DIW BERLIN

Infrastructure Policy in the 21st Century

Power sector effects of alternative production and storage options for green hydrogen

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MODEZEEN

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Background and research question

Background

- Plans to ramp-up of domestic production of green hydrogen in Germany

Research question

- What are the power system effects?
- In particular, optimal capacity investment and dispatch
- Effects of various scenario assumptions

Scope

- Focus on 2030 and Germany, 80% renewable share

2 The DIETER model

- DIETER: “Dispatch and Investment Evaluation Tool with Endogenous Renewables”
- Capacity expansion model
- System cost minimization, LP
- Solved for a full year in hourly resolution
- Implementation in GAMS and Python → DIETERpy
  (*SoftwareX* 2021, https://doi.org/10.1016/j.softx.2021.100784)
- Open source: https://gitlab.com/diw-evu/dieter_public
- Various previous applications: electricity storage, sector coupling, prosumage

scientific reports

2 The hydrogen module in DIETER

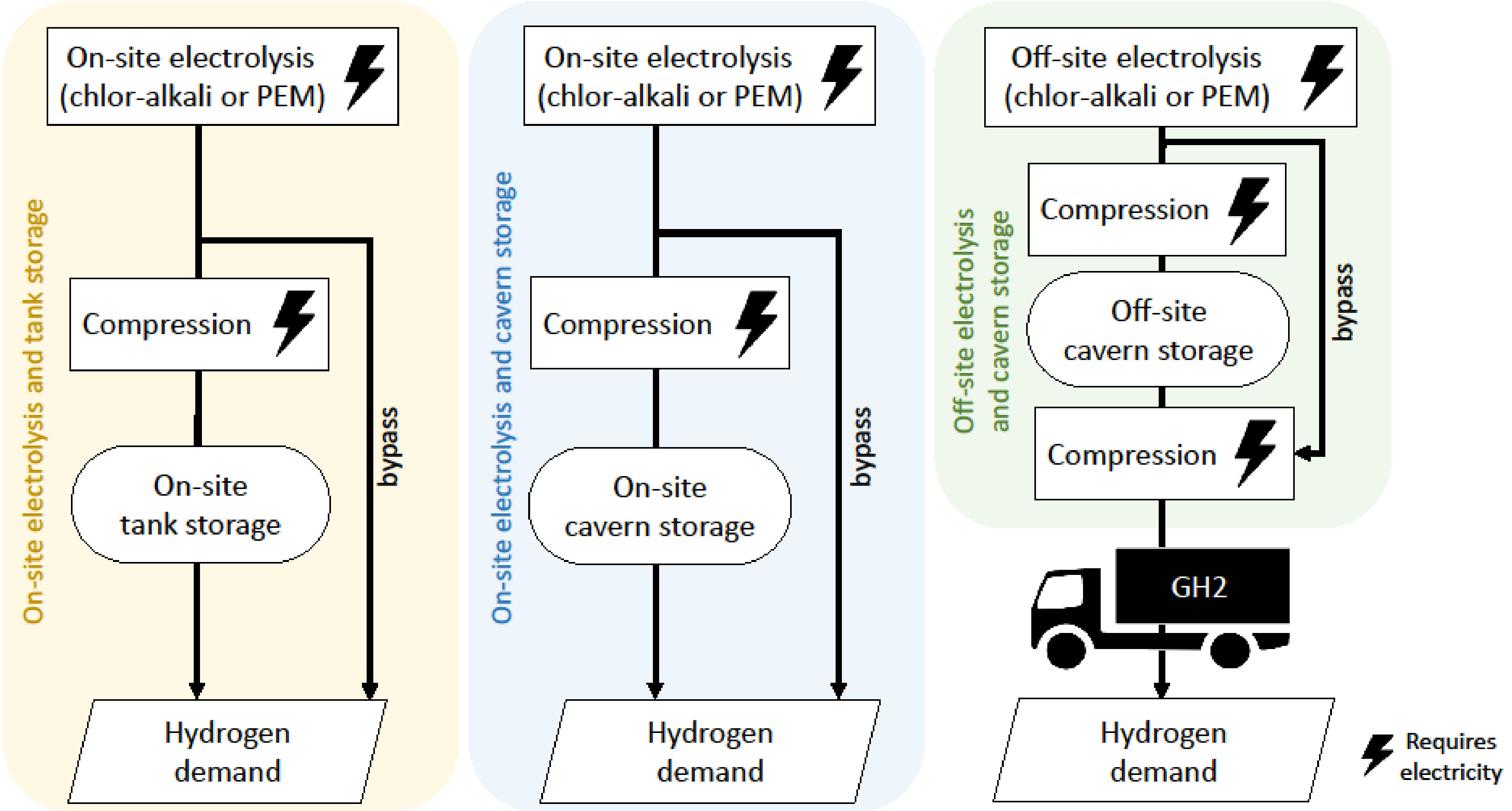
- Detailed representation of various green hydrogen supply chains:
  Scientific Reports 2021, https://doi.org/10.1038/s41598-021-92511-6

- Here, we use a reduced version of the hydrogen module:
  - Focus on gaseous hydrogen

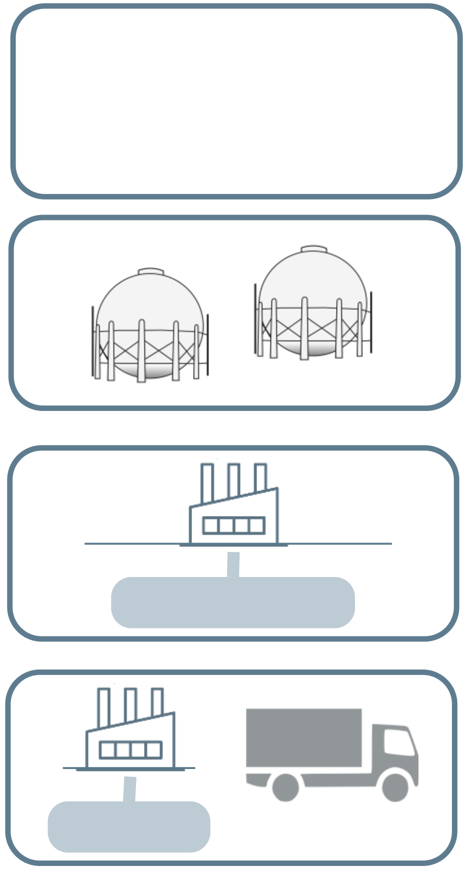
- Exogenous parameter:
  - Hydrogen demand

- Endogenous variables:
  - Investment and use of two electrolysis technologies
  - Investment and use of three H_2 storage options (mutually exclusive)

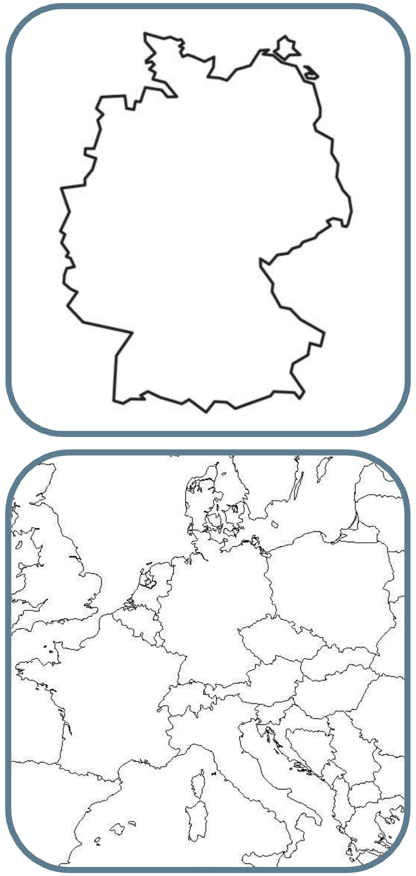
Hydrogen supply chains in the model



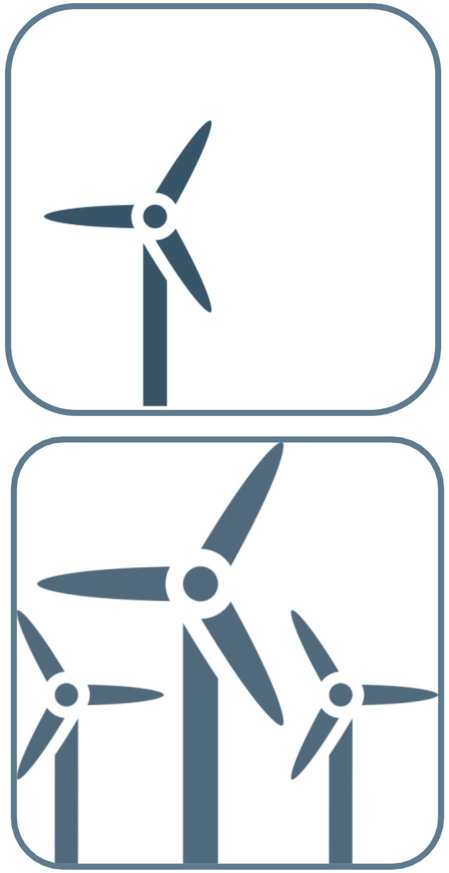
Four
hydrogen (storage) scenarios



Two
geographic scopes

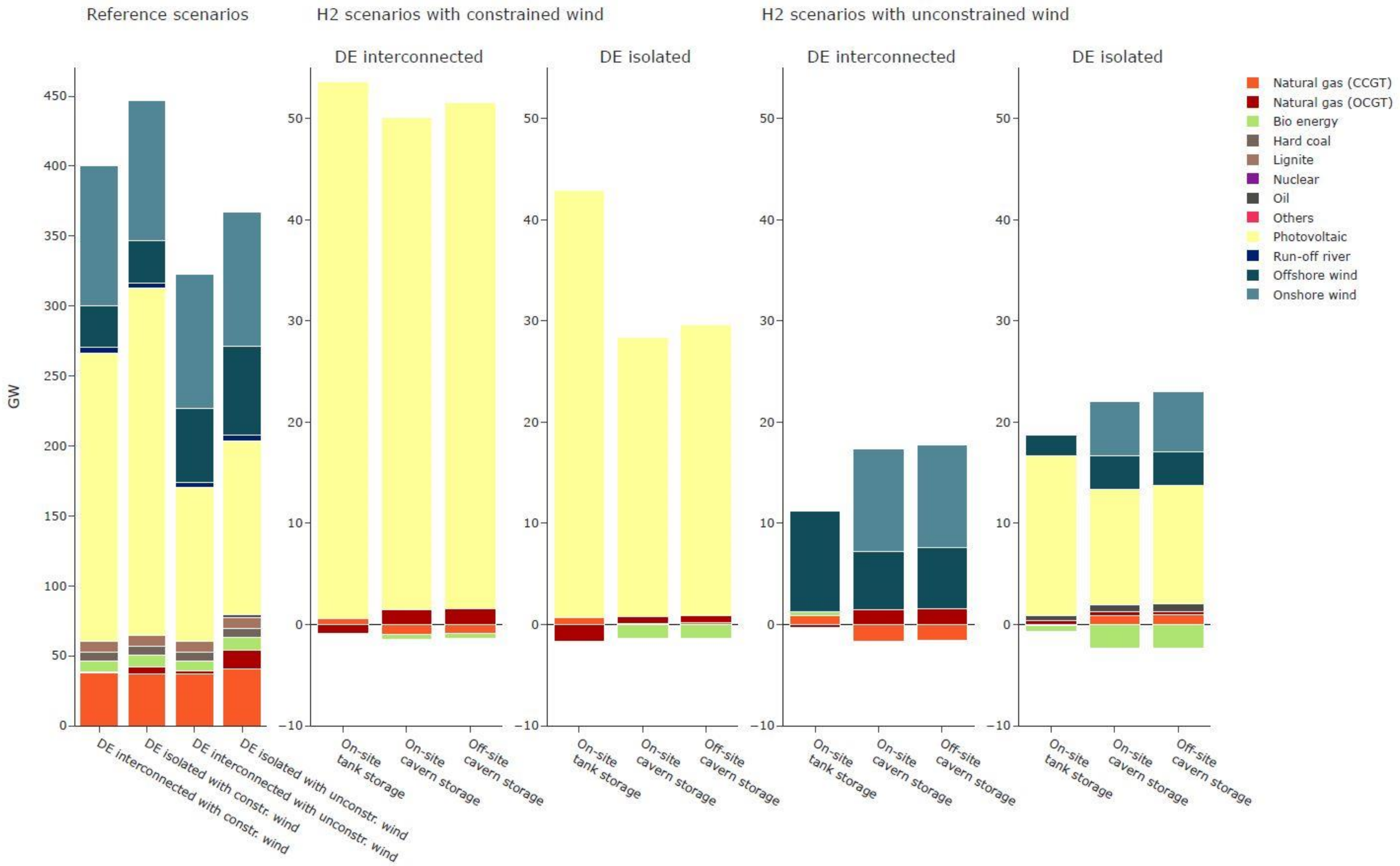


Two
assumptions on renewable energy expansion



= 16 individual model runs

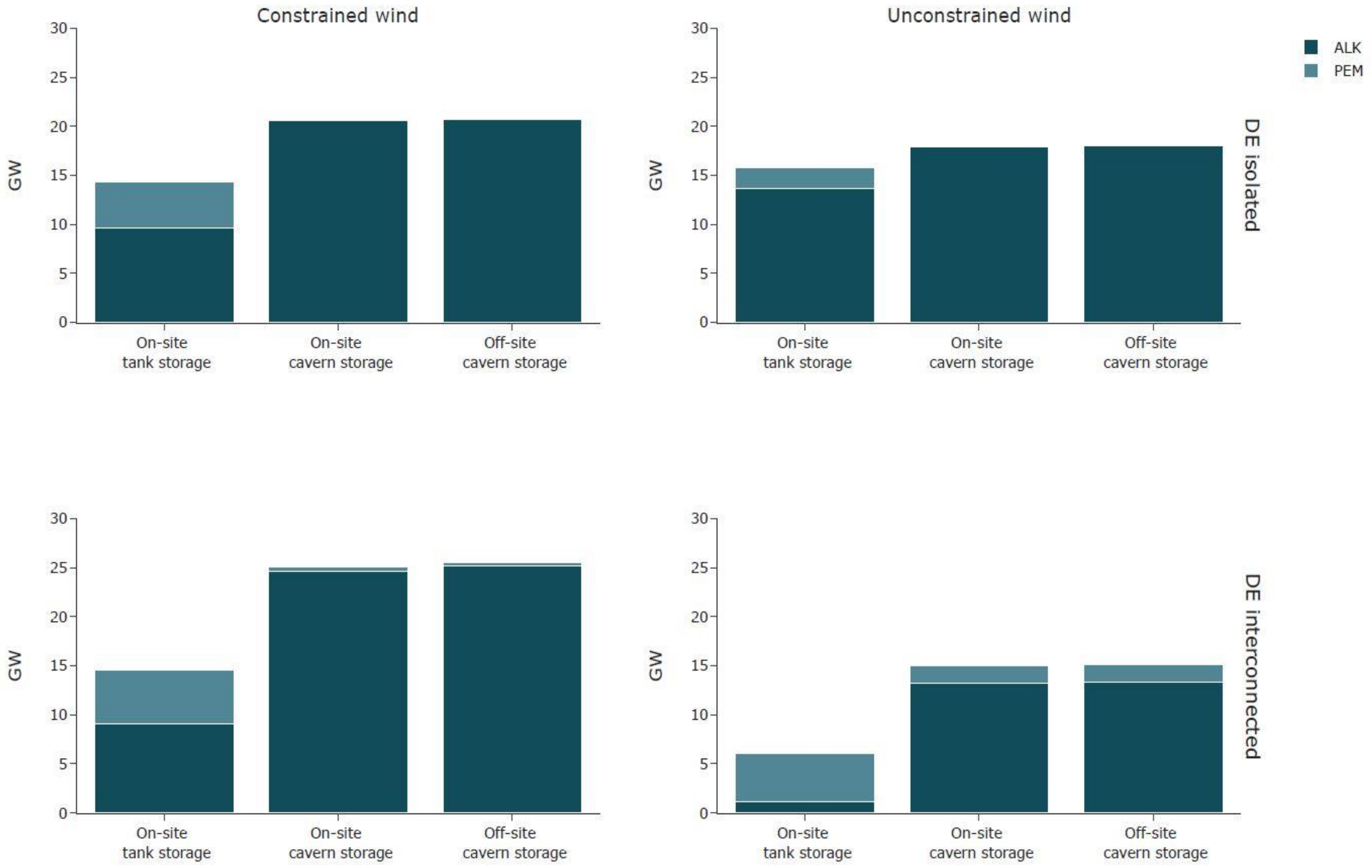
Results: Installed generation capacities in Germany



- Constrained wind: mainly solar PV
- DE isolated: lower investments, as capacities in reference case are higher
- Caverns: change optimal mix (better integration of renewable surpluses, balancing of seasonal fluctuations)

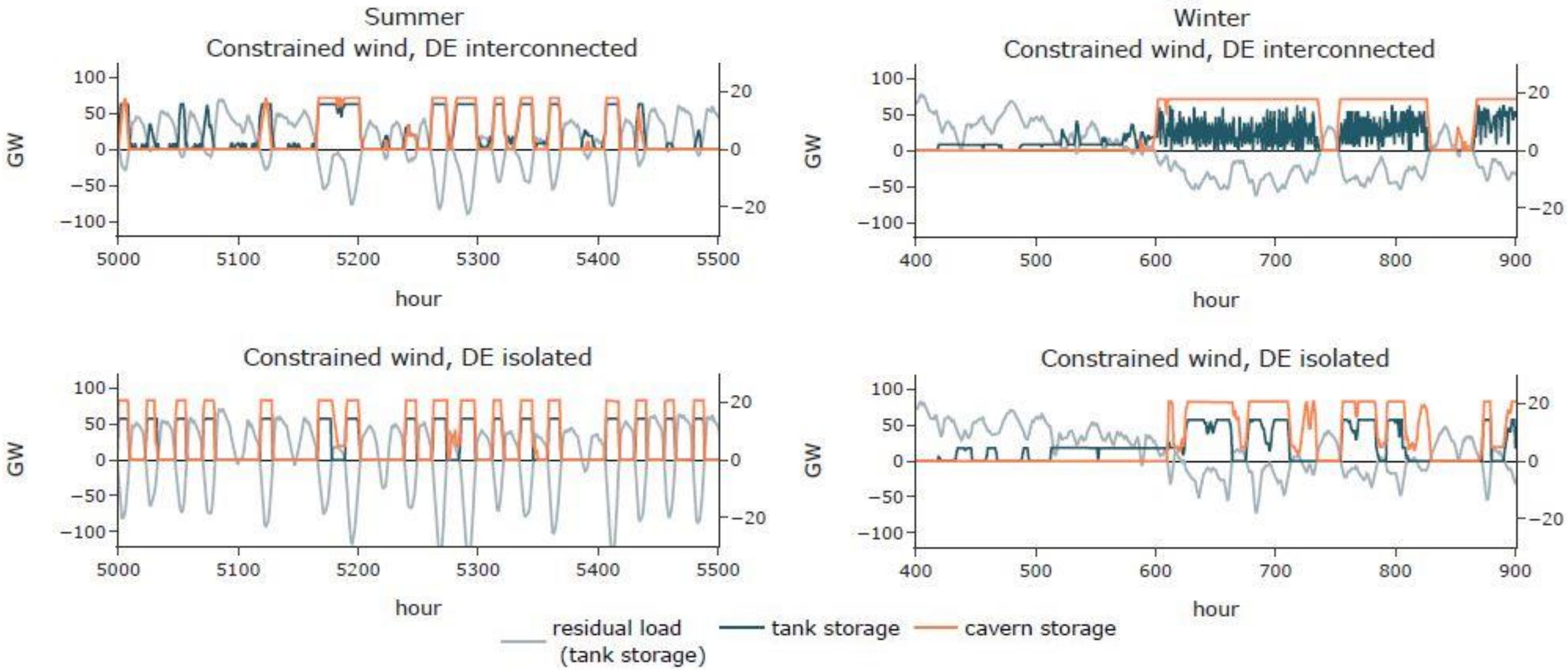
4

Results: Installed electrolyzer capacity



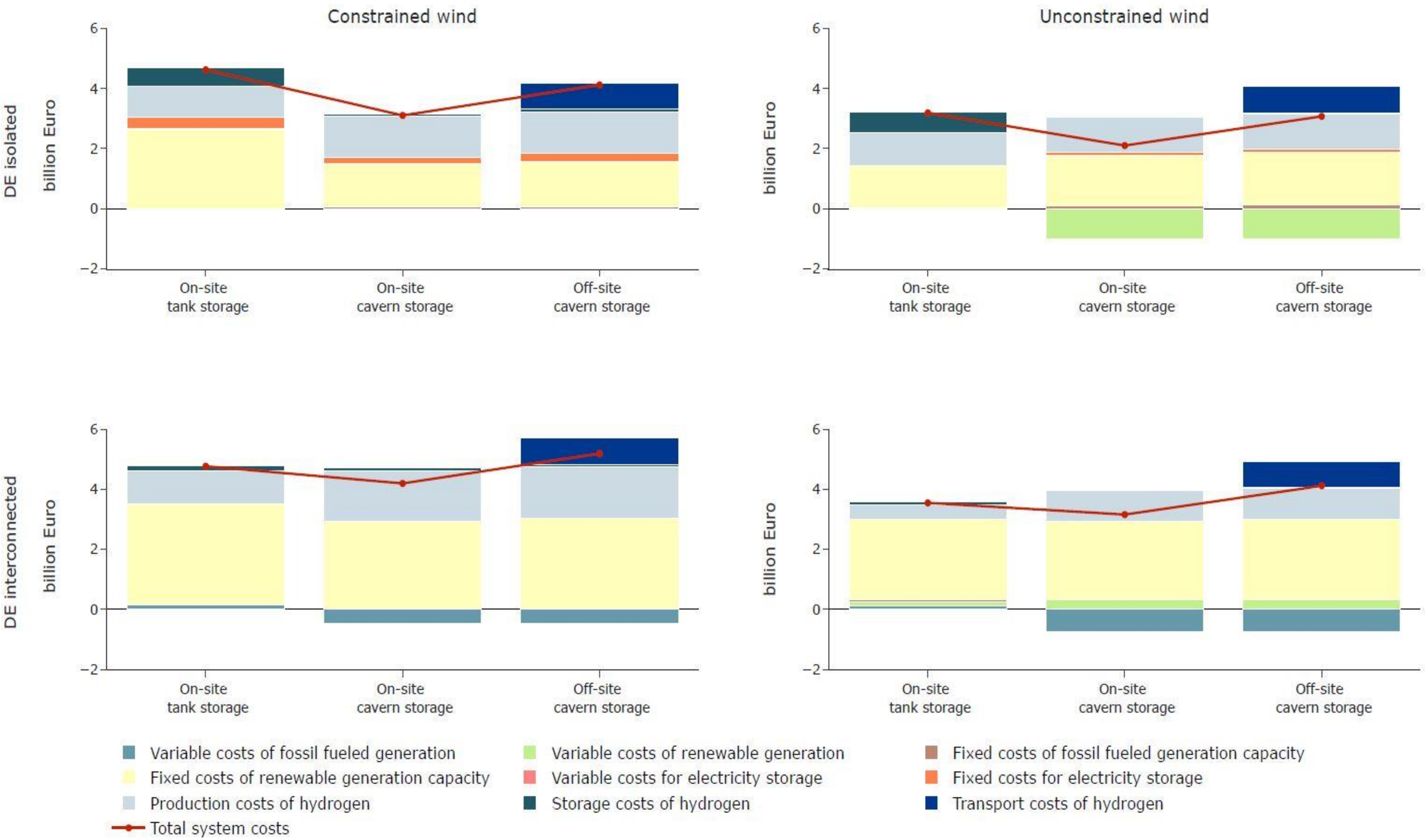
- Generally, higher capacity and higher share of ALK indicate higher use of renewable surplus
- Tank storage: less flexibility for taking up cheap renewable surplus energy → more PEM
- Caverns: higher electrolyzer capacity, lower FLH, higher use of renewable surplus energy
- Constrained wind: higher electrolyzer capacity because of higher PV surplus around midday

Results: Electricity consumption by electrolyzers



- DE isolated: larger renewable surpluses, especially in summer
- Cavern storage: enables higher use of electrolyzers in periods of renewable surplus generation
- Tank storage: higher use in hours with positive residual load

4 Results: Additional system costs compared to reference



- On-site caverns: flexibility leads to lowest costs
- Off-site caverns: transport costs may outweigh flexibility benefits
- Trade-off between electrolyzer costs and electricity generation costs
- Cavern storage reduces variable costs of firm generators
- Lower additional costs in DE isolated case because of larger renewable surpluses

Conclusions and policy implications

Main findings

- Changes in optimal capacity mix depend on scenario assumptions and H_2 storage
- Cavern storage can provide valuable (seasonal) flexibility, but transport costs may reduce benefits
- Flexibility benefits from green hydrogen production are lower with interconnection
  → also true for other flexibility options
- Potentially unintended distributional effects between green hydrogen producers and other electricity consumers

Policy makers should…

- …plan for an additional capacity expansion of renewables
- … support flexible H_2 production, e.g. by enabling the expansion of large-scale hydrogen storage options

Working Paper: https://arxiv.org/abs/2208.07302

Thank you for your attention.

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MODEZEEN

Modellierung (De-)Zentraler Energiewenden: Wechselwirkungen, Koordination und Lösungsansätze aus systemorientierter Perspektive

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