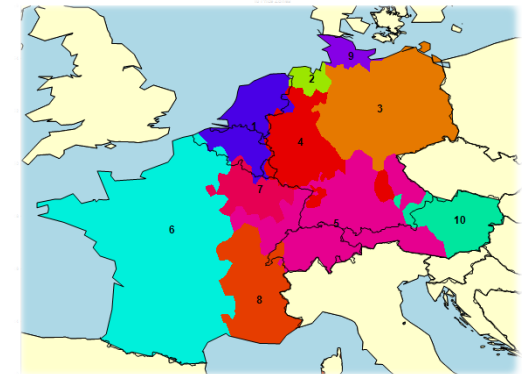
C.f:

Felling, Weber 2017: „Consistent and robust delimitation of price zones under uncertainty with an application to CWE“

Felling, Weber 2016: „Identifying price zones using nodal prices and supply and demand weighted nodes“

Result Step 3: New PZCs

Robust price zone configurations



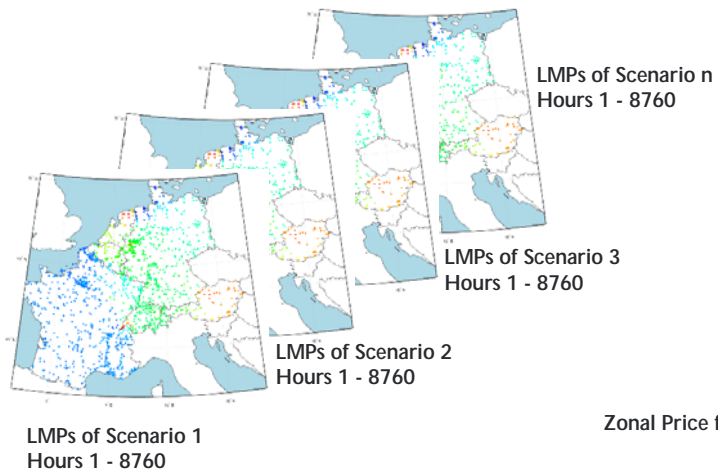
Price zone configuration robust against uncertainties

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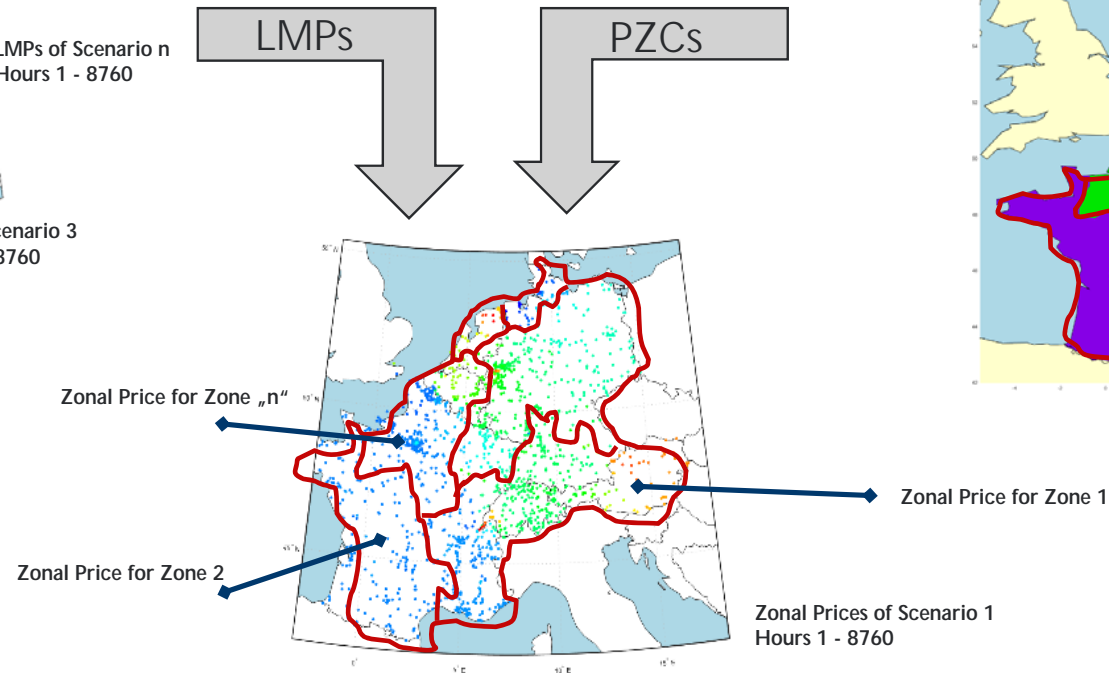
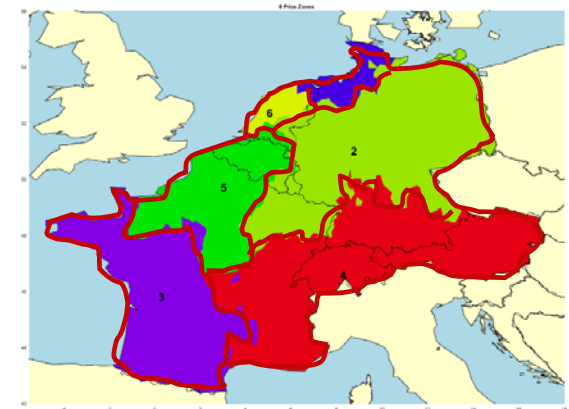
Step (4) Re-Aggregation of nodal prices to zonal prices

Step 4: Computation of PZC by cluster Algorithm

Input from Step (2): LMPs



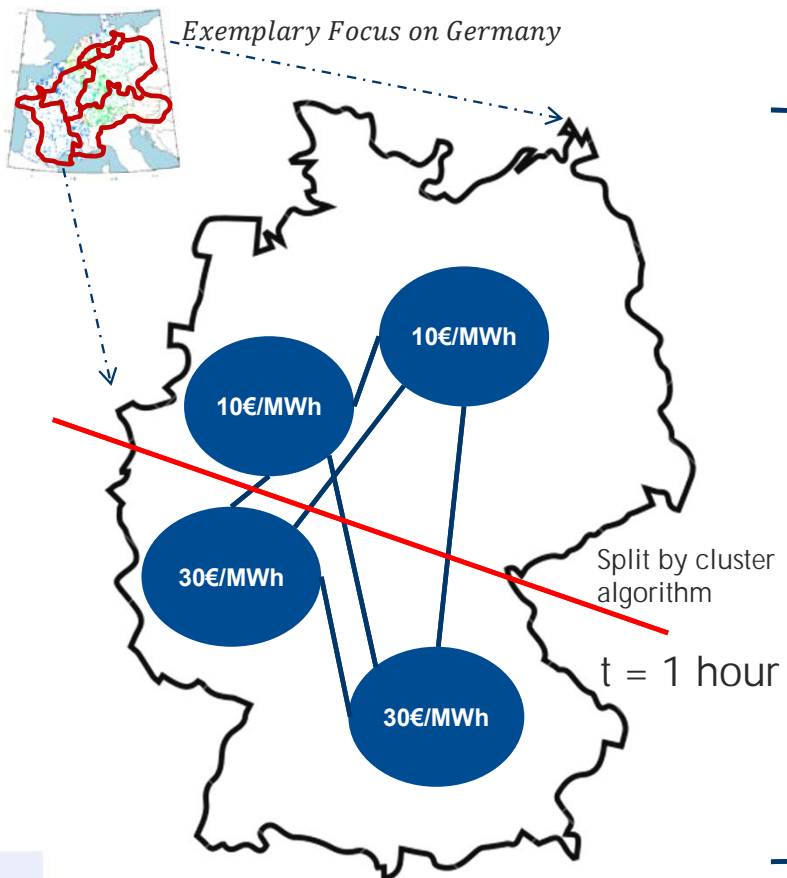
Input from Step (3): PZCs



- Zonal Prices for all selected scenarios
- 1 price for each zone for each hour

Step (4) Re-Aggregation of nodal prices to zonal prices - Example two zones in Germany

Step 4: Aggregation of Nodal Prices to Zonal Prices according to PZC



Two exemplary configurations:

- (1) „Country“ (Germany)
- (2) Price Zone Configuration from Cluster Algorithm with two German Zones (North and South)

Nodal Prices (LMPs) remain the same – the Zonal Prices differ depending on the configuration:

\emptyset – Zonal Price in configuration „Country“: 20 € / MWh

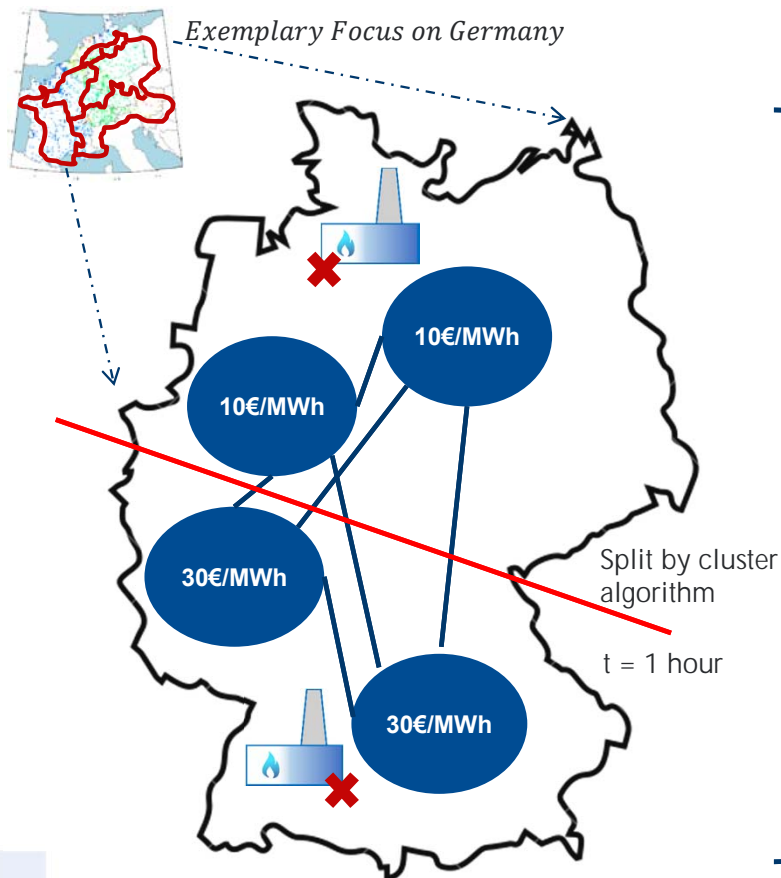
\emptyset - Zonal Price in configuration from Cluster Alg.:

„Germany-North“:	10 € / MWh
„Germany-South“:	30 € / MWh

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Step (5): Computation of contribution margin

Step 5: Computation of NPV of contribution margin



Two Power plants with variable Costs = 15 € / MWh 

Different Result for the two exemplary Configurations:

∅ – Zonal Price in configuration „Country“: 20 € / MWh
▶ Contribution margin: +5 € / MWh

∅- Zonal Price in configuration from Cluster Alg.:
„Germany-North“: 10 € / MWh
▶ Contribution margin: 0 € / MWh

„Germany-South“: 30 € / MWh
▶ Contribution margin: +15 € / MWh

Contribution margin changes by different aggregations of nodal prices

Step (5): Equations for computation of the contribution margin and NPV

Assesment of contribution margin in each scenario and computation of NPV

- Simplified computation of the contribution margin (CM) for each scenario

$$CM(s) = \sum_{t=1}^{t=8760} \max(0; (P(s, t) - varC(s)))$$

s: scenario

P: price for scenario s at timestep t

varC: variable costs of power plant for scenario s

- Computation of probability-weighted and discounted net present value (NPV) of contribution margin

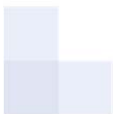
$$NPV = \sum_{n=1}^N \sum_{y=1}^Y p(n) \cdot d(y) \cdot CM(s(y, n))$$

n: path; y: year

p: probability of path n; d: discount factor

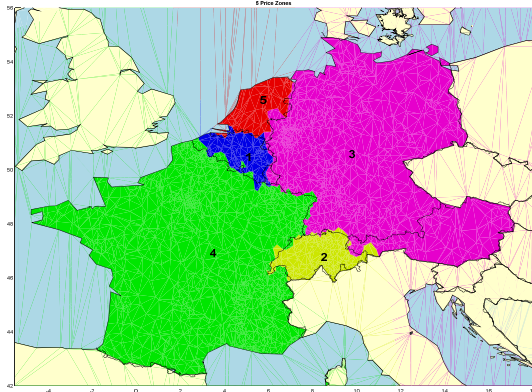
s(y, n): scenario of path n in year y

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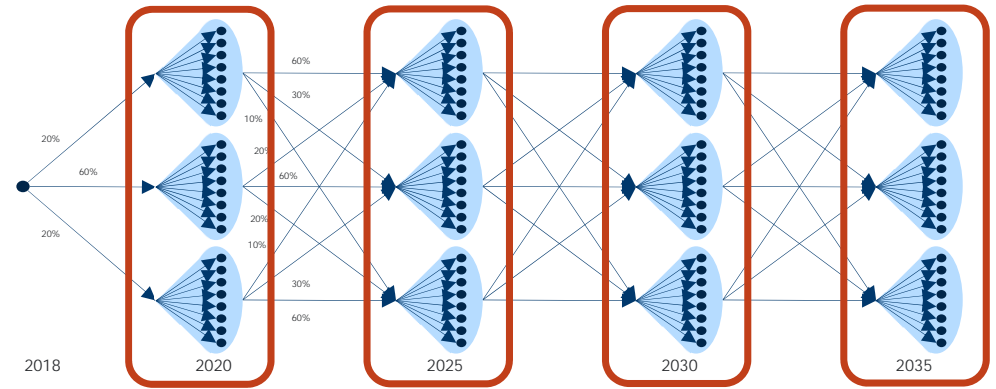


- Reconfiguration possible every five years
 - 2020, 2025, 2030, 2035
- Selection of configurations with pre-specified number of zones
 - 6 zones
 - 15 zones
- **Reconfiguration Schemes**
 - **Country**: existing zones remain unchanged
 - **Robust**: for all uncertainties, one configuration per year
 - **GivenGrid**: robust for all uncertainties except grid expansion, three configurations per year
 - **ScenarioSpec**: separate price zone configuration for each scenario and each year

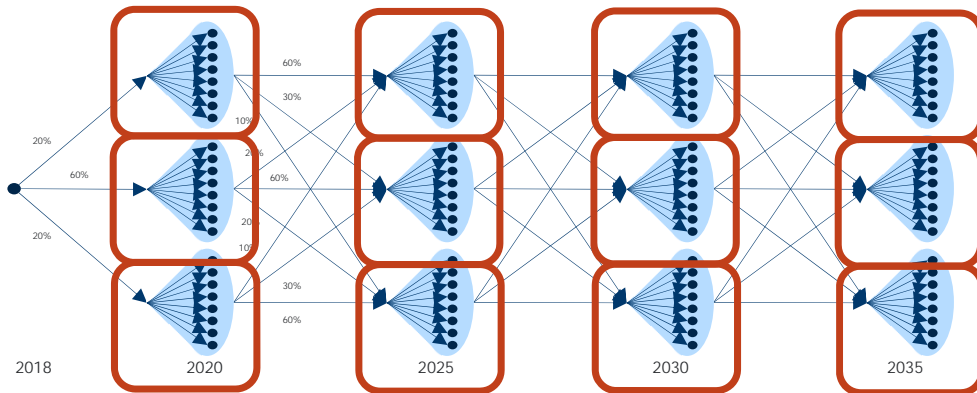
Reconfiguration schemes



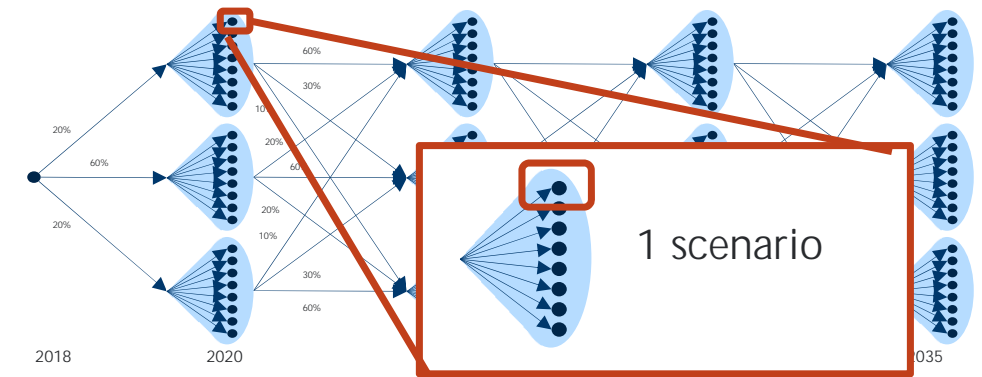
Country



Robust

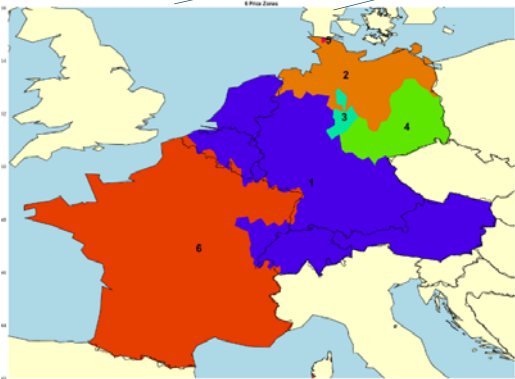
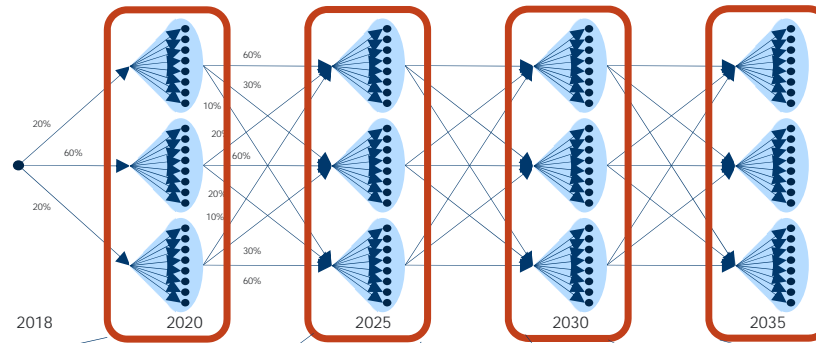


GivenGrid

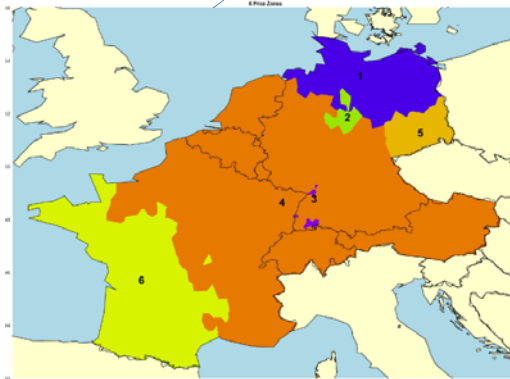


ScenarioSpec

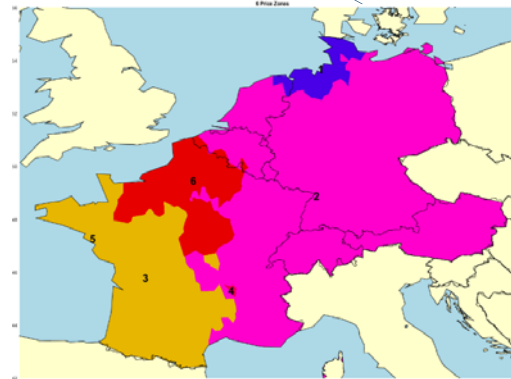
Exemplary Configurations for the „Robust” Scheme



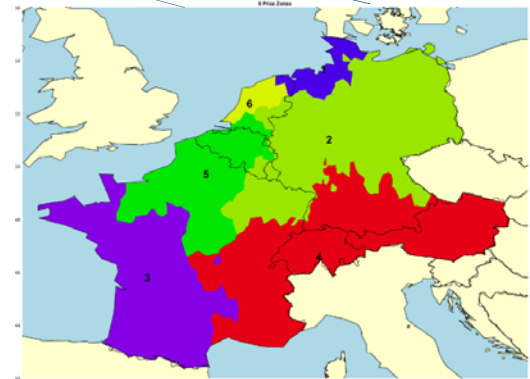
2020



2025



2030

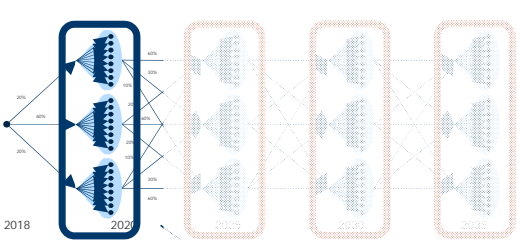


2035

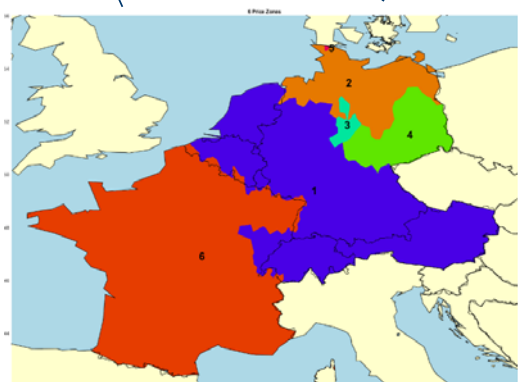
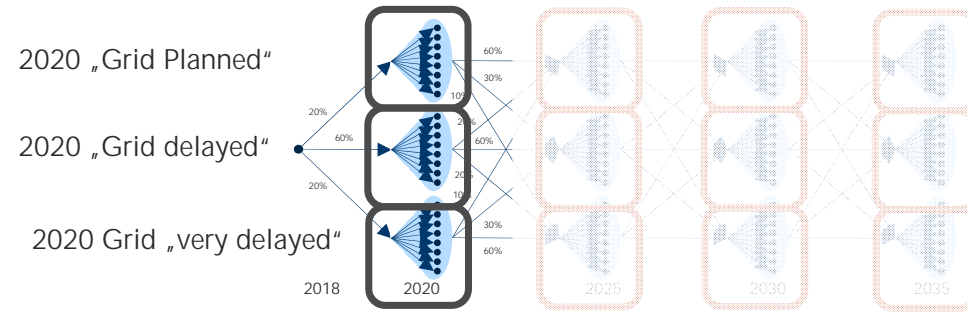
Comparison of the „Robust” and “GivenGrid” Scheme



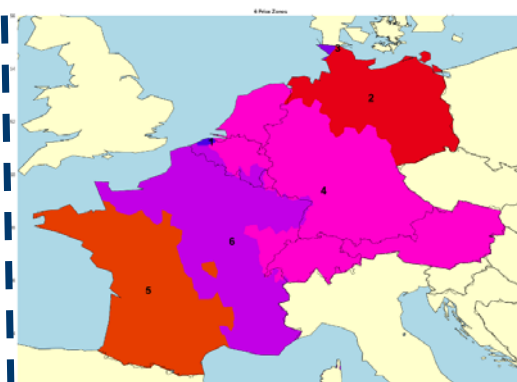
“Robust”



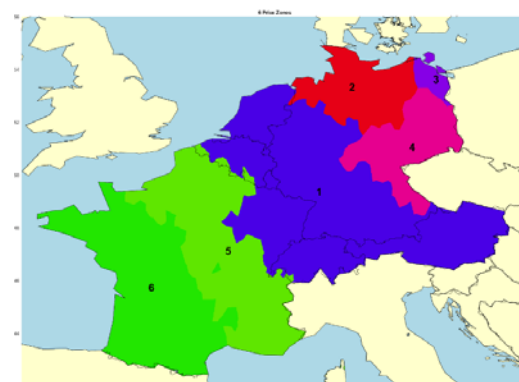
“GivenGrid”



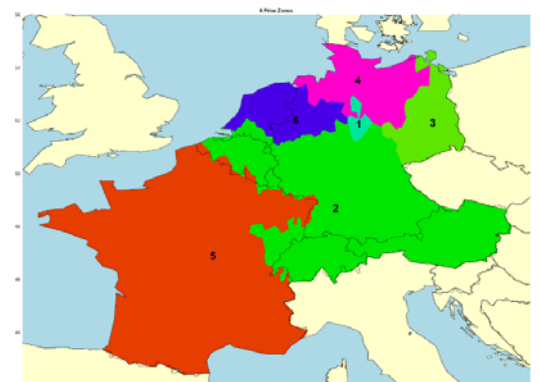
2020 „Robust”



2020 „Grid Planned”



2020 „Grid delayed”

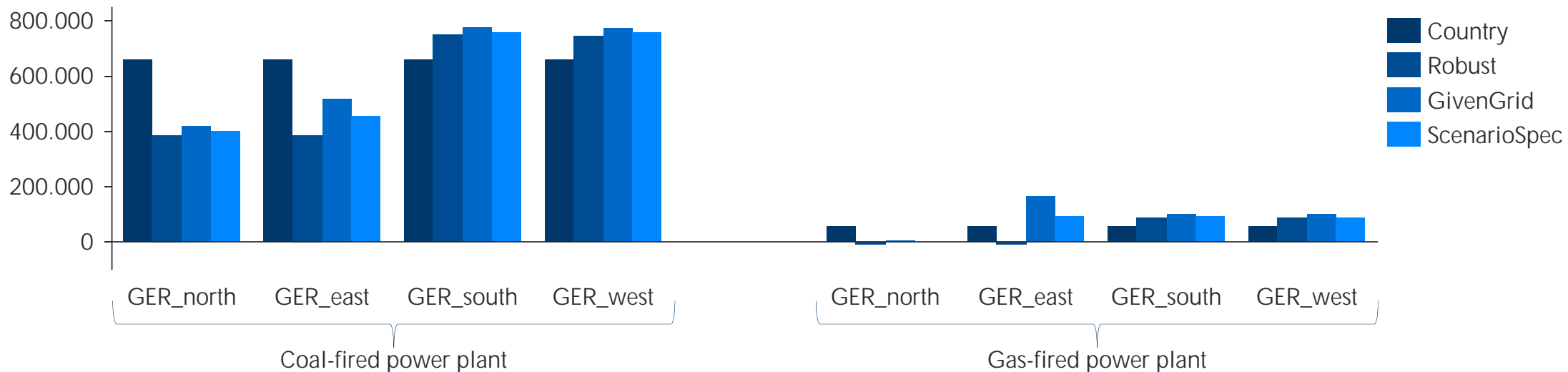


2020 Grid „very delayed”

First NPV Results for 4 Nodes in Germany for configurations with 6 Zones

First Results – 4 exemplary Nodes in Germany

Weighted NPV of contribution margin [€/MW]



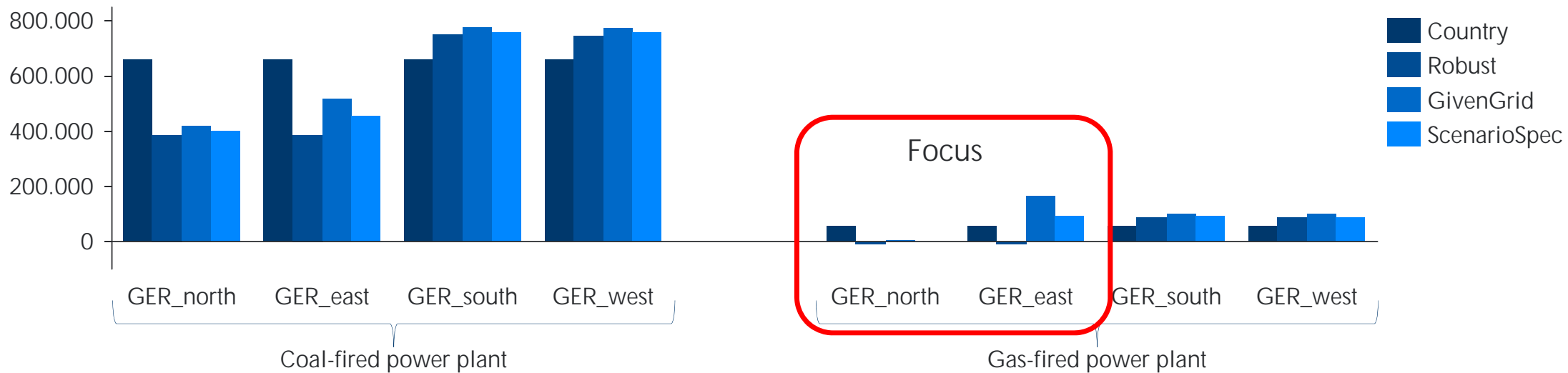
Findings:

- NPV of coal-fired plants positive in all schemes in comparison to gas-fired plants
- PZC positive for southern and western power plants due increasing prices (contribution margin)

First NPV Results for 4 Nodes in Germany for configurations with 6 Zones

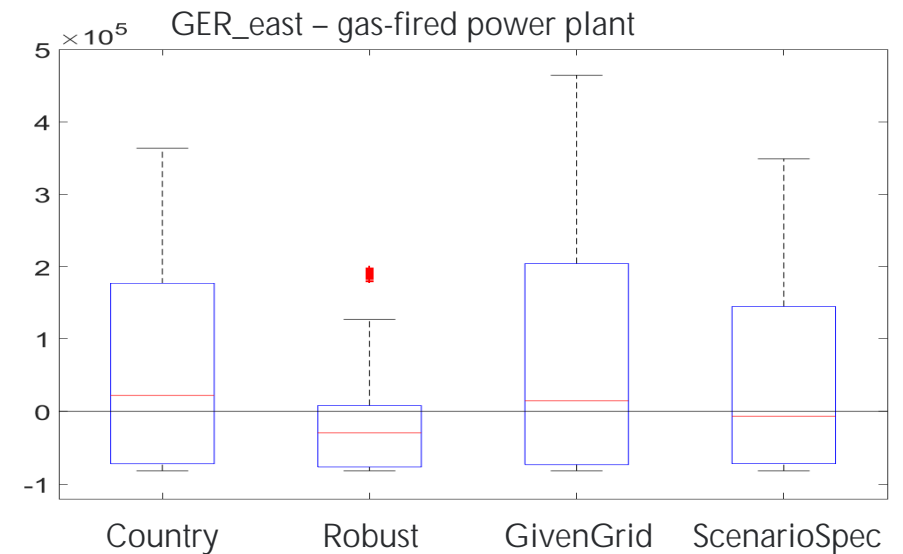
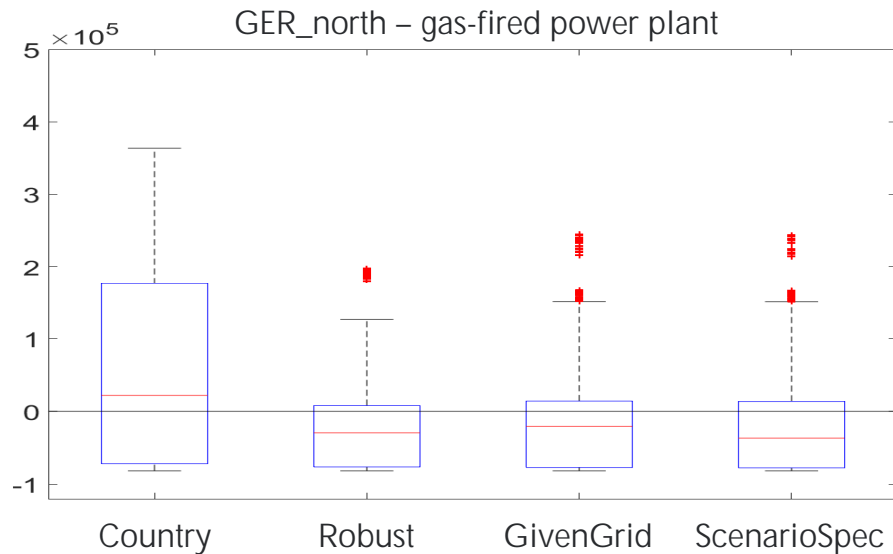
First Results – 4 exemplary Nodes in Germany

Weighted NPV of contribution margin [€/MW]



- Further focus on gas-fired power plants in north and east Germany

Focus on gas-fired power plants in "North" and "East" Germany for configurations with 6 Zones

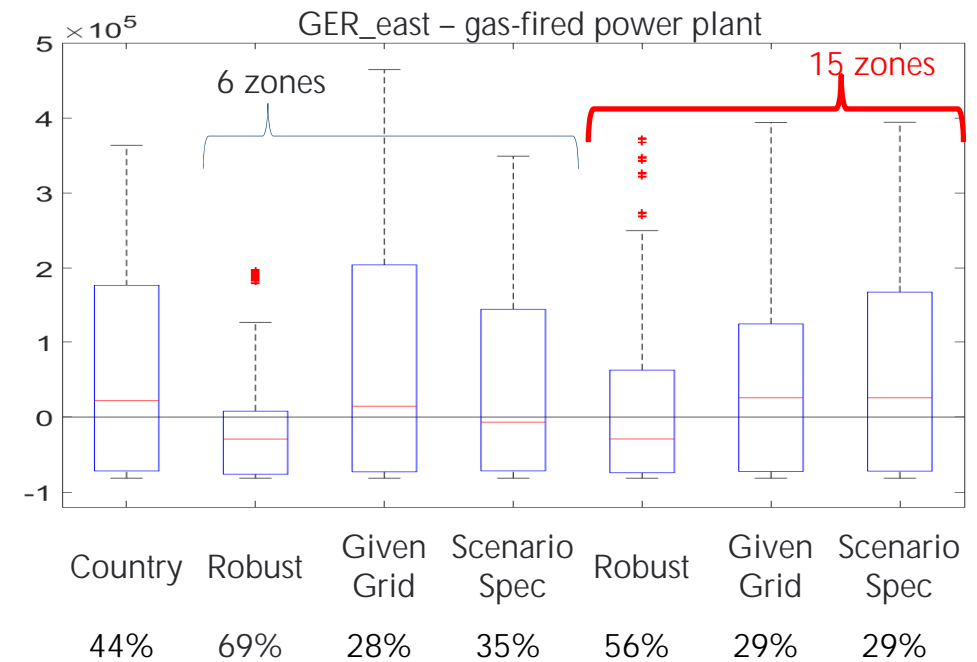
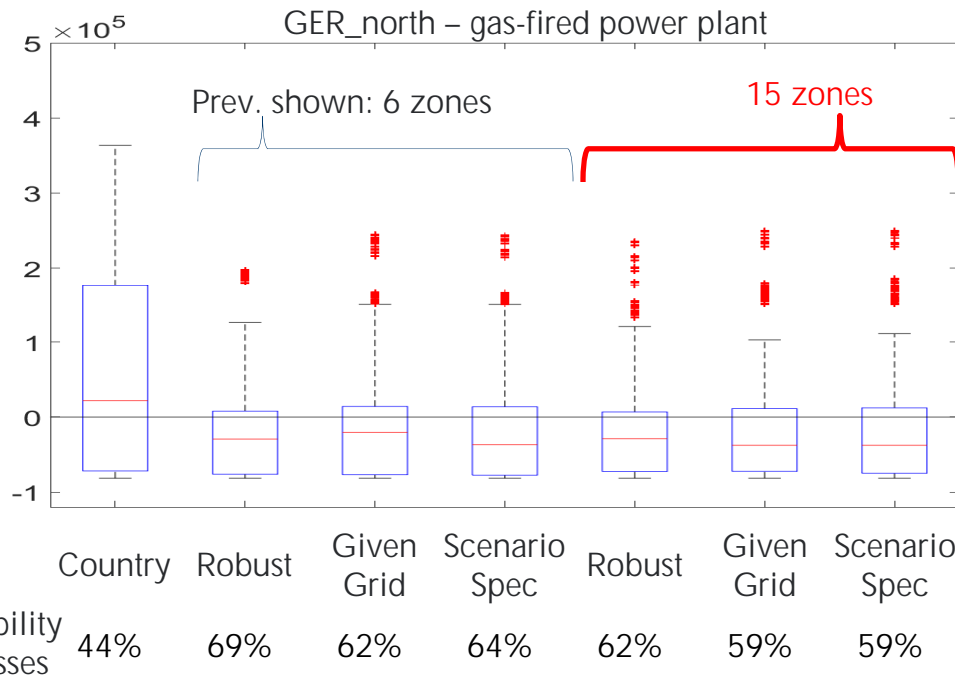


Probability
of Losses

Findings:

- Scheme of PZC has an impact on risks for (gas-fired-) power plants
- Different impact of PZC-Scheme in east and north of Germany

Focus on gas-fired power plants in "North" and "East" Germany for configurations with 6 and 15 Zones

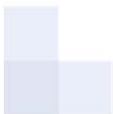


Findings:

- Number of price zones has more impact on the power plant in eastern Germany than northern Germany
- No clear picture how risk varies with number of price zones

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- Conclusion
 - Both the number of price zones and the „reconfiguration scheme“ influence the risk and NPV for investments in power plants
 - Impact depends on and varies with the location of the power plant (node)
 - Future investment in gas-fired powerplants in Germany seems risky and not profitable

- Outlook
 - Quantify risks of different configurations and schemes
 - Investigate potential benefits of the „robust“ scheme

 - Finalisation of grid expansion for 2035 (TYNDP 2016)
 - Extension of scope from CWE + to CEE & Italy

Thank you for your attention!

Please contact us for further information:

Robin Leisen

robin.leisen@uni-due.de

Caroline Deilen

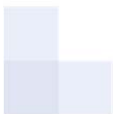
caroline.deilen@uni-due.de

Tim Felling

tim.felling@uni.due.de

Christoph Weber

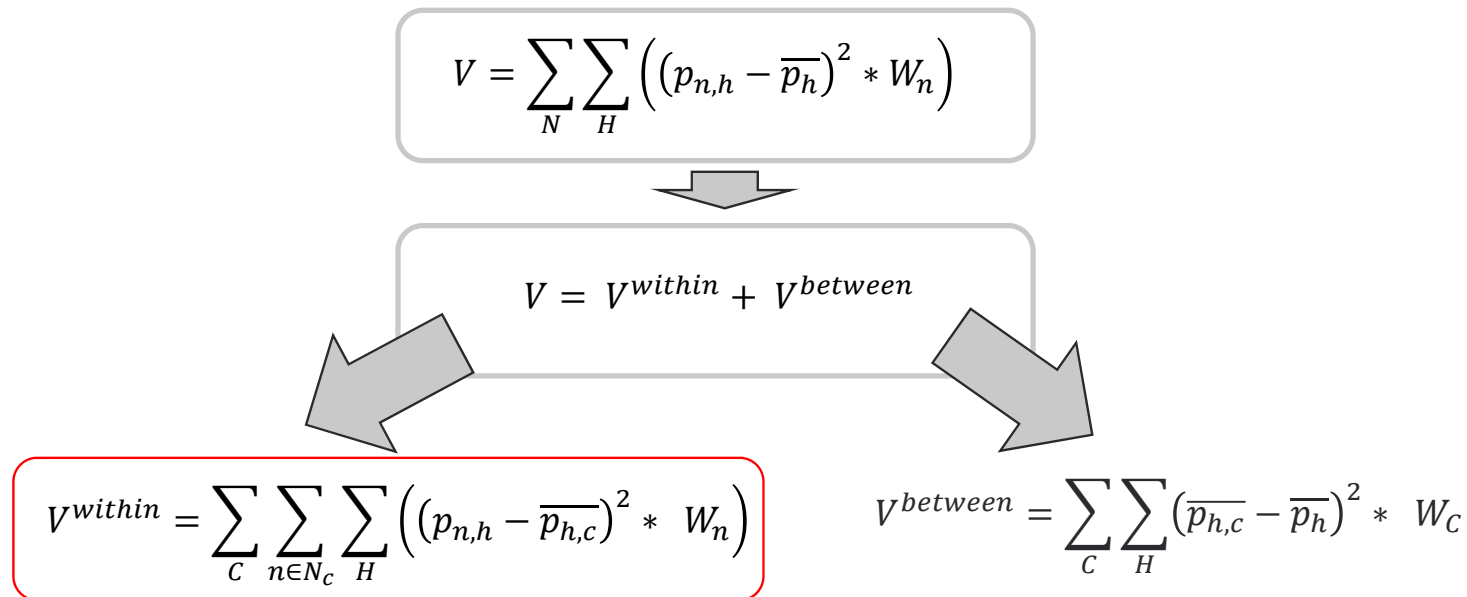
christoph.weber@uni-due.de



Explicit objective function of Cluster Algorithm

Methodology – Cluster Algorithm

Total variation in a configuration, e.g. electricity market of CWE, can be divided into the variations between and within the single zones



Objective to minimize the within-zone variance

Power plants and assumptions for calculation of contribution margin

Results of previous investigations

- Investigated power plant types

Power plant typ	efficiency [%]	Investment cost [€/MW]	Operating time [years]	annual fixed operating costs [€/kW]
„coal old“	38	1.400	43,3	14,34
„coal new“	46	1.400	43,3	15,06
„gas“	60	800	40,7	6,23
„lignite, BoA“	43	1.800	51,2	150,6

- Assumptions for calculation of limits for further operation or invest
 - Discount rate: 10 %
 - Limit for further operation of a power plant: $CM > 60 \% * \text{annual fixed operating costs}$
 - Limit for invest in new power plant: $CM > \text{annuity} + \text{annual fixed operating costs}$
- Approximate calculation of contribution margin through prices and variable costs of electricity generation
- Positioning of power plants at known power plant sites
 - Mannheim (DES, coal and gas), Hamburg (DEN, coal and gas), Niederaußem (lignite)

Following risk factors and conditions are reflected

Construction of partly meshed scenario tree

- Base year

2020	2025	2030	2035
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- Grid development

Planned grid - 0 years	Planned grid - 2 years	Planned grid - 5 years
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- Other uncertainties

Uncertainty factor	Model of uncertainty	(empirical) annual volatility	Scenarios (over 3 years)
Average fuel prices	Geometric Brownian Motion (GBM)	11,7 %	$P0^{*1,23}$, $(P0,)$ $P0^{*0,82}$
coal-gas spread (is combined with CO2)	GBM	6,6 %	$\Delta P0^{*1,12}$, $(\Delta P0,)$ $\Delta P0^{*0,89}$
CO2 (is combined with coal-gas spread)	GBM	18,9 %	$P0^{*1,39}$, $(P0,)$ $P0^{*0,72}$
demand	Brownian Motion	2 %	$D0^{*1,034}$, $(D0,)$ $D0^{*0,966}$
Expansion of renewable energies	Mean-Reversion, Zeitkonstante 2 J	20 %	$\Delta EEm^{*1,3}$, $(\Delta EEm,)$ $\Delta EEm^{*0,7}$

Example construction of scenario tree with three uncertainties (2/2)

Constuction of partly meshed scenario tree

- Transition probabilities

- Grid development

From→ to	Planned grid -0	Planned grid -2	Planned grid -5
Planned grid -0	60 %	20 %	10 %
Planned grid -2	20 %	60 %	20 %
Planned grid -5	10 %	20 %	60 %

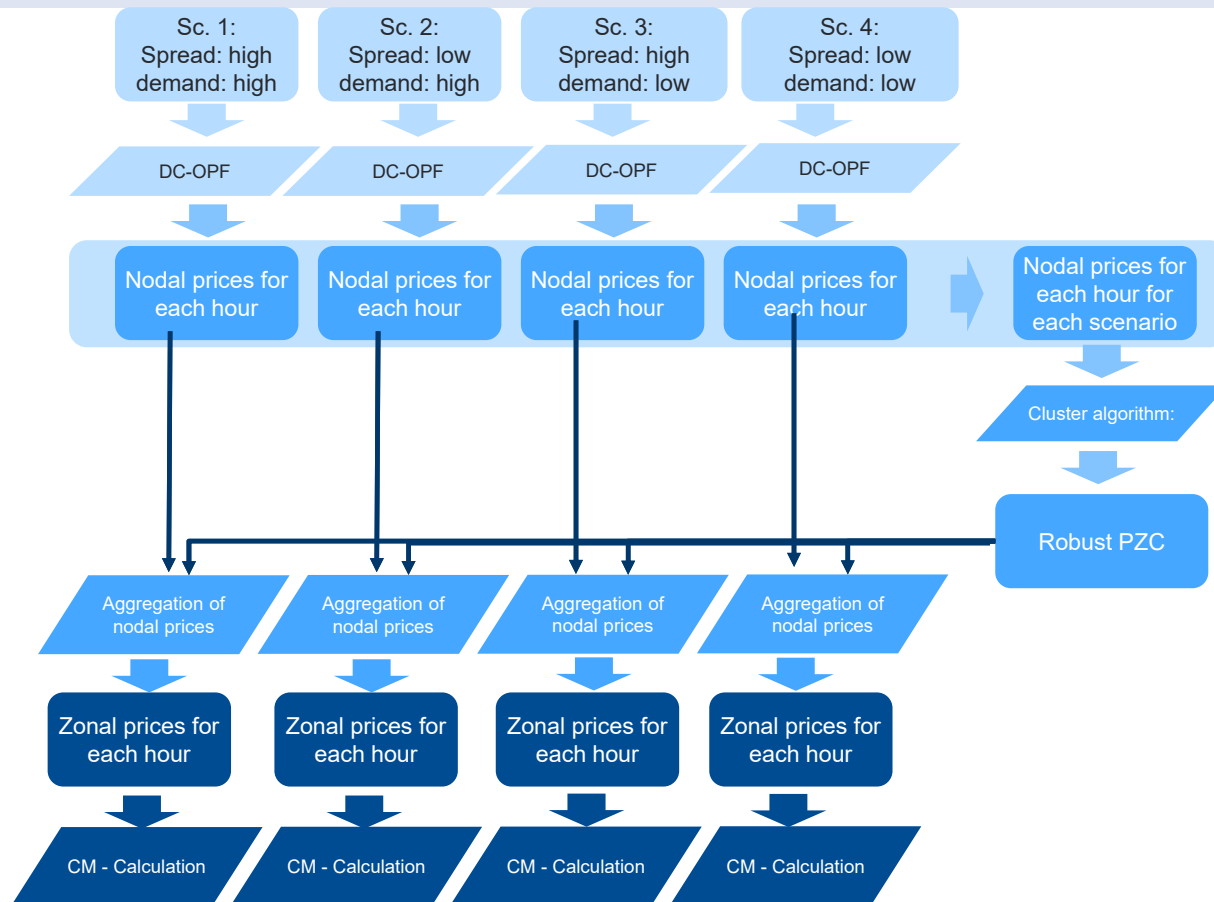
- Combination of uncertainties:
(coal-gas spread (high/low), demand (high/low),
development REN (high/low))

From→ to	High	Low
High	75 %	25 %
Low	25 %	75 %

- These assumptions result in

- 96 scenarios
 - 331,776 paths through scenario tree

General Approach



- Calculation of nodal prices for every single scenario
- Robust PZC (fixed assignment of nodes to zones) is used to aggregate nodal prices of separate scenarios to zonal prices
- Zonal price = average, weighted price of all nodes in one zone (defined by chosen PZC)
- Calculation of CM for selected power plants on the basis of zonal prices

$$CM_t = \max(0; \text{zonalPrice}_t - \text{var. Costs})$$
- Result: CM of the power plants for one year for each scenario