Hydrogen infrastructures in integrated energy systems – determinants and modelling options

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

- **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)
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%
- H₂ and e-fuel demand increases with the ambition level of GHG-target
- Biomass potentials and deployment has a strong impact on hydrogen demand
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**
- What is the hydrogen demand expected in different sectors?
- Which spatial distribution of demand will be expected?

**Infrastructures**
- To which extent should energy be transported by electricity and gas?
- What is the impact of the interaction between gas and electricity grids on their topology?

**Supply**
- Where will green hydrogen be produced? At which costs?
- 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

** Transport costs for new H₂ pipelines: 10 – 30 € / MWh / 1000 km

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 H₂

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

Spatial resolution
Temporal resolution
Field of application
Modelling-Ansatz

Copper plate
Transmission
Distribution
District

Year
Hour
Second

Investment-Planning
Operation
Simulation

Models for the analysis of integrated energy systems

Supply
Fix Portfolio of renewable energies, imports.

Transport electricity
Transport nat. gas
Transport H₂
Transformation
Storage

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

Spatial resolution
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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).**

Models for the analysis of integrated energy systems

Supply
Variable Portfolio renewable energies

Transport electricity
Transport natural gas
Transport H₂

Transformation
Storage

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

Spatial resolution
Temporal resolution
Field of application
Modelling-Ansatz

Copper plate
Year
Investment-Planning
Optimisation

Transmission
Hour
Operation

Distribution
Second
Simulation

District

Models for the analysis of integrated energy systems

Integrated models for Grid-based Multi-Energy-Systems

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.