The Sensitivity of Power System Expansion Models on Meteorological Parameters

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

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

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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

→ 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

\[ M_{\alpha_i}^{\alpha_j} = \Gamma_{\alpha_i \alpha_j}^{\alpha_i} - \Gamma_{\alpha_i \alpha_j}^{\alpha_j} + \Gamma_{\alpha_i \alpha_j}^{\alpha_j} - \Gamma_{\alpha_i \alpha_j}^{\alpha_i} \]

• Two scenarios \( \alpha_i \) and \( \alpha_j \)

• 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

1. Simulate scenario $\alpha_i$
2. Result from scenario $\alpha_i$
3. Simulate again
4. Constrain
5. Simulate scenario $\alpha_j$
6. Result from scenario $\alpha_j$
7. Simulate again
8. Difference
9. Sum
10. Result from $\alpha_i$ with constraint $\alpha_j$
11. Difference
12. Result from $\alpha_j$ with constraint $\alpha_i$
13. Difference
14. $M$
Computing the Metric: Cost of Capital Example

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

<table>
<thead>
<tr>
<th></th>
<th>Hom. reference</th>
<th>Inh. scenario</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCOE unconstr. [EUR / MWh]</td>
<td>72.2</td>
<td>70.8</td>
<td>-1.4</td>
</tr>
<tr>
<td>LCOE constr. [EUR / MWh]</td>
<td>74.7</td>
<td>72.8</td>
<td>-1.9</td>
</tr>
<tr>
<td>Difference</td>
<td>2.5</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

\( M = 4.5 \text{ EUR/MWh} \)

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:
  - 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

Solar PV

Onshore wind

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.

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