A Guideline through Complexity: Assessing the Security of Electricity Supply

1st IAEE Online Conference 2021
June 8, 2021

By Lars Nolting

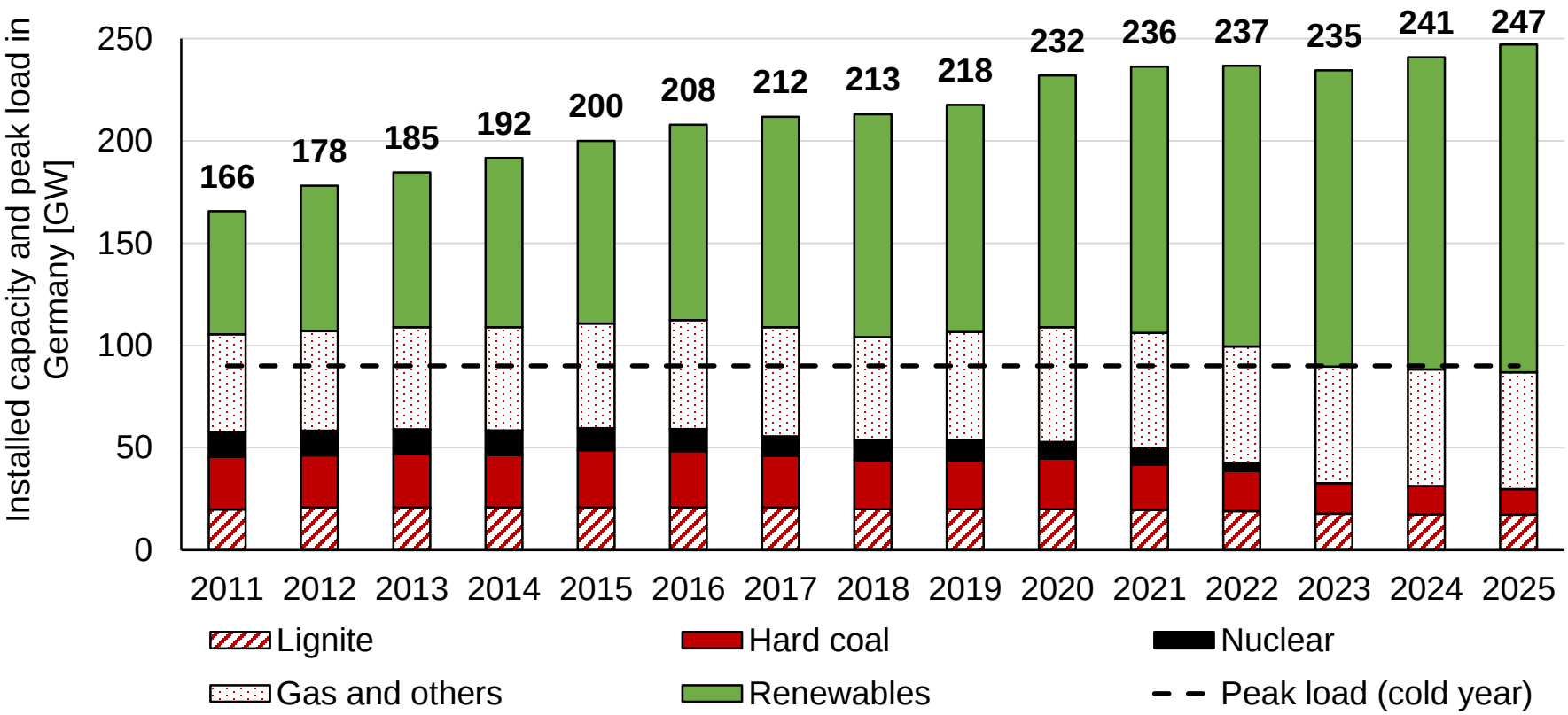
Chair for Energy System Economics (FCN-ESE)
RWTH Aachen University, Germany

FCN | Future Energy Consumer Needs and Behavior

E.ON Energy Research Center

RWTH AACHEN UNIVERSITY

Security of electricity supply in central Europe: the German case



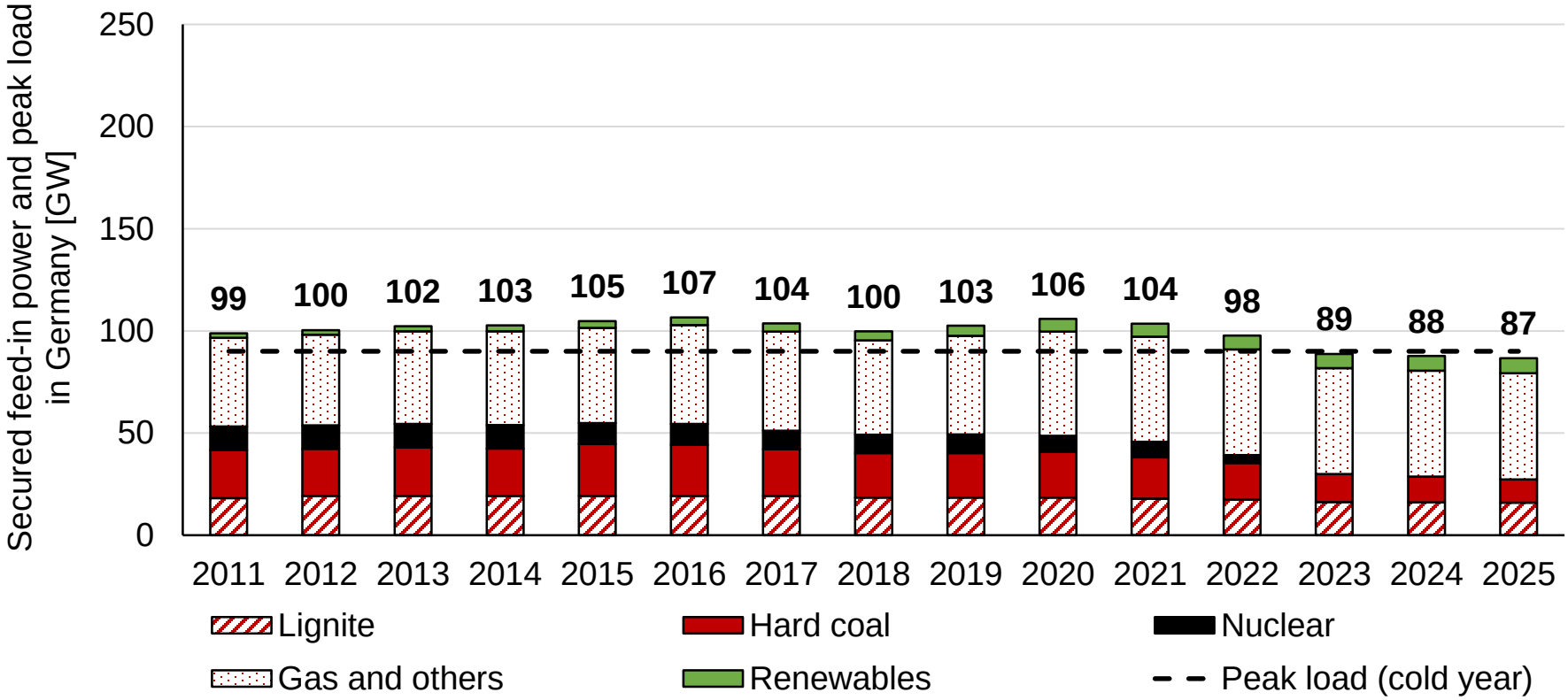
Sources of data: Federal Network Agency power plant list (BNetzA, 2020a), power plant decommissioning notification list (BNetzA, 2020b), Coal Phase-out Act (Federal Government, BMWi, 2020), Thirteenth Act Amending the Atomic Energy Act (Federal Government, BMU, 2011), Grid Development Plan 2030 (TSOs, 2019), MAF 2018 and 2019 (ENTSO-E, 2018a and 2019), and own calculations.

Growing capacities due to the **expansion** of **renewable energies**

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

E.ON Energy Research Center
RWTH AACHEN UNIVERSITY

Security of electricity supply in central Europe: the German case



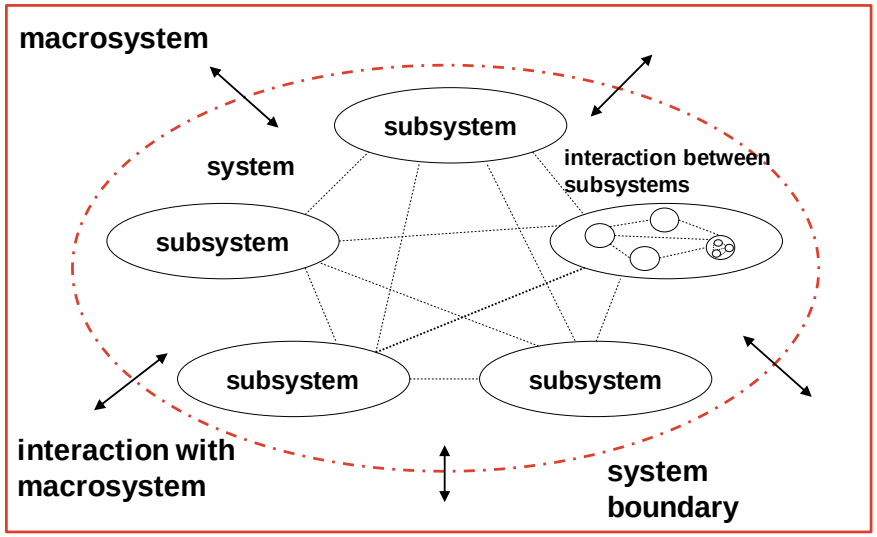
Sources of data: Federal Network Agency power plant list (BNetzA, 2020a), power plant decommissioning notification list (BNetzA, 2020b), Coal Phase-out Act (Federal Government, BMWi, 2020), Thirteenth Act Amending the Atomic Energy Act (Federal Government, BMU, 2011), Grid Development Plan 2030 (TSOs, 2019), MAF 2018 and 2019 (ENTSO-E, 2018a and 2019), and own calculations.

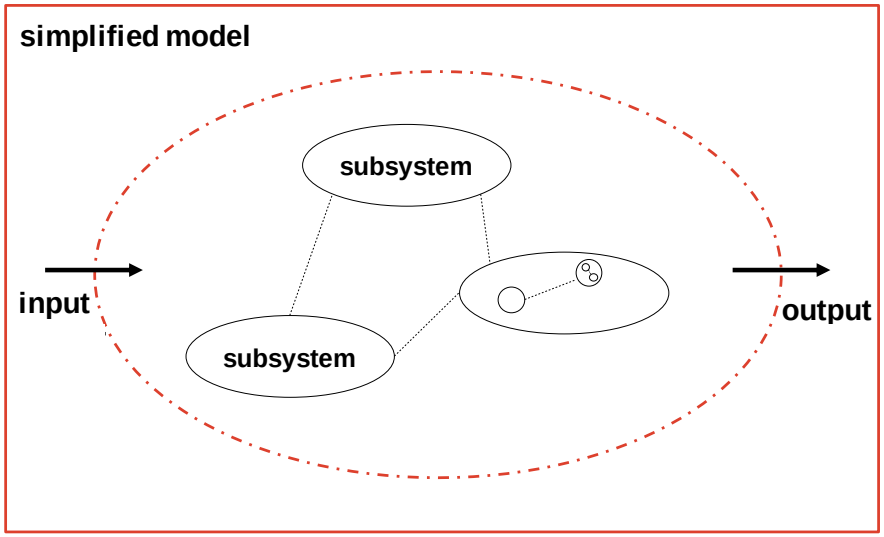
Decreasing secured feed-in due to the **decommissioning** of **nuclear** and **fossil energies**

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Introduction and motivation

Energy system modeling is needed to conduct “experiments” in energy sciences





Two key findings can be derived:

1) Energy systems are **complex systems** (see e.g. Bale *et al.*, 2015)
2) Current developments are further **increasing** the **degree** of **complexity**

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Identified research gap

Dedicated complexity management is needed in energy system analysis, but not implemented at this time

The following **research questions** arise:

*What are the **benefits** and **drawbacks** of **more complex models** to provide policy-relevant insights in the field of energy sciences?*

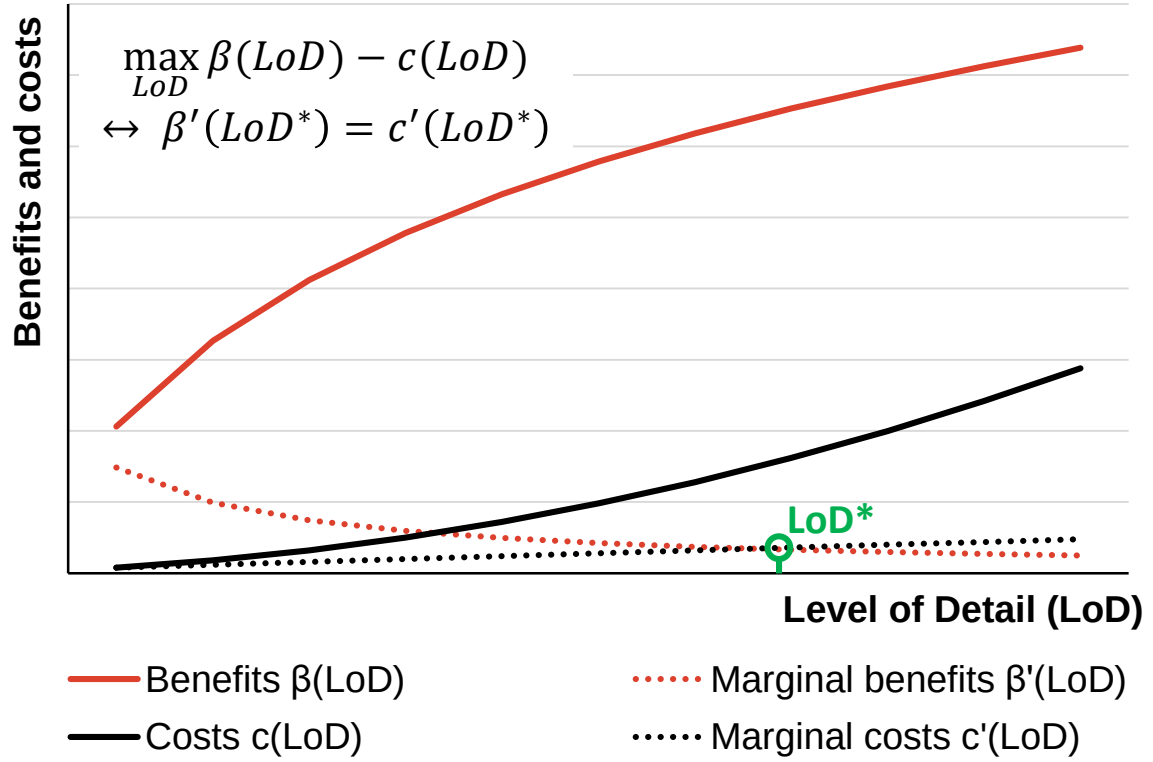
*How can an **optimal level of detail** for an energy system model be defined and reached?*

Assessing the security of supply with electricity as a suitable **field of application**

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

General mathematical model to derive the optimal *Level of Detail (LoD)*

Maximizing the net benefit of a modeling approach



Benefits:

- Utility from more detailed insights

Costs:

- Model implementation
- Model runtimes
- Interpretation of results
- …

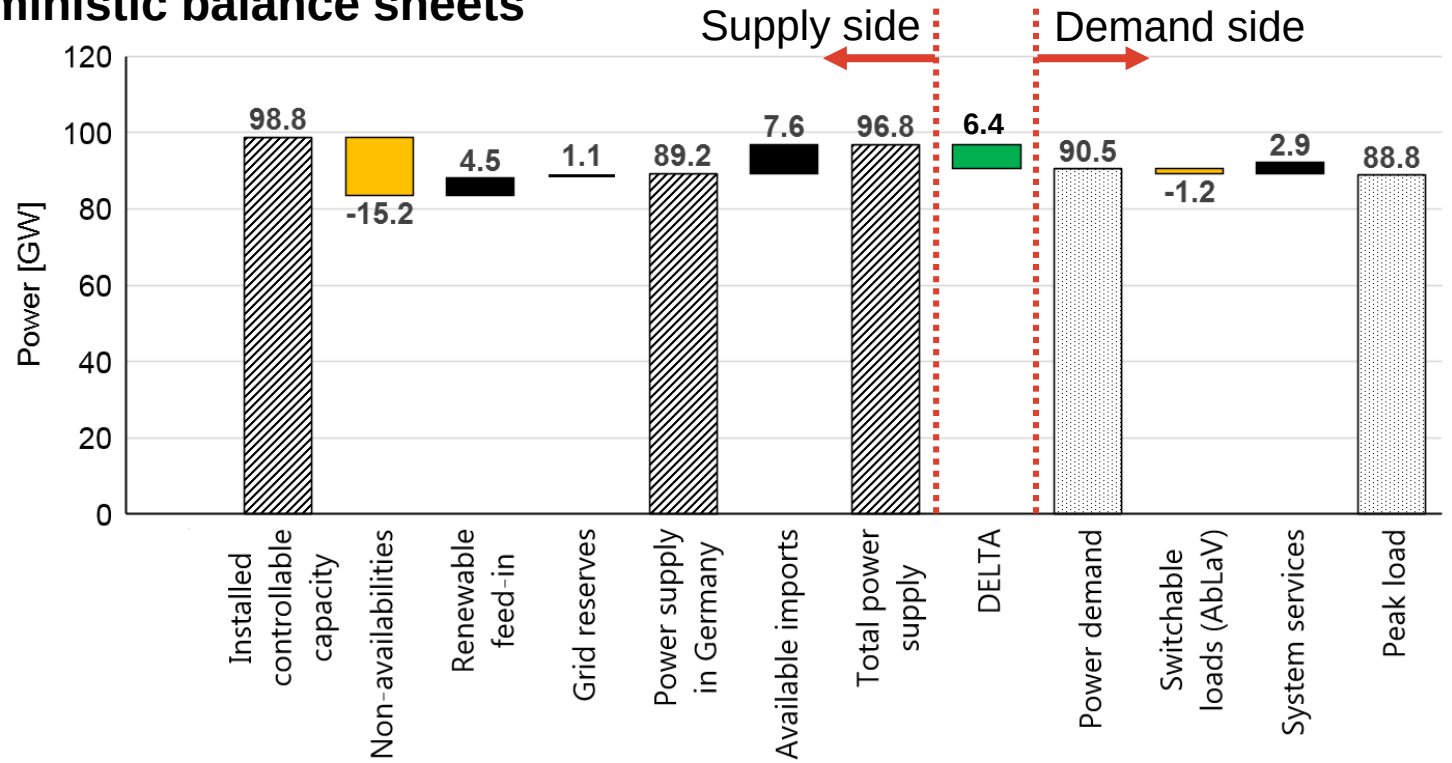
More complex models are not superior *per se*

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Possible modeling approaches for assessing security of electricity supply

Different approaches to model energy systems aim at different levels of the systems' emergent behavior

Deterministic balance sheets

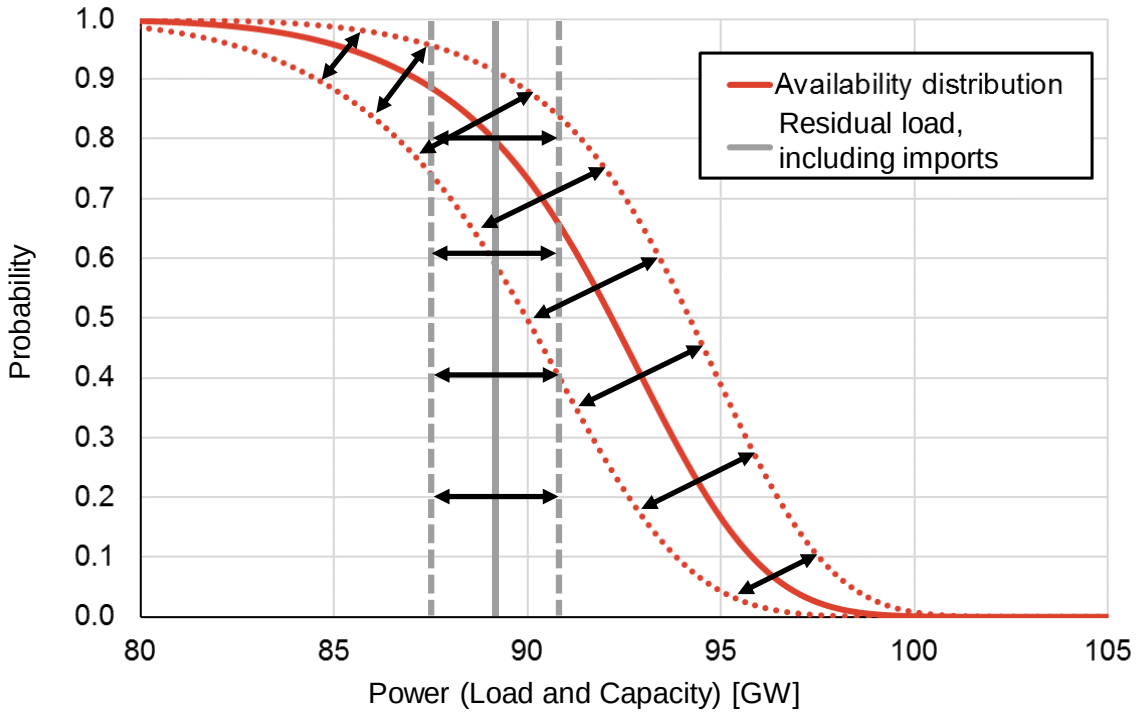


1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Possible modeling approaches for assessing security of electricity supply

Different approaches to model energy systems aim at different levels of the systems' emergent behavior

Probabilistic simulation models



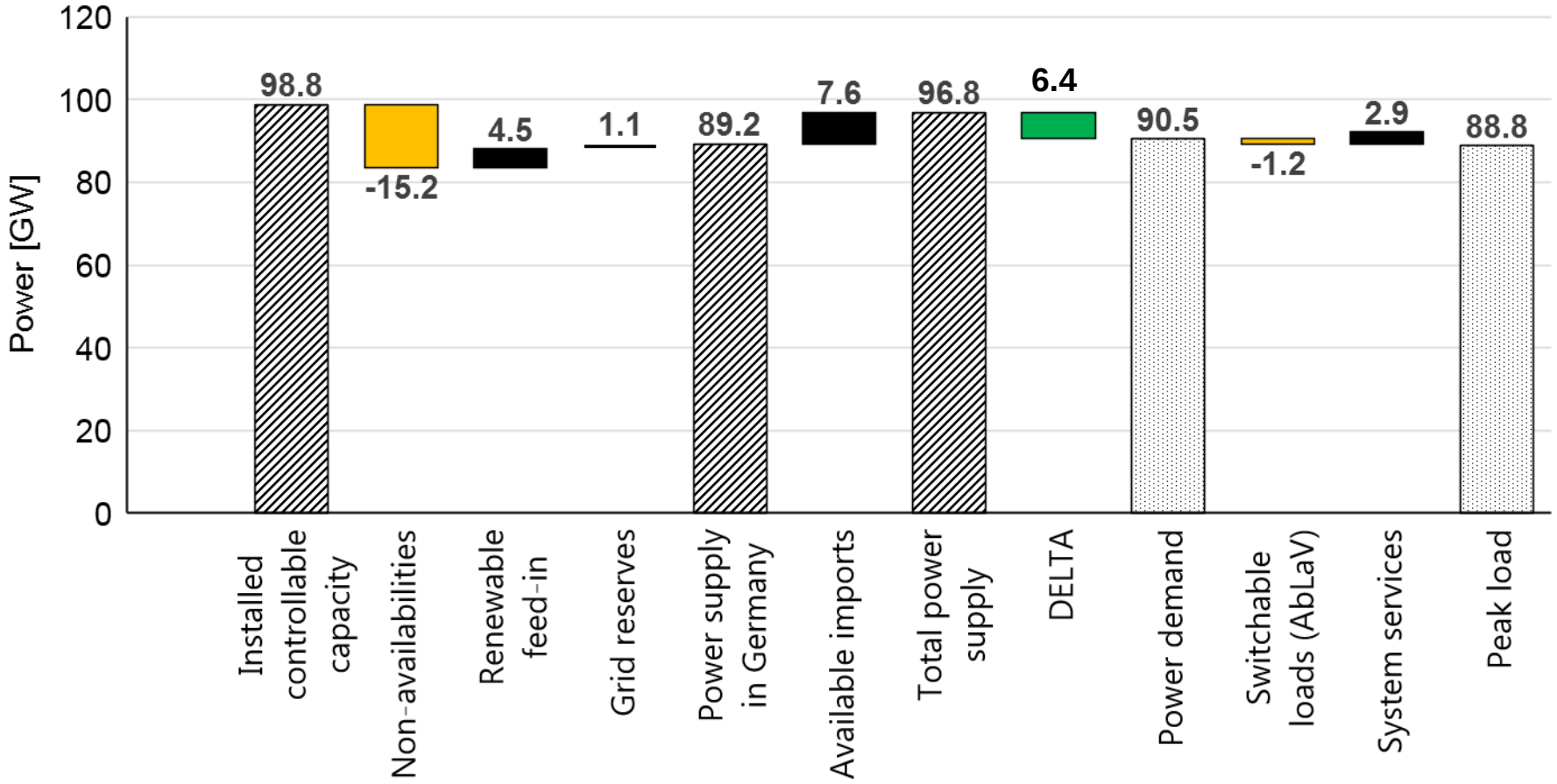
1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Deterministic balance sheets in Germany for 2023

~~Nuclear power~~

Coal capacities →

Capacity surplus of more than 6 GW, however imports are needed



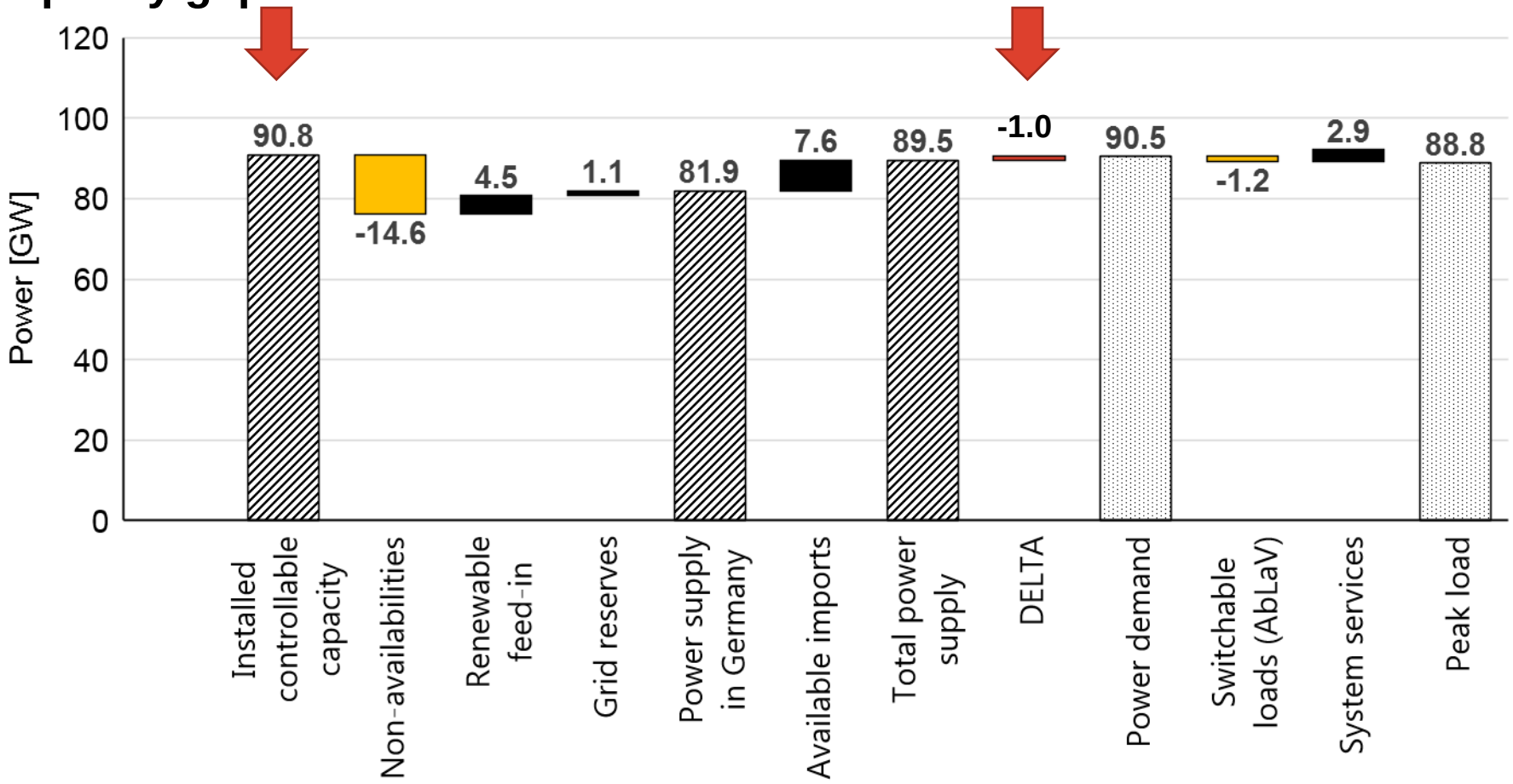
Lars Nolting, lnolting@eonerc.rwth-aachen.de

Deterministic balance sheets in Germany for 2023

~~Nuclear power~~

Coal capacities ↓

Additional mothballing of 8 GW coal-fired power plants might cause capacity gap

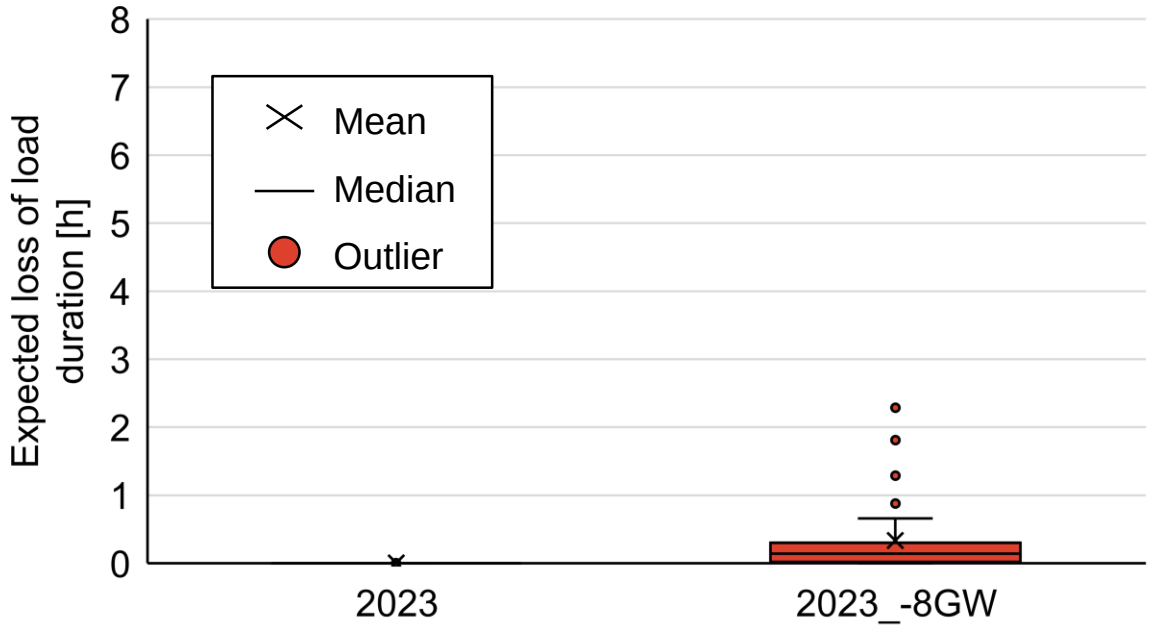


1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

Results of probabilistic simulation model in Germany for 2023

Loss of load is only to be expected in cold and calm weather years



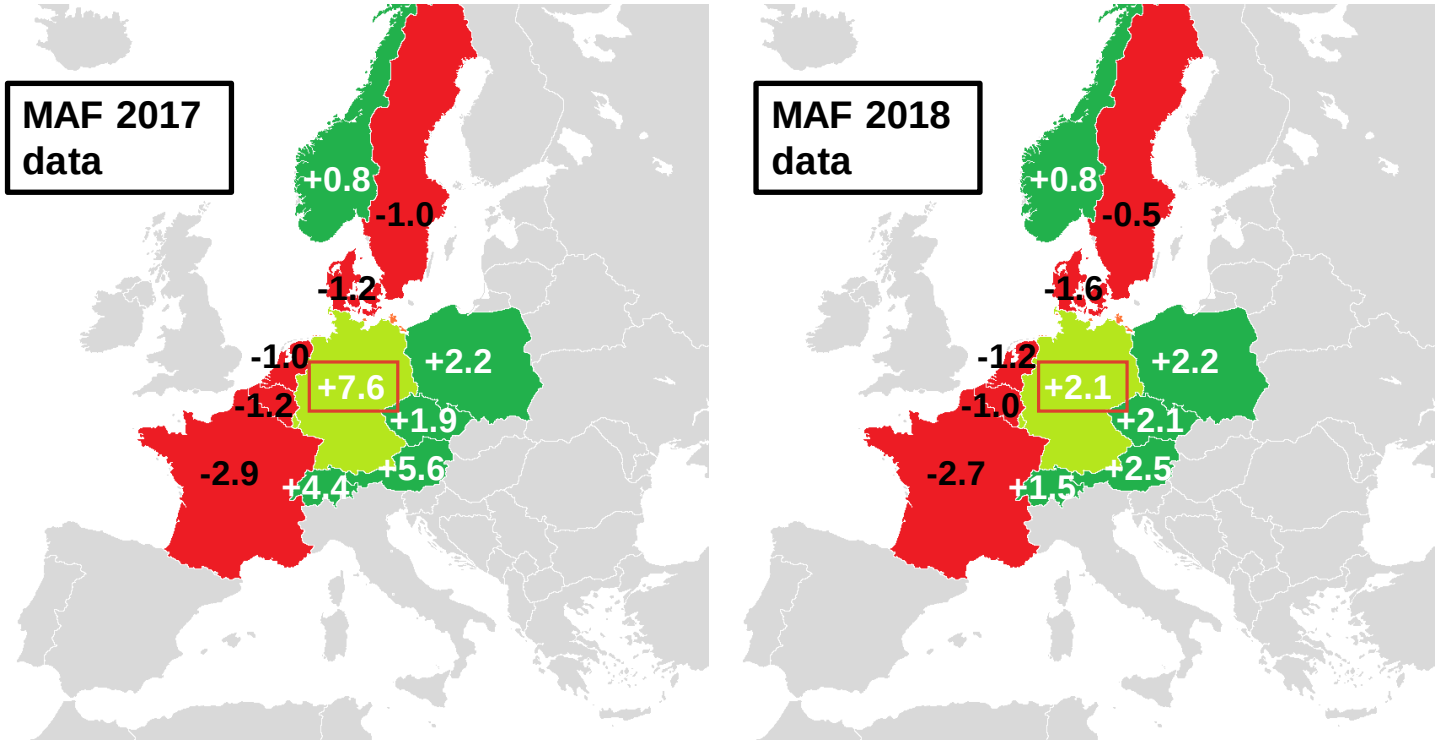
Expected loss of load duration [h]

	Mean	Median	Max	Min
2023	0.0	0.0	0.1	0.0
2023_-8GW	0.3	0.1	2.3	0.0

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Influence of uncertainty in input data

Change in available import capacities during peak load hour [GW]



"In fact, the reason behind this difference is not an error but an update of data due to better information-availability compared to last year."
(e-mail communication with representative from entso-e, 2018b)

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

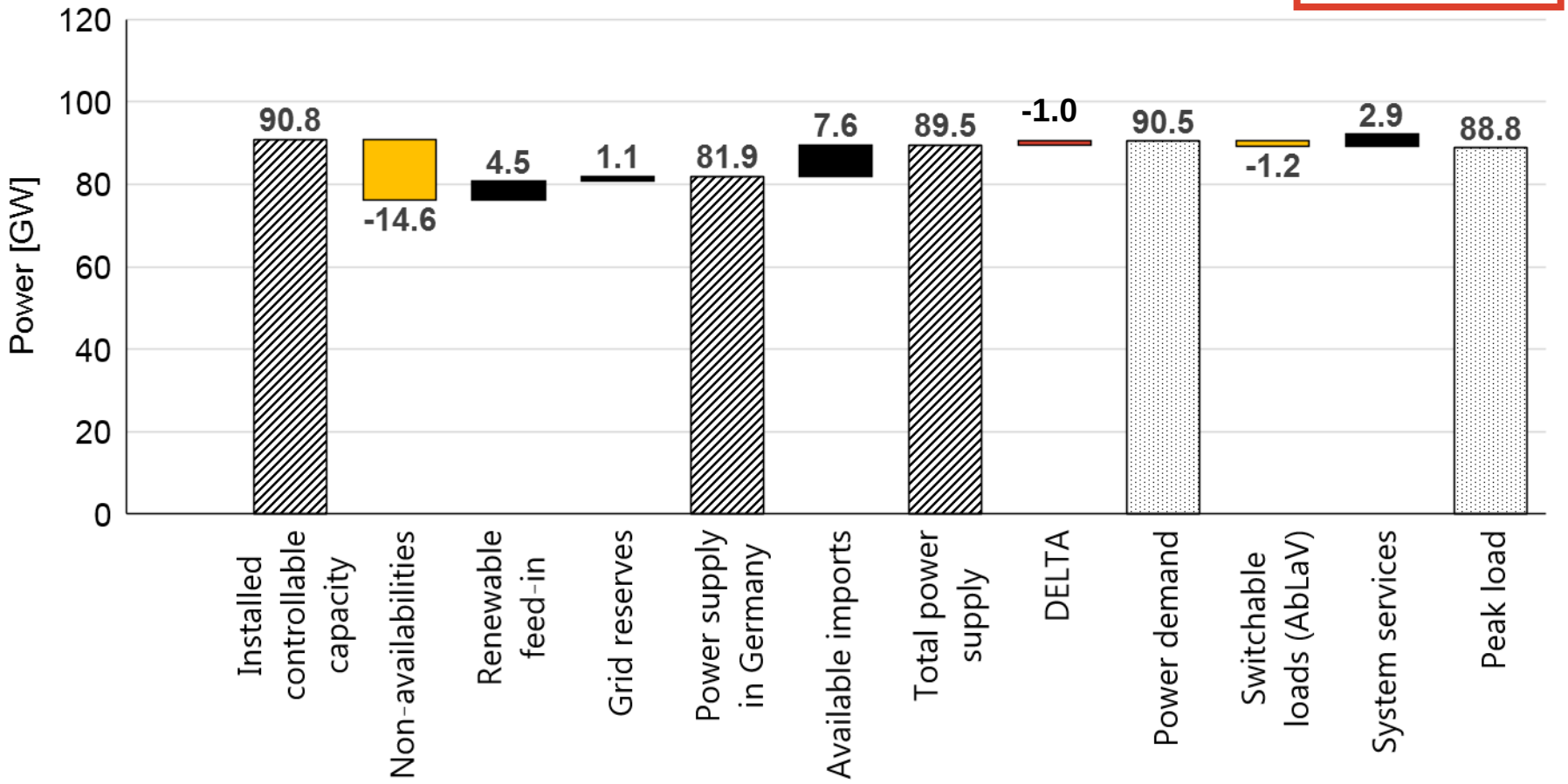
Sensitivity of model output – balance sheet year 2023, based on MAF 2017 data

~~Nuclear power~~

Coal capacities ↓

Additional mothballing of 8 GW coal-fired power plants might cause capacity gap

MAF 2017 data



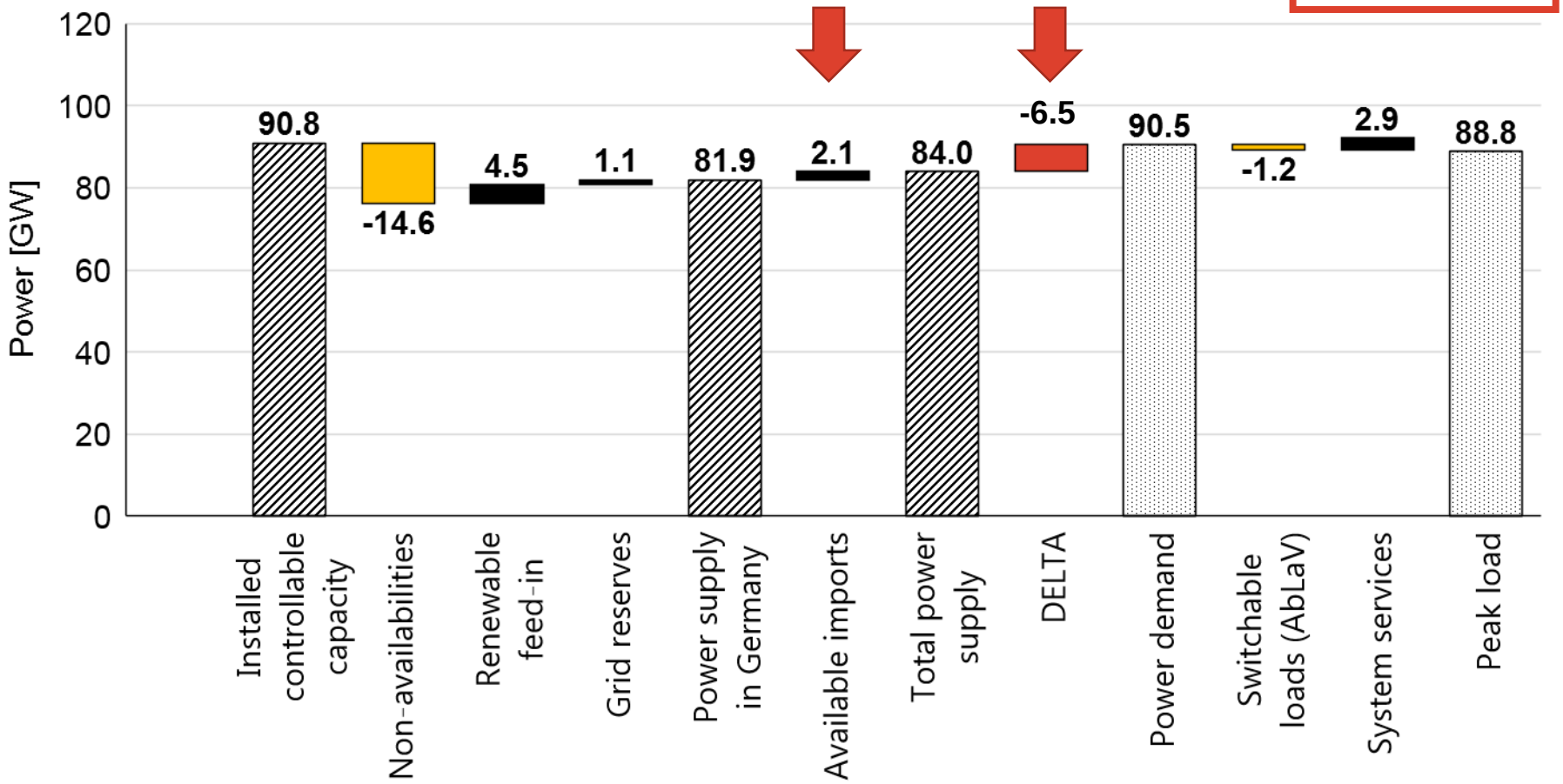
Sensitivity of model output – balance sheet year 2023, based on MAF 2018 data

~~Nuclear power~~

Coal capacities ↓

Additional mothballing of 8 GW coal-fired power plants causes severe capacity gap during peak load hour

MAF 2018 data

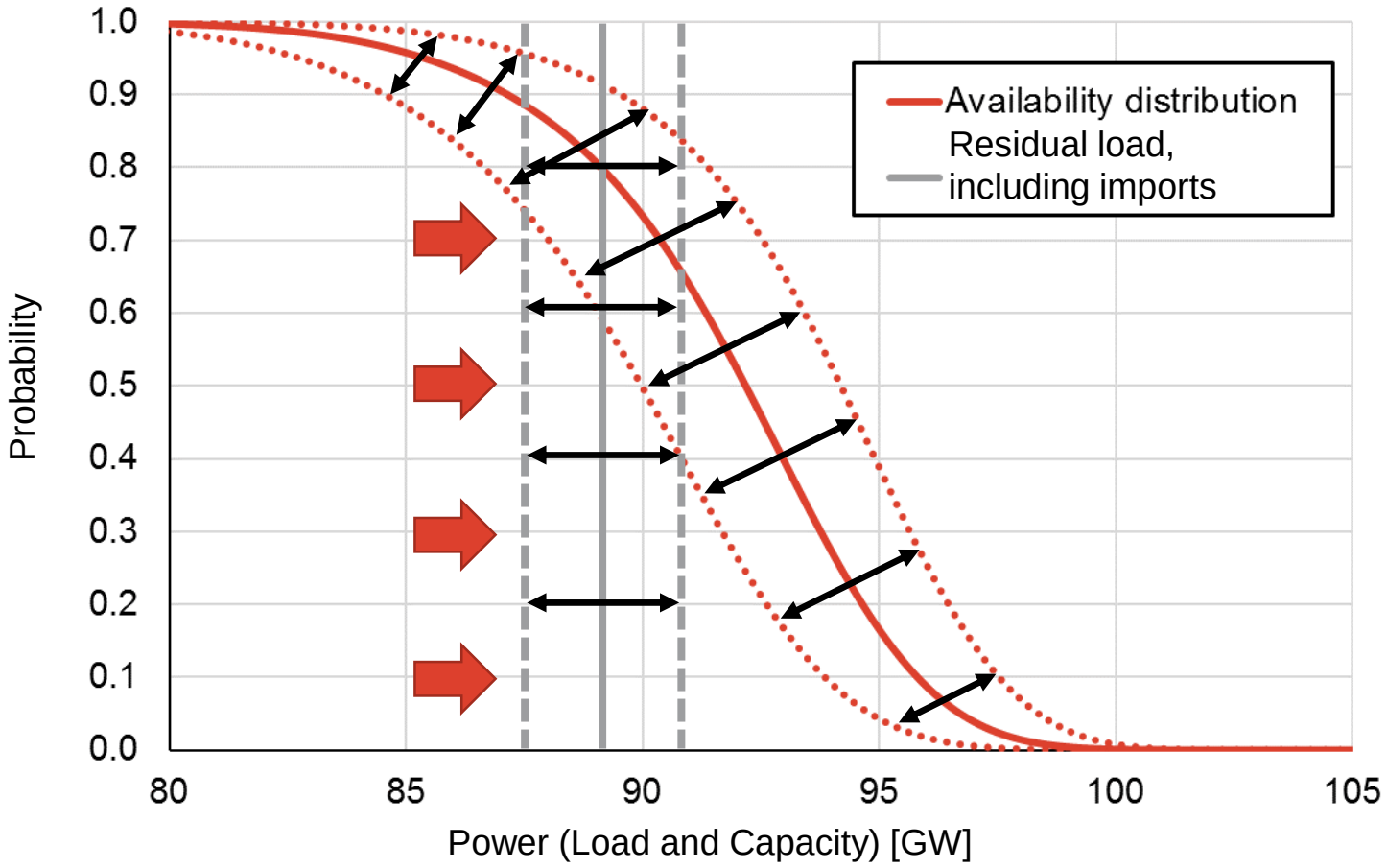


1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

Sensitivity of probabilistic simulation model

Changes in residual load cause non-linear reactions

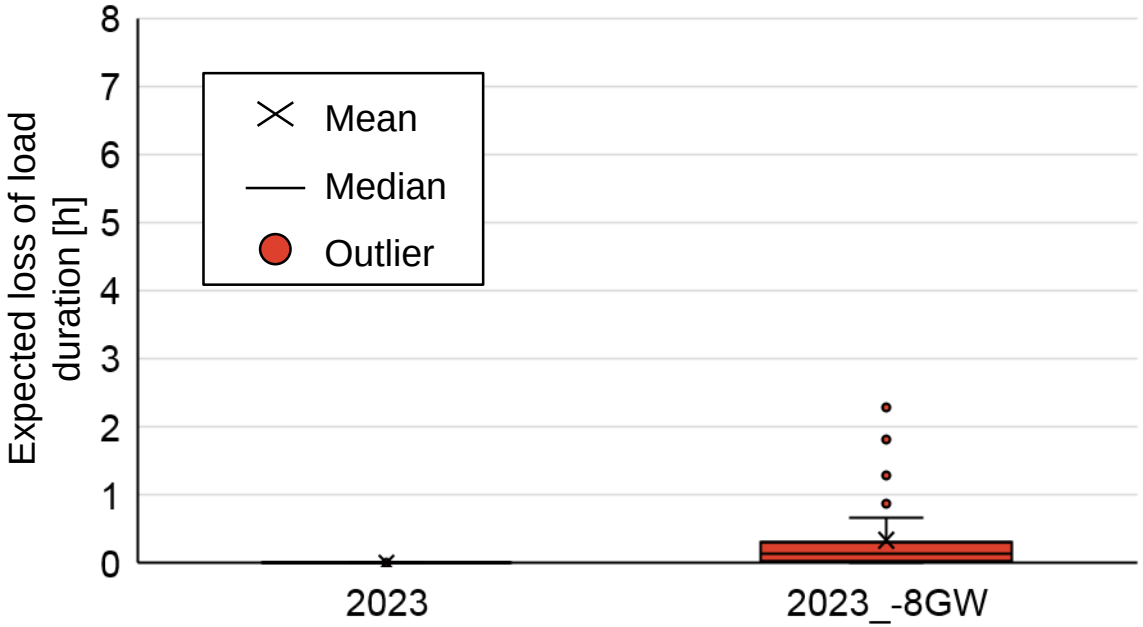


1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Sensitivity of model output – simulation model based on MAF 2017

MAF 2017 data

Loss of load is only to be expected in cold and calm weather years



Expected loss of load duration [h]

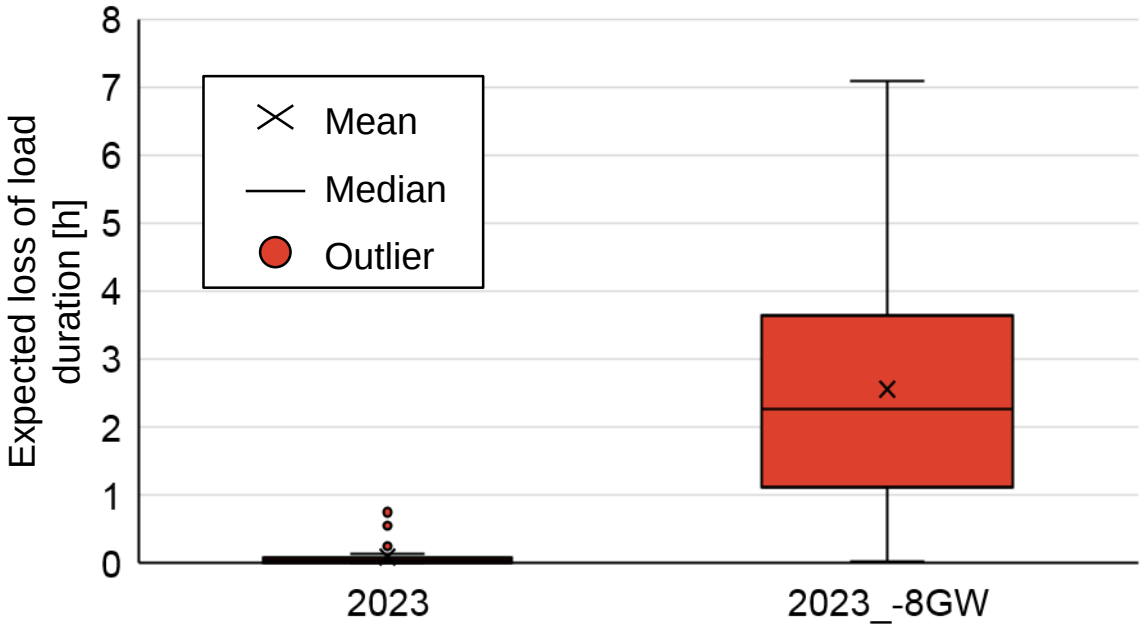
	Mean	Median	Max	Min
2023	0.0	0.0	0.1	0.0
2023_-8GW	0.3	0.1	2.3	0.0

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Sensitivity of model output – simulation model based on MAF 2018

MAF 2018 data

Capacity shortages can reach up to 7 h per year



Expected loss of load duration [h]

	Mean	Median	Max	Min
2023	0.1	0.0	0.8	0.0
2023_-8GW	2.6	2.3	7.1	0.0

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Comparison of modeling approaches

	Deterministic balance sheets	Probabilistic simulation models
Visualization of input-output relation	**Direct**	**Hard to anticipate**
Data requirements	**Low**	**High**
Interpretation of results	**Straightforward**	**Statistical capabilities needed**
Possible number of scenarios	**High**	**Low**
Implicit assumptions	**Severe**	**Less severe**

Complexity dilemma: More complex models require more uncertain input data and limit the amount of possible scenarios

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Stepwise approach towards finding the optimal Level of Detail (LoD)

(1) Determine **additional benefits** for a more detailed model ($\beta'(\mathrm{LoD})$)

(2) Determine **additional costs** for a more detailed model ($c'(\mathrm{LoD})$)

(3) Determine the **optimal model choice** that reflects both the preferences and the cost structure (LoD*)

Parsimony (see DeCarolis *et al.*, 2017) vs. **"Keep it complex"** (see Stirling, 2010)

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Conclusion and outlook

1) ***Mathematical framework***:
   The more complex model is not superior *per se*

2) ***Complexity dilemma***:
   More complex models require more uncertain input data

3) ***Three steps for modelers:***
   Finding the optimal level of detail

Accounting for **uncertainties** is **more important** than depicting **all details** of the energy system in particular for **future scenarios**

1st IAEE Online Conference 2021
Lars Nolting, lnolting@eonerc.rwth-aachen.de
June 8, 2021

Thank you for your attention!

Do you have any questions or comments?

References

- Bale, C.S., Varga, L., Foxon, T.J., 2015. Energy and complexity: New ways forward. *Applied Energy,* 138, 150–159.
- BNetzA, 2020a. Kraftwerksliste (power plant list). Bundesnetzagentur, Bonn.
- BNetzA, 2020b. Kraftwerksstilllegungsanzeigenliste (list of power plant closure notifications). Bundesnetzagentur, Bonn.
- DeCarolis, J. *et al.*, 2017. Formalizing best practice for energy system optimization modelling. *Applied Energy*, 194, pp.184–198.
- entso-e, 2017. Mid-Term Adequacity Forecast 2017.
- entso-e, 2018a. Mid-Term Adequacity Forecast 2018.
- entso-e, 2018b. Data Differences between MAF 2017 and MAF 2018. *Personal E-Mail communication.*
- entso-e, 2019. Mid-Term Adequacity Forecast 2019.
- Federal Government, BMWi, 2020. Kohleausstiegsgesetz (Coal Phase-out Act).
- Federal Government, BMU, 2011. Kernenergieausstiegsgesetz (Thirteenth Act Amending the Atomic Energy Act).
- Lloyd, S., 2001. Measures of complexity: a nonexhaustive list. *IEEE Control Systems Magazine*, 21(4), pp.7–8.
- Nolting, L., Praktiknjo, A., 2020. Can we phase-out all of them? Probabilistic assessments of security of electricity supply for the German case. *Applied Energy,* 263, 114704.
- Stirling, A., 2010. Keep it complex. *Nature*, 468(7327), pp.1029–1031.
- TSOs, 2019. Netzentwicklungsplan (grid development plan).