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Quantification of the impact of climate change on thermal power plants in Germany – A System Dynamics modelling approach

Bastian Hoffmann, Sebastian Häfele, Ute Karl

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Structure of the Presentation

1 Motivation

2 Development of a cooling system model

i. Input data

ii. Model description

3 Model results

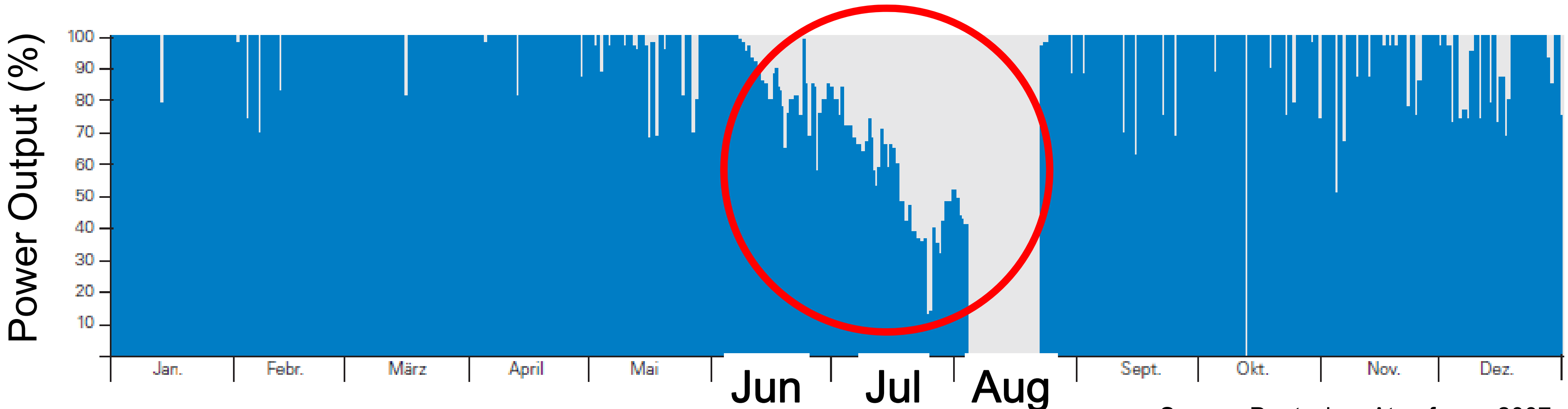
i. Validation

ii. Climate scenarios

4 Discussion & outlook

Motivation

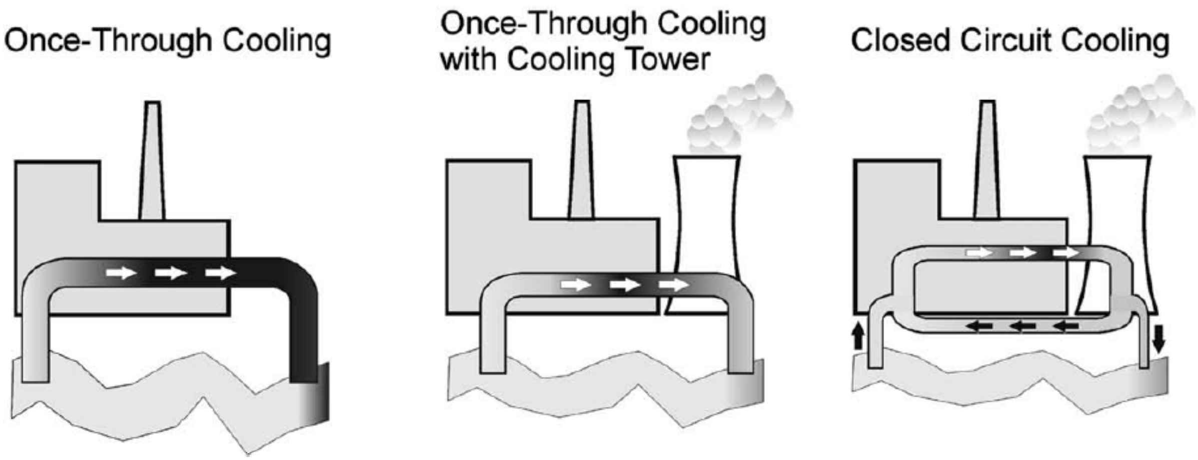
- An increase of river water temperature decreases the capacity of a river to absorb more heat. River water related thresholds limit heat discharge from thermal power plant units.
- High statistic probability of higher mean air and water temperatures due to climate change
  → Impact on the cooling operation of conventional thermal power plants?
- Example for a significant influence on power plant operation due to high temperatures: nuclear power plant Unterweser in Summer 2006 (August 5 - 23: Maintenance)



Source: Deutsches Atomforum 2007

Model Concept

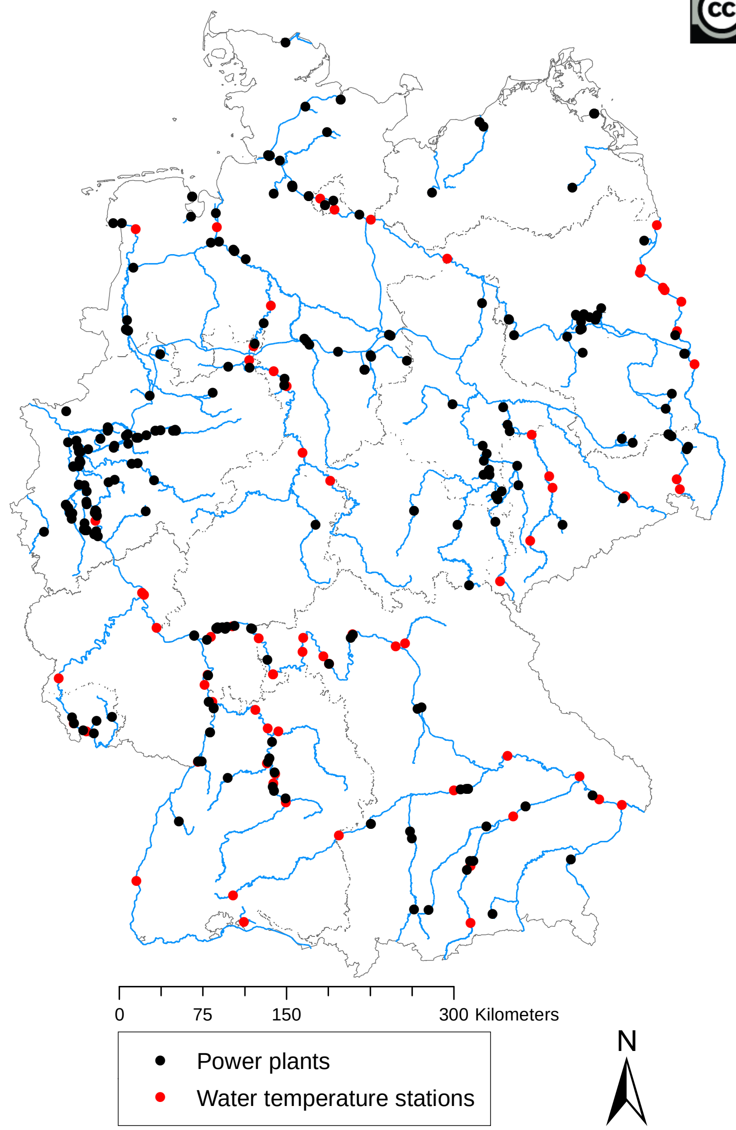
- Consideration of most important relations and dependencies of a cooling system
- Representation of most common cooling system technologies in Germany



Source: Koch and Vögele 2009

- Implementation of the dependence between power plant efficiency and cooling water temperature
- Modelling of a representative power plant capacity in Germany (26 units, 20 GW_{gr})

Model Input Data



Source: Strauch 2011

Hydro-meteorological parameters

- Climatic data across Germany:
  - air temperature
  - wet-bulb temperature
  - water temperature
- Observed data and projections for climate scenarios A1B, A2 and B1
- Regional climate model REMO (UBA run)

River water related thresholds

- Max. temperature of discharge
  - once-through: 30 °C (33 °C)
  - closed-circuit: 35 °C
- Max. incremental heating: 3 K
- Max. river temperature: 28 °C

Sources: 2006/44/EC, LAWA 1991

Technical parameters

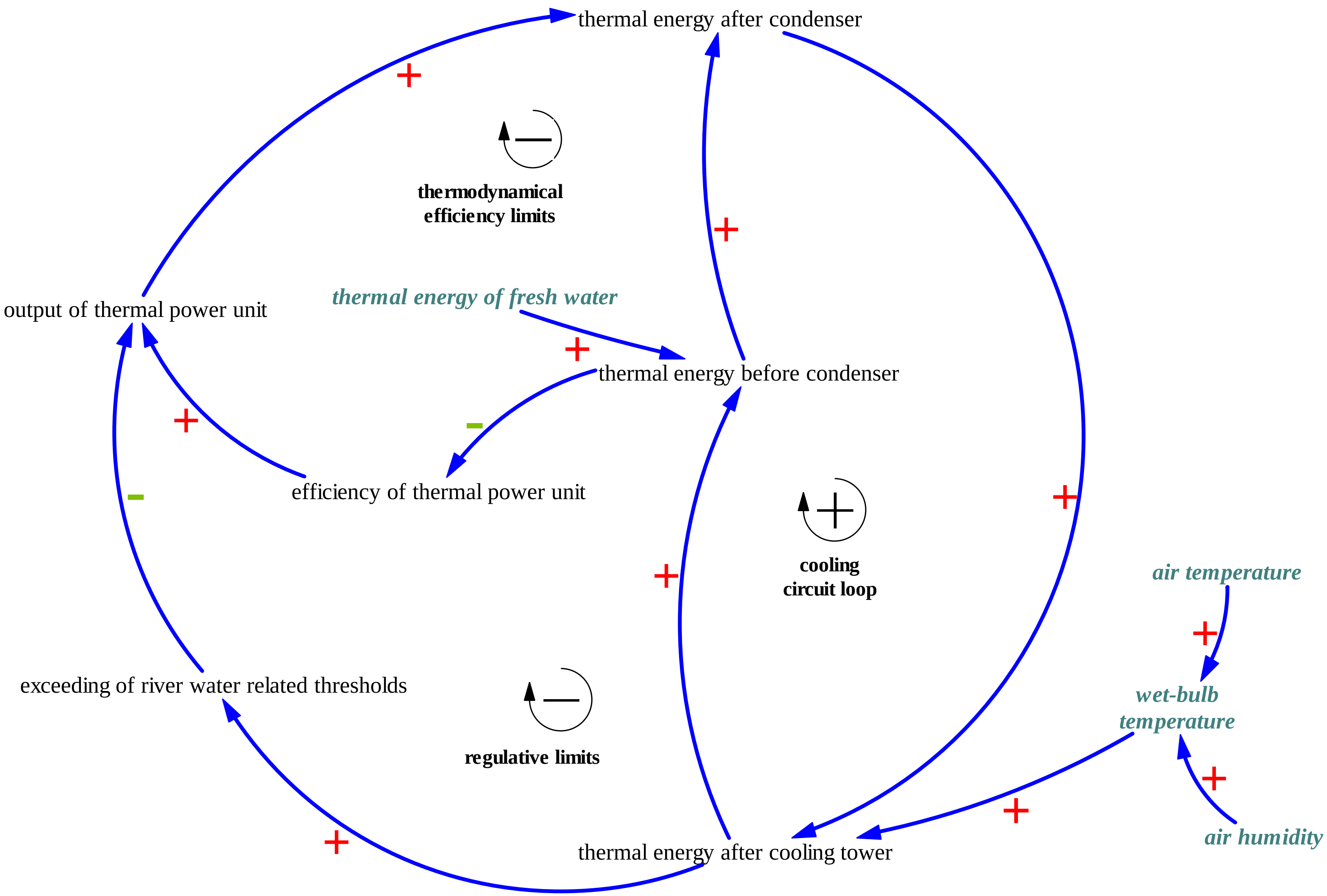
- Power output [MW]
- Efficiency [%]
- Quantity of cooling water [kg/s], etc…

Sources: data from power plant operators, Platts 2007

System Dynamics Model Approach

- Cooling system = dynamic system with feedbacks

  (river water related thresholds – hydro-meteorological parameters – cooling system operation)



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System Dynamics Model Approach

- Cooling system = dynamic system with feedbacks
  (river water related thresholds – hydro-meteorological parameters – cooling system operation)

- Implementation of complex thermodynamic relations

- Daily time steps, spatial resolution: power plant unit

- Analysis of climate scenarios A1B, A2 and B1: 2011-2040, 2041-2070
  control run 1961-1990

- Sensitivity scenarios on river discharge

- Adaptation scenarios: retrofit of once-through cooling system to closed-circuit cooling system

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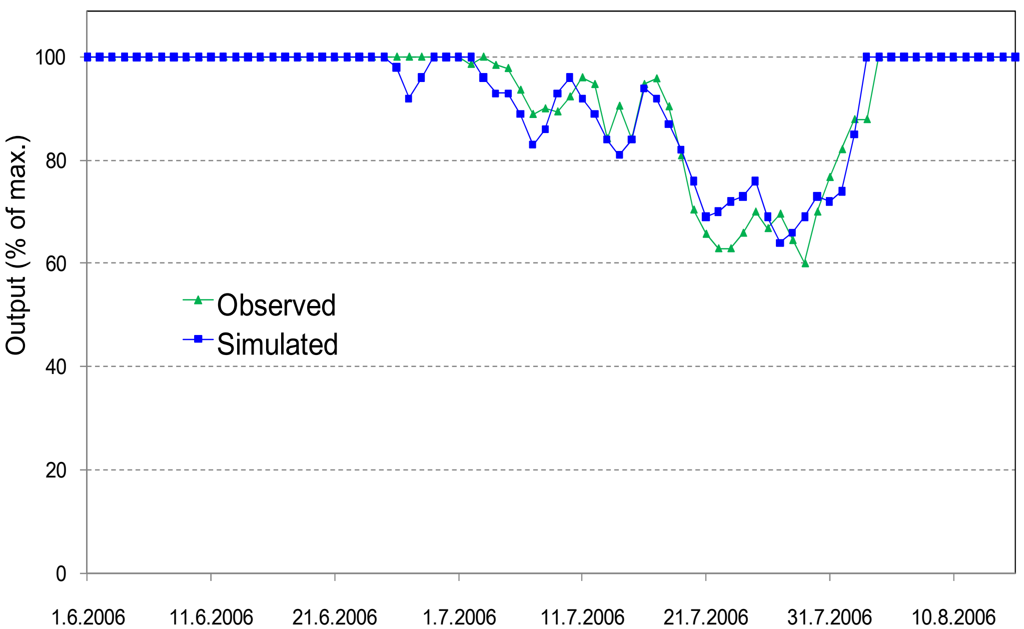
Results: Validation

Example: nuclear power units Krümmel and Grafenrheinfeld

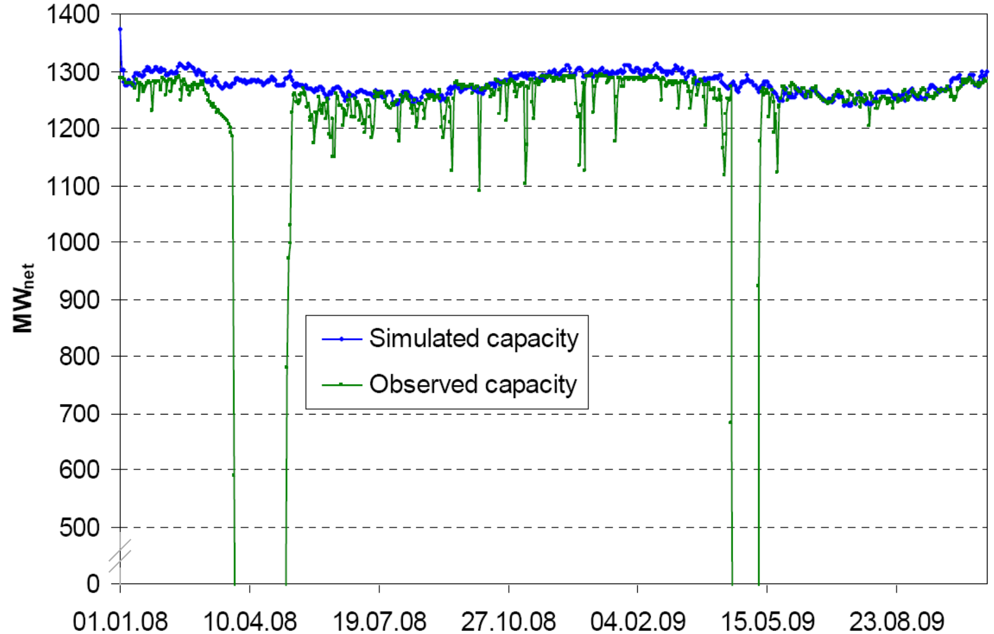
once-through cooling



Mean deviation

- annual: 0.6 %
- Jun-Aug: 2.3 %

closed-circuit cooling with efficiency variations



Mean deviation

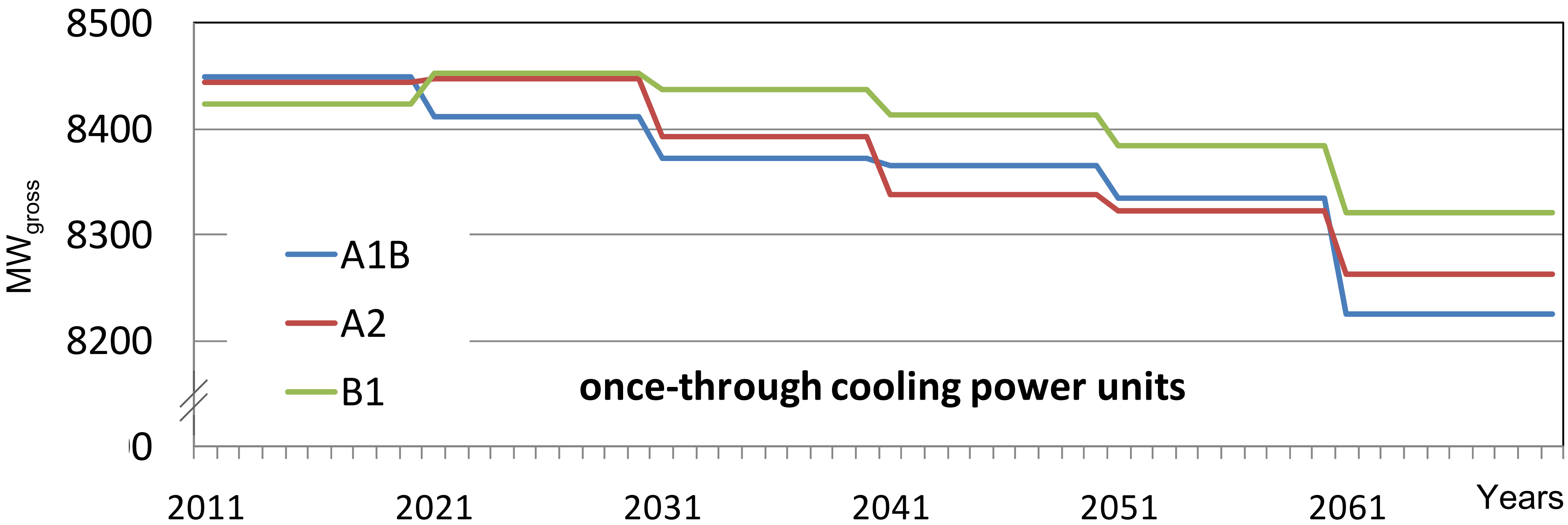
- annual: 2 %
- Jun-Aug: 1.1 %

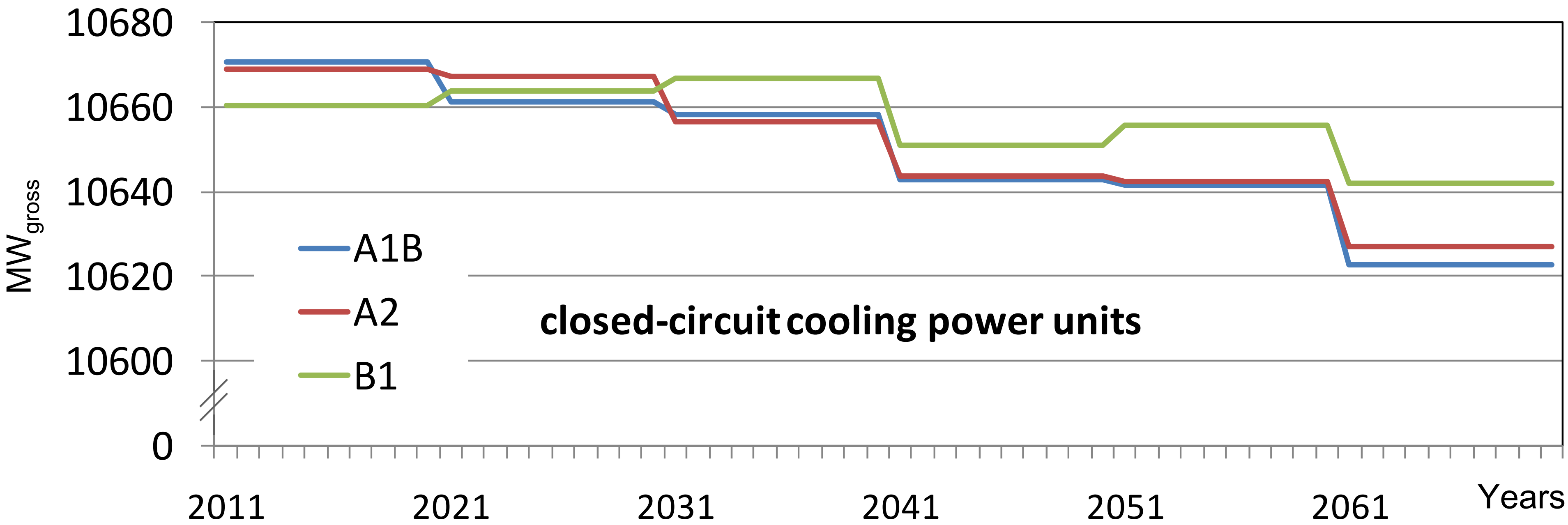
Excl. deviations in April 2008 and May 2009 (maintenance)

Sources: Deutsches Atomforum (2007), E.ON (2010)

Results – Climate Scenarios

Maximum load per climate scenario (decadal mean)





Results - Statistical Analysis

Climate scenario A1B, period 2011-2040

Technology	Units	Total capacity [MW_{gr}]	Cumulative trend[1] [MW/a]	Mean trend[1] [MW/a]	Min. trend[2] [MW/a]	Max. trend[2] [MW/a]
Once-through cooling	17	8738	-4.77	-0.28	-0.02	-0.73
Closed- circuit cooling	9	10625	-0.81	-0.09	-0.04	-0.13

Climate scenario A1B period 2041-2070

Technology	Cumulative trend[1] [MW/a]	Mean trend[1] [MW/a]	Min. trend[2] [MW/a]	Max. trend[2] [MW/a]
Once-through cooling	-6.44	-0.38	-0.04	-0.89
Closed- circuit cooling	-1.07	-0.12	-0.05	-0.17

[1] cumulative/mean trend over all units of a technology
[2] minimum/maximum negative trend of a single unit

Discussion & Outlook

Discussion

- Validation showed good results, model is able to simulate climate constraints on electricity production
- Model can be easily adapted to further power plant sites
- Results show significant negative trends in electricity production
- Uncertainties of climate model data
- No simulation of future river discharge

Outlook

- Variation of climate model: WETTREG
- Consideration of extreme weather events
- Extension of the model to further cooling technologies
- Economic evaluation of impacts and adaptation scenarios

Thank you for your attention!

Bastian Hoffmann, bastian.hoffmann@eifer.org, 0721 – 6105 1434

Sebastian Häfele, sebastian.haefele@eifer.org, 0721 – 6105 1413

Ute Karl, ute.karl@eifer.org, 0721 – 6105 1335