Institute of Engineering Thermodynamics

Mapping the challenge of renewable electricity market integration

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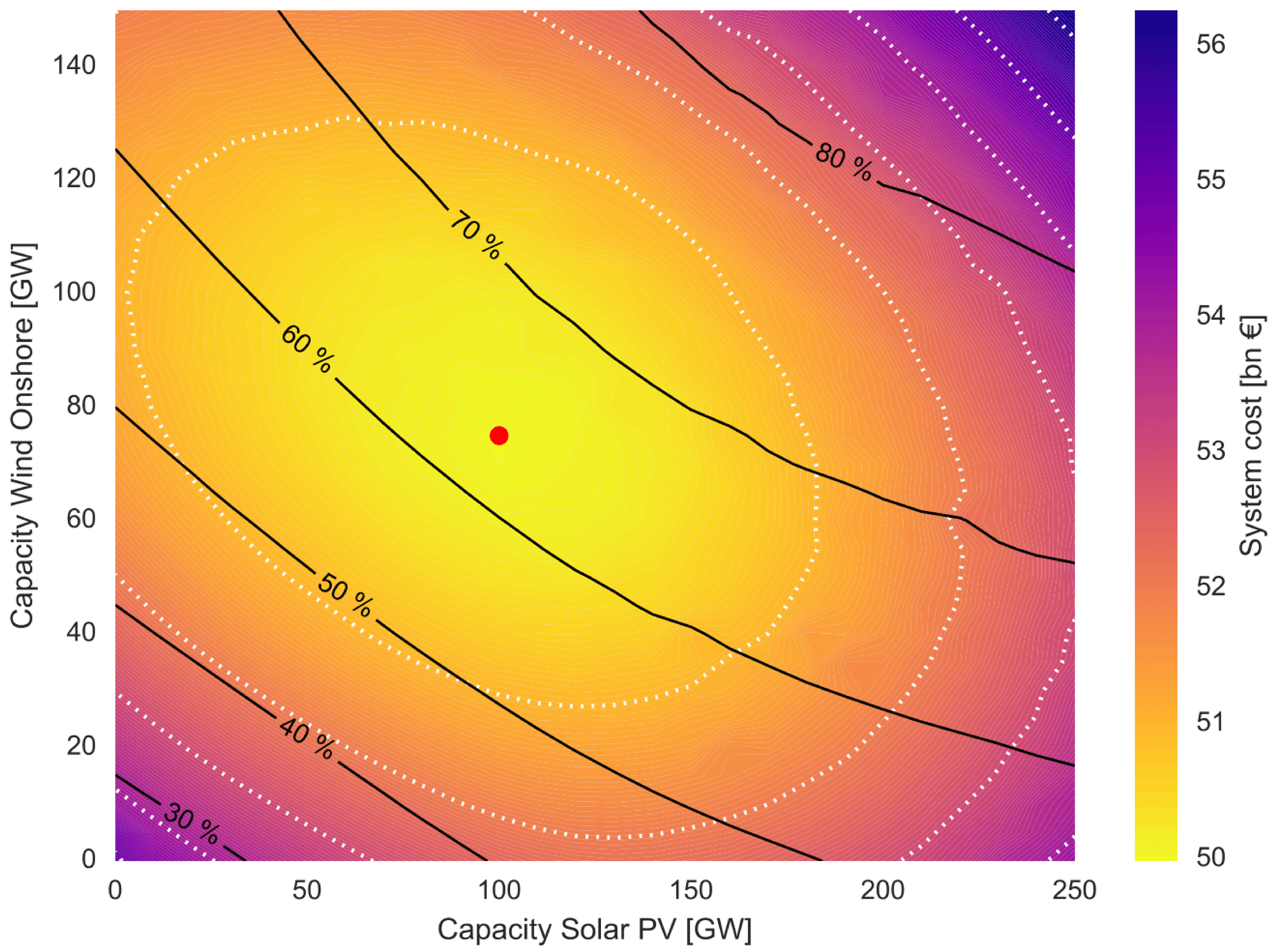
MOTIVATION

- **Electricity system = Complex system**
- Many dependencies are meshed in different and complex ways, and individual elements influence each other [1].
- How do *combination* of exogenous parameters influence results, and how *stable* are model solutions?

METHODOLOGY

- Exploration of analytical possibilities of an agent-based simulation of German electricity market [2] to study combination of influences in a structured way.
- **Run simulation with many parameter sets** (feasible due to fast execution speed of model), evaluate result for each combination, and *map in one plot.*
- Example: Systematical variation of solar photovoltaics (PV) and wind capacity; evaluation of overall system cost and CO_2 emissions. Possible future German electricity system, assumes partial coal phase-out, carbon price: 75€/t, 20 GW wind offshore, security of supply ensured by gas power plants, demand at ~650 TWh/a.

RESULTS



- *Colored area:* Annual system costs in billions of euros from yellow to violet
- Red dot: Lowest system costs.
- *Dashed white lines:* System configurations that have the same system costs (iso-cost lines) in 1 billion Euro step size.
- *Black lines:* Emission reductions compared to 1990. All system states on black lines exhibit same annual CO2 emissions (iso-emission lines).

System cost landscape is *extremely* flat around the minimum, many different emission reductions at roughly the same cost are possible.

DISCUSSION

Shape of cost landscape allows statements about system stability and how emission reductions can be achieved:

- **Economic intervention:** Increase of CO_2 price. Measure raises system cost in bottom left of graph, whereas upper right part remains almost unaltered, since in this region almost no electricity production is subject to CO_2 pricing. Shifts cost minimum further to top-right the top-right of the graph, i.e. towards systems with higher shares of renewables.
- **Technical intervention:** Increase system flexibility so that it can "absorb" higher shares of renewables without them having to be curtailed, by means of storage, sector coupling or transmission. More renewables could be integrated and system cost gradient per additional GW of renewables would be less steep. This measure would again shift cost minimum further towards systems with higher shares of renewables.

CONCLUSION

- **Novel display of system cost landscape**
- They display potentials and challenges of an energy system with high shares of renewable energy sources **at one glance**.

REFERENCES

[1] C. S. E. Bale et al., "Energy and complexity: New ways forward," Applied Energy, vol. 138, pp. 150–159, 2015.
[2] M. Deissenroth et al., "Assessing the Plurality of Actors and Policy Interactions - Agent-based Modelling of Renewable Energy Market Integration," Complexity, vol. 2017, pp. 1–24, 2017.

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