The Sensitivity of Power System Expansion Models on Meteorological Parameters

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Introduction

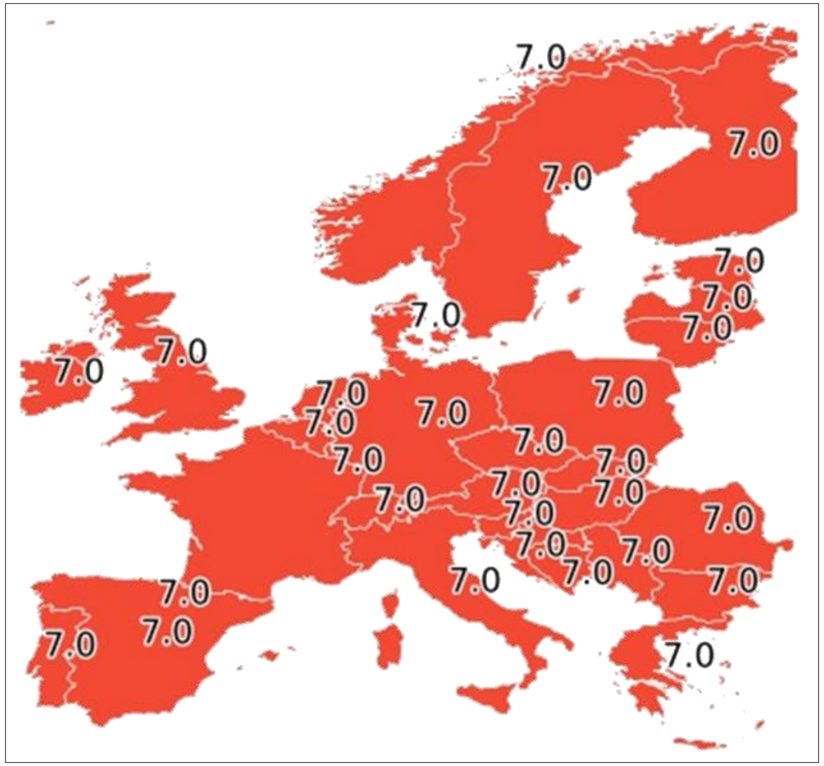
- Power system expansion models are a widely used tool to address research questions in the context of the energy transition.

- Based on their results far-reaching political and societal discussions are made.

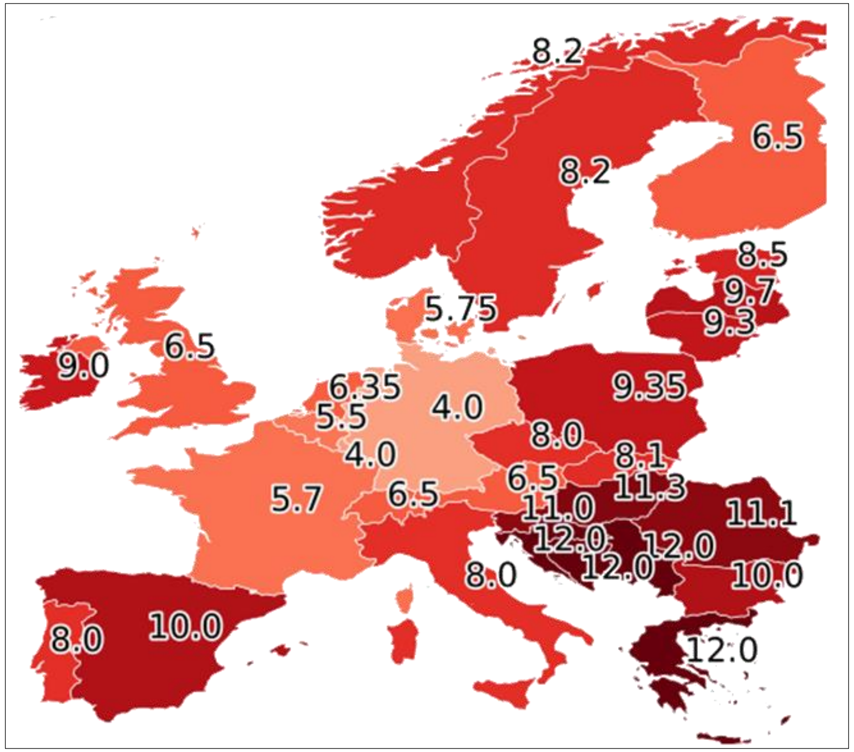
- Models are optimization problems and rely on different socio-economical, technical and meteorological parameters:
  - Demand
  - Cost
  - Capacity factors
  - Efficiencies, emissions, ramping abilities

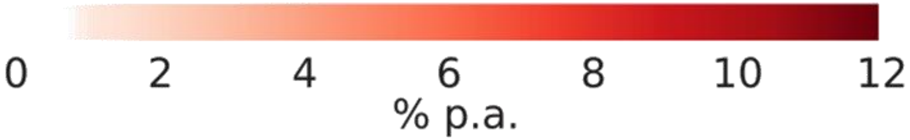
Parameter Uncertainty Example: Cost of Capital

Homogeneous reference



Inhomogeneous scenario





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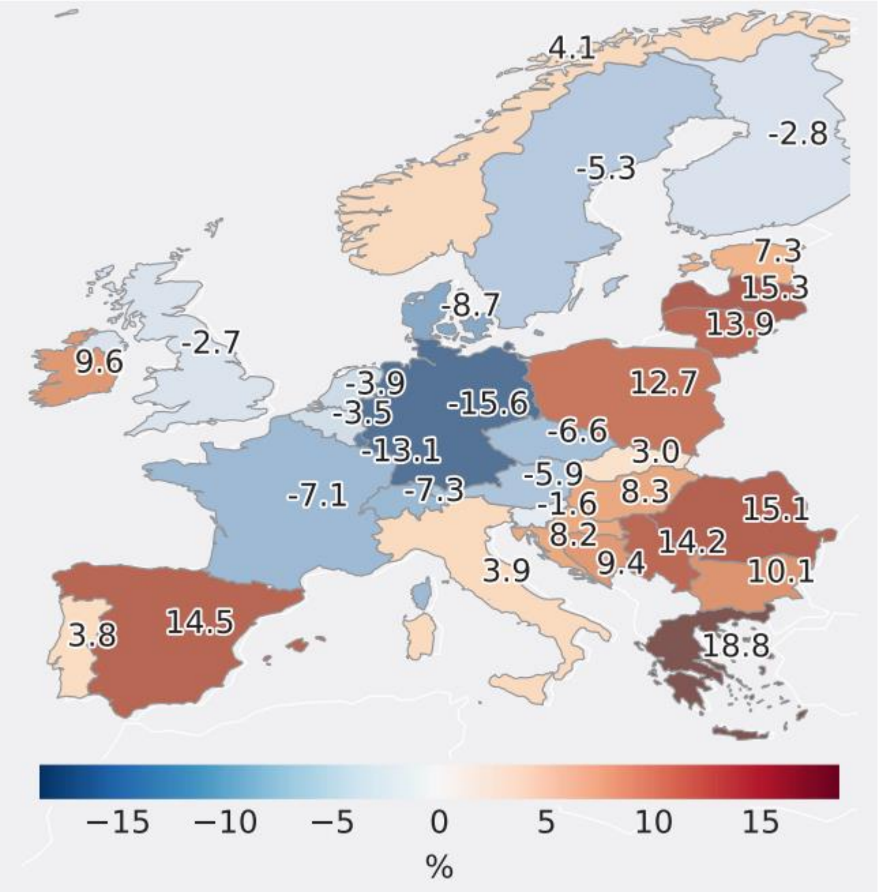

Relative change in expenditures for electricity [%]

– 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

Schyska and Kies (2020), Applied Energy, preprint on arxiv

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- 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
$\longrightarrow$ measure the sensitivity

Define a metric which:

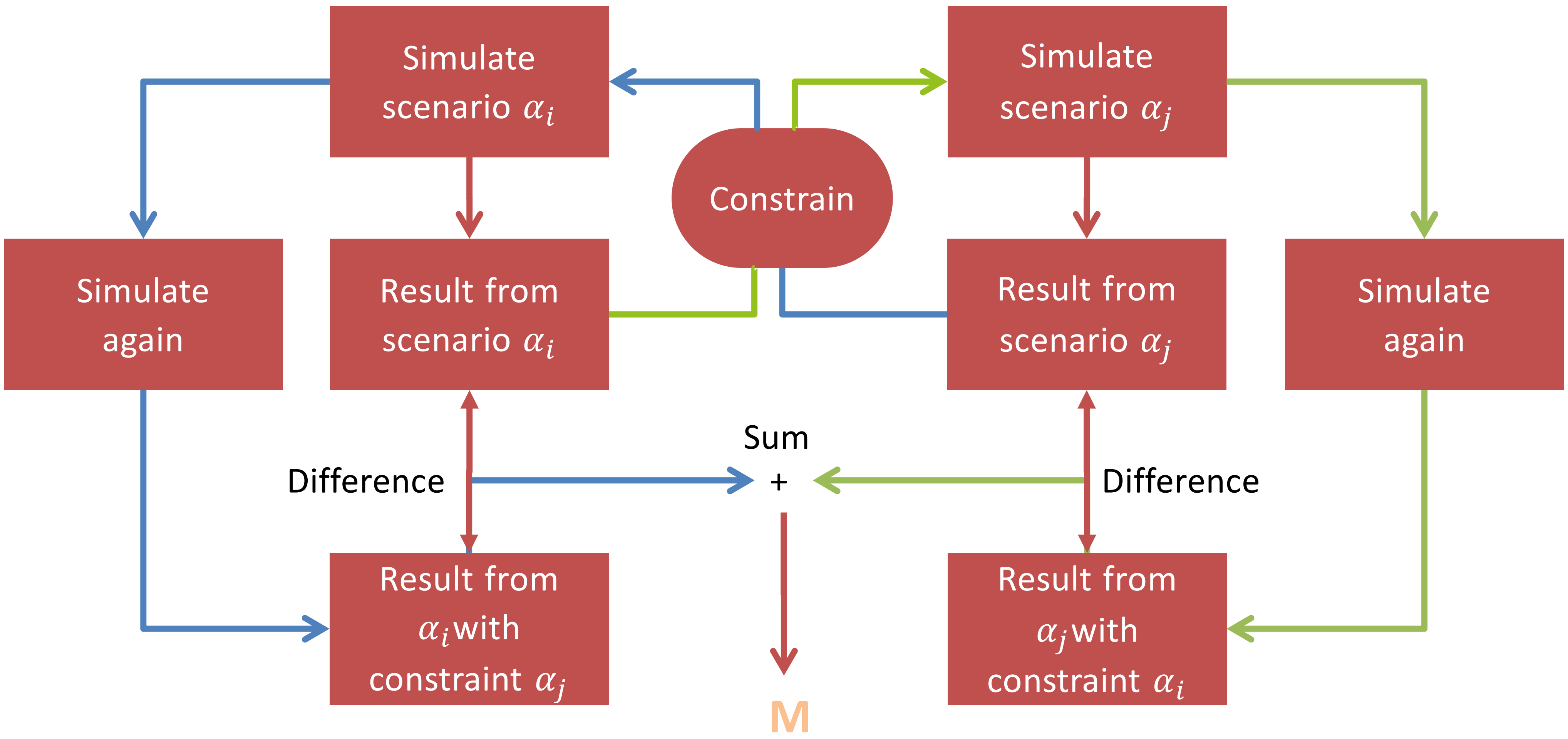
- quantitatively measures the sensitivity of power system expansion problems on specific parameter scenarios,
- allows to compare a great(er) number of scenarios,
- is symmetric about the choice/the order of the scenario,
- is greater equal zero

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

- 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

Schyska et al. (2020), to be submitted, preprint on arxiv

Computing the Metric



Computing the Metric: Cost of Capital Example

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

	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 EUR/MWh

Schyska et al. (2020), to be submitted, preprint on arxiv

The Sensitivity to Meteorological Parameters: Data

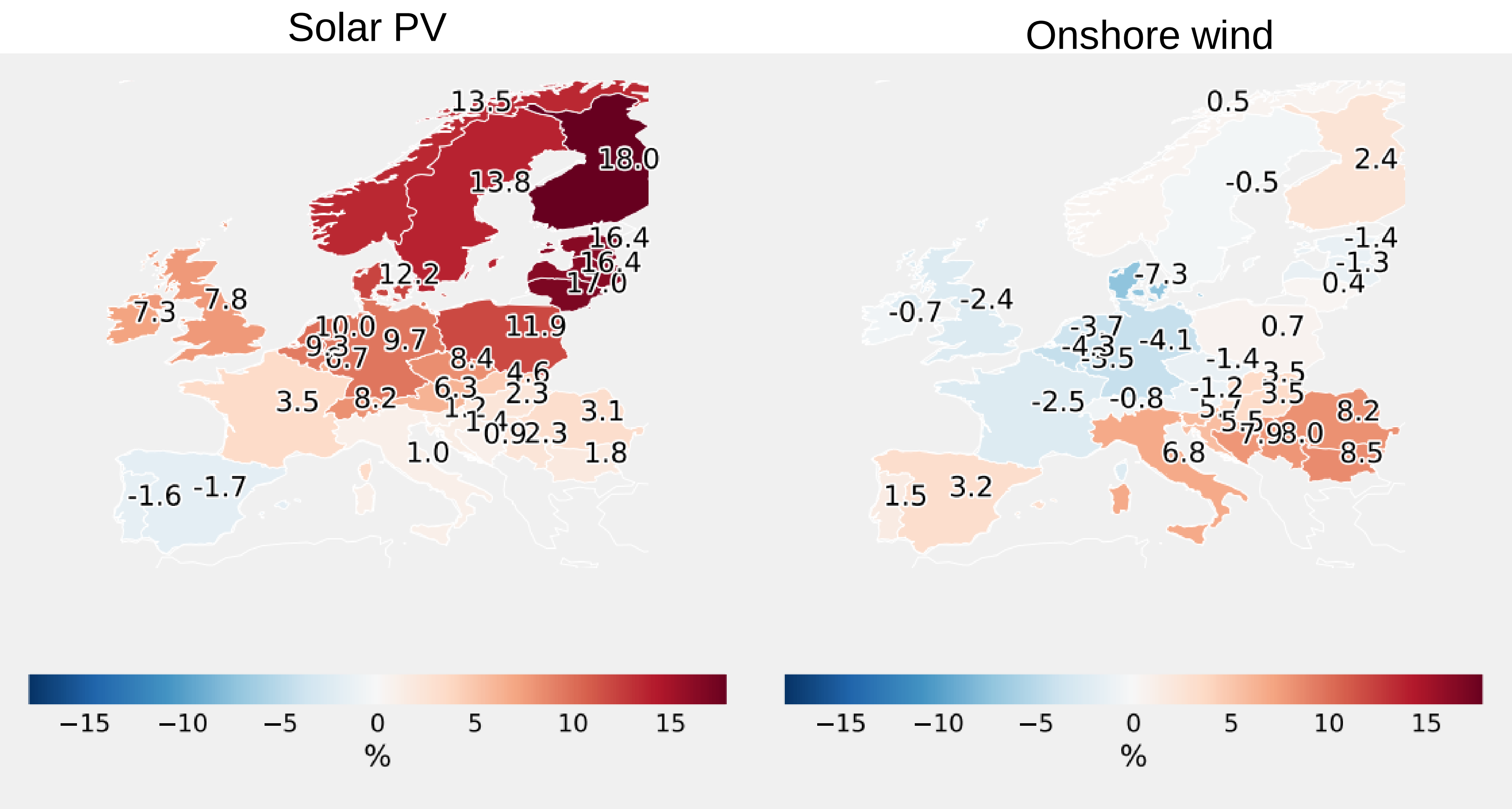
- RCP 8.5 climate projections from the *CNRM-CERFACS-CNRM-CM5*
- Scaled down within EURO-CORDEX
- Near-surface wind speed extrapolated to hub-height (90m) using the logarithmic wind profile
- Surface downwelling shortwave radiation and near-surface air temperature for solar PV
- Total runoff for hydro 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

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

- 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% CO_2 reduction scenario

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

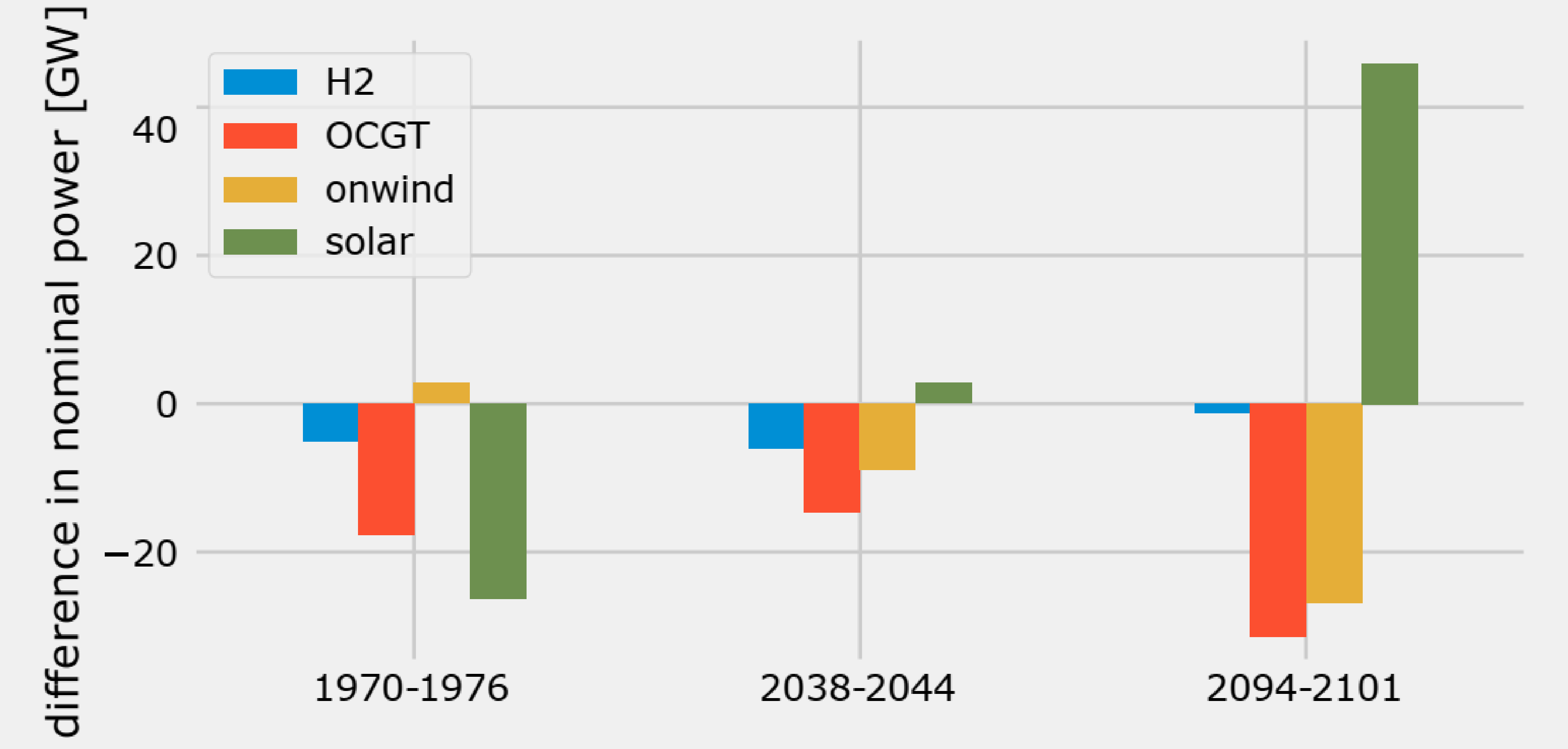
Capacity Factor Changes towards the End of the Century



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

Schyska et al. (2020), to be submitted, preprint on [arxiv]

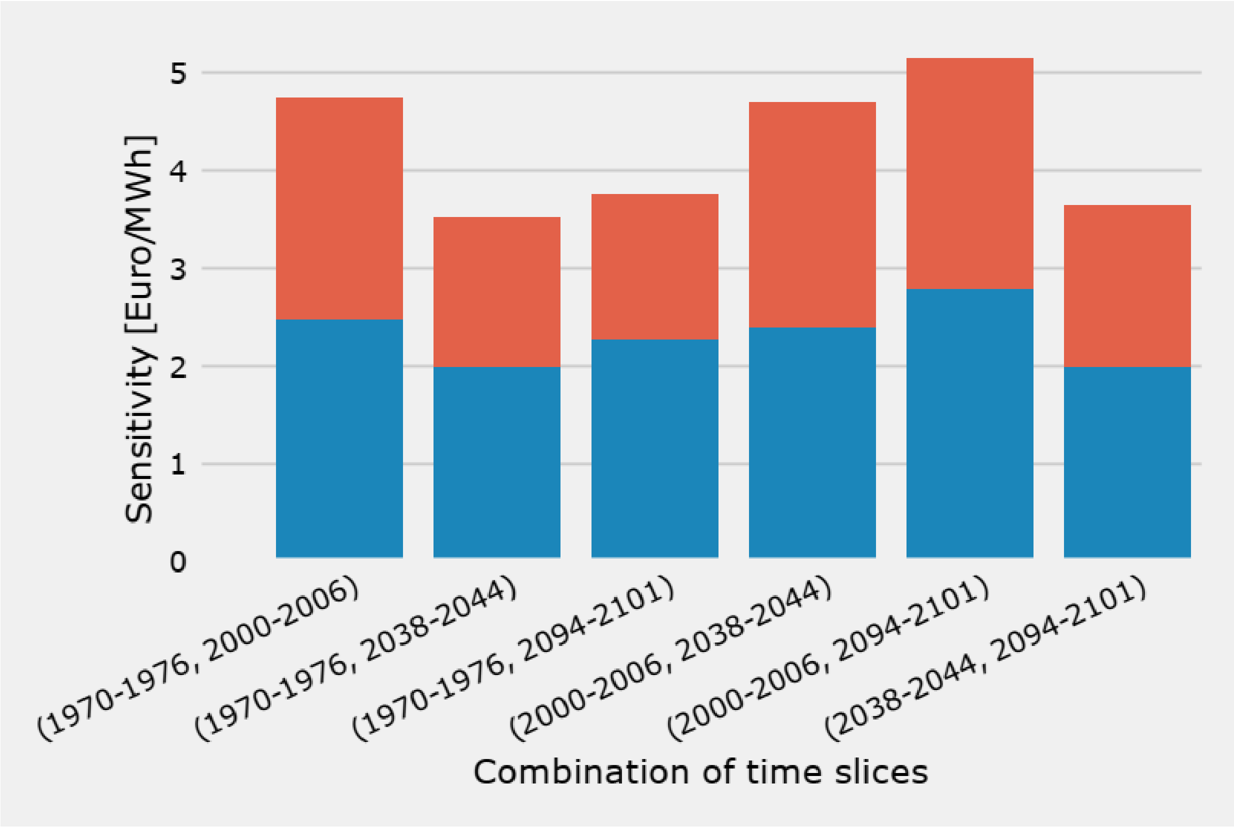
Differences in optimal Capacity Expansion



Difference in optimal capacity expansion compared to BOC [GW]

Schyska et al. (2020), to be submitted, preprint on arxiv

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!

Schyska et al. (2020), to be submitted, preprint on [arxiv]