

The Sensitivity of Power System Expansion Models on Meteorological Parameters

Bruno U. Schyska, Alex Kies, Markus Schlott, Lueder v. Bremen, Wided Medjroubi

vEGU 2021

2021-04-30

German Aerospace Center (DLR),
Institute of Networked Energy Systems

A large, high-resolution image of the Earth from space occupies the right half of the slide. It shows a curved horizon with a blue atmosphere, white clouds, and green landmasses. The text "Knowledge for Tomorrow" is overlaid in white on the lower right portion of the Earth image.

Knowledge for Tomorrow

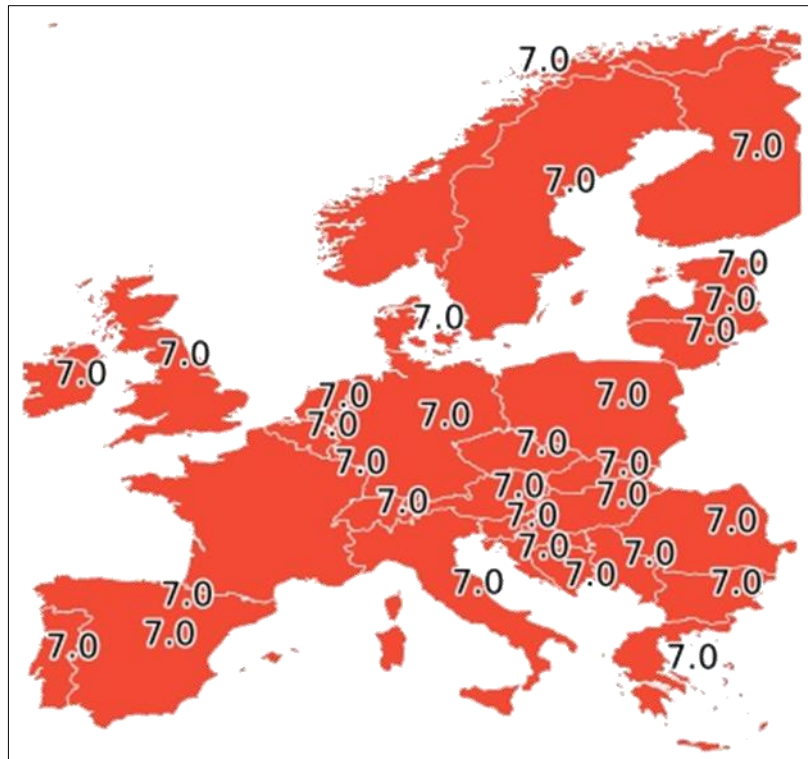
Introduction

- Power system expansion models are a widely used tool to address research questions in the context of the energy transition.
- Based on their results far-reaching political and societal discussions are made.
- Models are optimization problems and rely on different socio-economical, technical and meteorological parameters:
 - Demand
 - Cost
 - Capacity factors
 - Efficiencies, emissions, ramping abilities

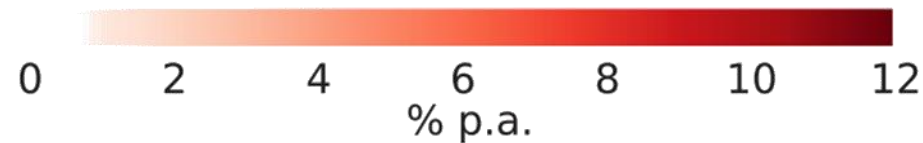
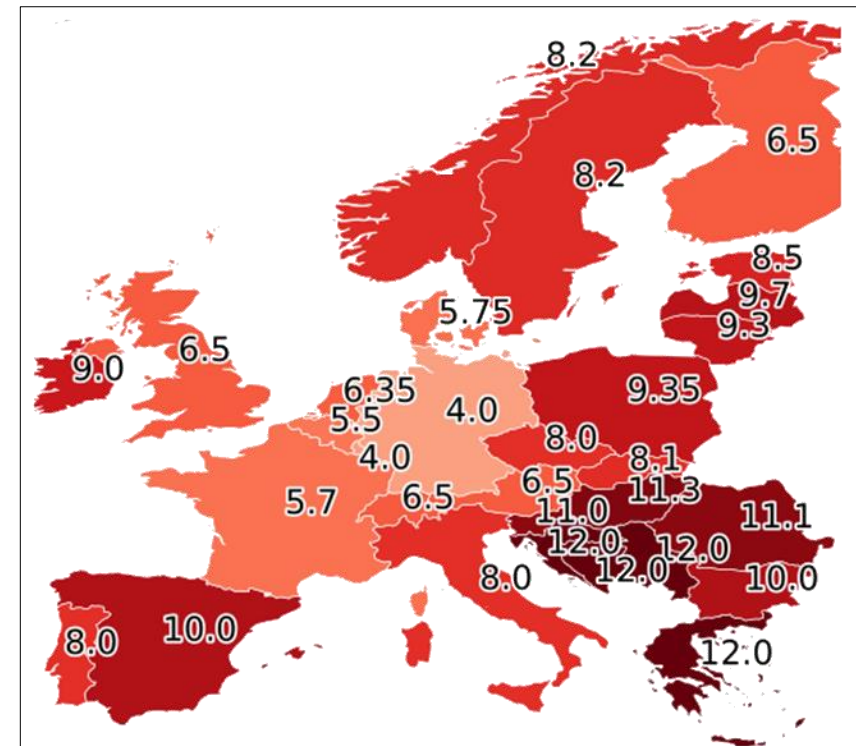


Parameter Uncertainty Example: Cost of Capital

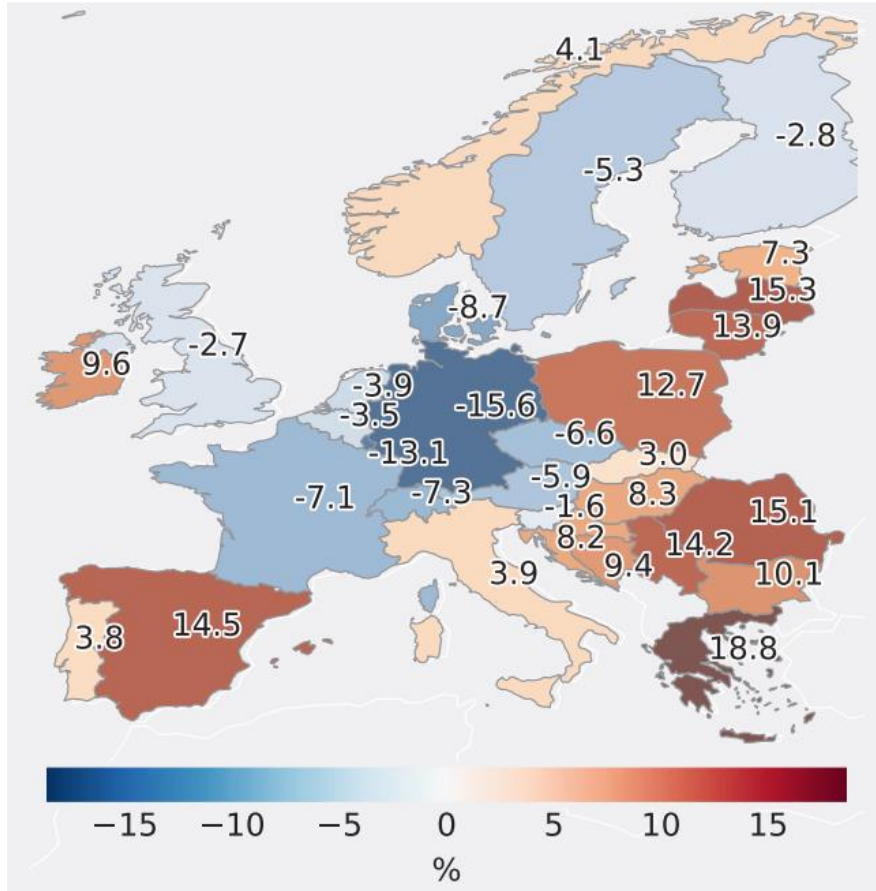
Homogeneous reference



Inhomogeneous scenario



Parameter Uncertainty Example: Cost of Capital



- Accumulation of generation capacity in countries with favourable conditions:
 - Higher share of wind power (esp. onshore)
 - Lower share of solar PV
 - Overall decrease in LCOE
 - Increasing inequality in expenditures for electricity between central Europe and the periphery

Relative change in expenditures for electricity [%]

Schyska and Kies (2020), Applied Energy, preprint on [arxiv](https://arxiv.org/abs/2012.00000)

Introduction

- Power system expansion models are a widely used tool to address research questions in the context of the energy transition.
- Based on their results far-reaching political and societal discussions are made.
- Models are optimization problems and rely on different socio-economical, technical and meteorological parameters:
 - Demand
 - Cost
 - Capacity factors
 - Efficiencies, emissions, ramping abilities
- Often, parameters are derived from **Future projections**, expansion is planned on **historical data** from **different data sources** (see poster of Alex Kies for a comparison of meteorological data sources).
- The choice of (uncertain) parameters affects the model results. But how?



Defining a Sensitivity Metric

Systematically describe the effect of different parameter choices on the simulation results
 → measure the sensitivity

Define a metric which:

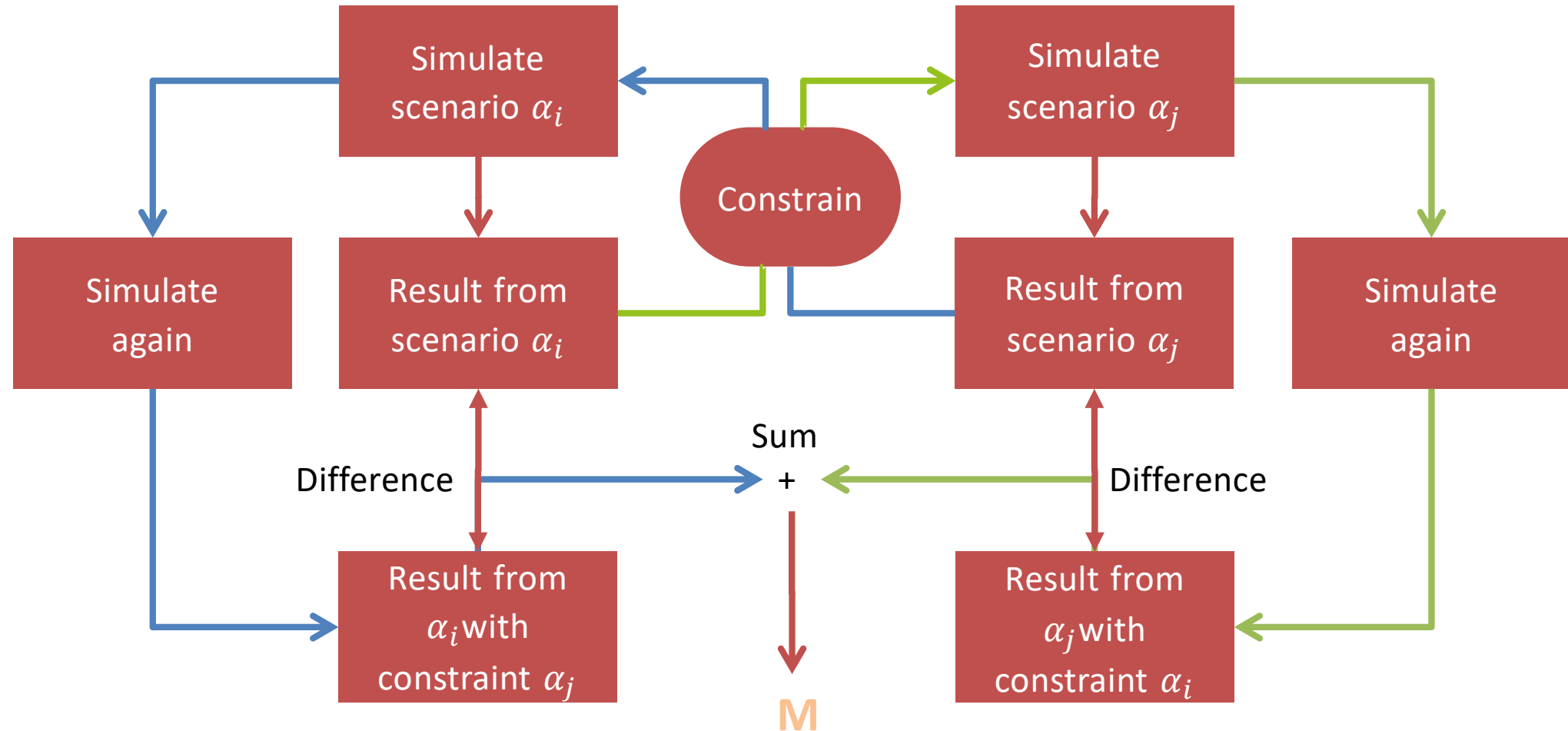
- quantitatively measures the sensitivity of power system expansion problems on specific parameter scenarios,
- allows to compare a great(er) number of scenarios,
- is symmetric about the choice/the order of the scenario,
- is greater equal zero

$$M_{\alpha_j}^{\alpha_i} = \Gamma_{\alpha_j}^{\alpha_i} - \Gamma_0^{\alpha_i} + \Gamma_{\alpha_i}^{\alpha_j} - \Gamma_0^{\alpha_j}$$

- Two scenarios α_i and α_j
- Two unconstrained solutions for the two scenarios
- Two solutions for the two scenarios constrained with the respective other scenario



Computing the Metric



Computing the Metric: Cost of Capital Example

$$\text{Levelized Cost of Electricity: LCOE} = \frac{\text{Cost for Investment and Operation}}{\text{Demand met}}$$

	Hom. reference	Inh. scenario	Difference
LCOE unconst. [EUR / MWh]	72,2	70.8	-1,4
LCOE constr. [EUR / MWh]	74,7	72,8	-1,9
Difference	2,5	2,0	

$$M = 4.5 \text{ EUR/MWh}$$

Schyska et al. (2020), to be submitted, preprint on [arxiv](https://arxiv.org/abs/2012.00000)



The Sensitivity to Meteorological Parameters: Data

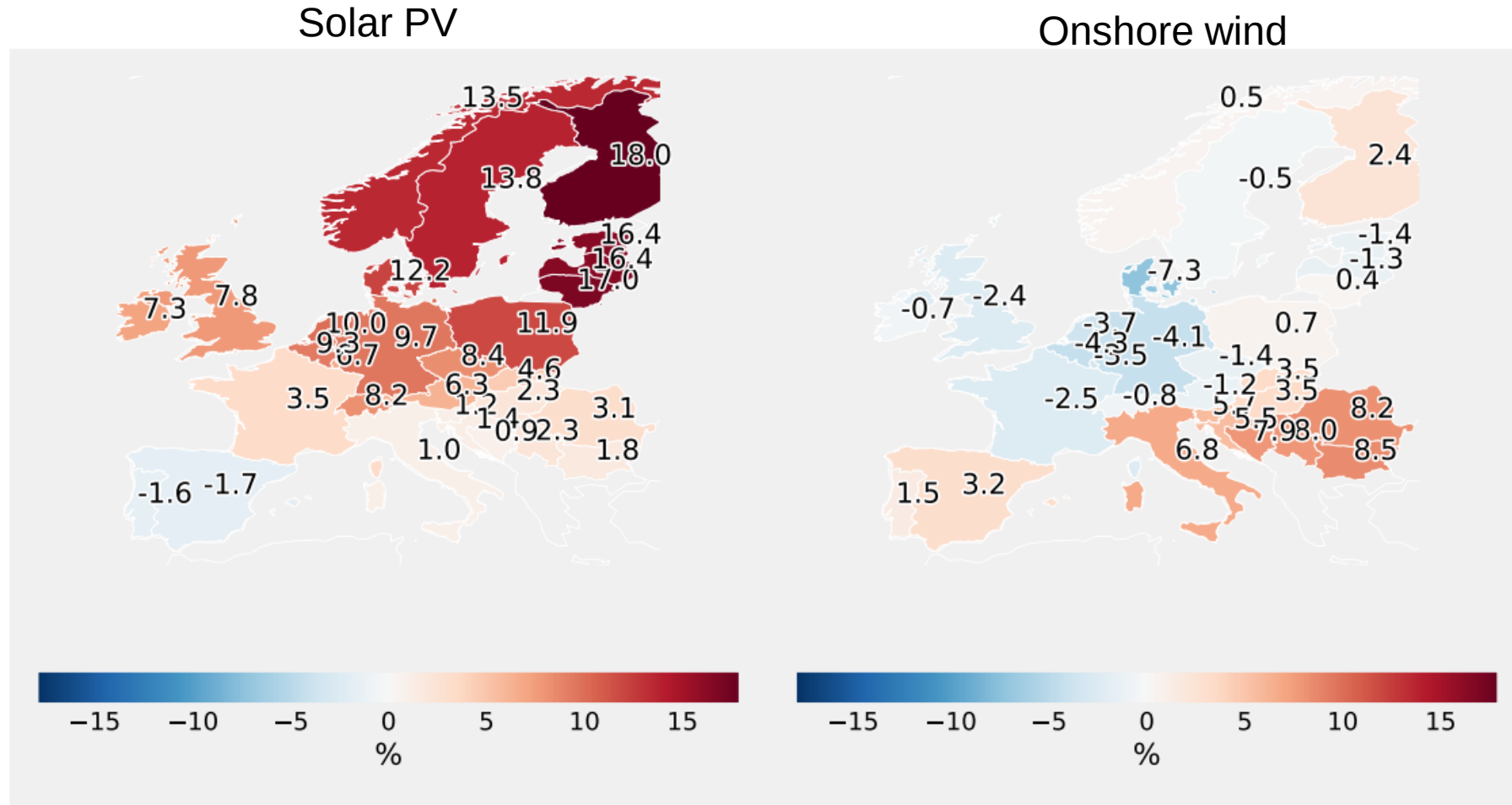
- RCP 8.5 climate projections from the *CNRM-CERFACS-CNRM-CM5*
- Scaled down within EURO-CORDEX
- Near-surface wind speed extrapolated to hub-height (90m) using the logarithmic wind profile
- Surface downwelling shortwave radiation and near-surface air temperature for solar PV
- Total runoff for hydro power
- 5 time slices:
 - Historical (HIS): 1970 – 1976
 - Begin of century (BOC): 2000 – 2006
 - Mid of century (MOC): 2038 – 2044
 - End of century (EOC): 2094 - 2101
- PyPSA-Eur (one node per country)
- Including:
 - Load time series
 - Renewable potentials
 - Cost
 - Technologies
- Onshore + offshore wind, solar PV, OCGT, hydro, batteries, hydrogen storage
- 95% CO₂ reduction scenario

Schlott et al. (2018), Applied Energy, preprint on [arxiv](#)

Hörsch et al. (2018), Energy Strategy Reviews, [arxiv](#) preprint



Capacity Factor Changes towards the End of the Century

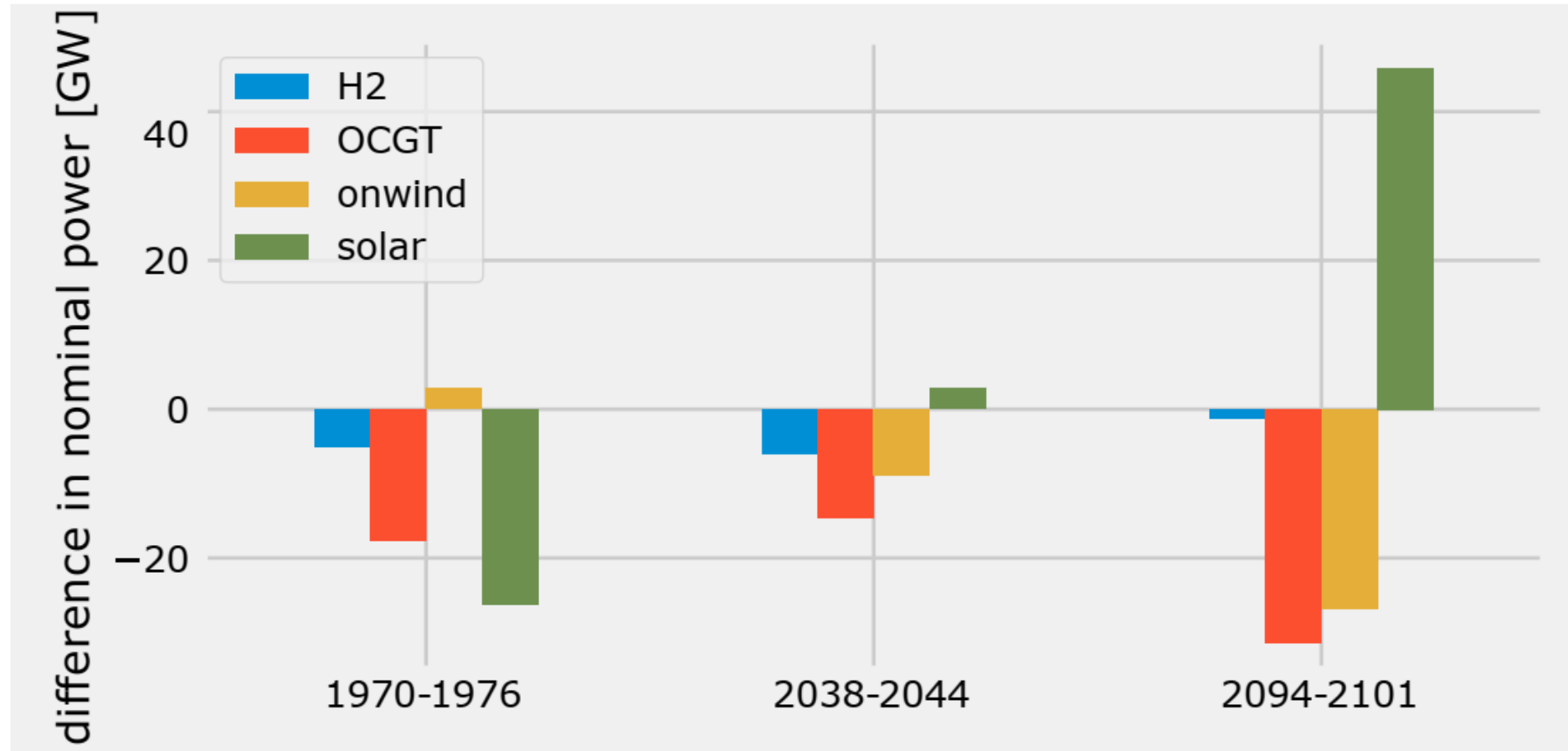


Relative change in 2094-2101 compared to 2000-2006 [%]

Schyska et al. (2020), to be submitted, preprint on [arxiv](https://arxiv.org/abs/2012.04111)



Differences in optimal Capacity Expansion

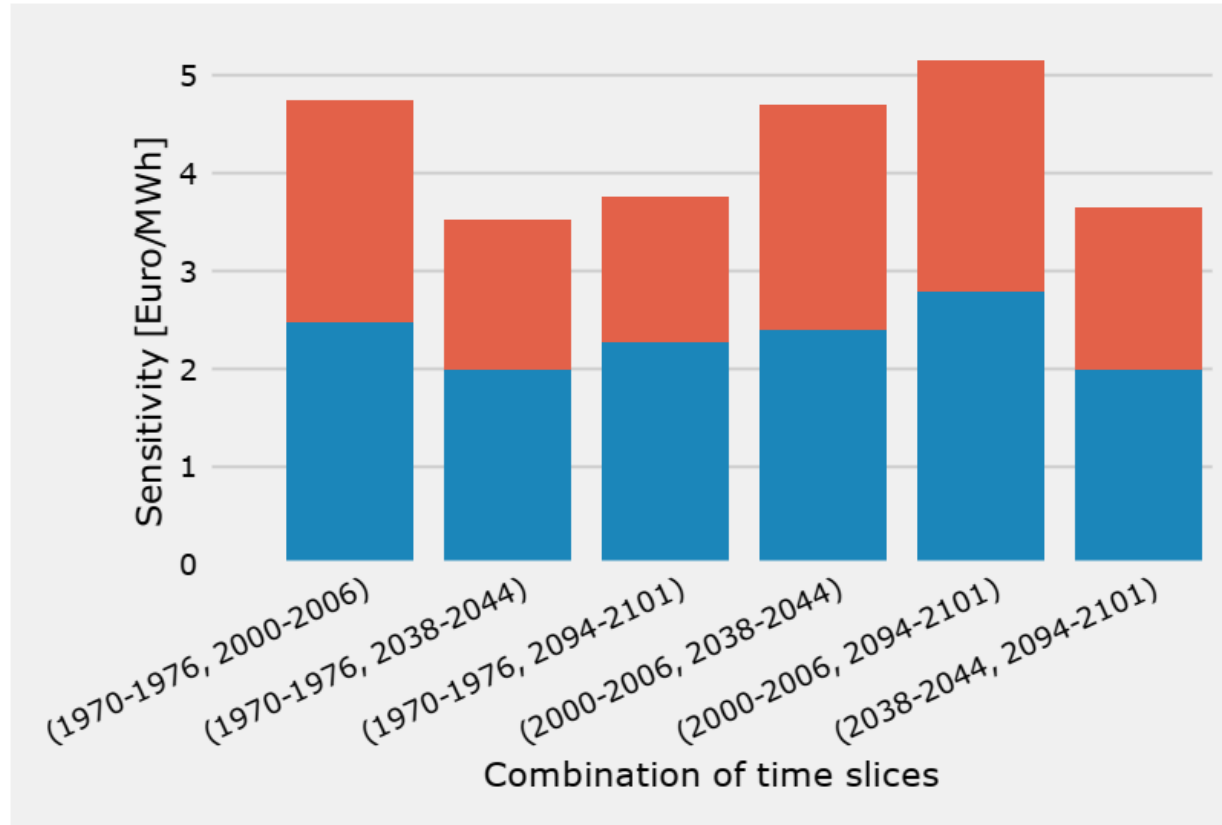


Difference in optimal capacity expansion compared to BOC [GW]

Schyska et al. (2020), to be submitted, preprint on [arxiv](https://arxiv.org/abs/2012.00000)



The Sensitivity to Meteorological Parameters



- Same order of magnitude as sensitivity to cost of capital
- Combinations with 2000 – 2006 exhibit highest sensitivities, e.g. higher as HIS + EOC
- 2000-2006 leads to *extraordinary* solution -> not representative
- Comparably low sensitivity on scenarios HIS, MOC and EOC

Conclusions

- Choosing the right weather data is as important as choosing the right cost.
- Better do not choose 2000-2006. You might get unrepresentative results.

Thank you!

