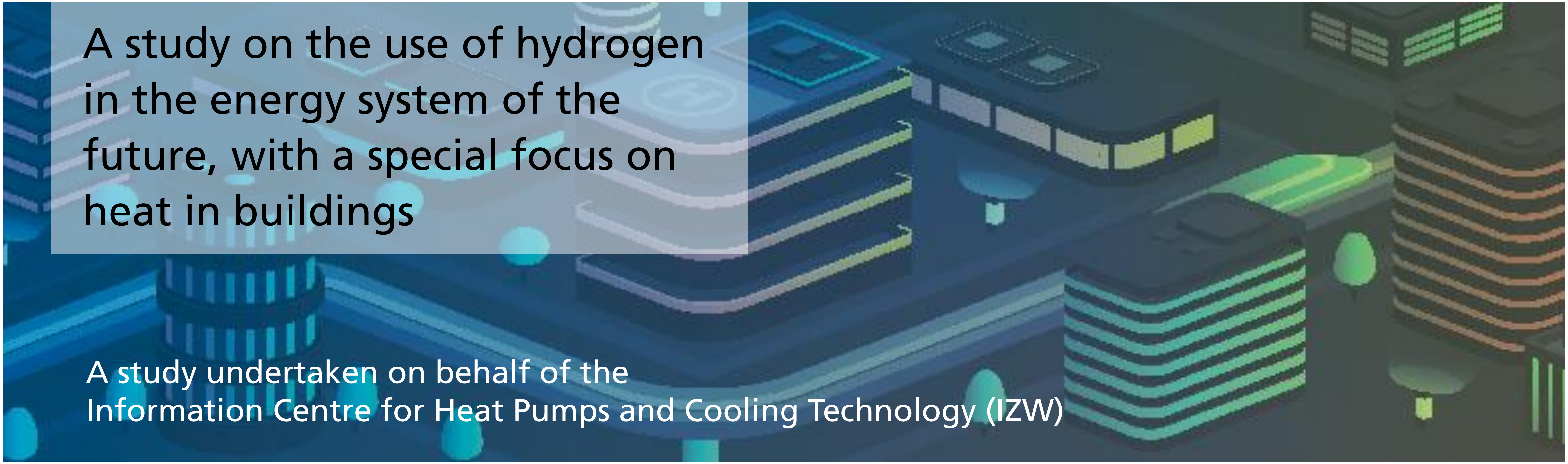
HYDROGEN IN THE ENERGY SYSTEM OF THE FUTURE: FOCUS ON HEAT IN BUILDINGS

Norman Gerhardt, Jochen Bard, Richard Schmitz, Michael Beil, Maximilian Pfennig, Dr. Tanja Kneiske
Fraunhofer Institute for Energy Economics and Energy System Technology (IEE)



A study on the use of hydrogen in the energy system of the future, with a special focus on heat in buildings

A study undertaken on behalf of the
Information Centre for Heat Pumps and Cooling Technology (IZW)

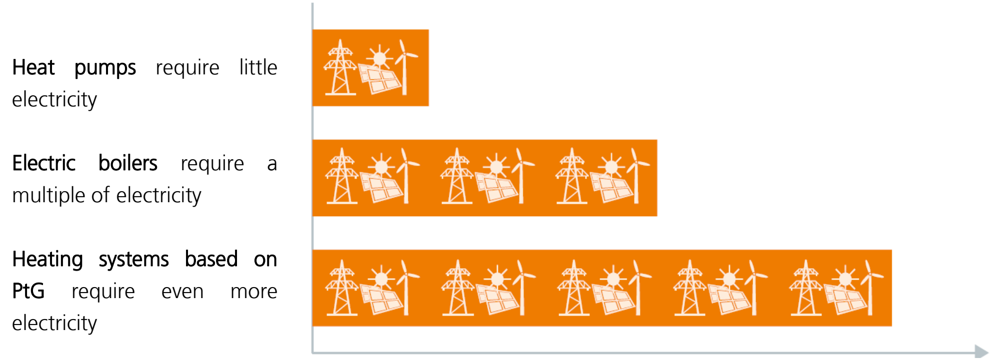
HYDROGEN IN THE ENERGY SYSTEM OF THE FUTURE: FOCUS ON HEAT IN BUILDINGS

Norman Gerhardt, Jochen Bard, Richard Schmitz, Michael Beil, Maximilian Pfennig, Dr. Tanja Kneiske
Fraunhofer Institute for Energy Economics and Energy System Technology (IEE)

- **Introduction**
- **Ranking applications and evaluating future demand**
- **Evaluating future supply**
- **Technical requirements and implications for natural gas grids**
- **Comparison: Decentralized heat supply with heat pumps**
- **Conclusions**

Introduction

- **Current discussion – Direct use of hydrogen (H_2) / infrastructure**
- **European Green Deal / German Hydrogen Strategy:**
  - Carbon-neutral Europe by 2050 & increased ambition for 2030
  - Industrial policy opportunities as a supplier of key technologies
  - Transformation of industrial production & options in transport
  - → Unresolved issue in building heating → current European Ecodesign Directive
- **A consensus on PtG has arisen in recent years**
  - The direct use of electricity should be maximized whenever technically feasible
  - PtG is not an option for supplying heat energy to buildings (figure)
    - Conversion losses
(electricity → electrolysis → methanation → heat)
    - Efficiency advantages with heat pumps
(electricity + environmental heat → heat)



Source: Federal Ministry of Economics and Energy, "Strom 2030: Langfristige Trends - Aufgaben für die Zukunft", 2017

Ranking fields of application for hydrogen from an energy system perspective

1. Where grey H_2 is used today

- Replacement of natural gas reformers with green hydrogen, especially for ammonia and methanol production

2. Direct use of H_2 in industry

- Generation of process heat in industrial facilities, e.g. for steel production

3. Direct use by power plants during dark doldrums

- Use of H_2 for power generation and CHP operation during low renewables feed-in, as well as for industrial process heat and district heating grids (during heating periods)

4. Unavoidable consumption of hydrocarbons

- International air and sea transport
- Substitution of fossil raw materials in the chemicals industry

5. Direct use of H_2 in transport

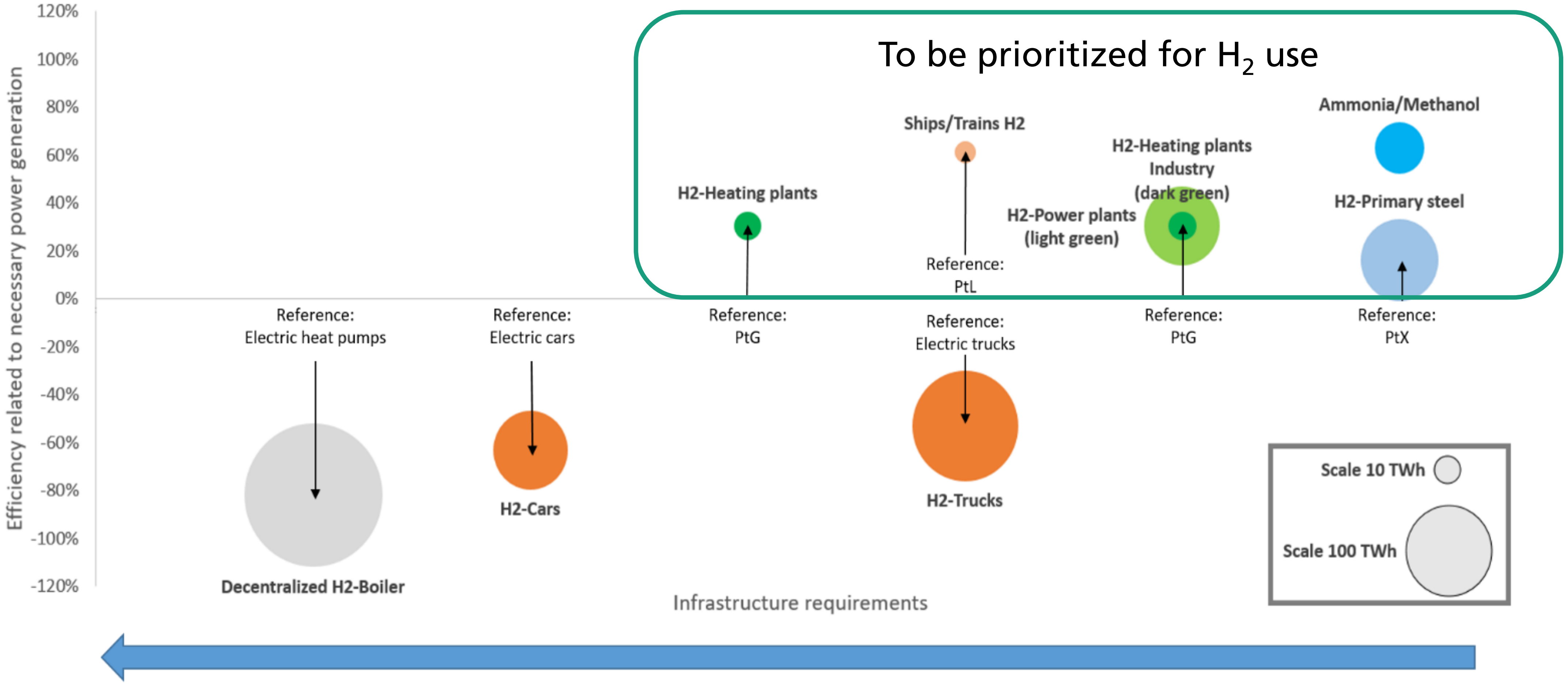
- In competition with electric vehicles; niche technology for trains/ships

6. Direct use of H_2 for low temperature heat

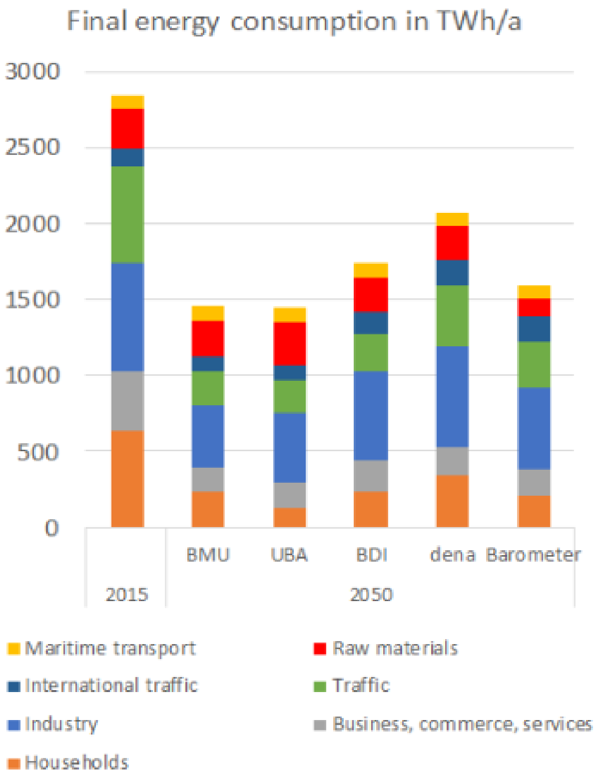
- In competition with air and ground source heat pumps

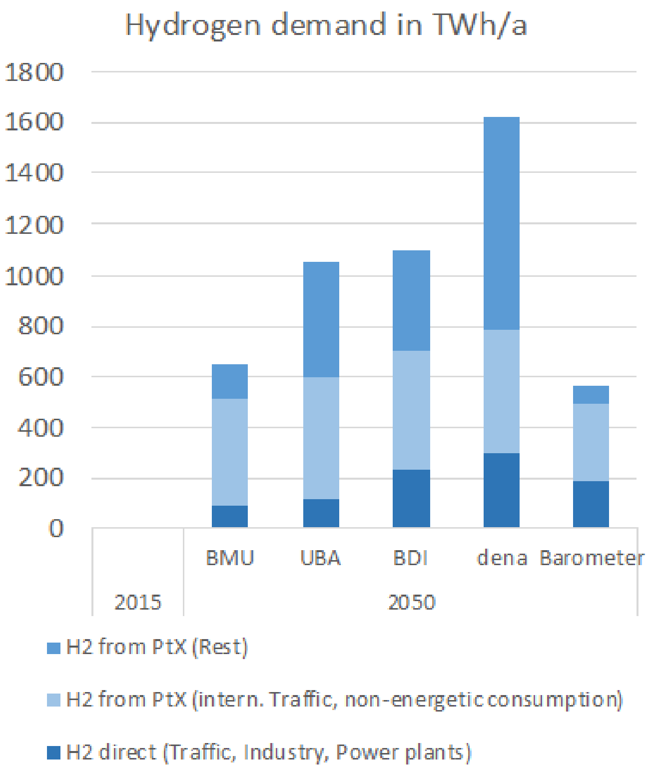
Ranking fields of application for hydrogen from an energy system perspective

Fields of application can be clearly prioritized according to efficiency and infrastructure requirements



Energy consumption estimates in recent in studies – spotlighting hydrogen



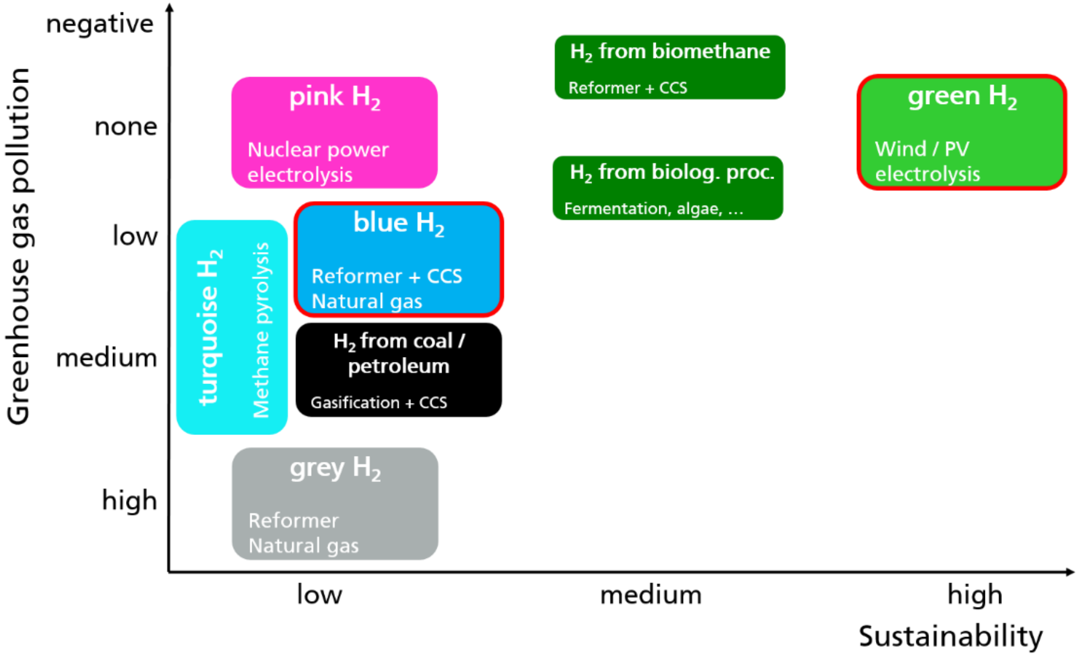


Authors' figure based on data from studies and their extrapolation, as the cost of creating centralized hydrogen infrastructure has not yet been estimated to date.

In efficient scenarios that project -95% GHG reduction, hydrogen demand (direct/indirect) is 600 to 1,000 TWh/a (depending on biomass use).

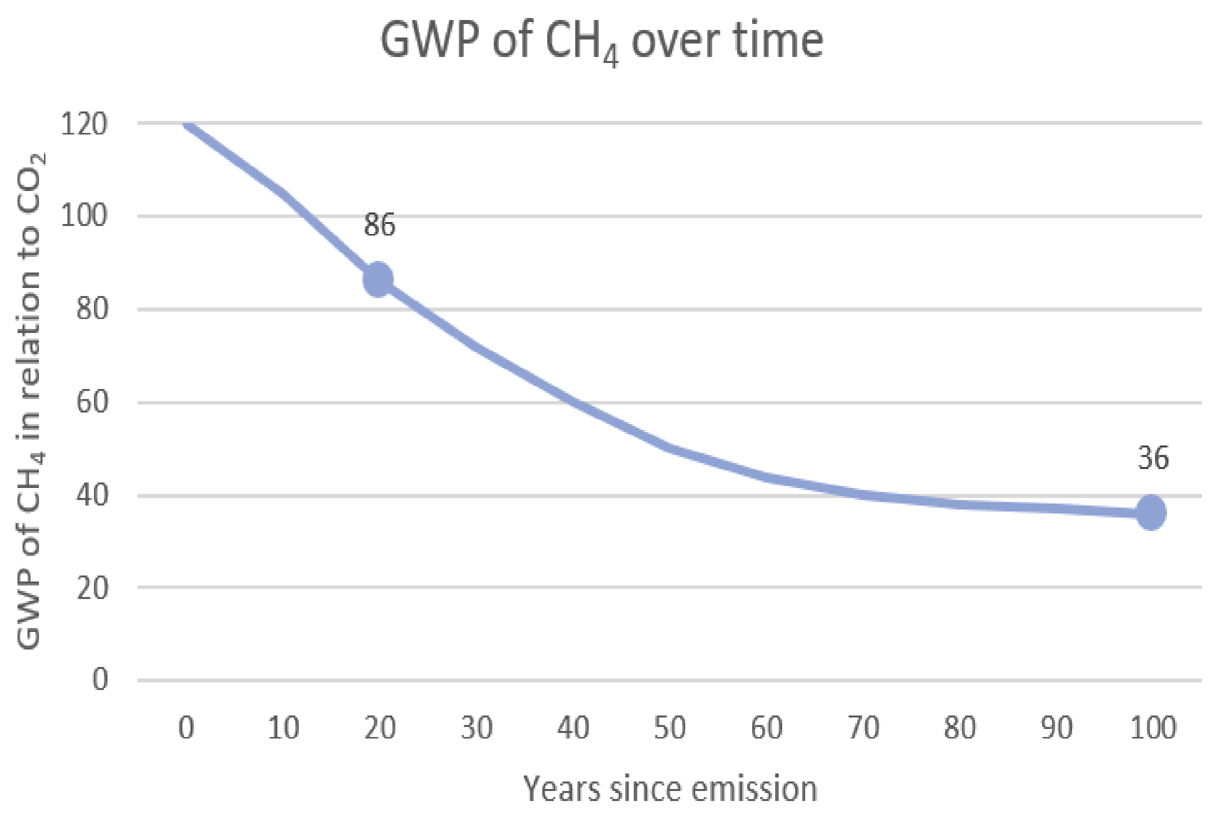
Energy consumption estimates in recent in studies – spotlighting hydrogen

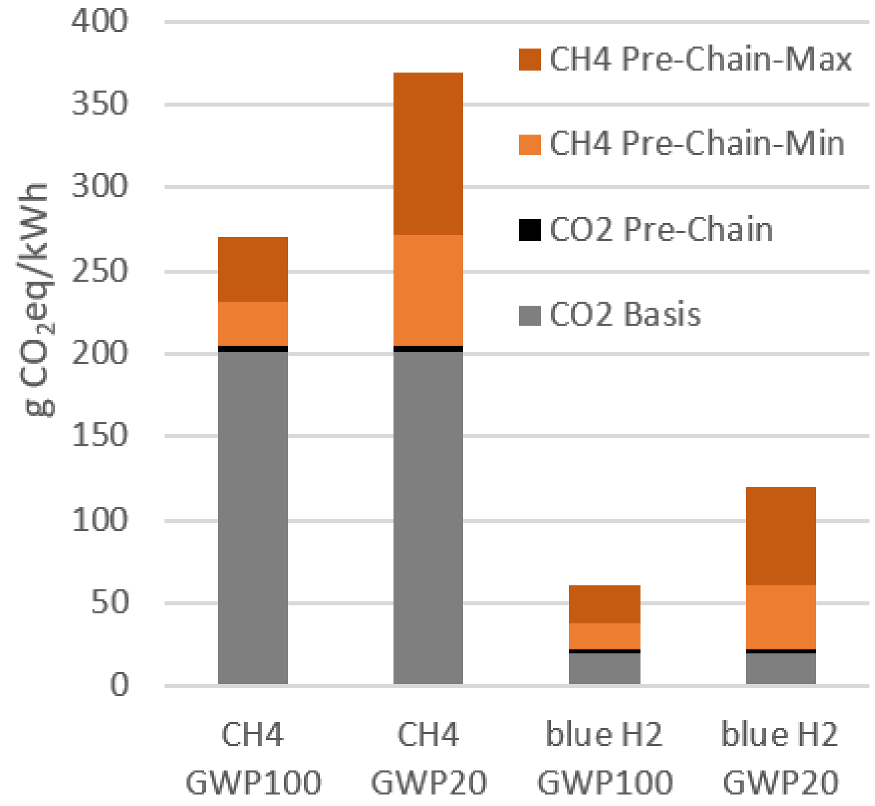
- **Green H_2**
  - Production is from renewable sources and is carbon free
  - Import from regions with high wind and solar resources
- **Blue H_2**
  - Steam reforming with CO_2 capture and storage (CCS)
  - Low (rather than zero) $CO2_{eq}$ due to methane leakage from pipelines (see next slide)
- **More H_2 colors...**
  - Turquoise H_2 – produced through methane pyrolysis
    → decentralized, without need to build H_2 or CO_2 infrastructure →
    but efficiency clear worse than H_2 / methane leakage



Green hydrogen is the only sustainable hydrogen!

Blue hydrogen is not emissions free, but CO_2-equivalent emissions are low



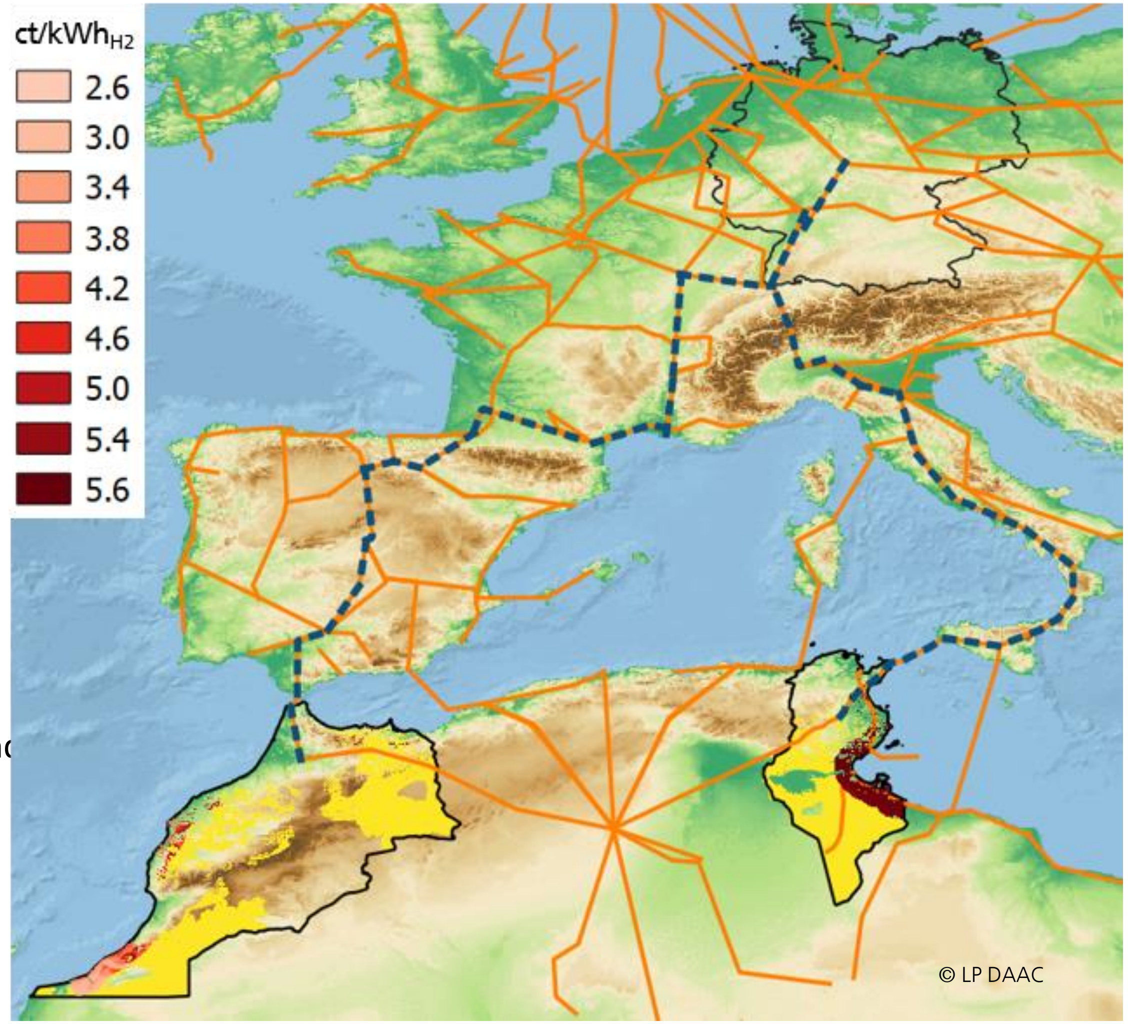


Authors' figure based on Intergovernmental Panel on Climate Change, "Climate Change 2014: Synthesis Report", 2014.

International production potential and future H_2 availability in Germany and Europe

- H_2 production potential has only been estimated in studies concerned with **individual countries**
- **Imports: Liquid H_2 is more expensive** → therefore, economic incentives to import **gaseous H2 by pipeline from North Africa**
  - Pipeline import potential (including transport losses) from Morocco and Tunisia is **400 TWh/a**
  - EU hydrogen demand* in 2050 between **800 and 2,259 TWh/a**

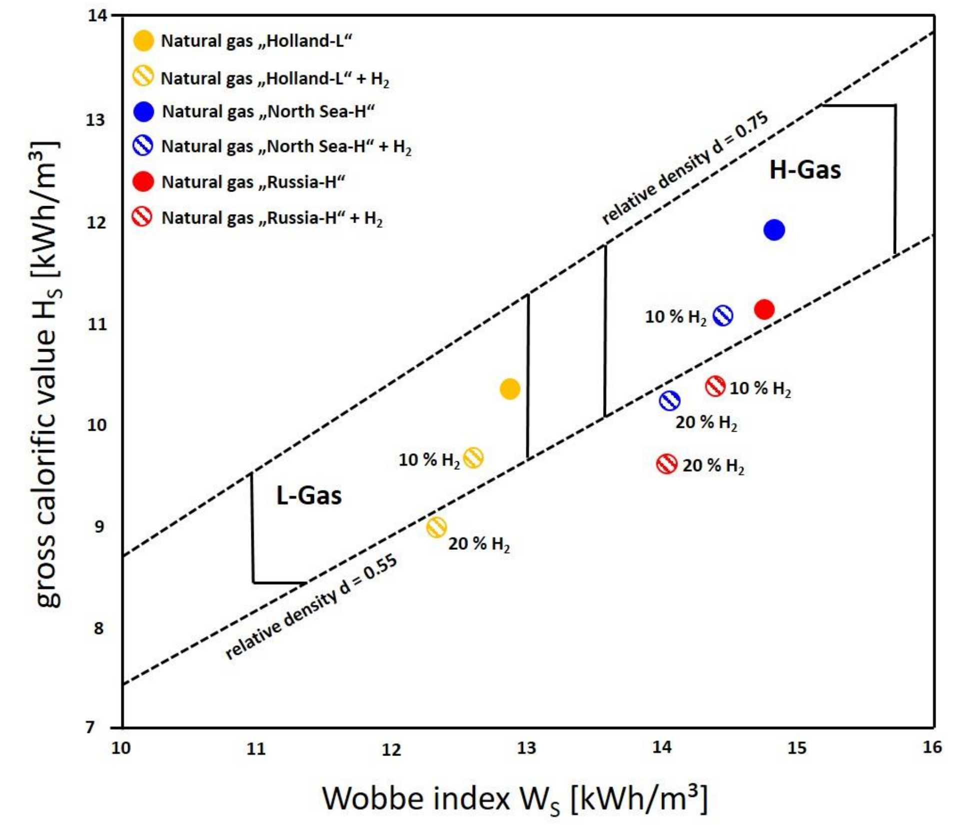
    *without building heat demand
- **National/European production**
  - Power peaks have limited economic potential for H_2
  - Extensive offshore build out will cause regional reductions in wind speeds → potential is more expensive and limited



> There is limited land area potential for gaseous hydrogen production destined for pipeline import.

Technical requirements and implications for natural gas grids

- **Depending on the type of natural gas, highly divergent H_2 shares are possible**
  - Relative density, calorific value, and Wobbe index thresholds
  - Knock resistance of petrol engines (CHP, CNG vehicles)
- Technical requirements of **DVGW Code of Practice G 262**
  - H_2 in combustive gas is restricted to 5% by volume, but <10% acceptable in many cases
- The blending of **20% H_2** in all areas of the natural gas grid is subject to additional **restrictions**, however:
  - **Existing gas burners, gas turbines, and CNG vehicles**
  - **Certain industrial processes, pore storage**



A medium-term increase to 20% H_2 by volume in the gas grid would only produce low emission reductions (7-8%).

Authors' figure based on:
Deutscher Verein des Gas- und Wasserfaches e. V., "Technische Regel – Arbeitsblatt: DVGW G 260 (A)", 2013 / Gas- und Wärme-Institut Essen e.V., "Untersuchung der Auswirkung von Wasserstoff-Zumischung ins Erdgasnetz auf industrielle Feuerungs-prozesse in thermoprozesstechnischen Anlagen", 2017 / G. Müller-Syring et al., "Power-to-Gas: Entwicklung von Anlagenkonzepten im Rahmen der DVGW-Innovationsoffensive", 2011

Is the national expansion potential for wind and PV in Germany sufficient to cover the high demand potential for direct electricity consumption?

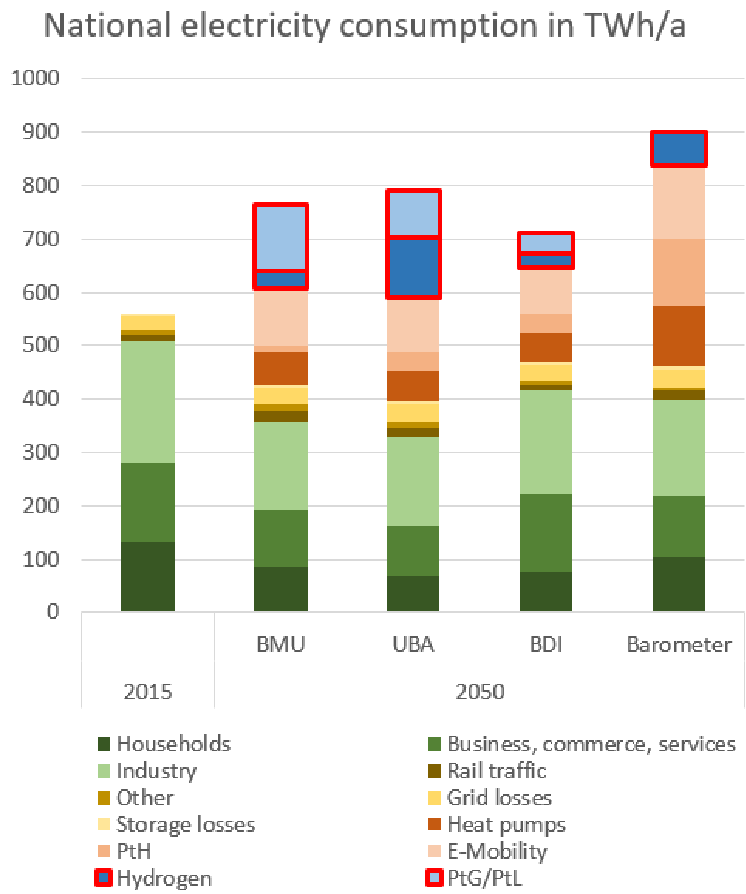
Generation

- **Offshore Wind** (100 TWh direct use)
  - expansion potential of approximately 40–50 GW, of which a **minimum of 25 GW is directly usable**
- **Onshore Wind** (450 TWh direct use)
  - Potential of approx. 200 GW for weak turbines, conservatively, **150 GW**
- **PV** (250 TWh direct use)
  - potential of approximately 420 GW, of which a **minimum of 250 GW is directly usable**

→ Plus other producers to cover national demand potential of at least 900 TWh/a

→ By comparison, national electricity demand in efficient GHG reduction scenarios with a very high share of heat pumps ranges between 700 and 900 TWh

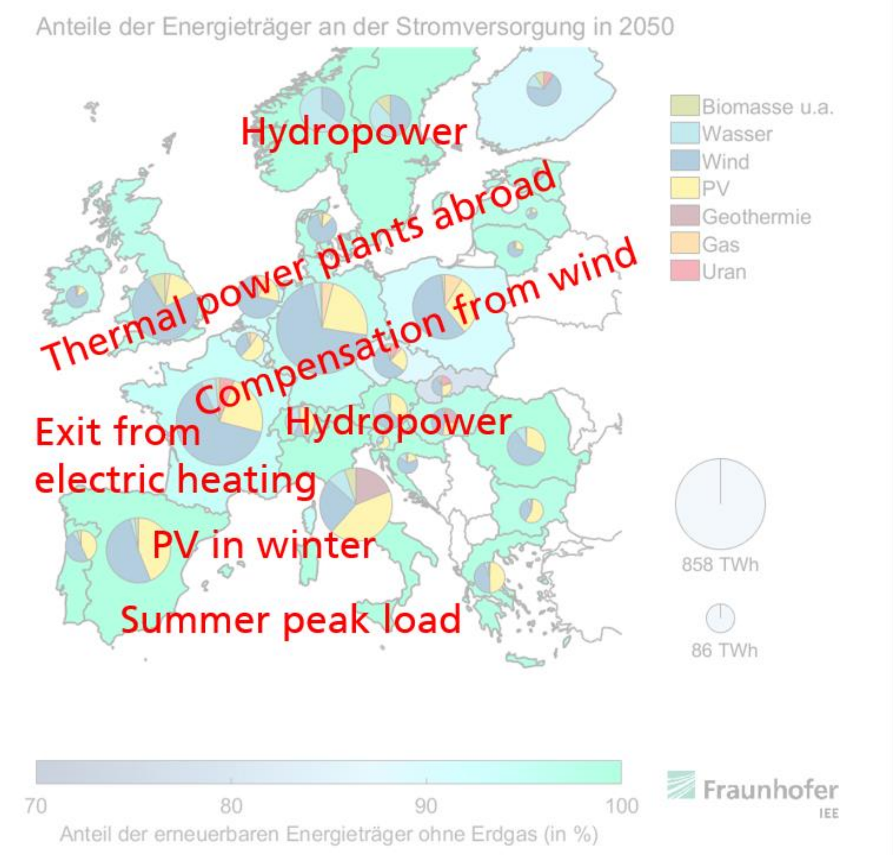
Consumption



Fraunhofer IEE

Decentralized supply of heating energy to buildings using heat pumps: System integration

- The German sales market for heat pumps is dominated by new construction (accounting for 55–60% of sales)
  - **To achieve climate targets, early deployment of heat pumps in the existing building stock is necessary**
- High security of supply is guaranteed by European electricity balancing
- For the **expansion of low-voltage distribution grids** there are surmountable technical requirements that entail moderate additional costs
  - Opportunities in the area of smart meters and load management
  - Integrating variable renewables and electric vehicles will entail higher grid expansion costs



Reliance on H_2 is not necessary for the sustainable supply of heating energy in the building sector.
The supplementary costs for ensuring security of supply and expanding power distribution grids are low.

Fraunhofer IEE

Key Insights: Energy System

- The development of hydrogen infrastructure is essential for the industrial, transport, and energy sectors.
- Hydrogen demand in Germany is expected to range between 600 and 1,000 TWh in 2050.
- Blue hydrogen is not carbon free, and the storage of carbon has not been resolved technically or politically.
- The greater our reliance on blue hydrogen, the more expensive it becomes to switch to green hydrogen later.
- Only green hydrogen is sustainable.
- The majority of hydrogen will have to be imported.
- Import potential from North Africa can only cover a fraction of European demand.
- The higher the demand for hydrogen, the more expensive it will become.

Key Insights: Building Heat

- The blending of H_2 in the natural gas grid is technically limited
  - Natural gas quality, grid infrastructure, diverse consumers
- H_2 blending of 20% by volume will require the replacement of all customer equipment/systems in the gas grid.
- H_2 has a lower energy density than natural gas. Blending of 20% H_2 by volume will only lead to CO_2 reductions of 8%.
- The H_2 deployment curve is not steep enough to meet carbon reduction targets in building heating.
- H_2 is the worst energy carrier for building heating with a view to efficiency and infrastructure requirements.
- Supplying heat demand with heat pumps is 5 to 6 times more efficient than H_2.
- Reliance on heat pumps will reduce H_2 demand by 150–400 TWh per year.
- Demand for electricity to run heat pumps can be met cost-effectively from national sources.