Hydrogen infrastructure in future integrated energy systems

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German Aerospace Center

DLR Institute of Networked Energy Systems

- Space Administration
- Research institution
- Project Management Agency

- Aeronautics
- Space research and technology
- Transport
- Energy
- Security (cross-sectoral)
- Digitalisation (cross-sectoral)


Energy Systems Analysis


Energy System Technologies


Solar Energy

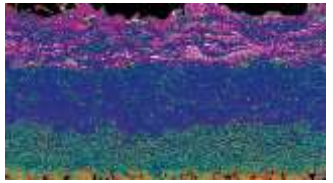

Wind Energy

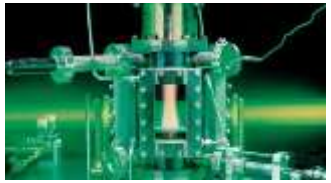






Image: Nonwarit/Fotolia


Energy Storage

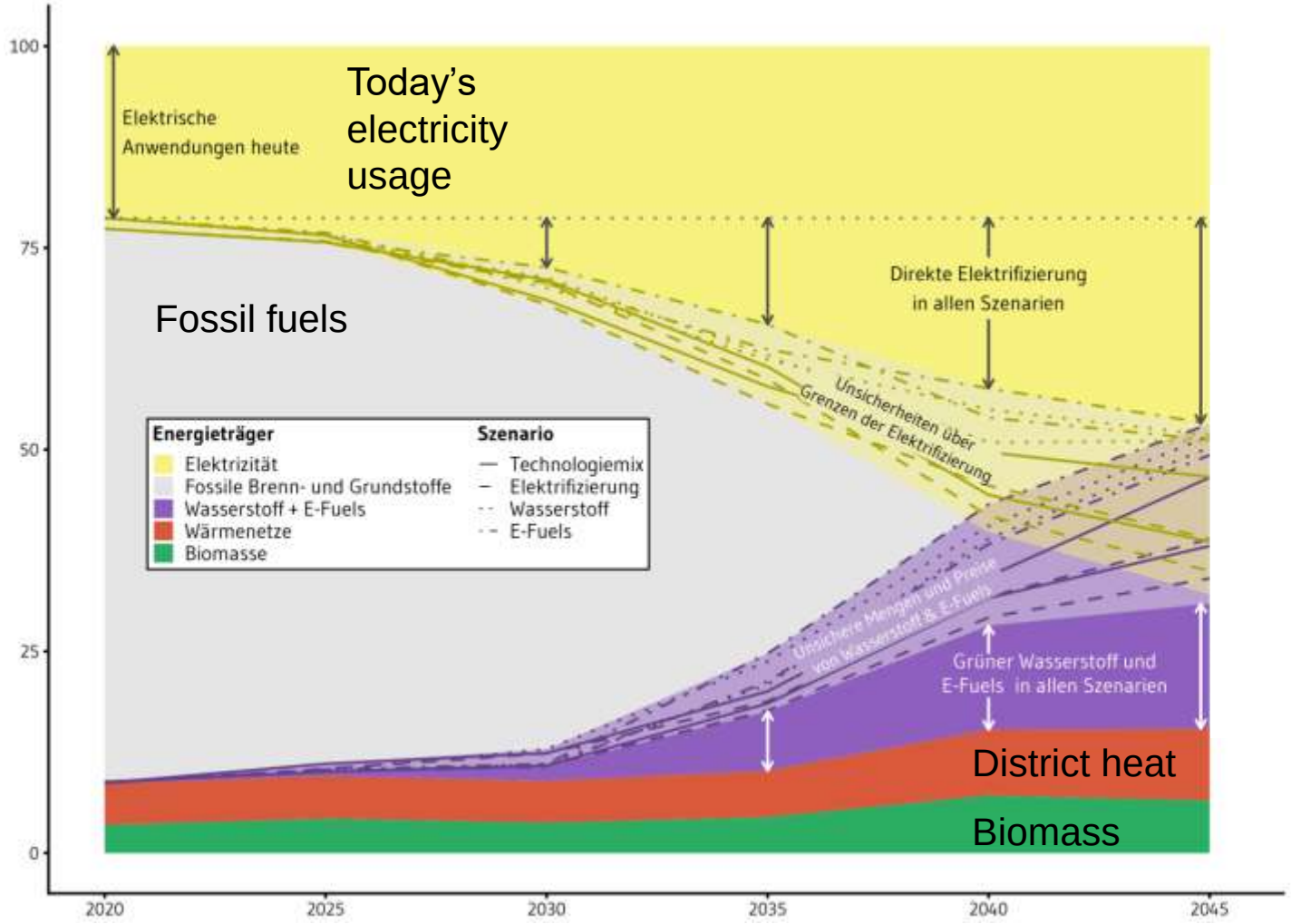

Energy Converters

DLR

Background

Complete decarbonization of the energy system cannot be realized without synthetic fuels, but what demand is to be expected?

Share in final energy



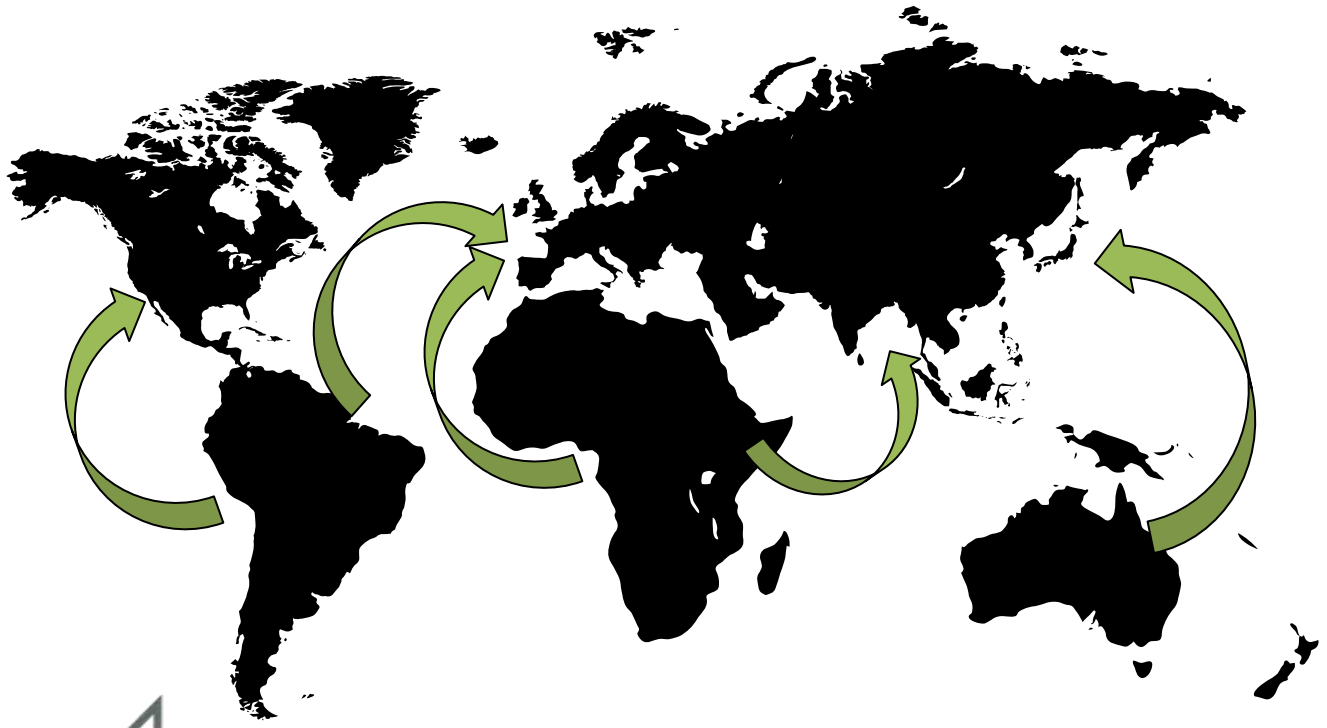
Direct electrification: passenger cars, buildings, industry

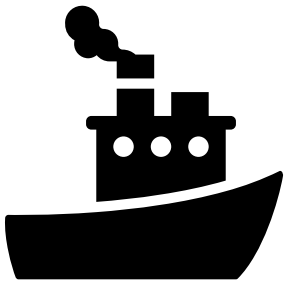
Either direct or indirect electrification: heavy-duty traffic, process heat

Indirect electrification (hydrogen and e-fuels): air traffic, ships, industry

Adapted from: Ueckerdt et al. 2021

Uncertainty about preferable technologies, fuels, production sites, transport means and routes





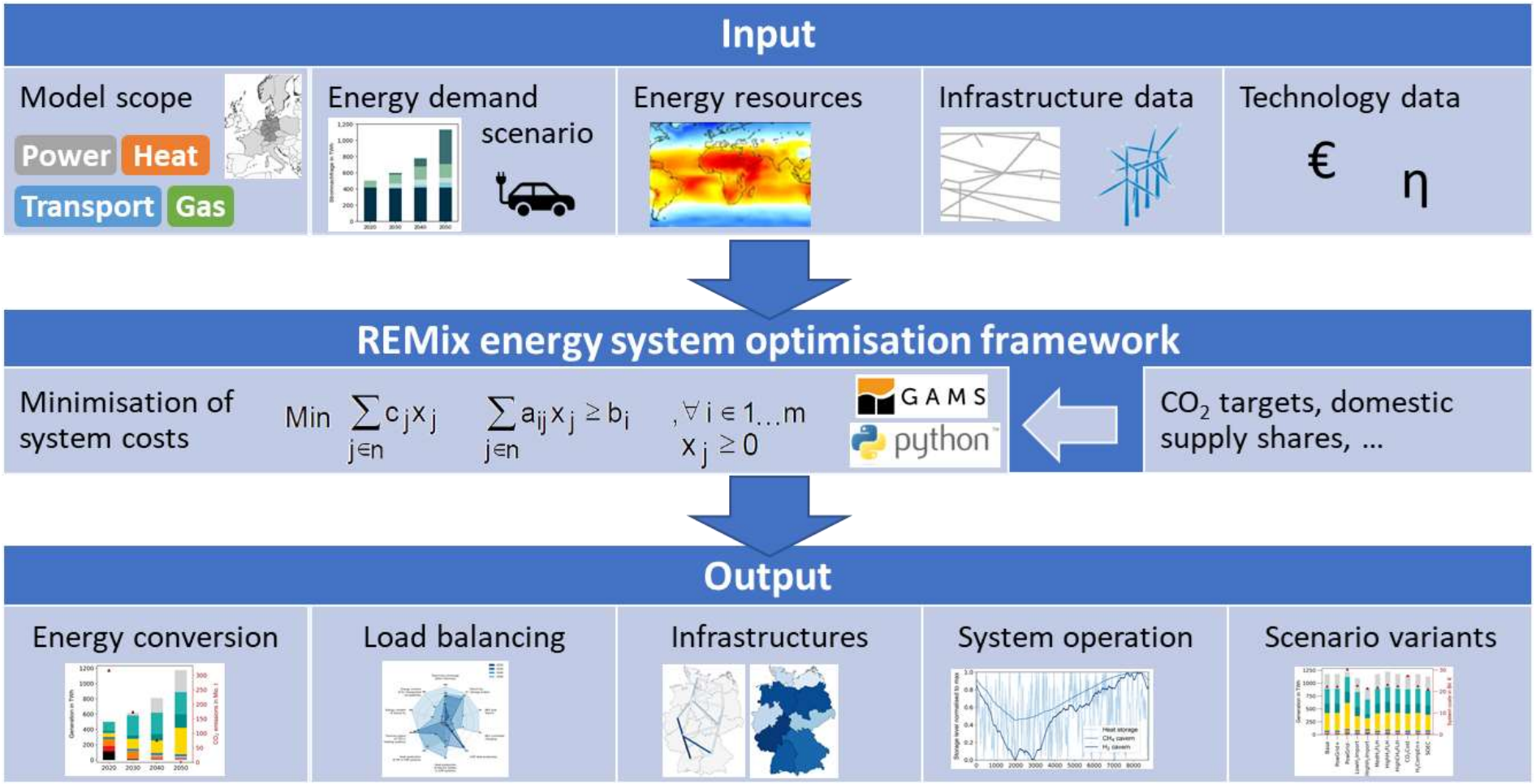
NH_3

GH_2 LH_2

CH_3OH

CH_4

Scenario analyses applying the REMix energy system modelling framework with integrated optimization of capacities and dispatch of all technologies

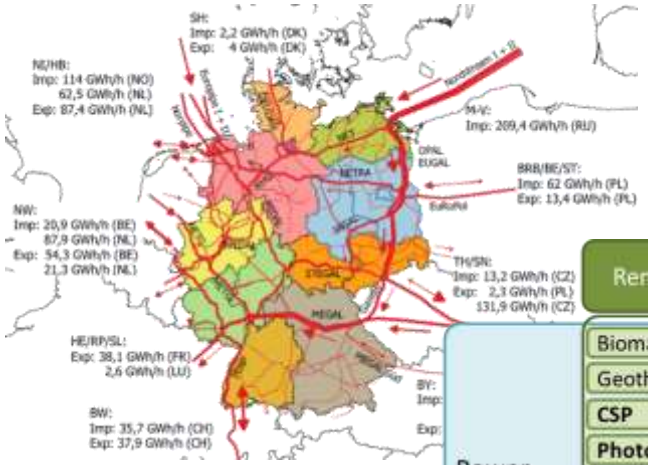


Hydrogen infrastructure deployment along the transformation to a zero-emission energy system – the case of Germany

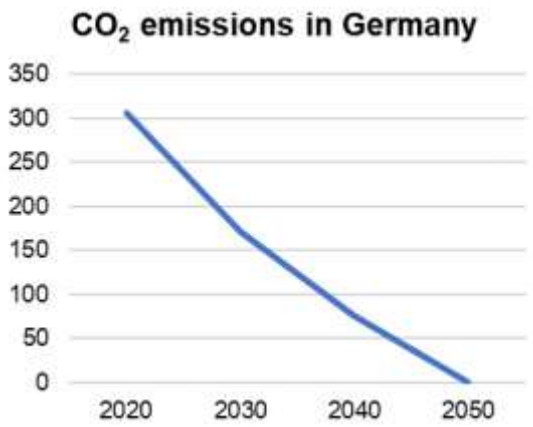
Model-based investigation of flexible sector coupling infrastructures requires regionalization, high temporal resolution, and a broad technology portfolio

Model scope

- Power sector
- Heat sector (buildings/industry)
- Electric / H_2 vehicles
- Liquid fuel usage
- Non-energy fuel usage

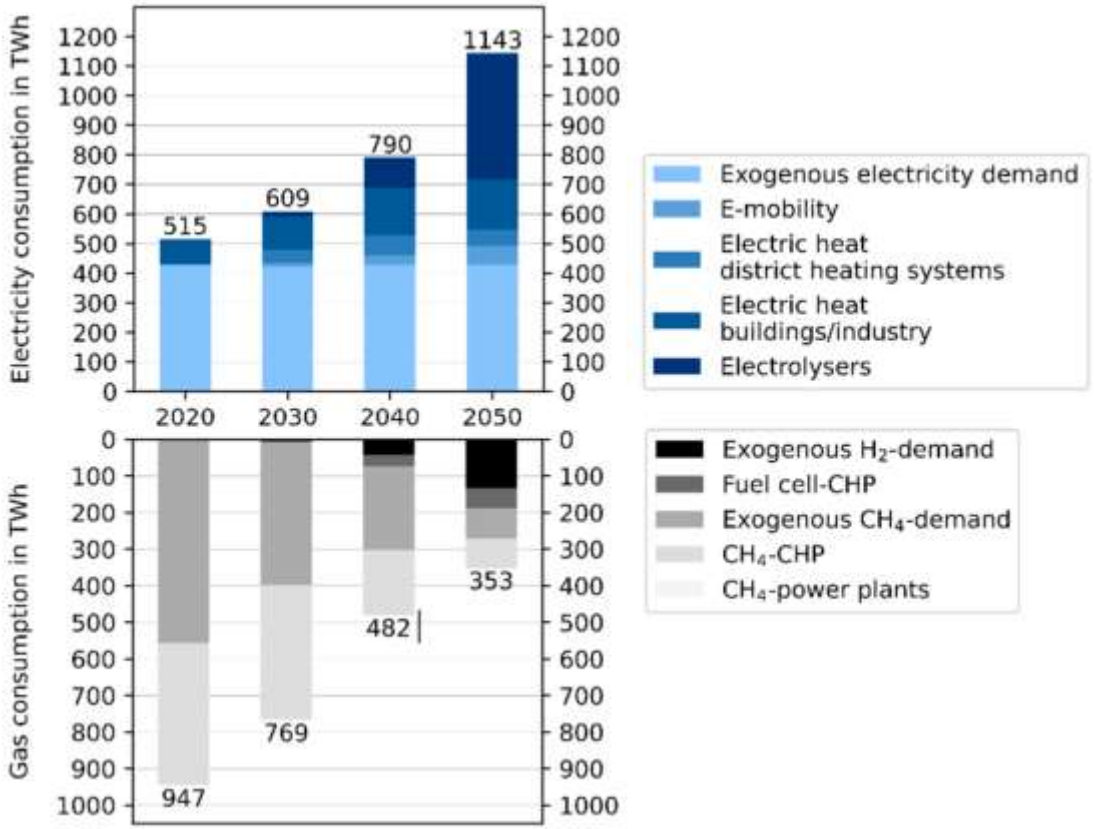


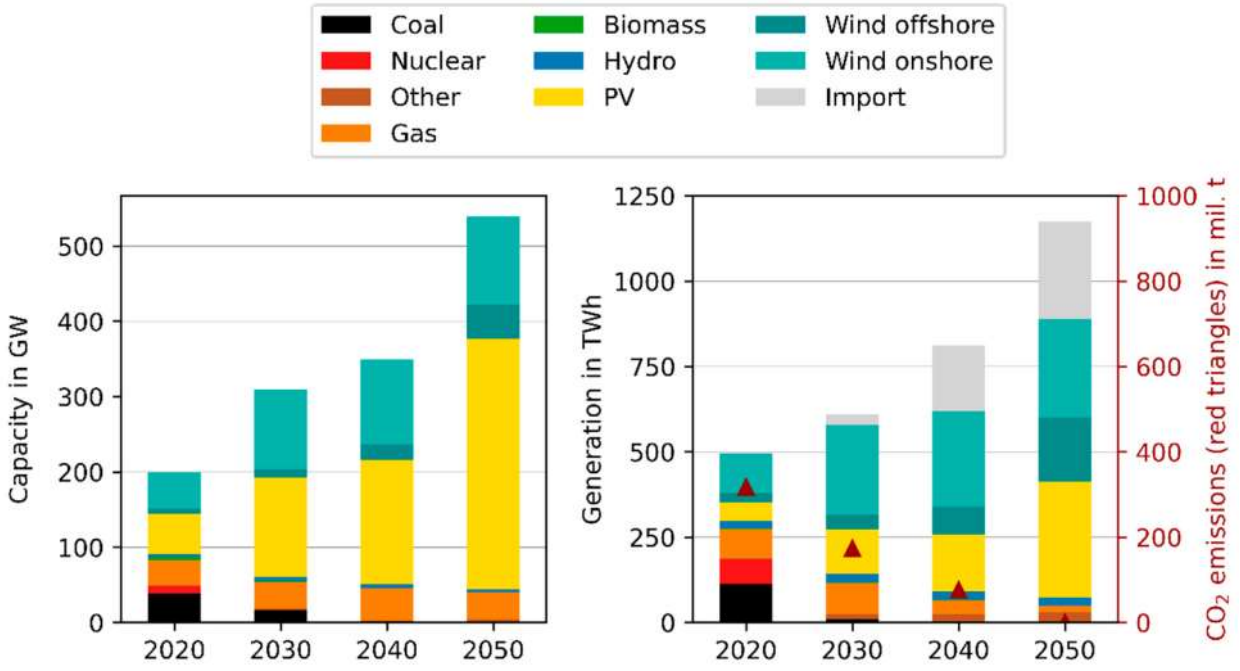
Sources: Gils et al. 2021, Schaffert et al 2022



	Renewable Energy	Conventional Energy	Balancing	
Power	Biomass power	Coal power	HV alternating current	Energy Transport
	Geothermal power	Lignite power	HV direct current	
	CSP	Nuclear power	Hydrogen pipelines	
	Photovoltaic	Gas turbines	Methane pipelines	
	Onshore wind power	Combined cycle (CCGT)	Pumped hydro storage	Storage
	Offshore wind power	Oil turbines	Battery storage	
	Run-of-the-river hydro		Gas cavern storage	
	Reservoir hydro power		Thermal storage (6 x)	
Heat (& Power)	Biomass CHP (2 x)	Gas engine CHP (3 x)	Hydrogen tank storage	
	Biomass heat	Gas CCGT CHP	Hydrogen cavern stor.	
	Solar heat (3 x)	Gas turbine CHP	Demand response (4 x)	Flexible Loads
	Fuel cell CHP	Coal CHP (2 x)	Hydrogen electrolysis	
		Lignite CHP (2 x)	Methanation	
		Oil CHP (2 x)	Battery vehicles (2 x)	
		Waste incineration CHP	Electr. heat pumps (7 x)	
			Electric boilers (11 x)	

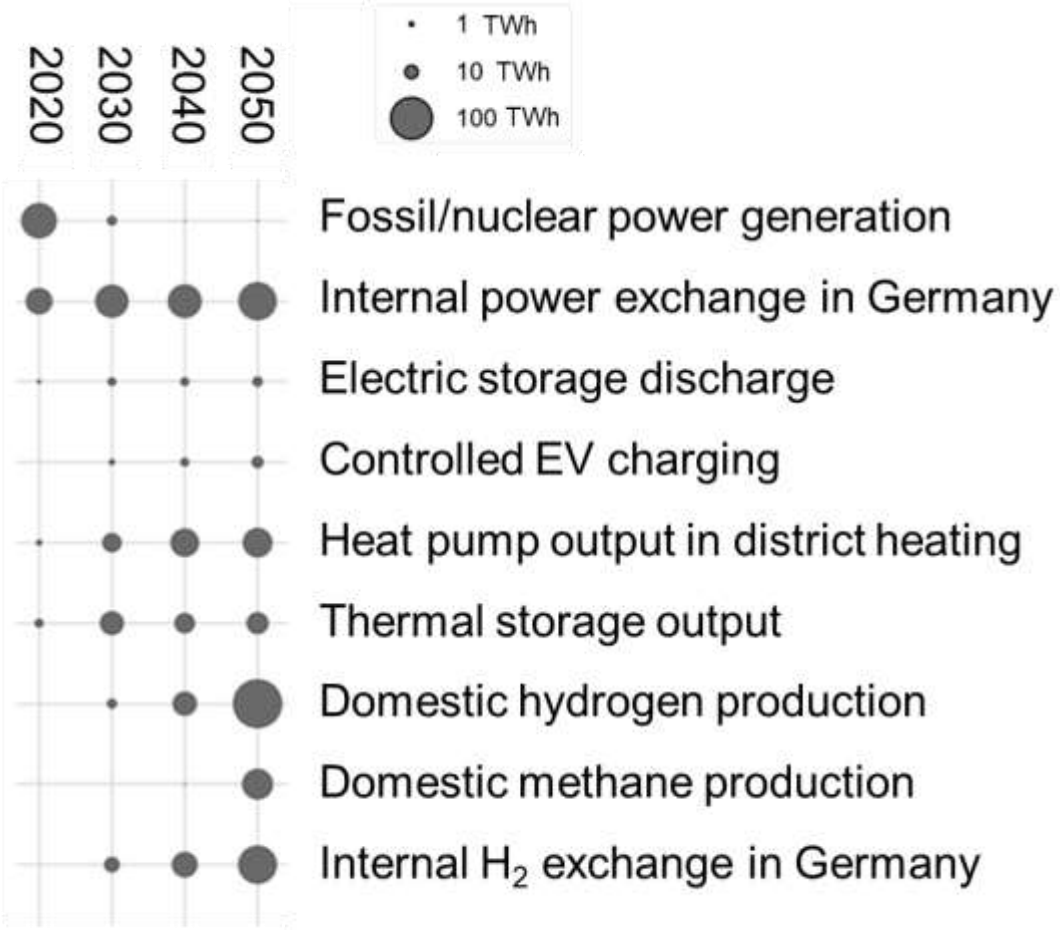
Urgent need for a steep increase in renewable energy capacities and sector coupling implementation





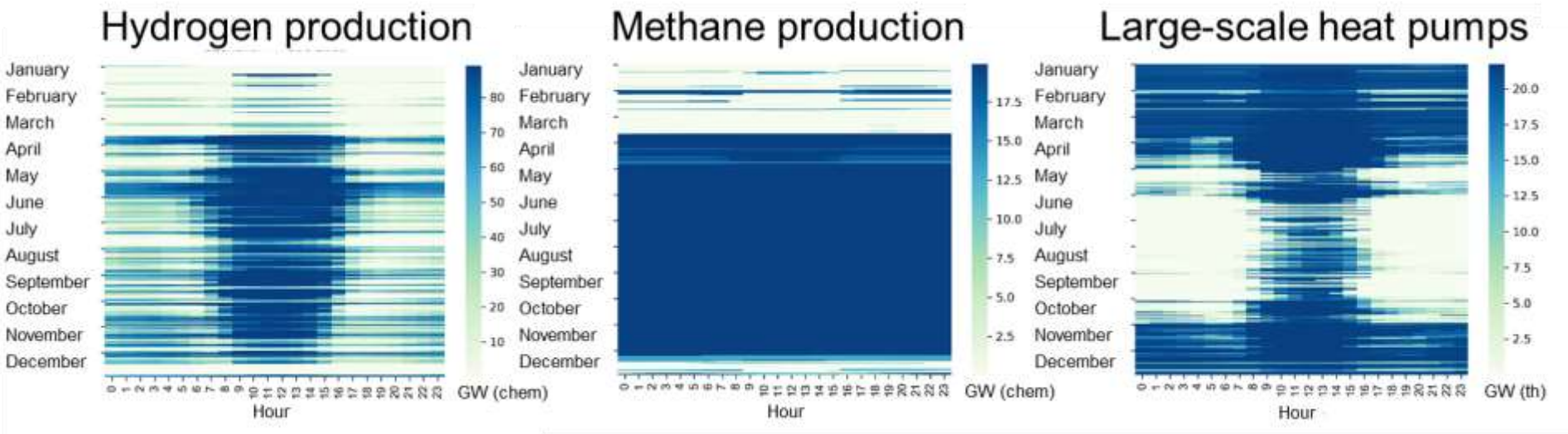
Source: Schaffert et al 2022

Flexible hydrogen production is one but not the only important element of energy sector coupling

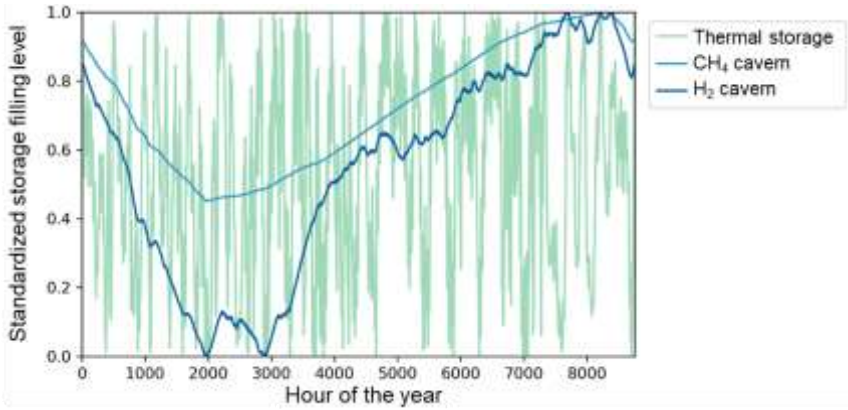


Source: Gils et al. 2021

Hydrogen is key element for providing seasonal balancing within a climate-neutral energy system

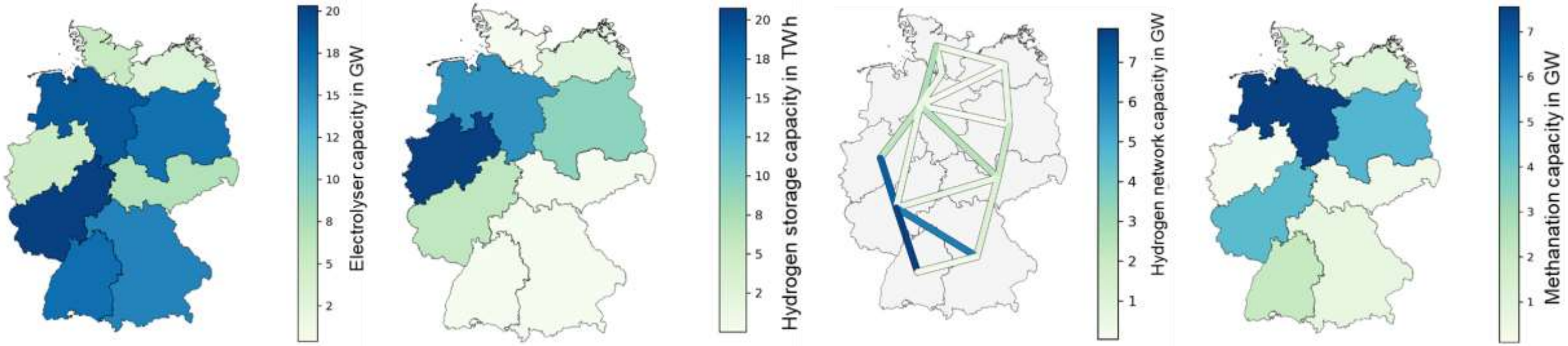


- Hydrogen production follows renewable power generation
- Methane production concentrates outside the heating season



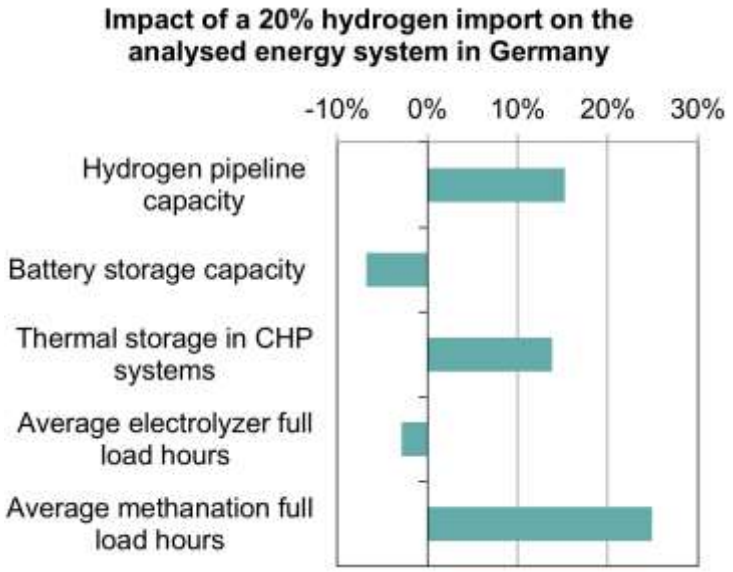
Source: Gils et al. 2021

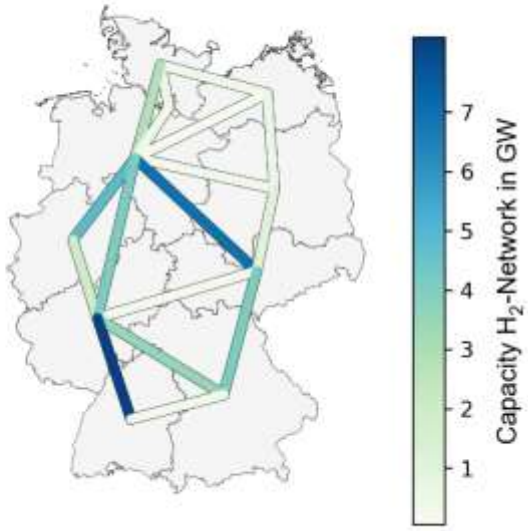
Assumptions on available and accessible potentials for renewable energy technologies strongly drive the spatial distribution of hydrogen infrastructure



Source: Gils et al. 2021

Power system benefits justify large-scale European hydrogen production despite higher specific costs





- Comparison to a model run with optional, ship-based hydrogen import realized at the North Sea coast
- Import is only chosen at fuel prices of ~ 1 €/kg of H_2

A broader scenario space analyzing hydrogen infrastructures and imports in a carbon-neutral European energy system

The role of energy imports from the Maghreb and the British Isles and their dependency on national sourcing strategies as well as grid expansion

Sector-coupled energy system with broad capacity expansion

Not considered: air and ship traffic, CCS, Power-to-Liquid

Zero emission

2050

Energy souvereignity in continental Europe

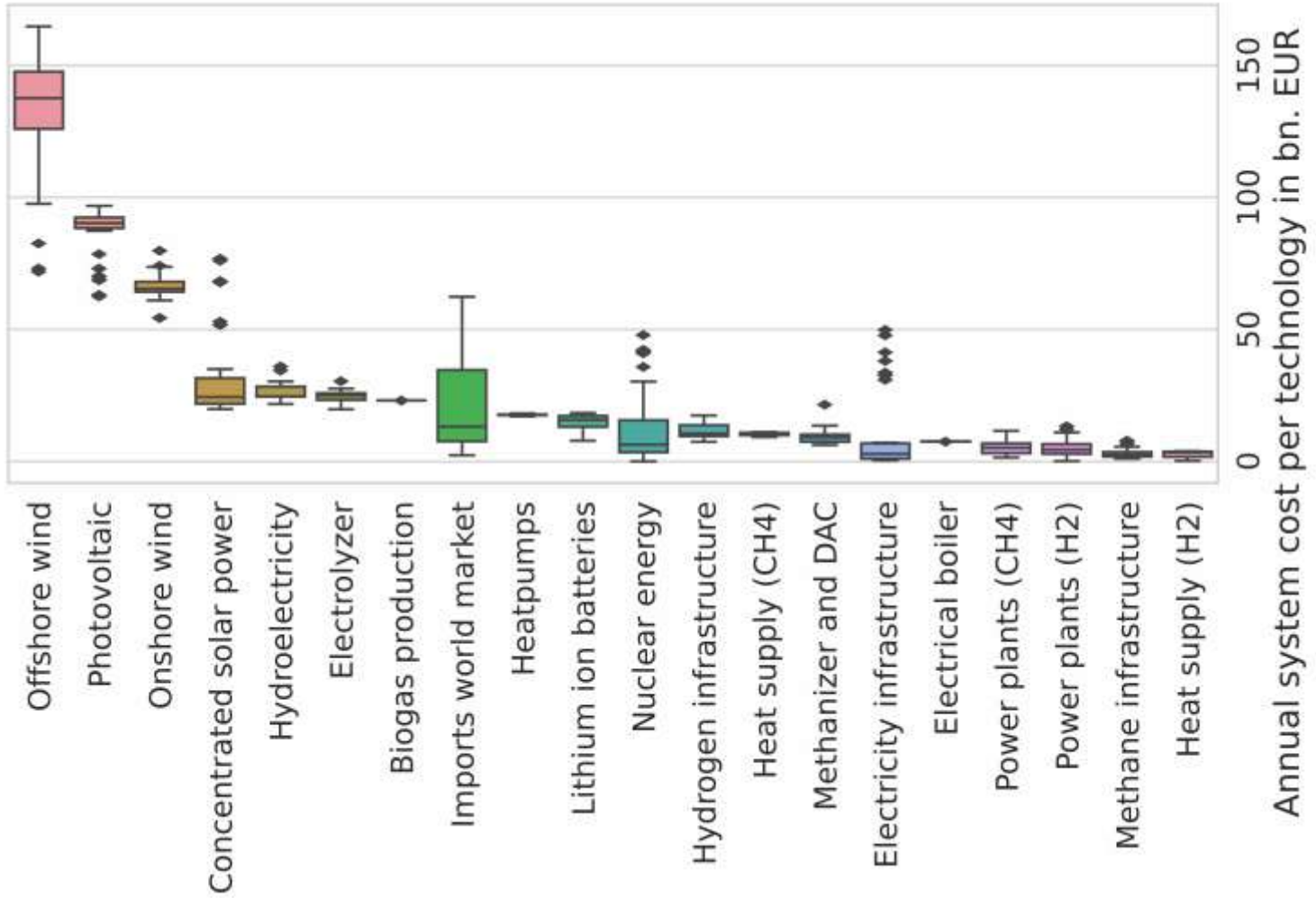
- All energy carriers are produced in continental Europe to the extent possible.
- Cross-border trade with Maghreb contries and British Isles has neutral energy balance.

Energy partnerships enable imports

- Energy partnerships ensure imports from Maghreb countries and British Isles for all energy carriers.

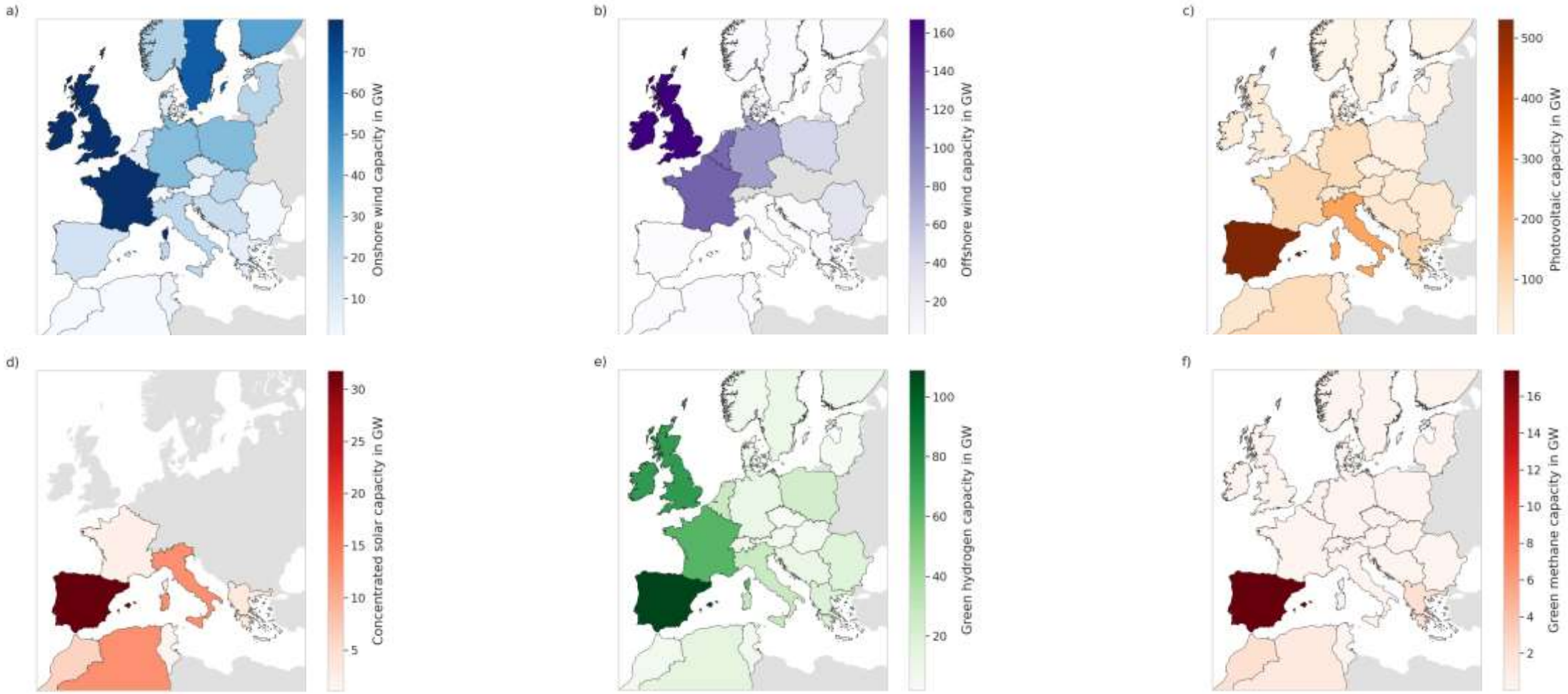
Source: Wetzel et al.

Robust investments into onshore wind, PV and most sector coupling options, higher scenario dependency for offshore wind, CSP and nuclear power



Source: Wetzel et al.

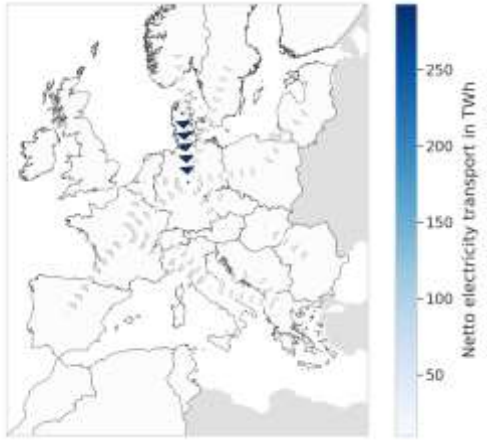
Broad distribution of onshore wind and PV across Europe, spatial concentration of offshore wind, CSP and hydrogen production

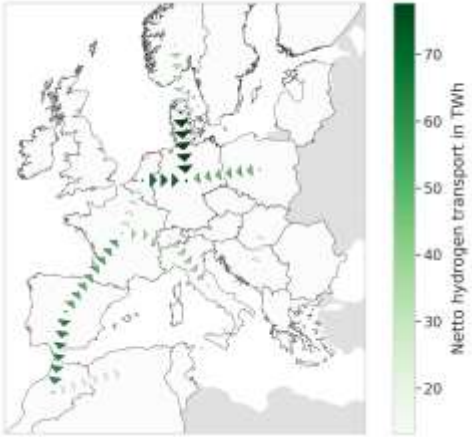


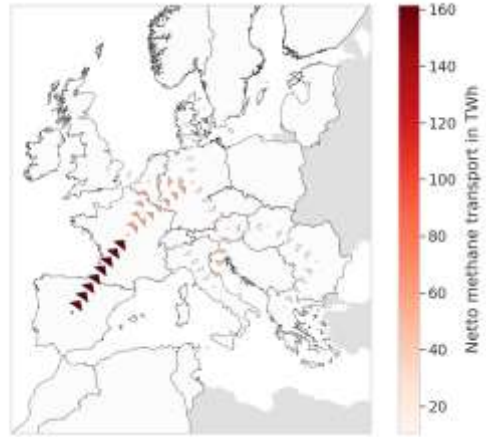
Source: Wetzel et al.

Network structure heavily dependent on energy policy, with some trends, e.g. central Europe being a major importer from the peripheral regions

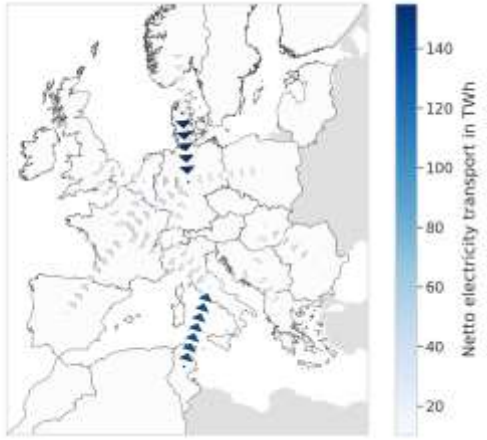
Energy souvereignity in continental Europe

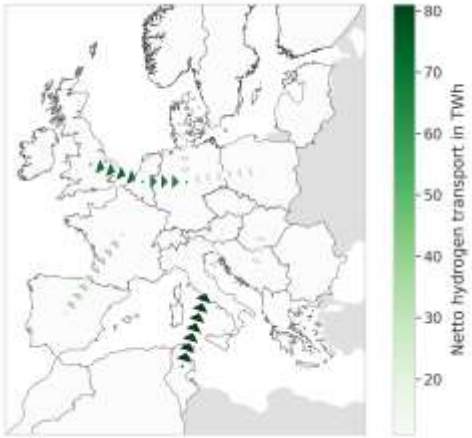


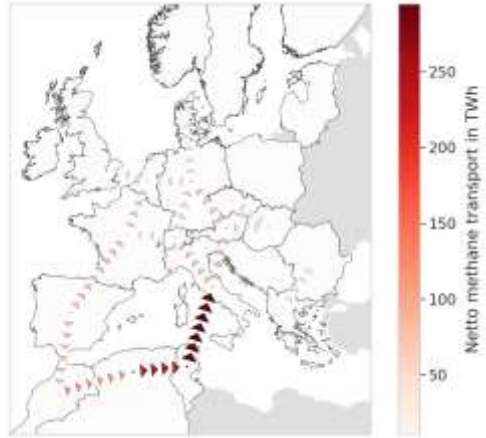




Energy partnerships enable imports







Source: Wetzel et al.

Concluding thoughts

- Domestic hydrogen production and storage has huge power system benefits and should complement imports
- To realize these benefits, electrolyzers should be considered part of the energy system, not the industry
- There is a range of options for a more centralized or decentralized hydrogen production with similar costs
- Pipeline imports of green hydrogen to Europe, e.g. from the MENA region are promising
- The installation of a European hydrogen network can to a high degree rely on repurposed of gas pipelines

Acknowledgement and contact

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