Karlsruhe Institute of Technology

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

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The Near-Optimal Feasible Space of a Renewable Power System Model

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Find the long-term cost-optimal European power system

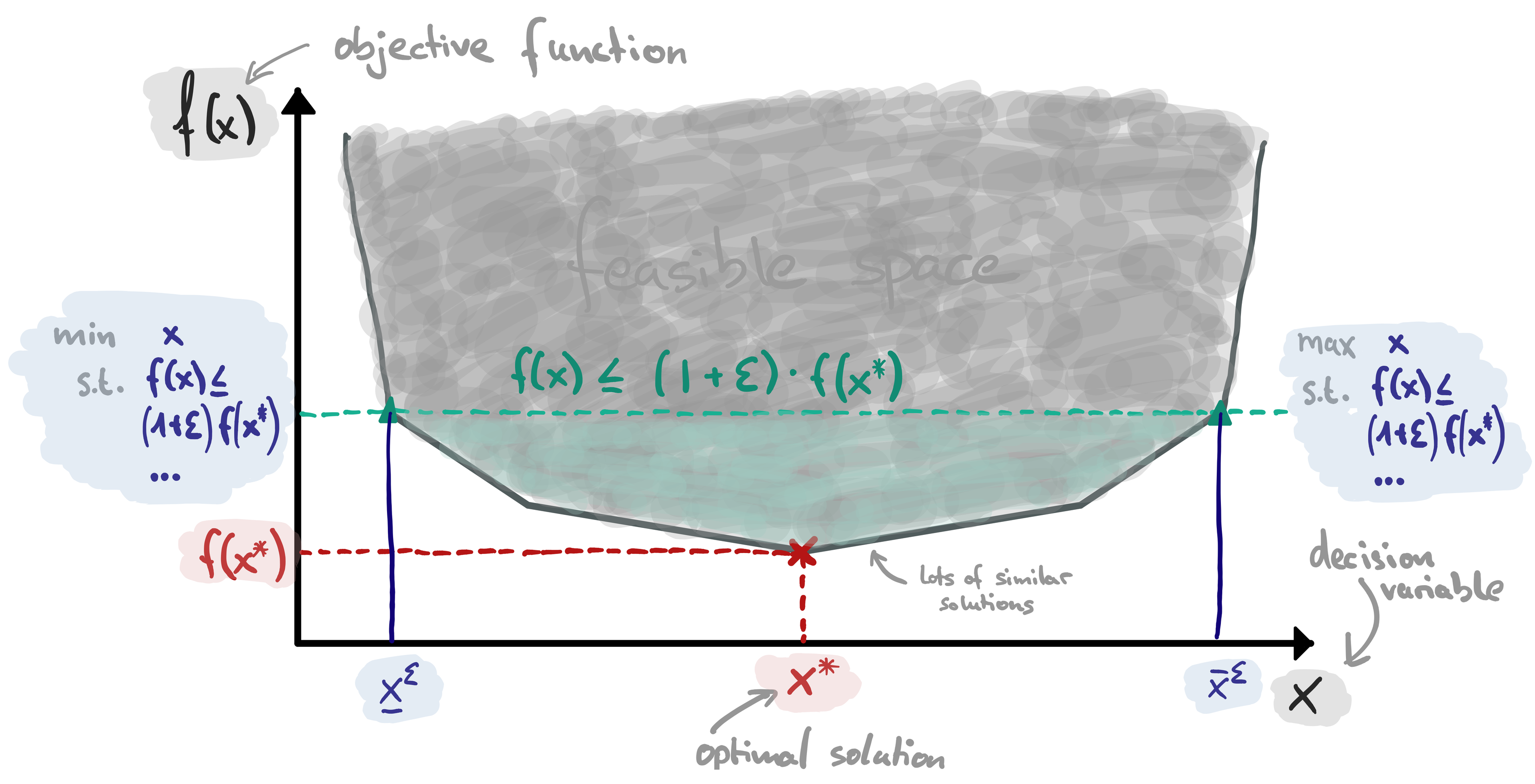
$$\text{Min}\left(\text{Yearly system costs}\right) = \sum_n \left(\text{Annualised capital costs}\right) + \sum_{n,t}\left(\text{Marginal costs}\right)$$

subject to

- meeting energy demand at each node n and time t
- transmission constraints between nodes and linearised power flow
- wind, solar, hydro availability time series $\forall\, n, t$
- installed capacity $\leq$ geographical potentials for renewables
- fulfilling 100% CO_2 emission reduction target
- Flexibility from gas turbines, HVDC links, battery/hydrogen storage

But there may be many nearly optimal solutions!

→ How flat is the feasible space close to the optimum?
→ Determine a set of technology-specific boundary conditions.



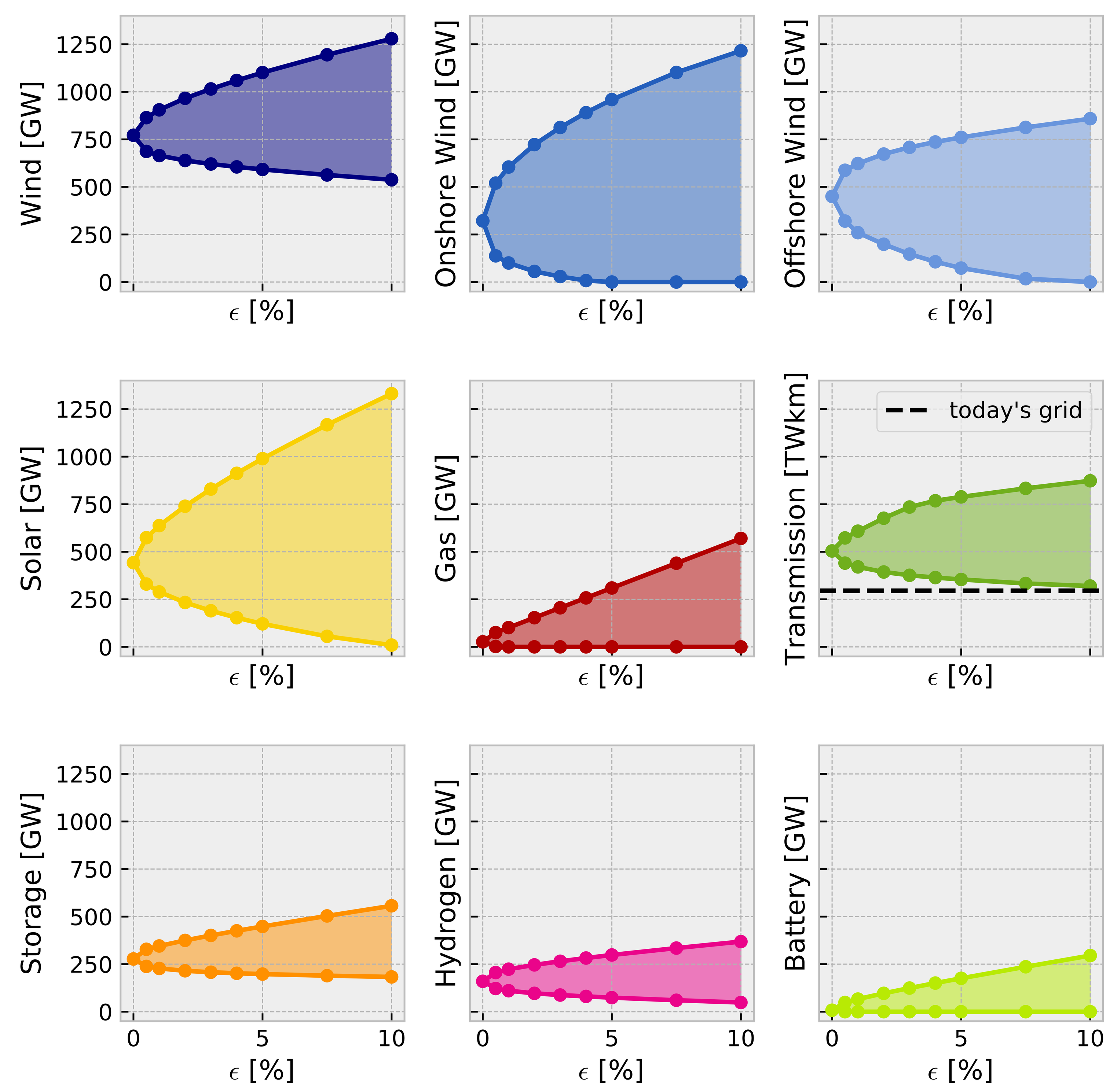
Method: Modelling to Generate Alternatives (MGA)

To find **near-optimal solutions** encode the cost objective as a constraint allowing for an ε increase in total annual system costs. Then, for each $\varepsilon \in \{0.5, 1, \ldots, 10\}$% **minimise** / **maximise**

- generation capacity `(onshore / offshore wind, solar)`,
- storage capacity `(hydrogen, batteries, total storage)`,
- transmission volume `(HVAC lines, HVDC links)`.

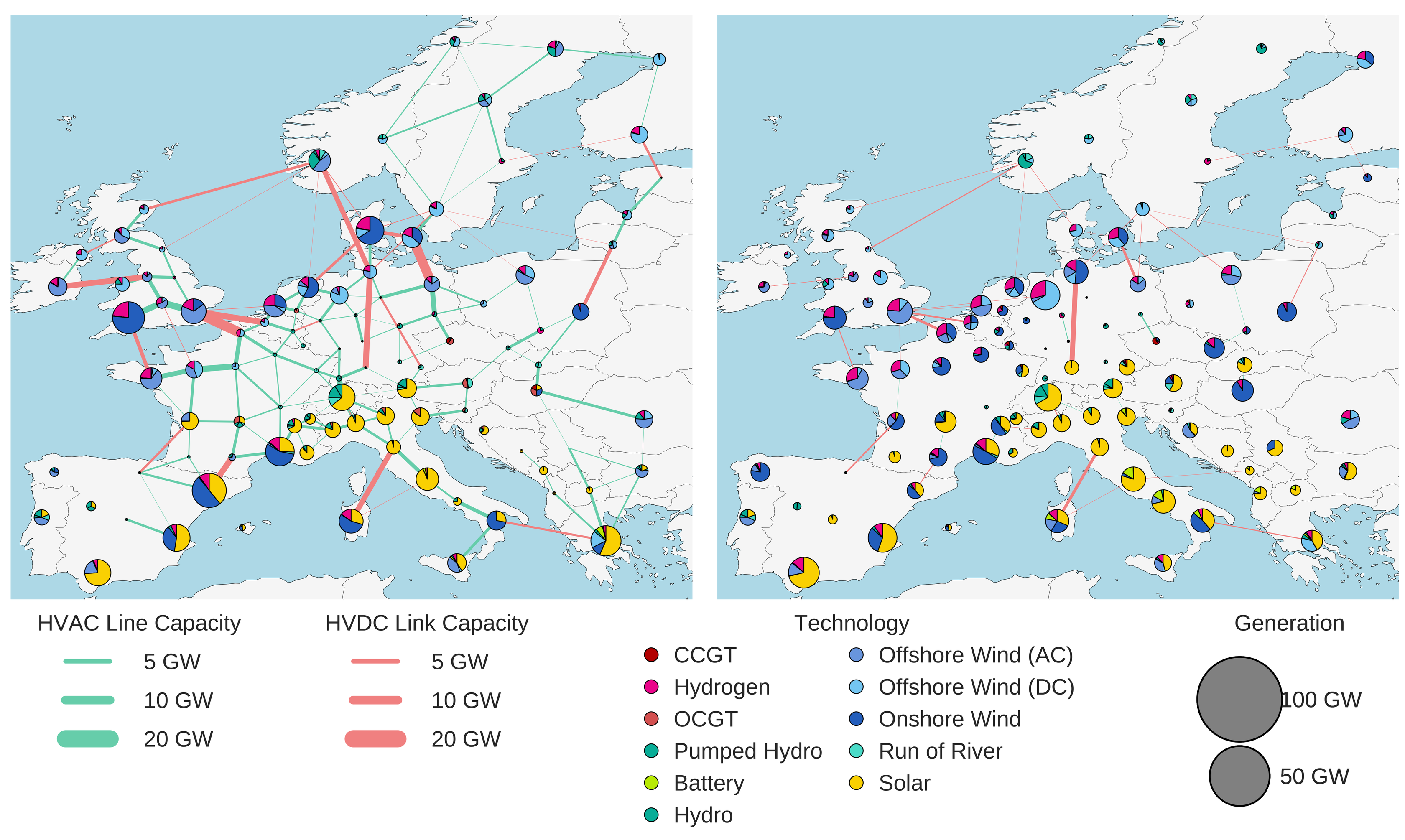
Near-optimal total system capacity expansion ranges

by technology groups for varying cost deviations ε from the optimum



Capacity expansion in the European power system

- (left) at the cost-optimum and
- (right) with minimal transmission network expansion with $\varepsilon = 10\%$.



Brief Conclusions

- **high variance** in the deployment of individual system components
- need either offshore or onshore wind with some hydrogen storage and transmission grid reinforcement

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Model: `https://github.com/pypsa/pypsa-eur`
Code: `https://github.com/pypsa/pypsa-eur-mga`
arXiv: `https://arxiv.org/abs/1910.01891`