The impacts of weather uncertainty on the future European electricity system

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Brandenburg University of Technology Cottbus - Senftenberg

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Research focus

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- European nations have set ambitious climate targets to achieve the goal of becoming a climate-neutral continent by 2050.
- Future energy systems are challenged by seasonal and interannual variability, but also extreme weather events that can affect the output of variable renewable energy sources.
- Long-term planning should be robust in order to provide a reliable roadmap for society.

Research questions

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- ***What are the extra costs of a renewable energy system which is robust to weather induced uncertainty realizations of solar and wind availability?***

- ***How can energy systems adapt to extreme weather situations by optimizing energy production to ensure renewable energy supply?***

Methodology – Adaptive Robust Optimization (ARO)

The three-stage optimization problem follows the min-max-min structure and can be formulated as follows:

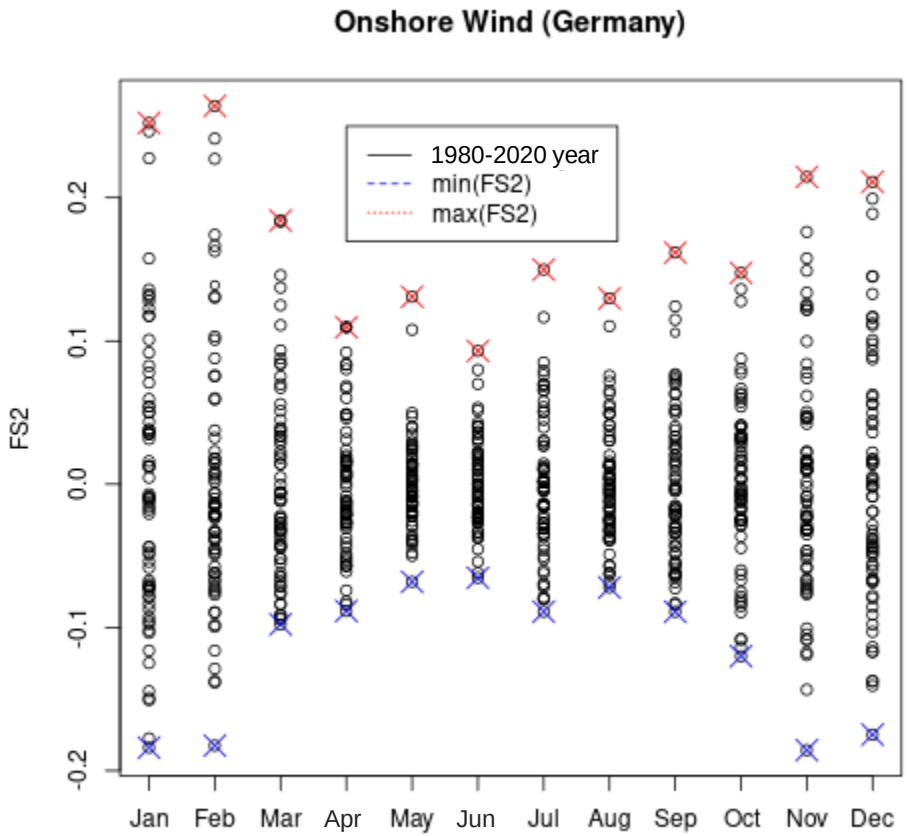
(i) $Min_x \; IC^T x$
s.t.
$h(x) = 0$
$g(x) \leq 0$

(ii) Max_u
s.t.
$u \in U$

(iii) $Min_y \; [OC(x,u)]^T y$
s.t.
$y \in \Omega(x,u) = \{$
$A(x,u)y = B(x,u): \lambda$
$D(x,u)y \geq E(x,u): \mu \}$

(Based on Baringo et al., 2020)

Methodology – Finkelstein-Schäfer statistics



Case Study

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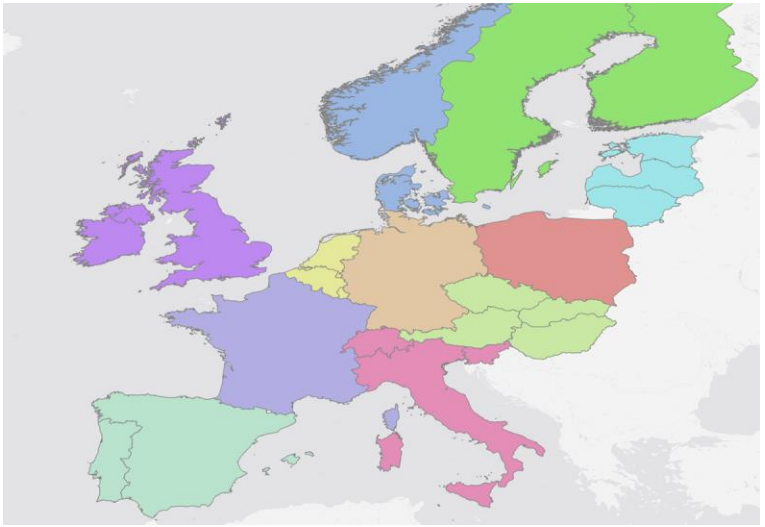
Pan-European electricity system formulated as a DC optimal power flow.

The model determines generation expansion planning and dispatch in partial equilibrium for a clustered 50 node electricity market.



Uncertainty budget	ARO PV	ARO Wind	ARO PV&Wind
UBo,pv	4	0	4
UBo,wind	0	4	4
UBr,pv	1	0	1
UBr,wind	0	1	1

Results

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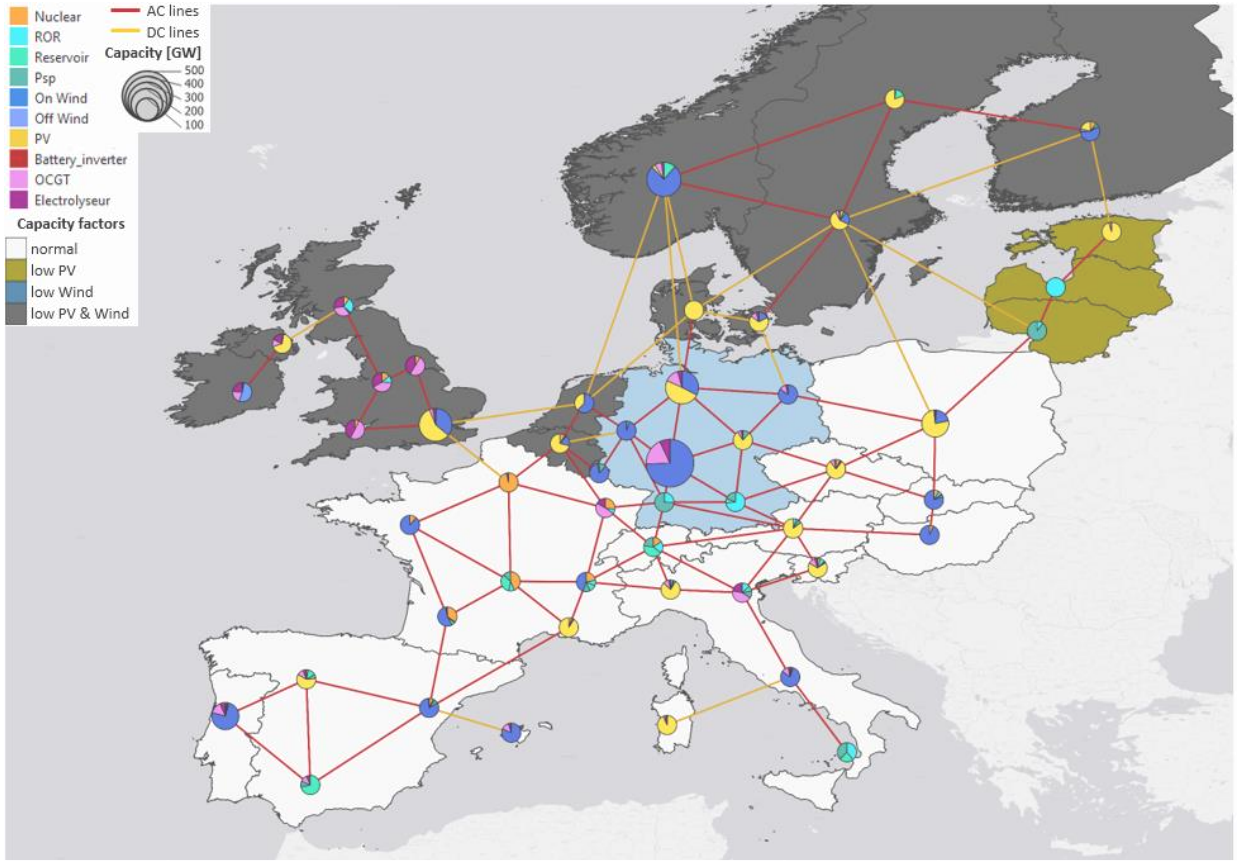

Scenario	Increase in TCs compared deterministic
ARO **PV**	0.1%
ARO **Wind**	40%
ARO **PV & Wind**	102%

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Limitations and further work

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- Each country can experience weather uncertainties in the model independently. We aim to set uncertainty budgets and define regions of weather similarities.
- Investigating more scenarios and their influences on the system:

→ increased transfer capacity of the gird

→ policy scenarios: fixed hydrogen and nuclear capacities

→ adding other layers of uncertainty which would affect hydro availability and electrical load realizations.

Thank you!

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Open questions – where are the climate experts?

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- We would like to define optimal weather zones depending on similarity between countries.
  If extreme events occur in country X, which other countries are expected to experience the same events?
- How often can the extreme weather events happen? How long do they persist?
- What is the correlation between solar and wind regarding weather zones? Do we have to assign different weather zones for both, or should they be treated independently?
- How to find the compromise between weather zones and temporal resolution?
  Are 11 weather zones enough for Europe?