Hydrogen infrastructures in integrated energy systems – determinants and modelling options

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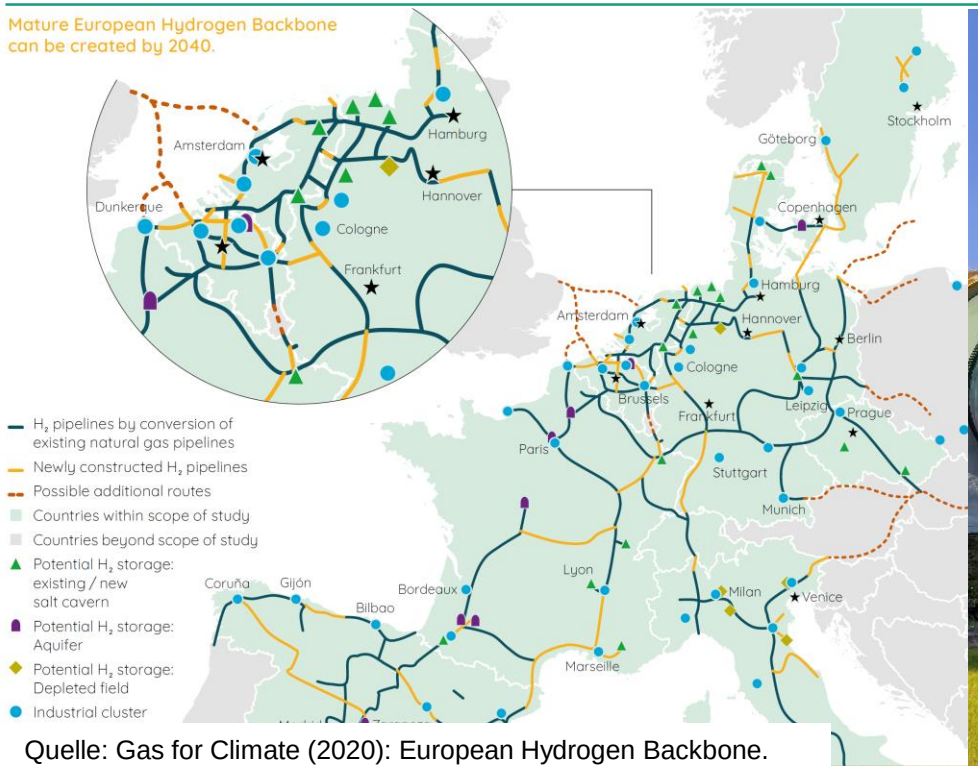
Prof. Dr. Mario Ragwitz



Quelle: Gas for Climate (2020): European Hydrogen Backbone.

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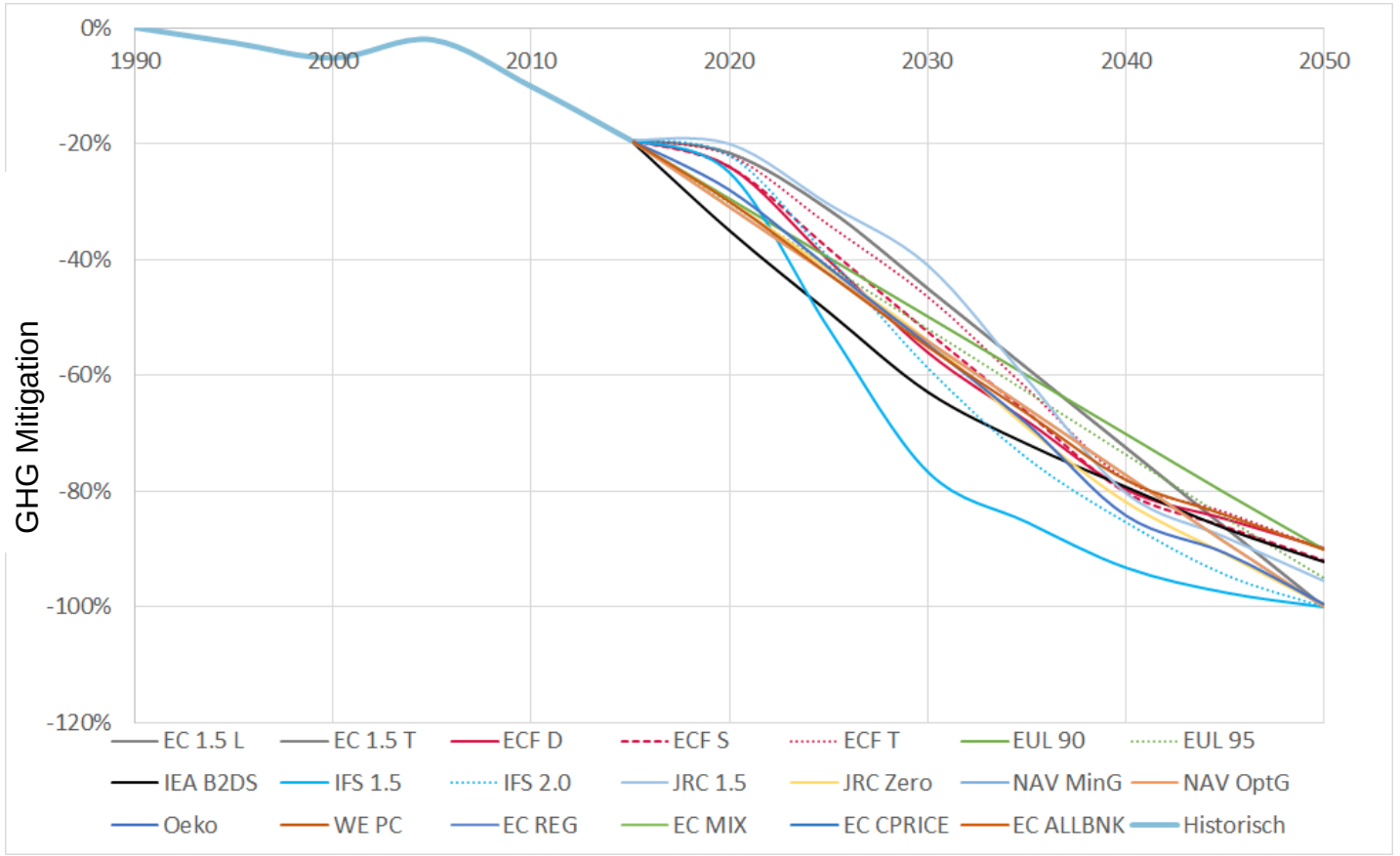
Meta-Analysis of main recent EU scenarios on GHG-neutral energy systems

Studie

EU

Kürzel	Studien
EC 2020	Commission Staff Working Document – Impact Assessment
JRC 2020	Towards net-zero emissions in the EU energy system by 2050
EC 2019	Industrial Innovation – Pathways to deep decarbonisation of industry Part 2
EC 2018	A Clean Planet for all

- 20 Scenarios
- GHG-Mitigation
  - 2030: 41 to 77 %
  - 2040: 70 to 93 %
  - 2050: 90 to 100 %



Source: Wietschel, Hebling, Ragwitz, et al. 2021, Study for the National Hydrogen Council (NWR)

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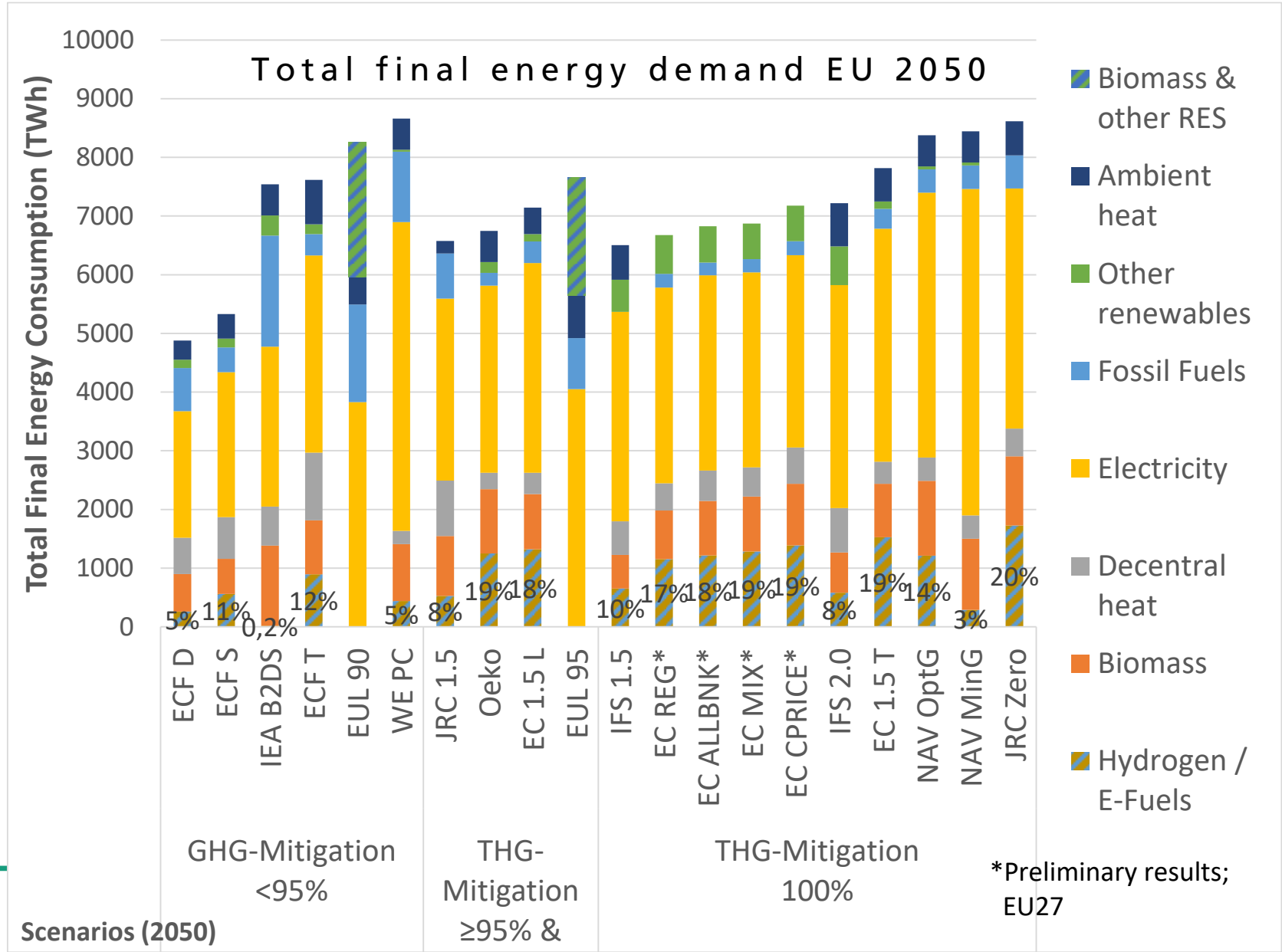
Meta-Analysis of main recent EU scenarios on GHG-neutral energy systems

- Direct use of electricity dominates in all scenarios
- Hydrogen / e-fuel demand in GHG-neutral scenarios varies between 3% and 20%
- H_2- and e-fuel demand increases with the ambition level of GHG-target
- Biomass potentials and deployment has a strong impact on hydrogen demand



*Preliminary results; EU27

Three components will define the future of hydrogen transport options

None of these questions can be answered independently! Therefore new models are needed to consider the relevant interactions.

Demand	Infrastructures	Supply
What is the hydrogen demand expected in different sectors?	To which extent should energy be transported by electricity and gas?	Where will green hydrogen be produced? At which costs?
Which spatial distribution of demand will be expected?	What is the impact of the interaction between gas and electricity grids on their topology?	What is the contribution of transport cost compared to generation costs?

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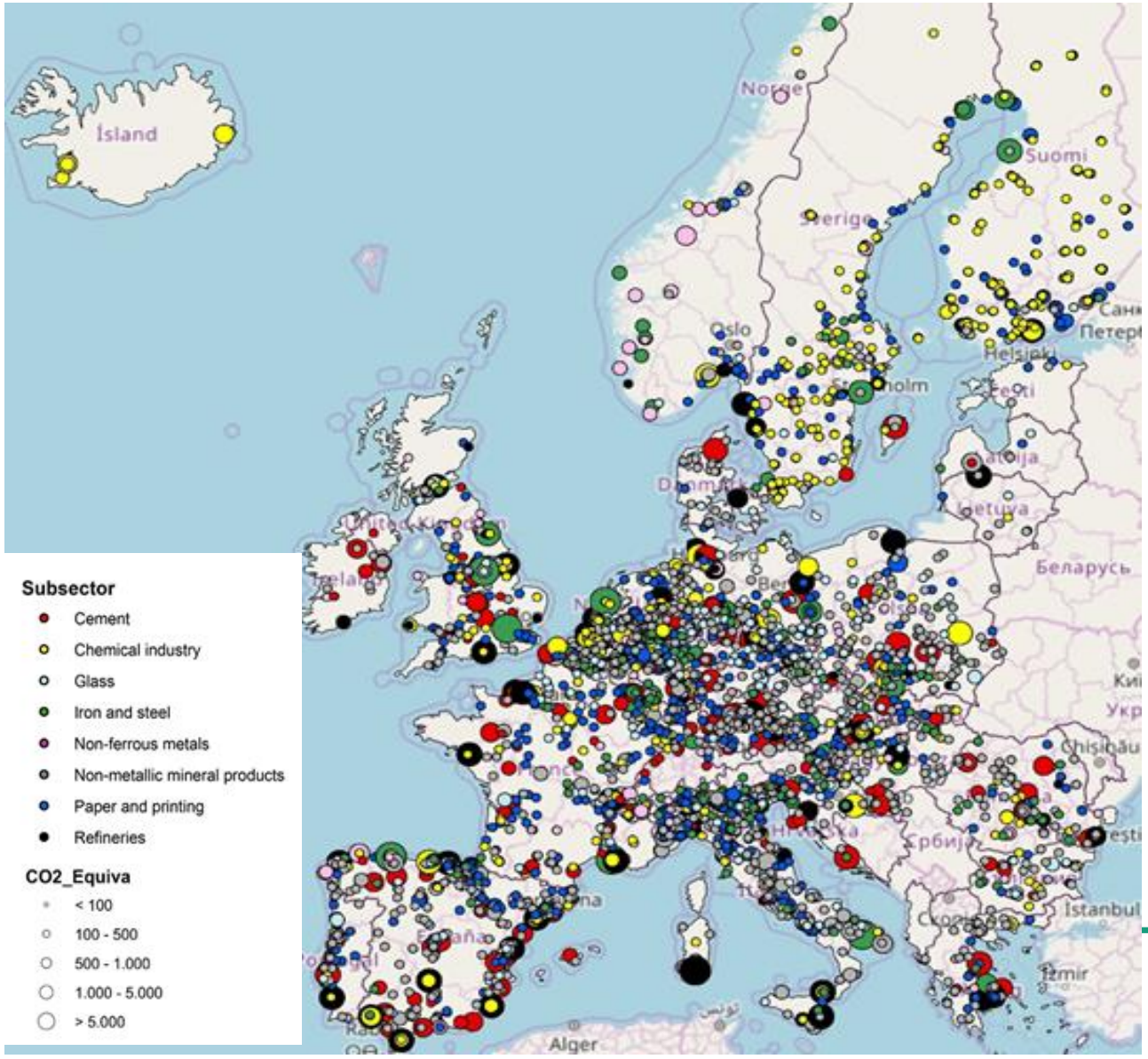
Which industry sectors will use hydrogen as a feedstock or fuel?



Forecast - Open database of energy-intensive industry in Europe

- Database of energy-intensive industrial sectors: cement, basic chemicals, glass, iron & steel, non-ferrous metals, non-metallic minerals, paper, refineries
- In particular hydrogen demand can be calculated, site specifically based on known reinvestment cycles
- Coverage: ca. 5500 companies in the EU – based on the emission registries E-PRTR** und EU-ETS***
- Spatial resolution: NUTS 3

Sources: P. Manz, et al. Sustainability 2021, 13(3), 1439, Fraunhofer ISI
European Pollutant Release and Transfer Register
European Union Emission Trading System

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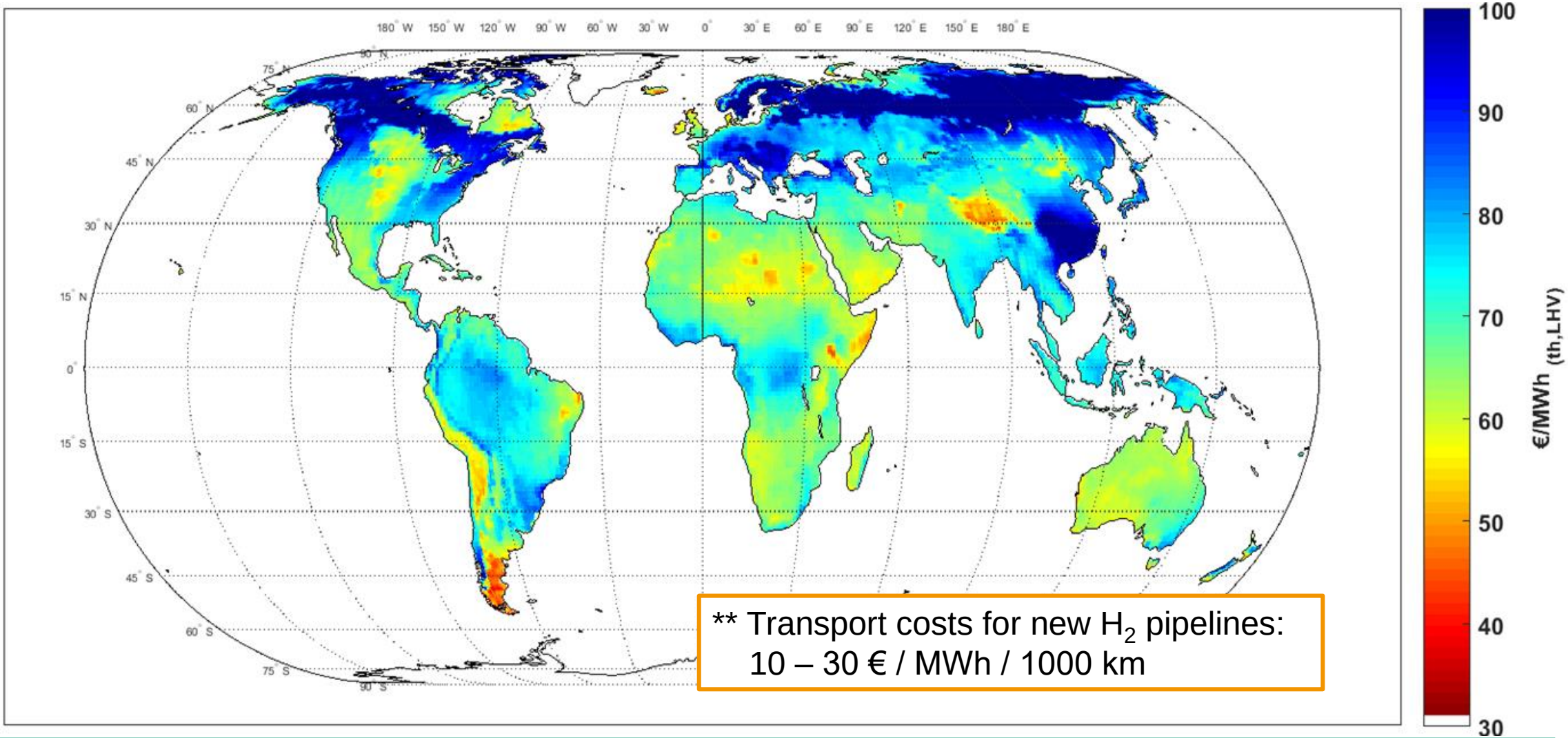
Import of synthetic fuels (E-fuels) - Generation costs of green hydrogen *



Source: * Jensterle et al. 2019 (LUT-model)

** Source: AGORA (2021)

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Models for the analysis of integrated energy systems

Supply

Fix Portfolio of renewable energies, power plants, storage, imports.

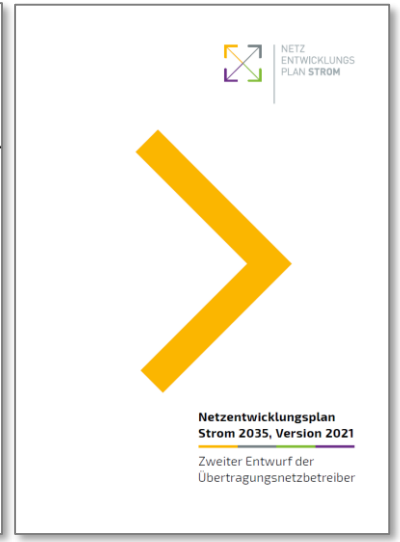
Transport electricity

Transport natural gas

Transport H_2

Demand

Fix Portfolio electricity, natural gas hydrogen, liquid fuels, biomass.



Spatial resolution	Copper plate	Transmission	Distribution	District
Temporal resolution	Year	Hour	Second	
Field of application	Investment-Planning		Operation	
Modelling-Ansatz	Optimisation		Simulation	

Quelle: FNB (2021): Netzentwicklungsplan Gas 2020–2030

Quelle: ÜNB (2021): Netzentwicklungsplan Strom 2035, Version 2021

Models for the analysis of integrated energy systems

Supply

Fix Portfolio of renewable energies, imports.

- Transport electricity
- Transport nat. gas
- Transport H_2
- Transformation
- Storage

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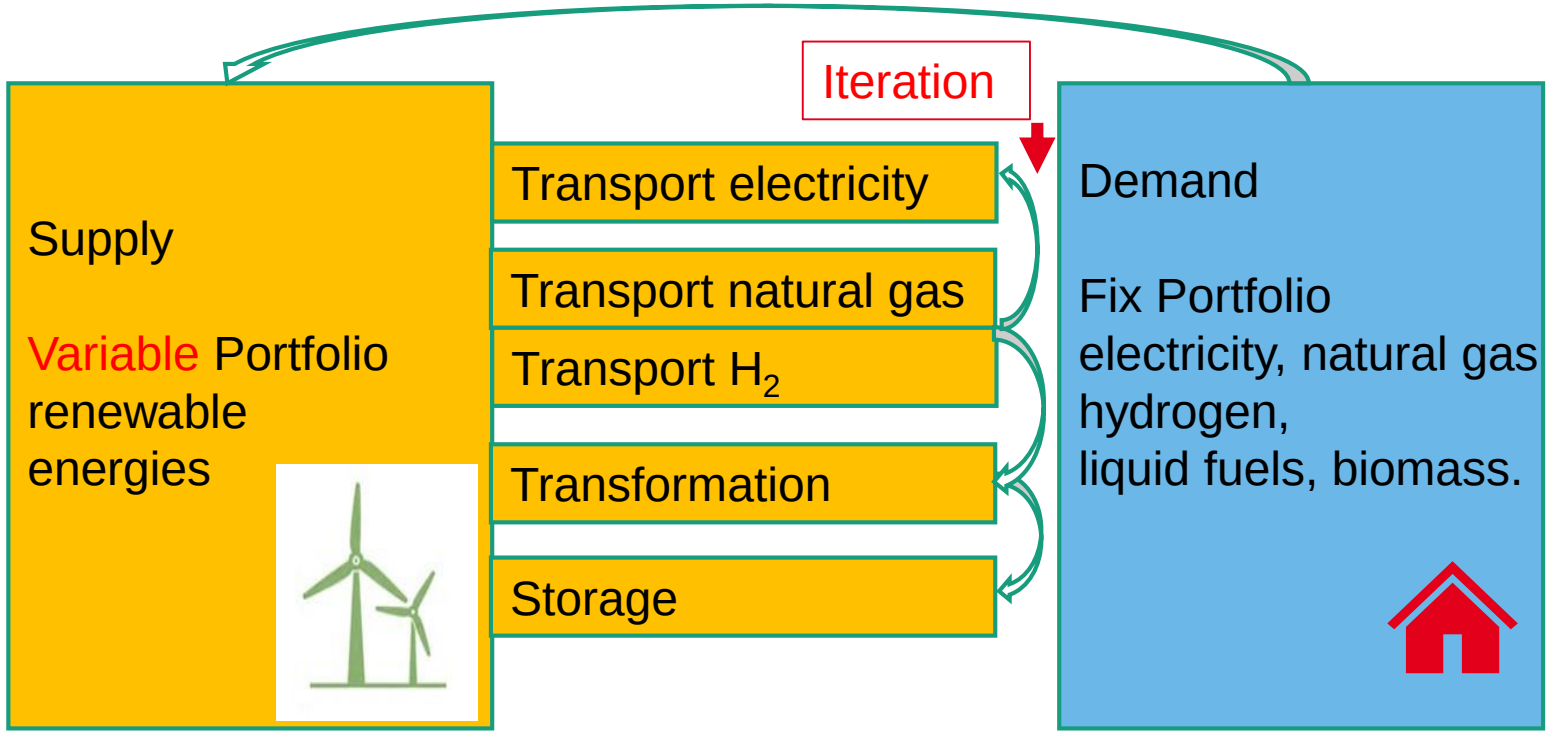
**Quelle: Infrastructure Outlook 2050: A joint study by Gasunie and TenneT on integrated energy infrastructure in the Netherlands and Germany (2019).
https://www.gasunie.nl/en/expertise/system-integration/infrastructure-outlook-2050

Models for the analysis of integrated energy systems



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Quelle: Pfluger et al (2018)

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Models for the analysis of integrated energy systems

Supply

Variable Portfolio renewable energies

Transport electricity

Transport natural gas

Transport H_2

Heat grids

Transformation

Storage

Demand

Variable Portfolio Final energy demand

Integrated models for **Grid-based Multi-Energy-Systems**

[1] **PyPSA**, [2] Calliope
[3] oemof, [4] urbs

Spatial resolution	Copper plate	Transmission	Distribution	District
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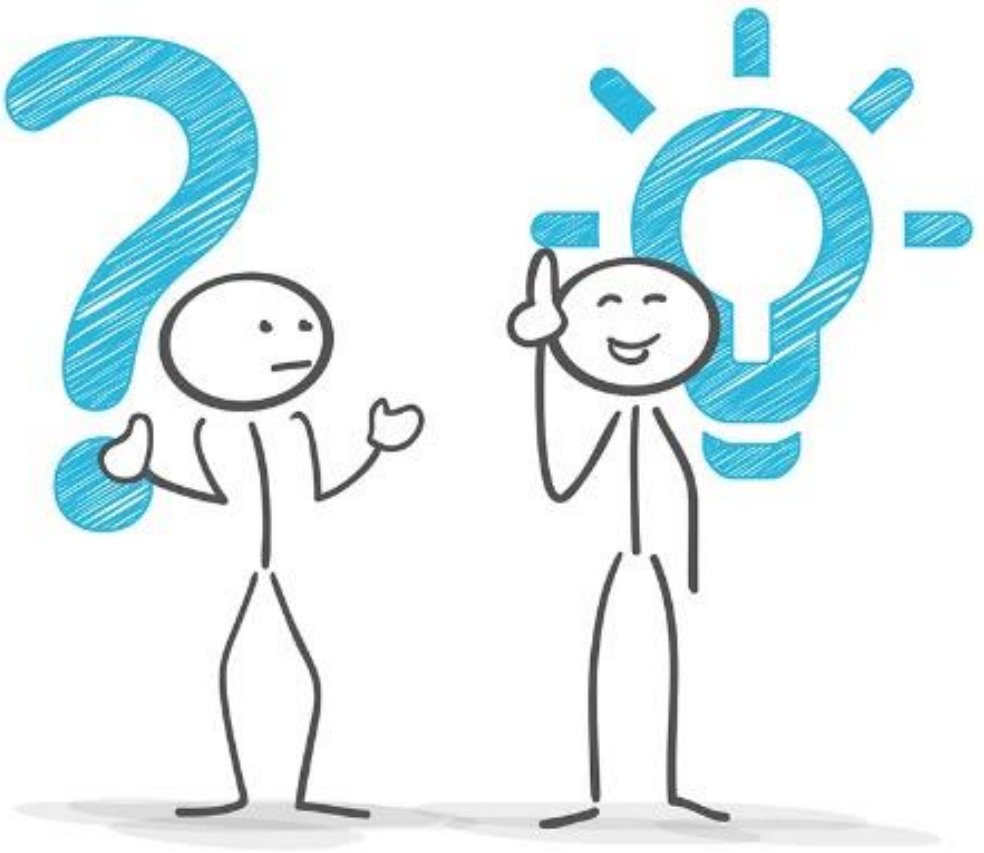
Conclusions

- Sector coupling will be a dominant property of future climate neutral energy systems.
- The share of electricity based sector coupling, hydrogen and synthetic fuels is characterized by high uncertainty in current studies.
- Besides uncertainties in general input data the challenge of fully integrated modelling of sector coupled infrastructure is a main reason for the broad spectrum of results.
- Most studies show a high demand of hydrogen, therefore dedicated hydrogen infrastructures will be needed.
- The detailed assessment of hydrogen demand and supply at high spatial resolution is needed in order to determine the topology of the infrastructures.
- Fully integrated modelling of demand, supply and electricity, gas / hydrogen / heat infrastructures at high resolution are required to assess the optimal energy infrastructures.
- Therefore models for grid-based multi-energy-systems are needed.

Q&A



Source: Rheumalis 2019