

Value of diversification in 100% renewable energy scenarios

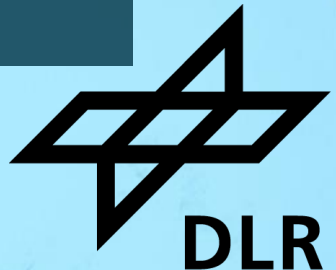
Hans Christian Gils, Thomas Pregger, Tobias Naegler

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

4th International Forum on Long-term Scenarios for the Clean Energy Transition

Session 4: Role of 100% renewable electricity for the energy system transition in scenarios

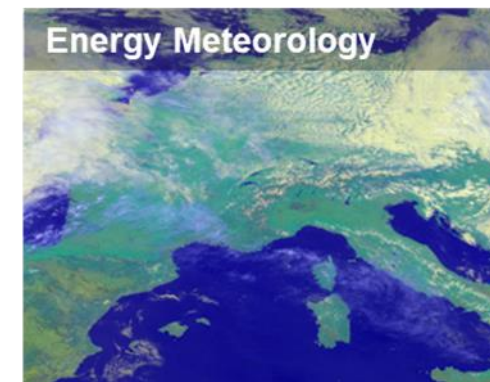
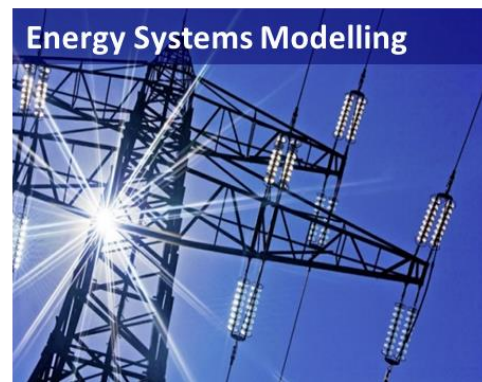
Bonn, 7 - 9 December 2022



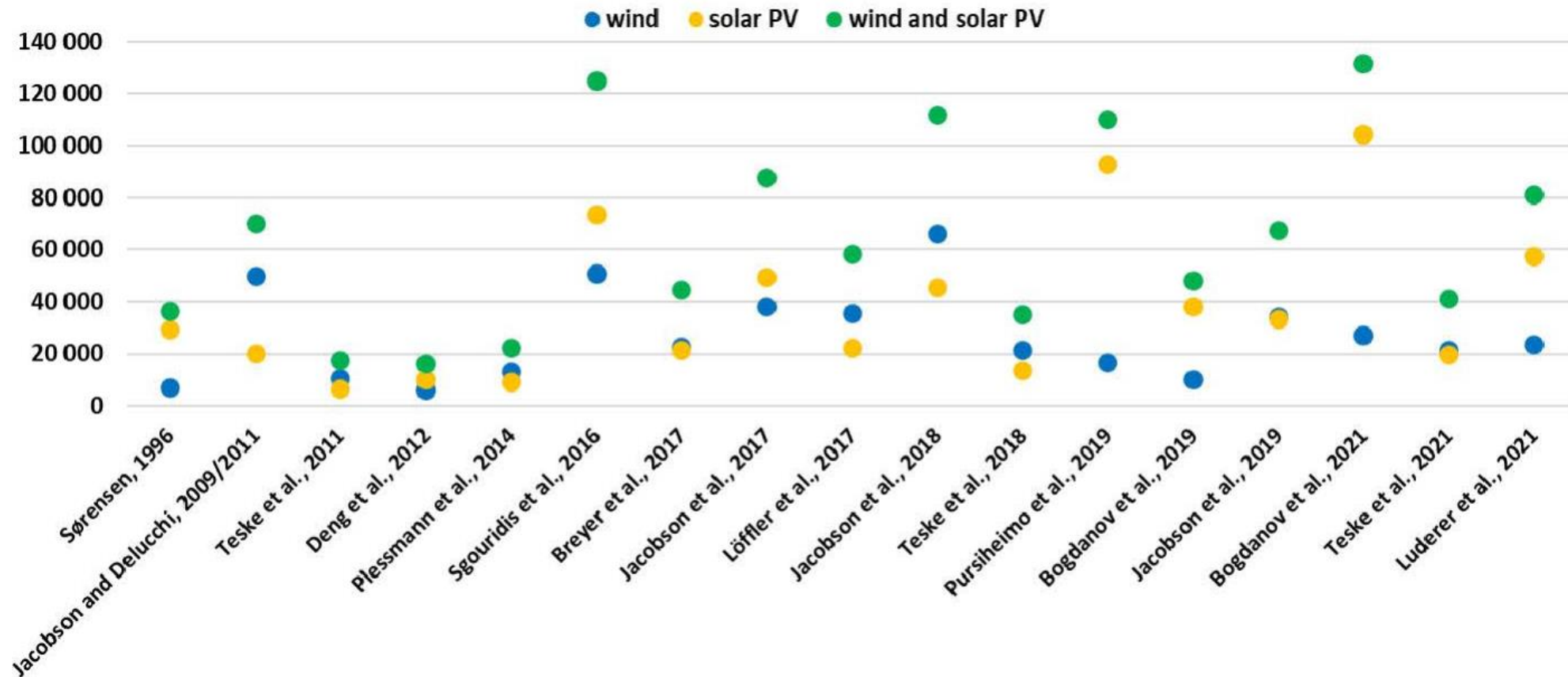
DLR activities in energy scenario development and assessment



- Studies on the energy transition and green hydrogen supply since the 1970s, e.g. book „Hydrogen as an Energy Carrier“ from Winter/Nitsch of 1988 (Springer)
- Lead scenarios for the German Ministry for the Environment starting around 2000, e.g. German „Long term scenarios 2012“ with a first bottom-up outlook on 95% GHG reduction
- Development of global and country scenarios for NGOs since 2005, e.g. Teske et al. 2019 „Achieving the Paris Climate Agreement Goals...“
- Infrastructure modelling in high temporal and spatial resolution since around 2005 (REMix model)
- Research on methods for socio-technical scenarios, agent-based market analyses, prospective LCA-based assessment and analysis of critical resource demand, resilience, RE potentials, ...



Various technological options for future energy systems conceivable



Solar PV and wind electricity generation in TWh/yr in global 100% RE scenarios in the year 2050

Which target system is to be preferred depends on numerous parameters, which can be weighted differently

Energy efficiency

Resilience

Supply costs

Land /water use

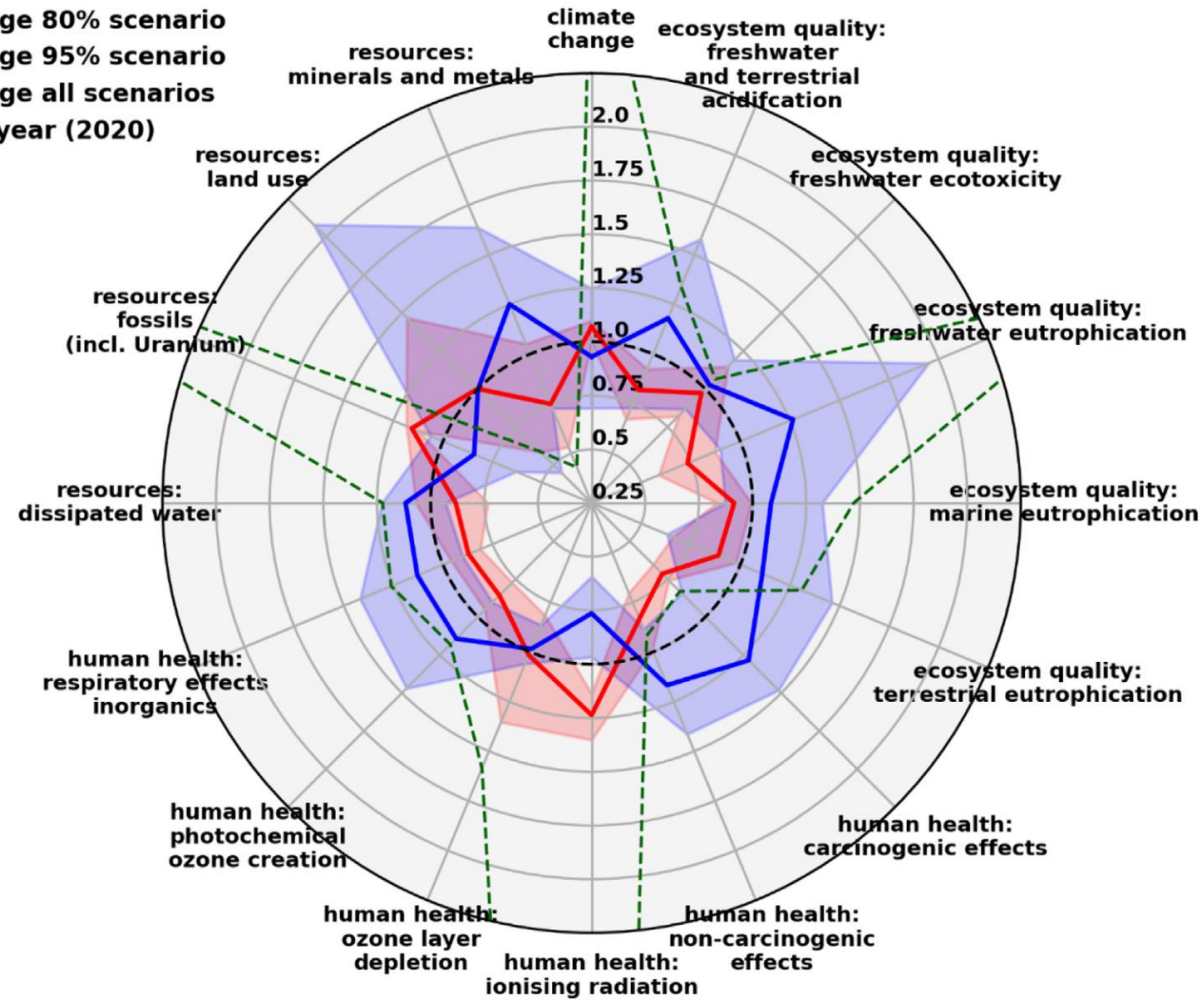
Social acceptance

Import dependency

Mineral resources

...

- average 80% scenario
- average 95% scenario
- - - average all scenarios
- - - base year (2020)



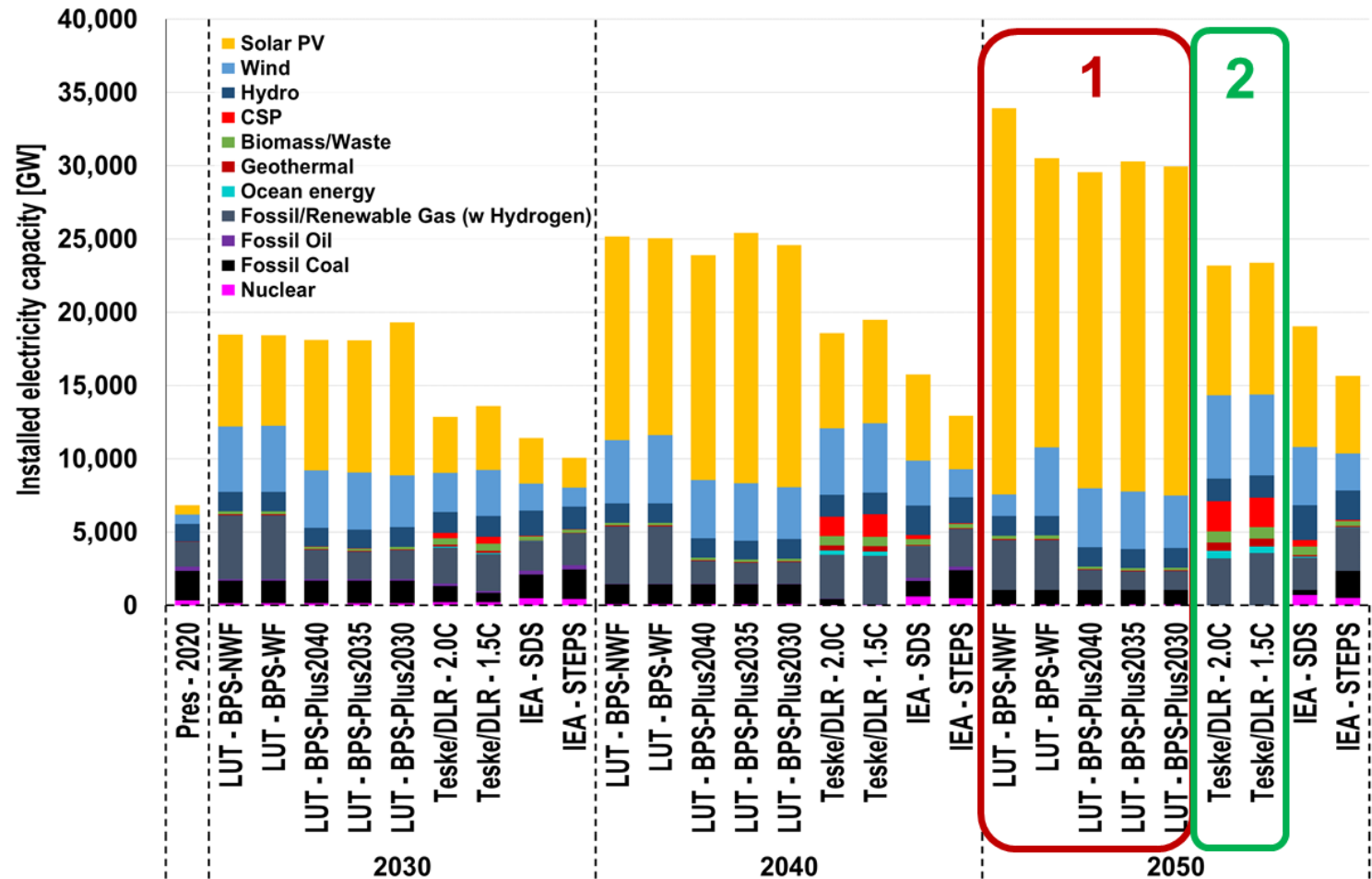
Source: [Naegler et al \(2022\)](#)

100% renewable energy power supply systems: Example of cost optimization (1) vs. diversity approach (2)



Teske et al. 2019 scenarios (2) with diverse power generation structure from storyline & simulation approach:

- Higher security of supply through technological diversity
- Consideration of technology acceptance and thus lower societal risks
- Parallel expansion of technologies offers broader economic opportunities
- Possible co-benefits of esp. CSP* (heat use, water desalination)
- Compared to optimized LUT scenarios (1), LCOE** are 10% to 20% higher.



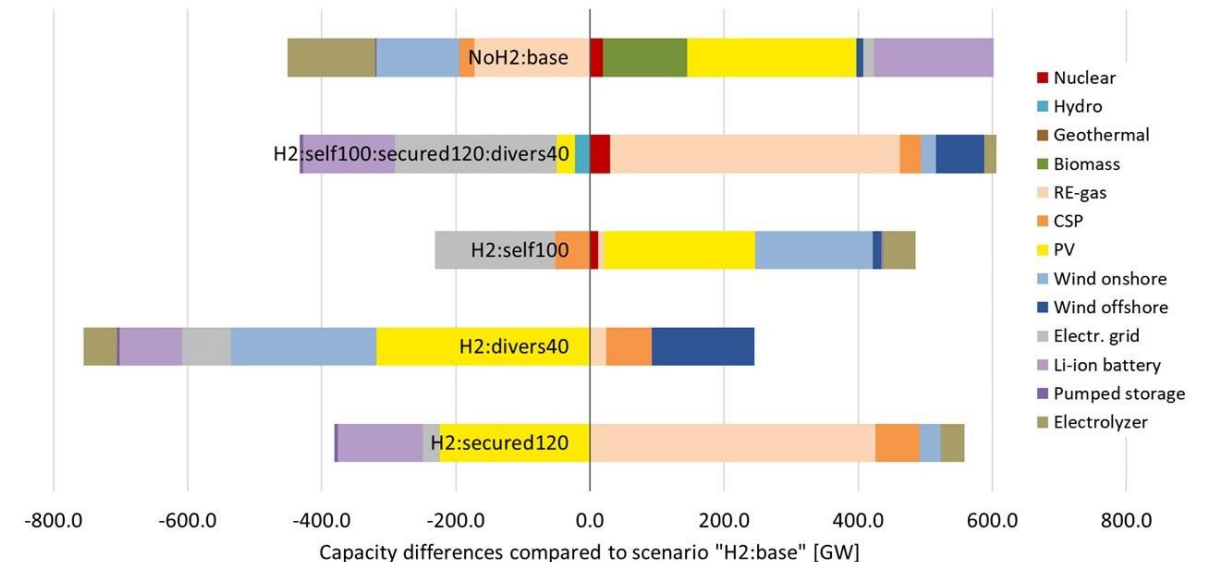
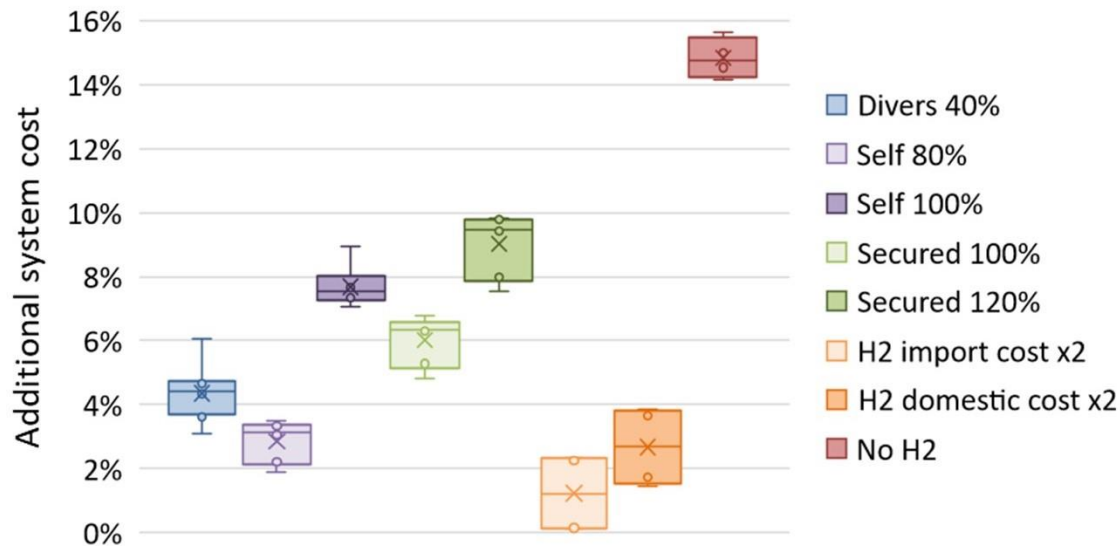
* Concentrating Solar Power

** Levelized costs of electricity

Sources: [Aghahosseini et al. 2022](#); [Teske et al. 2019](#)

Europe in detail: diversity of supply reduces risks and increases resilience at comparably low additional cost

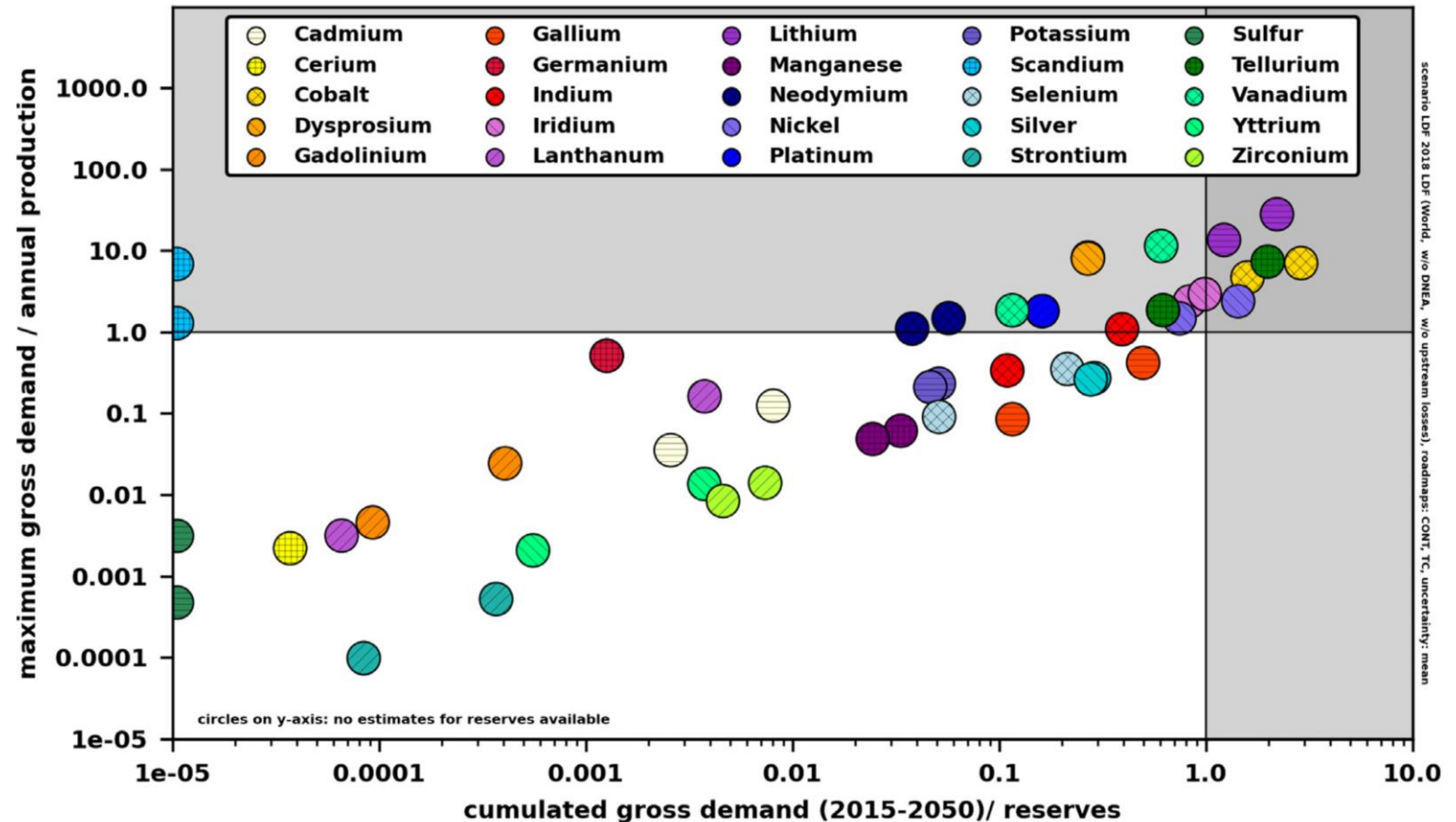
- Power supply diversity favorable in many regards
 - 2050 system cost for Europe 3-6% higher if no technology supplies more than 40%
 - Reduced vulnerability towards external stress cases (extreme weather, hacker attacks)
- Diversity in 100% RE power systems mostly through CSP and offshore technologies



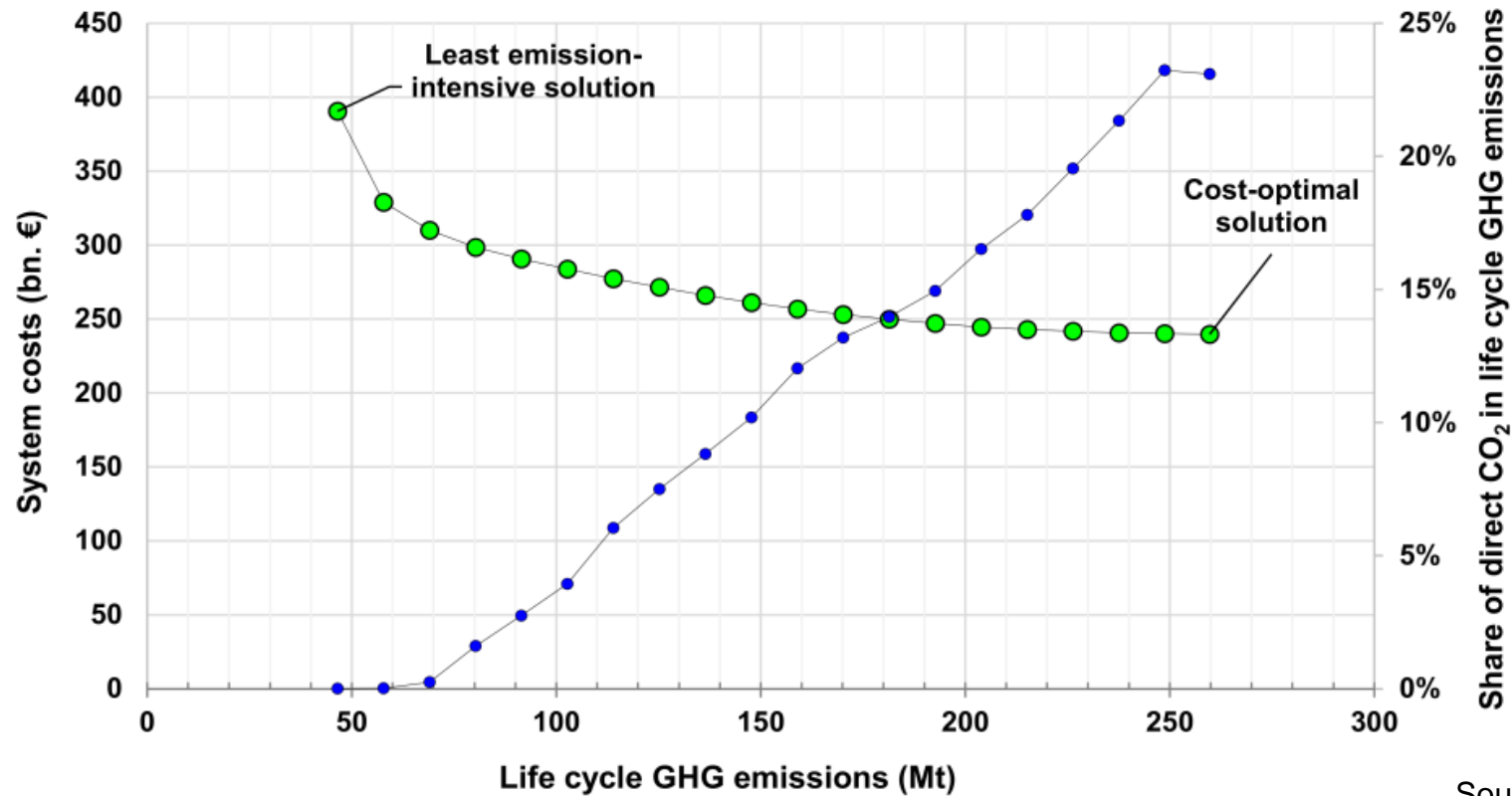
Source: [Sasanpour et al. \(2021\)](#)

Energy scenarios pay too little attention to risks associated with costs and availability of scarce materials

- Increasing demand for critical raw materials in energy and transport technologies
- Short- to mid-term shortages possible for e.g. Lithium, Cobalt and Nickel required in stationary and mobile batteries
- Energy system transformation strategies should take into account potential raw material bottlenecks and price increases
- Efforts for recycling and lower specific demands required



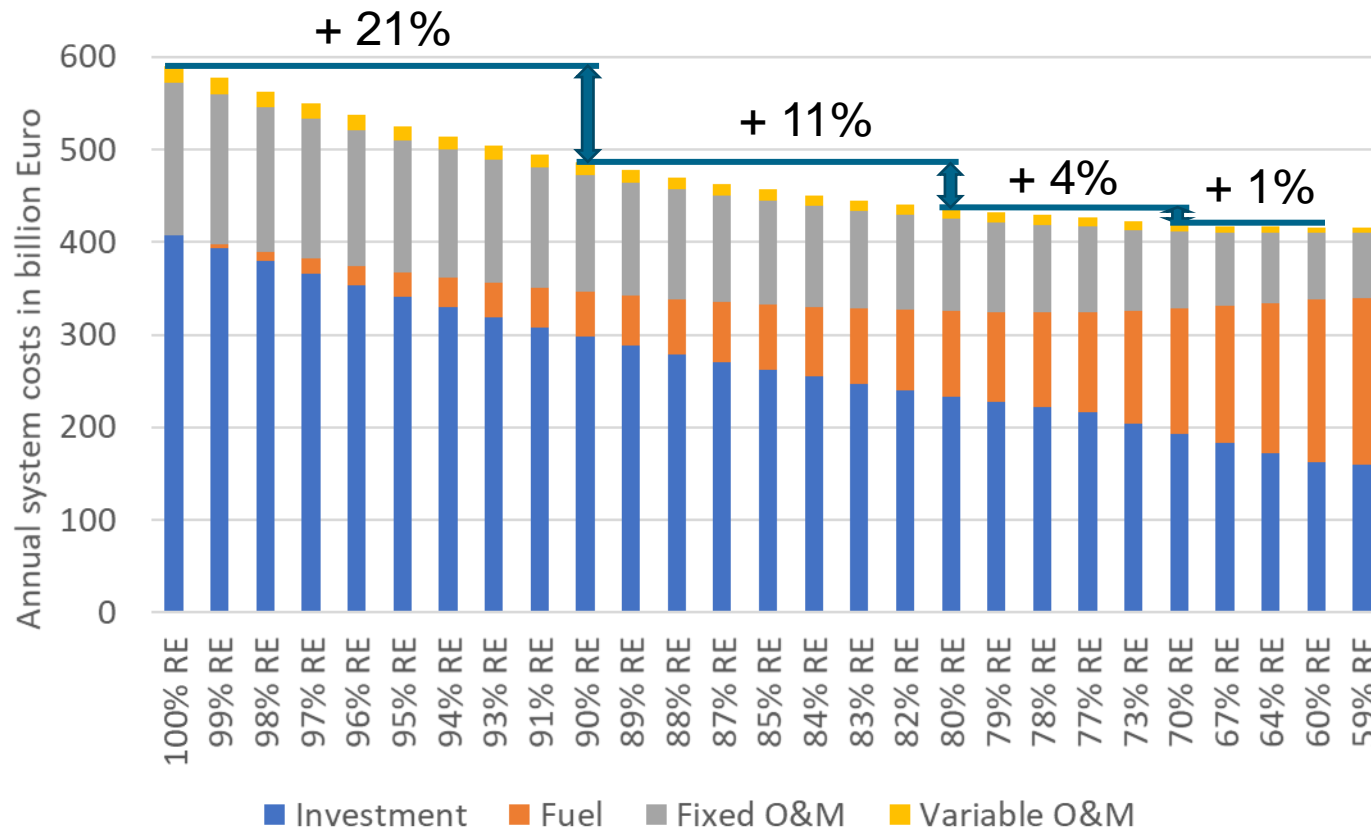
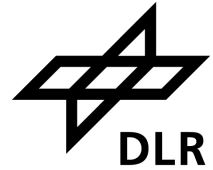
Role of material recycling and tradeoffs between costs and resource usage must be further explored



Source: [Junne et al. \(2021\)](#)

- Consideration of a criticality index in multi-objective system optimization
- Better data on resource availability and demands in future energy and transport systems and beyond?
- Uncertainties with regard to future recycling/circulation potentials and substitution possibilities

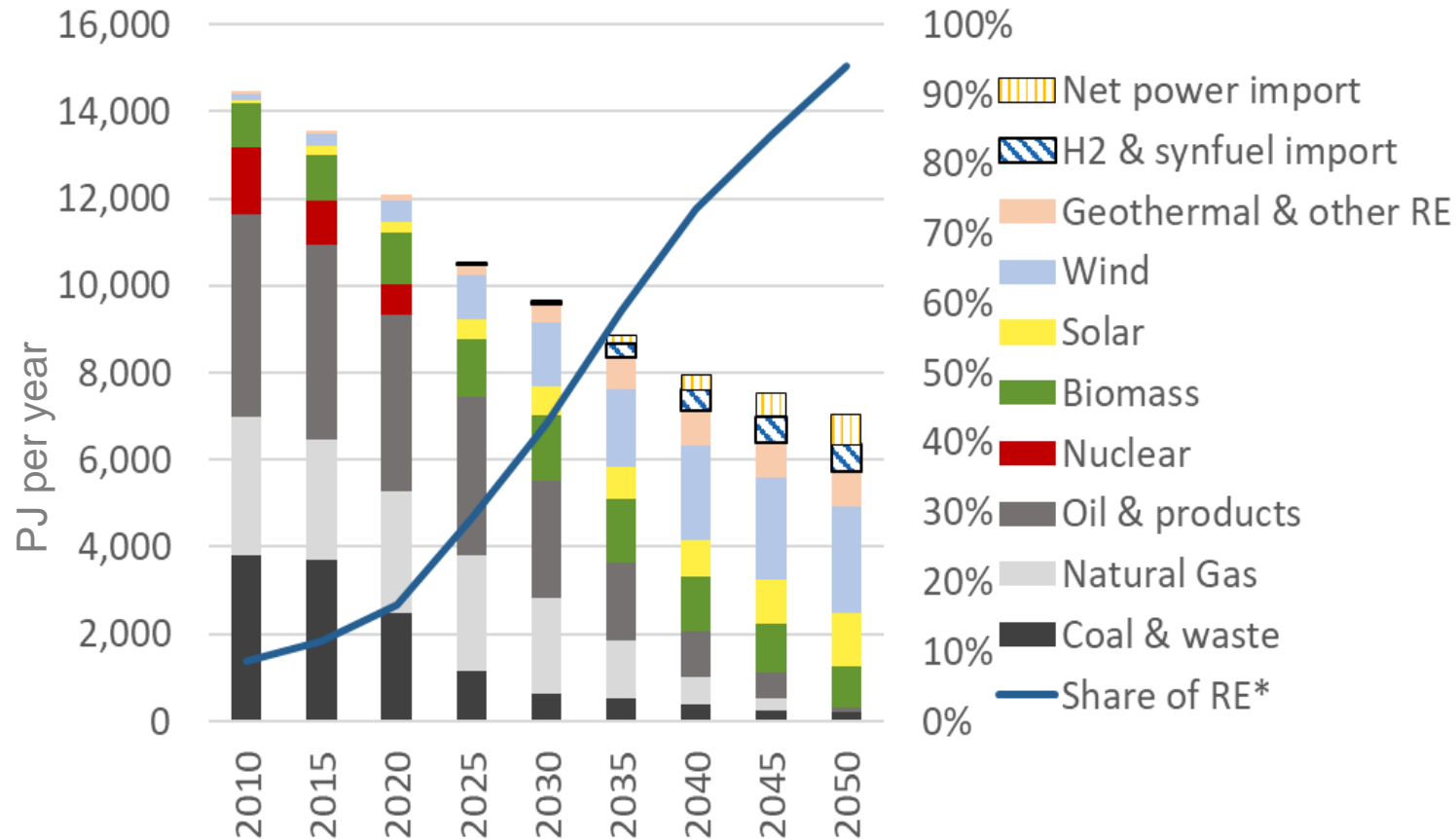
Tradeoff between implementation of a zero-emissions system and negative emissions need to be explored in more detail



- Specific cost of emission reductions increase sharply for high RE shares
- This contrasts with uncertain costs for CDR and CCS
- Conclusive assessment requires comprehensive consideration of infrastructure costs for RE, fossil fuel use, and negative emissions

Consideration of a highly stylized power system for central Europe, adopted from [Gils et al. \(2022\)](#). The relative numbers provide an estimate of the additional costs of further increasing the RE share.

Import strategies will be important part of the solution for many countries: example net-zero scenario for Germany

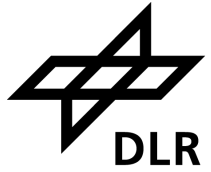


- Scenarios should consider all energy needs and infrastructures
- Sector coupling addresses (in)direct electrification of heat and transport
- E-fuels for hard-to-abate activities drive electricity demand strongly
- Example Germany: from ~600 to approx. 1500-2500 TWh/yr in 2050

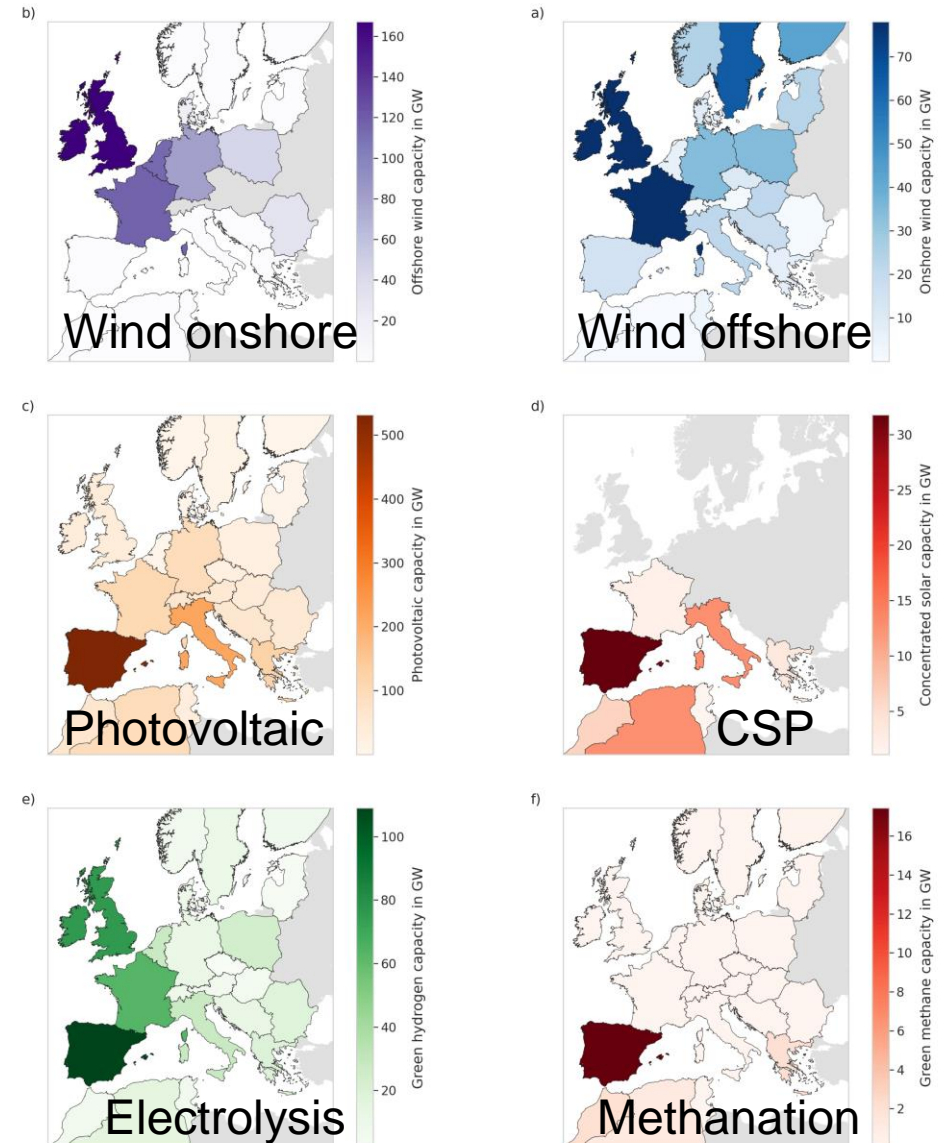
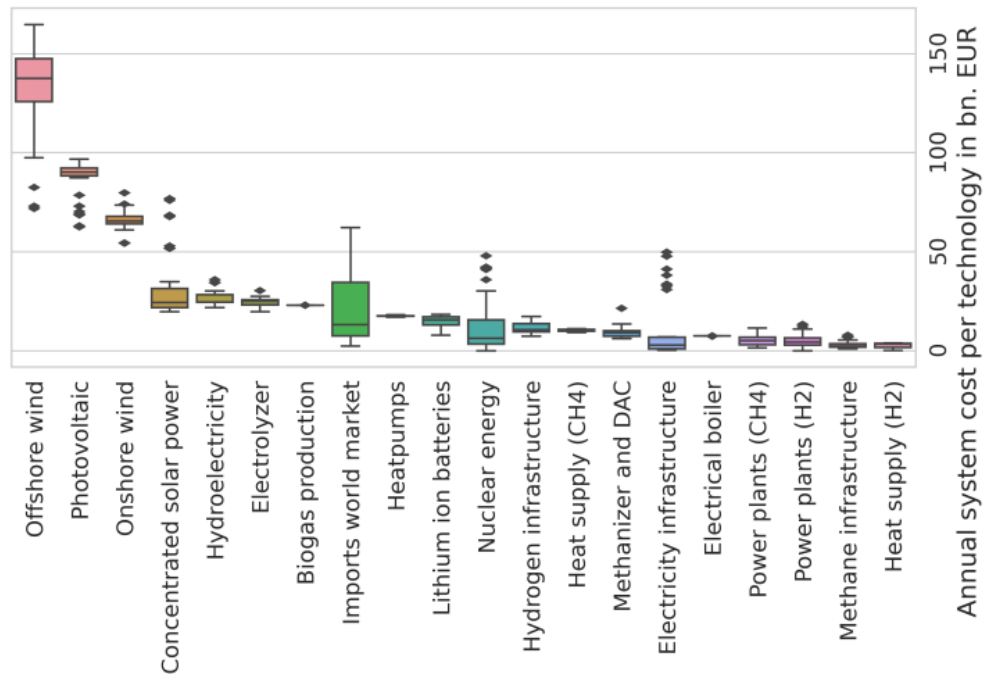
Imports must be considered in infrastructure development

Primary energy supply in the Net-zero scenario for Germany according to [Simon et al. \(2022\)](#). Total (theoretical) green electricity demand in this high-efficient scenario reaches 1500 TWh in 2050, of which more than 500 TWh are imported as power, H₂ or e-fuels. CDR measures are assumed for the last ~5% CO₂ reduction.

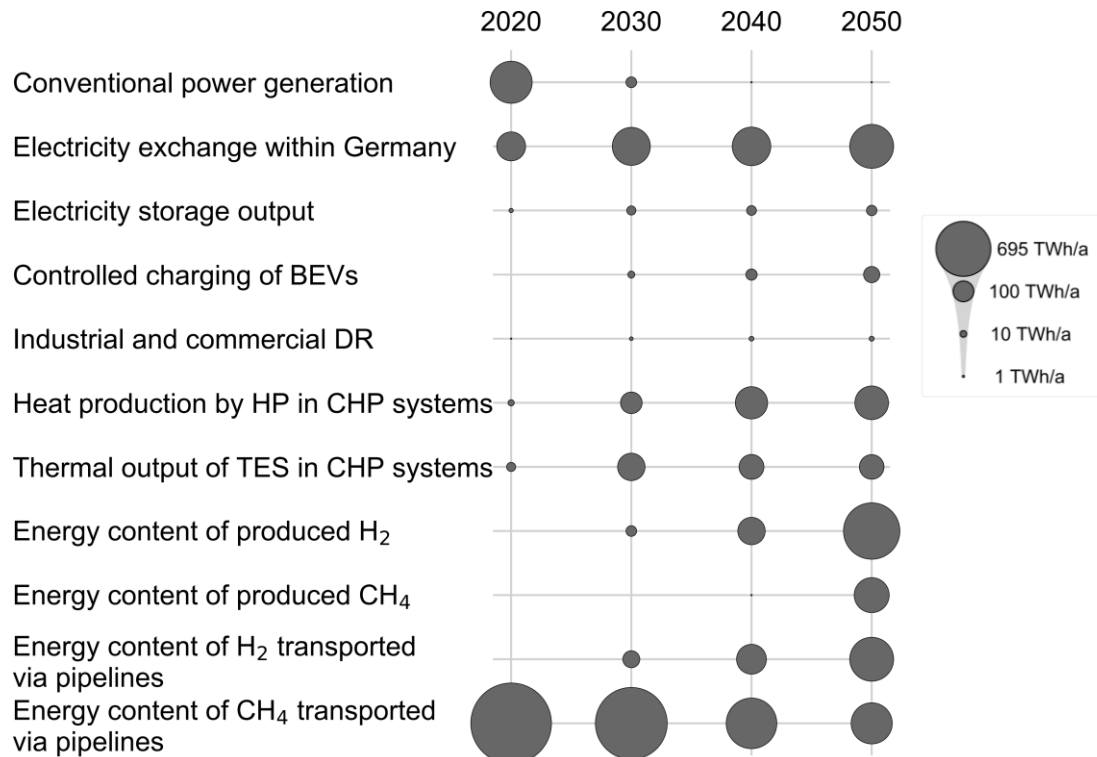
While there is some flexibility in the regional use of RE, robust investments can be seen in different scenarios



- Decision on import strategy has high impact on RE allocation
- Repurposing CH₄ pipelines is no-regret option
- H₂ flows depending on scenario storyline

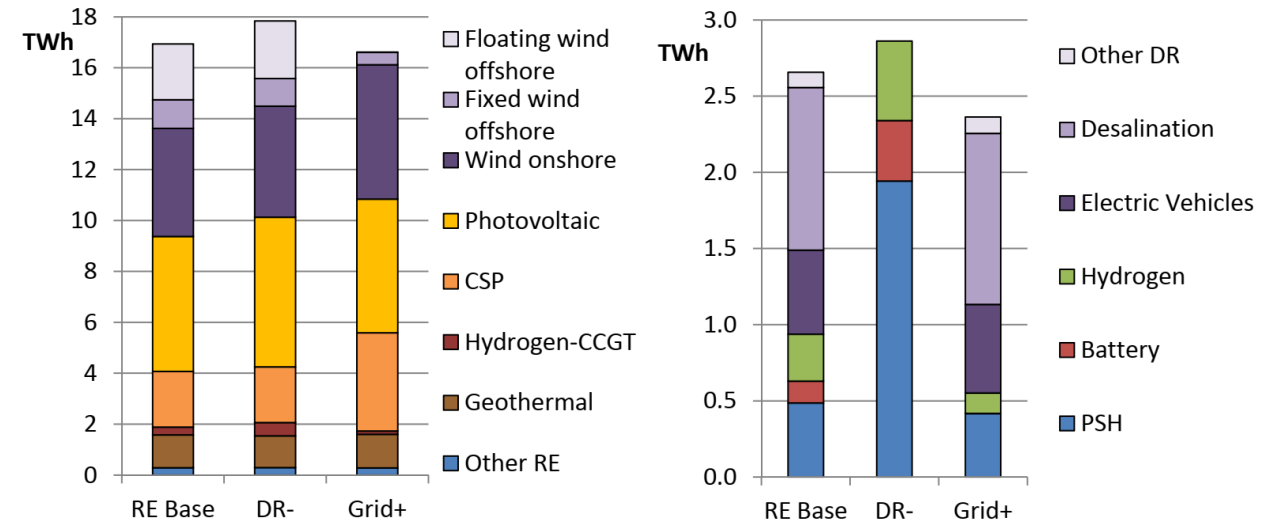


Use of decentralized flexibility lowers supply costs and reduces the need for transport networks



Source: [Gils et al. \(2021\)](#)

Dispatchable renewables to be combined with a broad range of flexibility options



Source: [Gils et al. \(2017\)](#)

Decentralized power system flexibility is competitive and not displaced by large-scale grid expansion and hydrogen production

Incentives for the installation and operation of decentralized flexibility technologies required

Conclusions



- Diversity of supply reduces risks and increases resilience at comparably low additional cost
- Tradeoff between implementation of a zero-emissions system and negative emissions need to be explored in more detail
- Energy scenarios pay too little attention to risks associated with costs and availability of scarce materials
- Role of material recycling and tradeoffs between costs and resource usage must be further explored
- Import strategies will be important part of the solution for many countries
- While there is some flexibility in the regional use of RE, robust investments can be seen in different scenarios
- Use of decentralized flexibility lowers supply costs and reduces the need for transport networks

Contact



Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR)

German Aerospace Center

Institute of Networked Energy Systems | Energy Systems Analysis |
Curierstraße 4 | 70563 Stuttgart | Germany

Dr. Hans Christian Gils | Head of the Energy Systems Modelling Group

Telefon +49 711 6862-477 | hans-christian.gils@dlr.de

www.DLR.de/ve