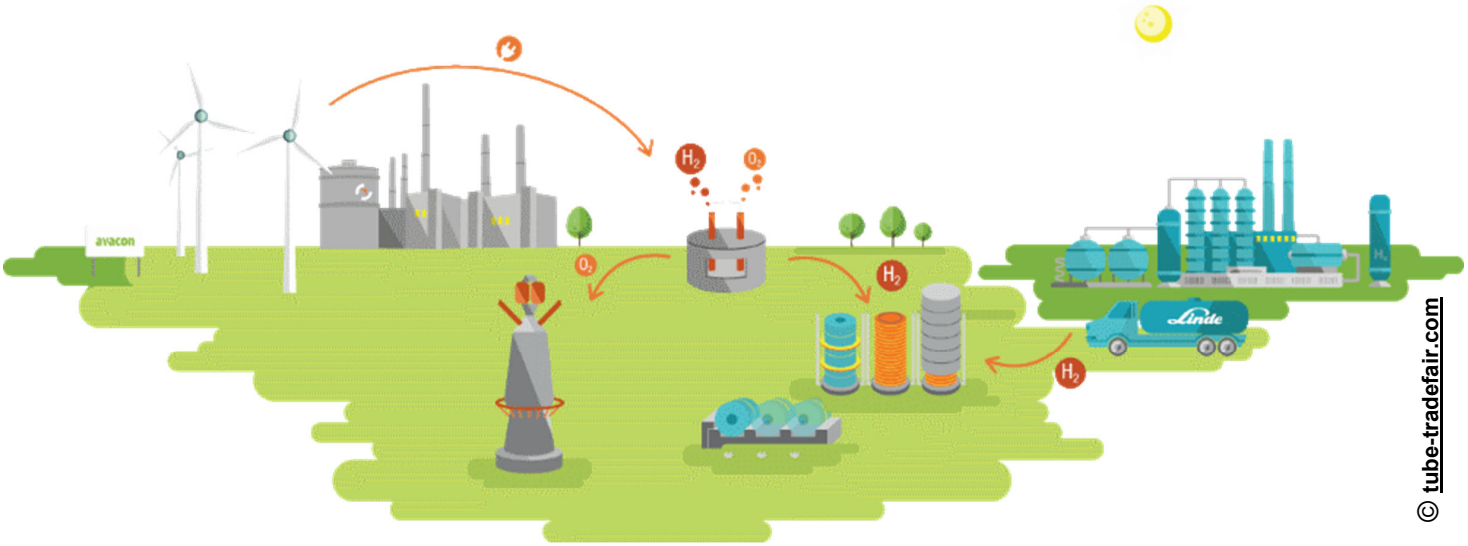
Hydrogen – Markets and Infrastructure



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University of Birmingham

Overview

- hydrogen uses
- hydrogen markets and pricing
- hydrogen handling and distribution

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Hydrogen Applications in Industry

- Ammonia synthesis
- Crude oil refining
- Methanol production
- Hydrogenation of fats in food processing
- Metallurgy
- Cooling in gas turbines
- Production of artificial diamonds
- Chemical industry
- Energetic use
- Town gas

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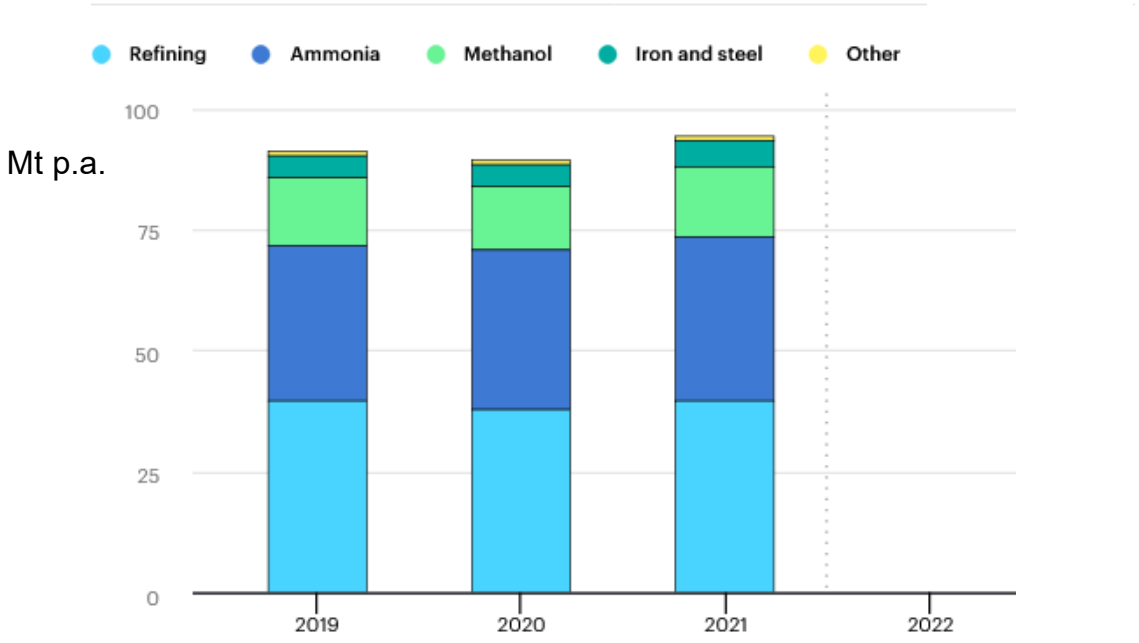
Global Hydrogen Markets

94 Mt is equivalent to 1,050 billion cbm, i.e. the size of the European natural gas market

40% refineries
40% fertilizers (Urea)
15% methanol
5% iron and steel
0.04 % others = DRI, FCEV, HT heat in industry
-> 40 kt in 2021

data source: IEA

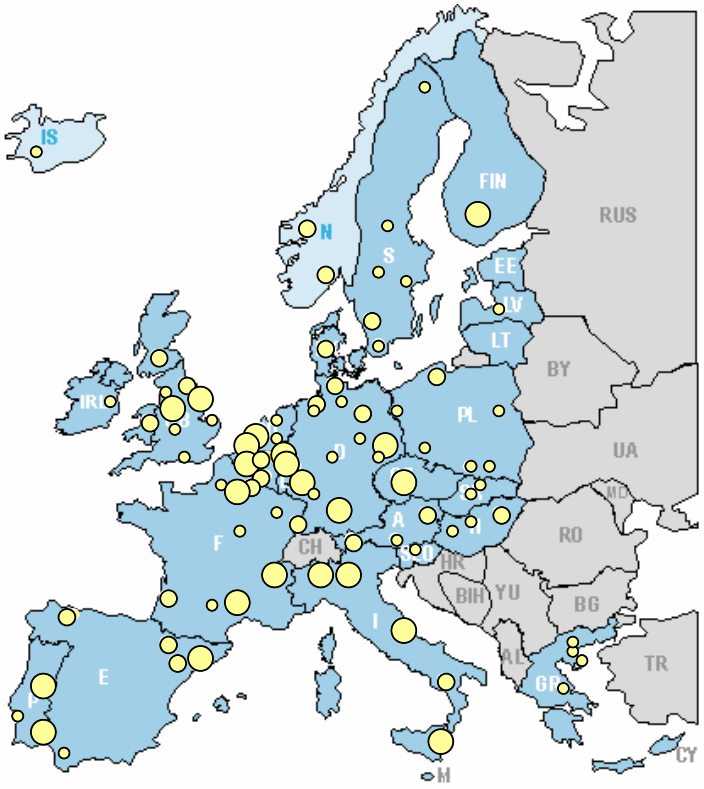
Global Hydrogen Markets



91 Mt/yr 94 Mt/yr

source: IEA

European Hydrogen Production Sites

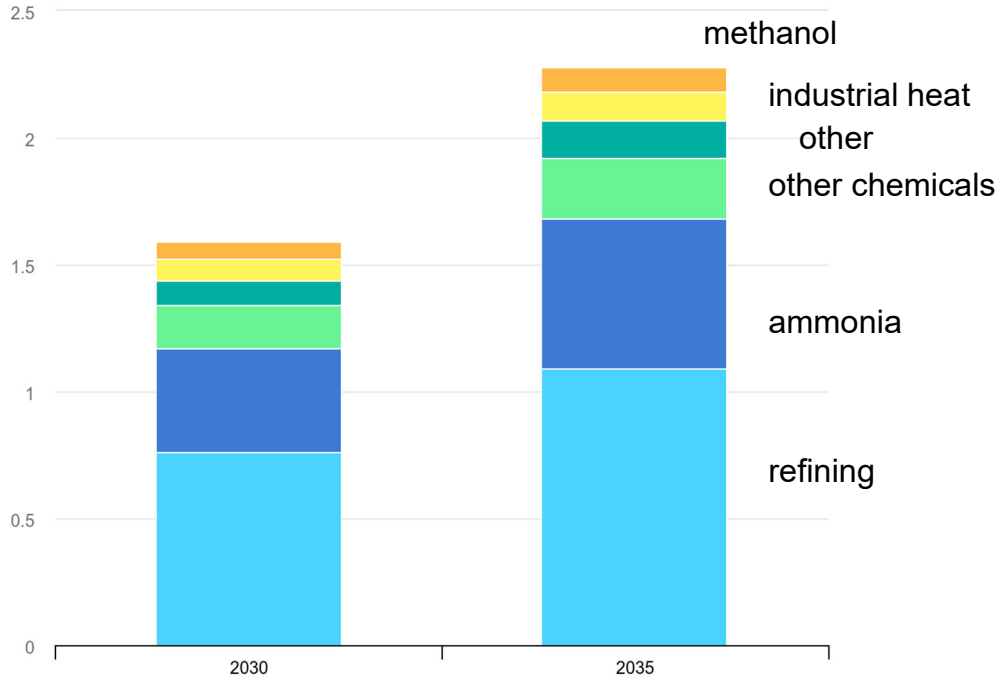


- Production Sites (1-3)
- Production Sites (4-7)
- Production Sites (>7)

source:

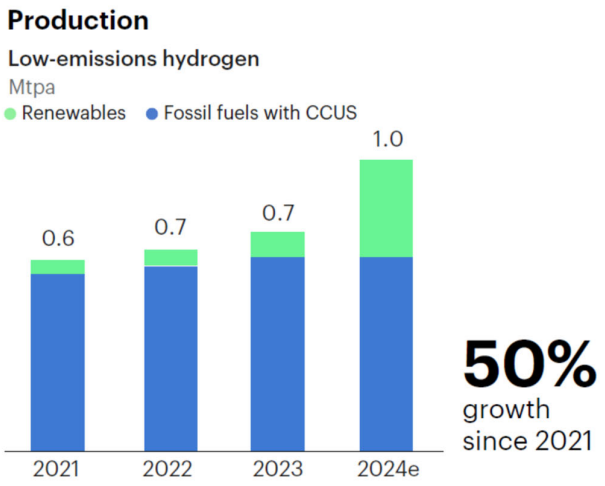
ROADS2HYCOM
www.roads2hy.com

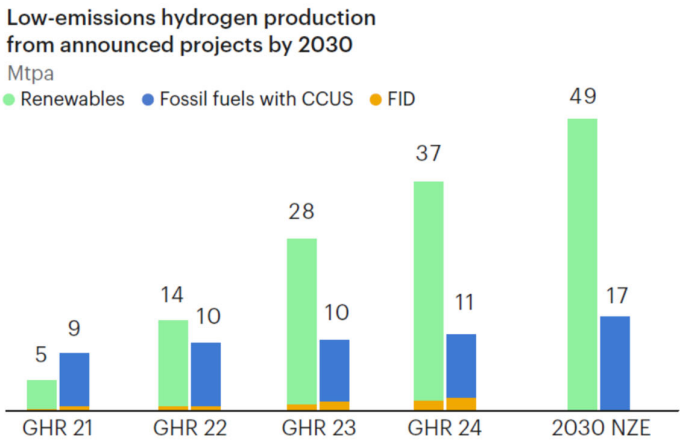
Global Hydrogen Applications



data source: IEA

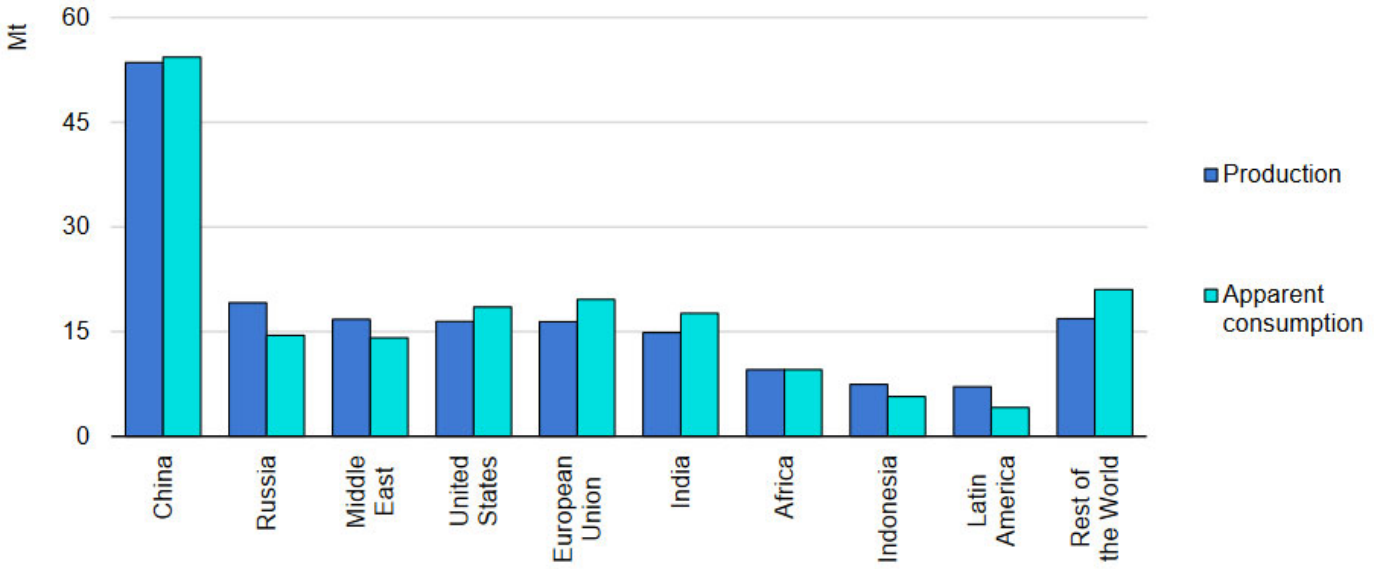
Global Hydrogen Markets





source: IEA

Global Ammonia Markets

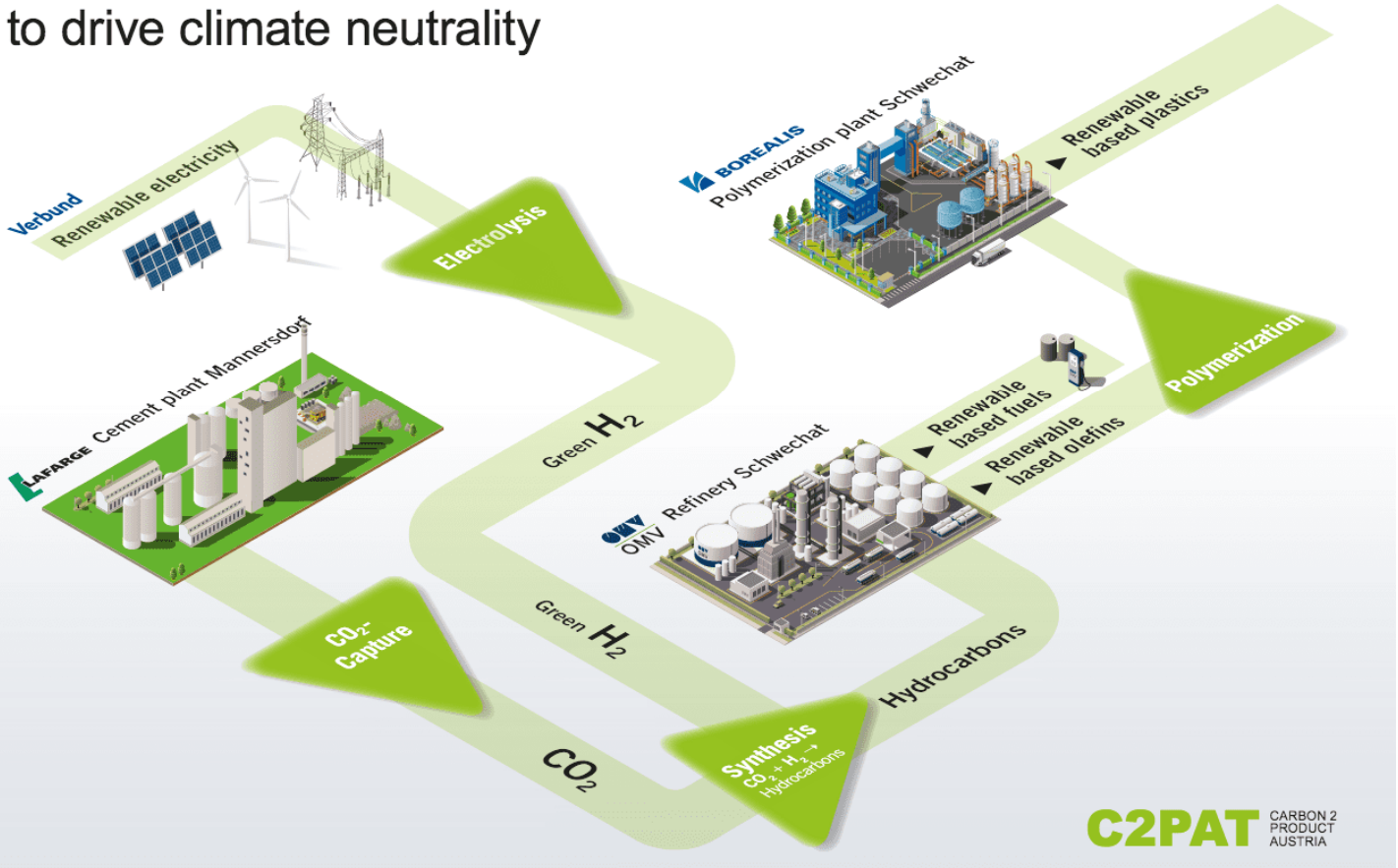


IEA, 2021.

total ~ 200 Mt/yr

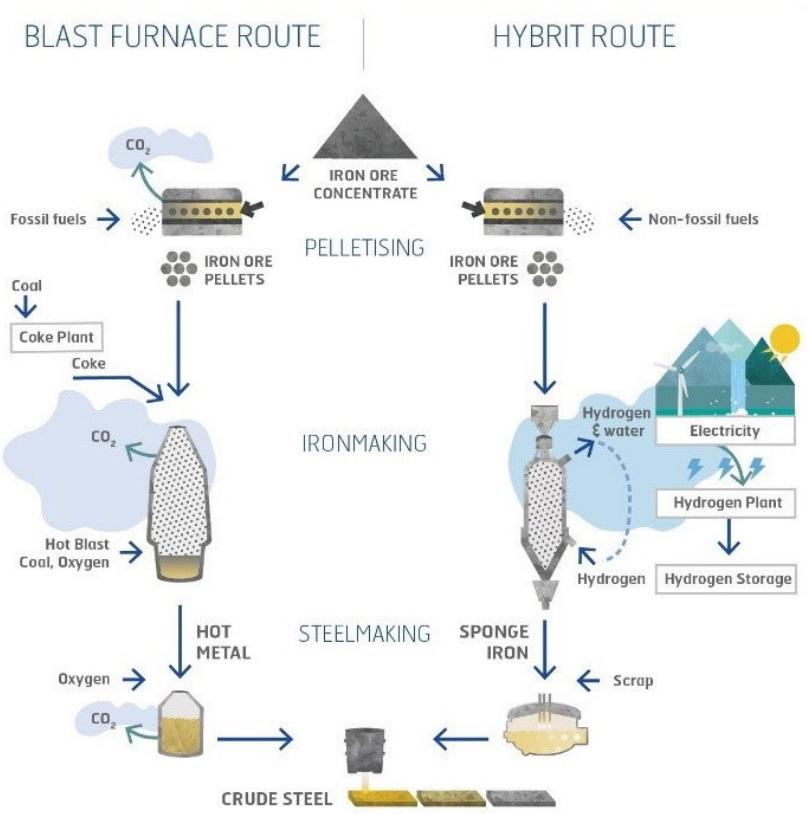
Cross sectoral value chain

to drive climate neutrality



source: chemengonline.com

Green Steel Making



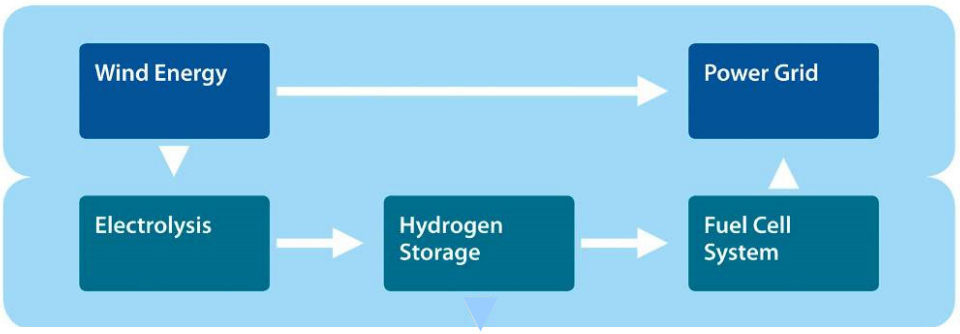
source: fchea.org

Hydrogen Fuels

10% of global total hydrogen consumption

sources: autoesporte.globo.com, zimonews.com, evcentral.com.au, transportenmilieu.nl/, Alstom

Renewable Energy – Hydrogen System



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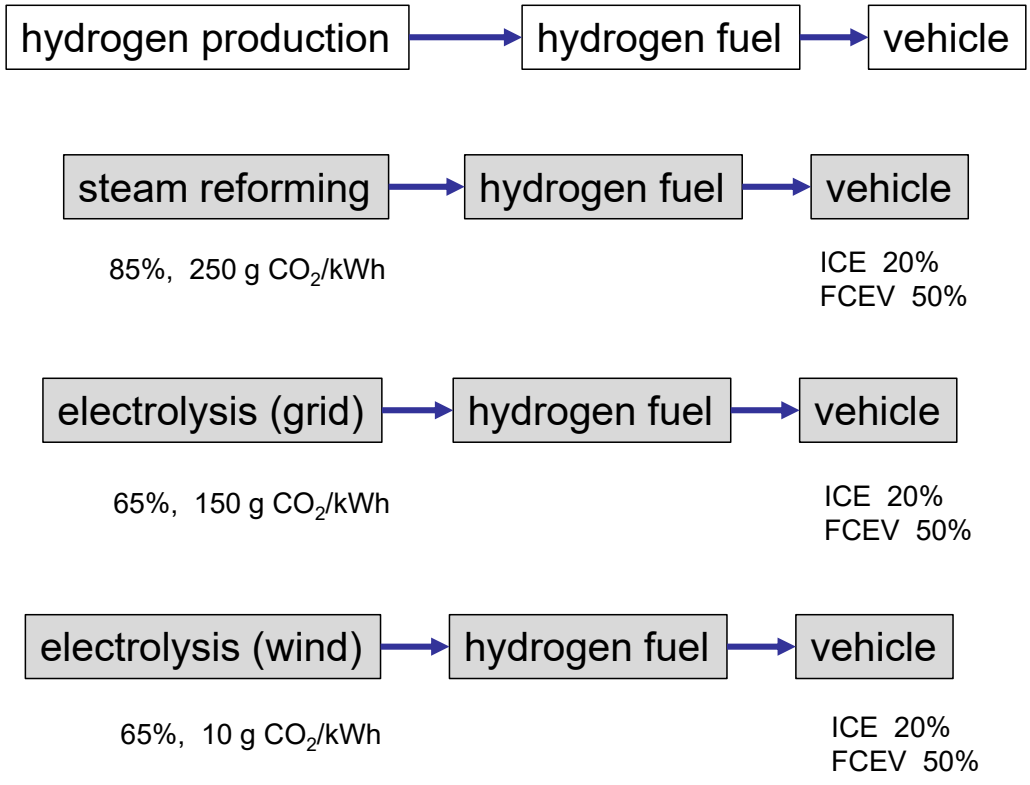
2. Why does the quality of Hydrogen matter?

Conversion chains and carbon footprint



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Colours of Hydrogen

- MSR of natural gas
- MSR of natural gas with CCS
- electrolysis with renewable electricity
- electrolysis with nuclear electricity
- pyrolysis of hydrocarbons
- from coal gasification
- from PV electricity
- found in nature

Certification of Hydrogen Origin

- guarantee of ‘premium quality’
- ‘premium’ attribute helps to address first markets with high quality standards

‚Green‘ vs. ‚Low Carbon‘ attribute

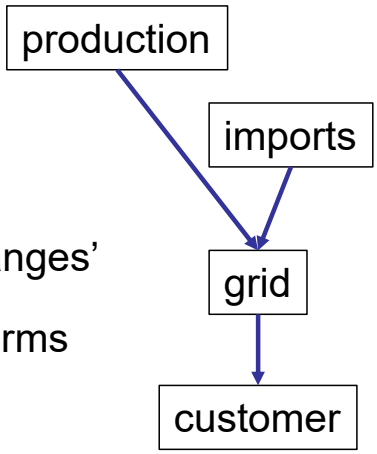
- pushback on use of ‘colours’
- lobbying to bring non-renewable sources into the picture:
  - nuclear
  - CCS

UK Low Carbon Standard

- UK (Sunak) Government:
  “New UK certification to boost British hydrogen sector”
- introduces more than renewable energies
  (i.e. pink and blue hydrogen)
- constitutes a ‘diversion’ from the EU standards
- prevents hydrogen exports to EU

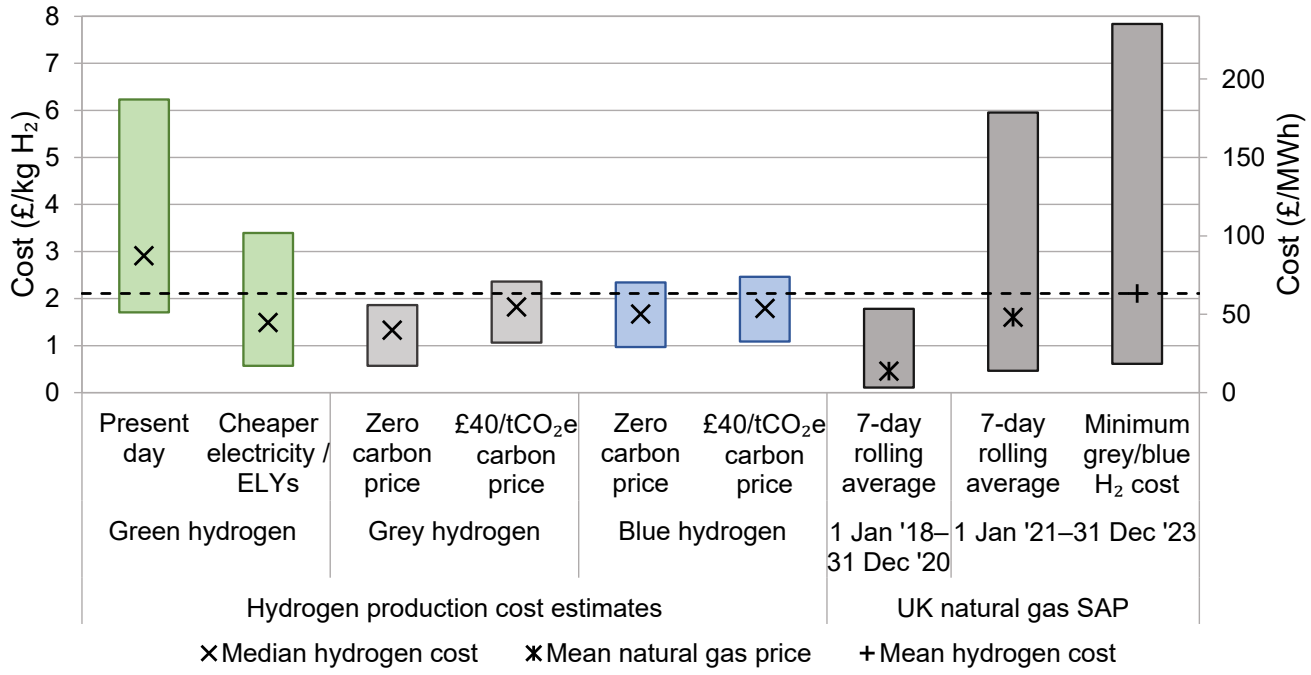
3. Hydrogen Markets and Pricing

Energy Markets and Hydrogen



- energy markets work with an infrastructure
- market participants ‘feed in’ to the grids
- market prices are determined at ‘energy exchanges’
- commodity markets work with wholesale platforms (market places)
- hydrogen is perceived as an energy carrier, but the hydrogen market currently works like those for commodities – transport from source to user is on the supplier
- this will change with the advent of infrastructure

Cost of Hydrogen



source: Walton/Steinberger-Wilckens

Price of Hydrogen

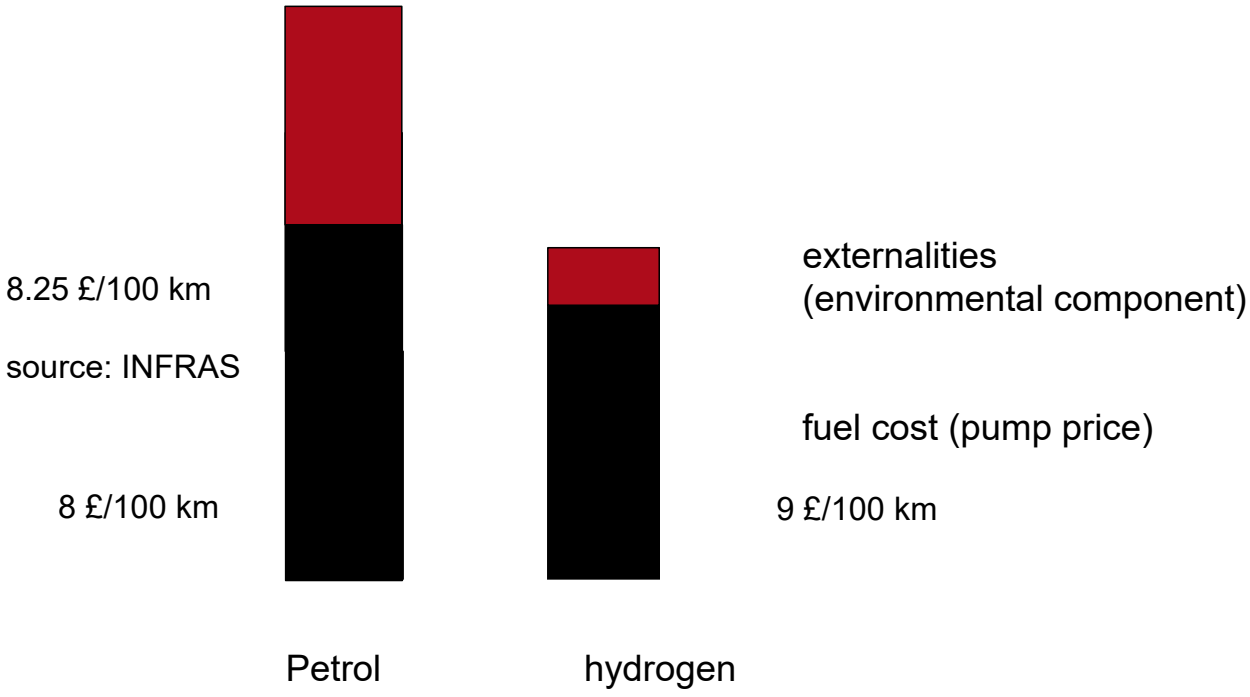
production	transport	retail	margins	tax/levies
1£/kg	1 to 4 £/kg	0 to 2 £/kg	%%%	VAT, CO_2

typical for HRS across EU: € 10/kg

green hydrogen
2£/kg → price increase ~ 10 to 20%

Externalities of Passenger Vehicle

values for Daimler A-class (2007) / (2022)



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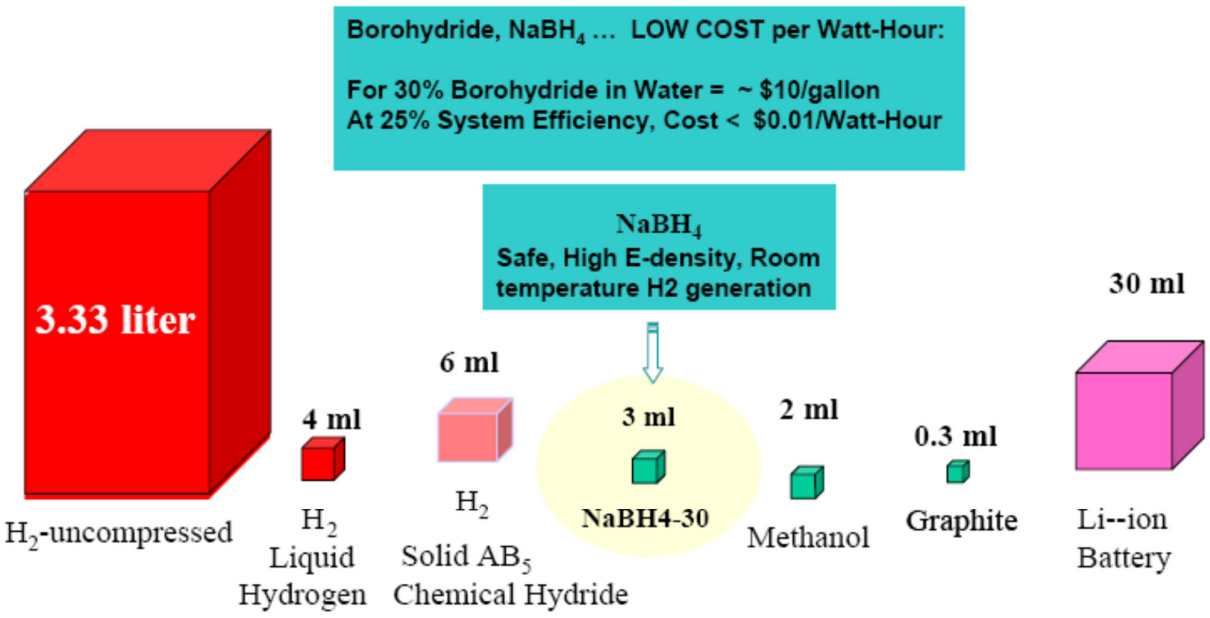
3. Hydrogen Handling

Hydrogen Storage

- compressed gas (CGH2)
  200 bar, 250 bar, 350 bar, 500 bar, 700 bar (10,000 psi)
- liquified (cryogenic) (LH2)
- ab- or adsorption on solid (MeH)
- chemical compound

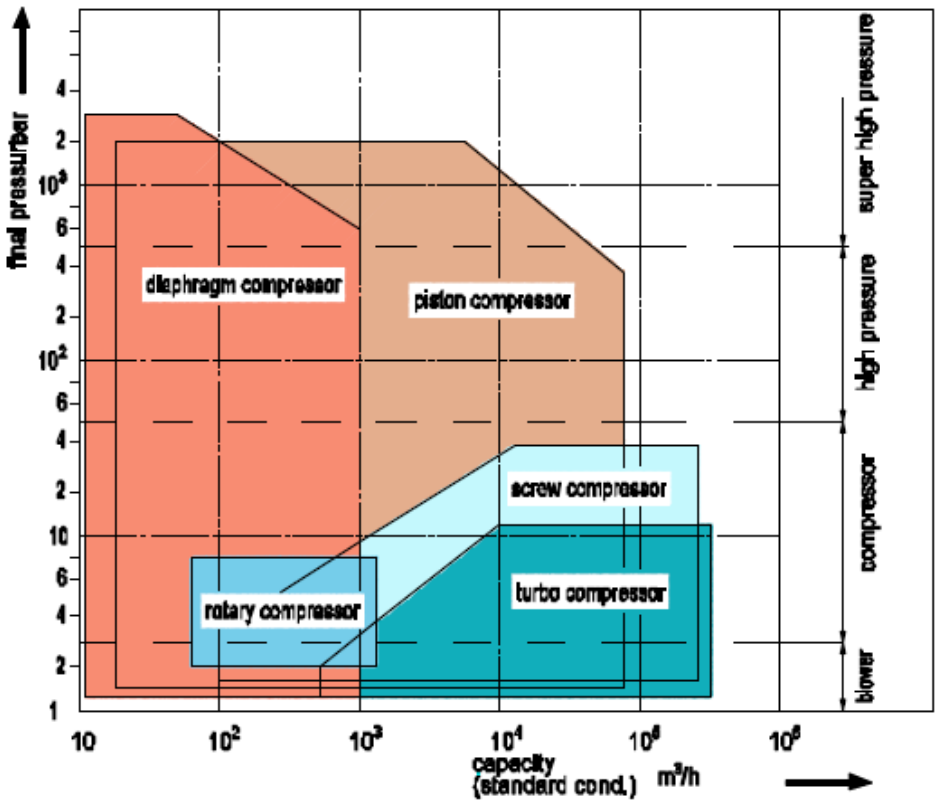
Hydrogen Storage: Energy Density



Volumes of different Fuels equivalent to ~10 Watt-hours of Electrical Energy at 100% Chemical to Electrical Conversion Efficiency.

Source:AZ State Univ

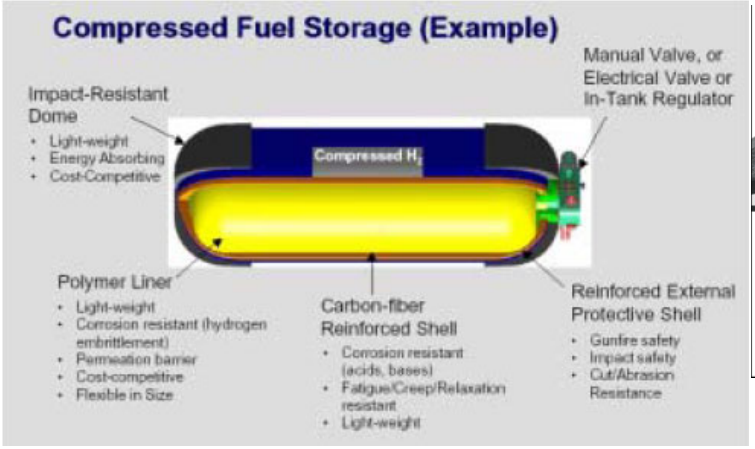
Hydrogen Compression: Choice of technologies

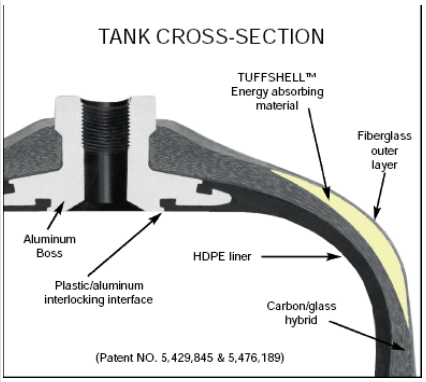


Pressurised Electrolysis

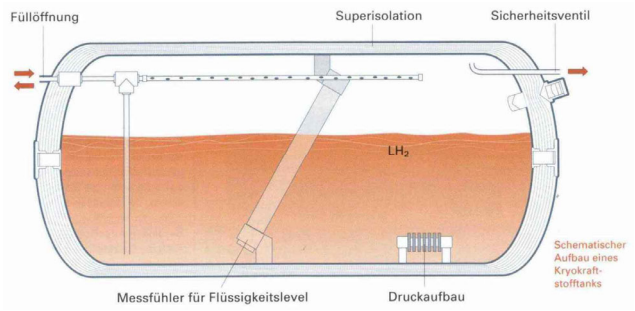
- High pressure, high temperature
- High efficiency due to high partial pressure at electrodes
- Low compression energy due to fluid compression
- Production of pressurised hydrogen at 30 to 100 bar

Hydrogen Pressure and Cryogenic Storage



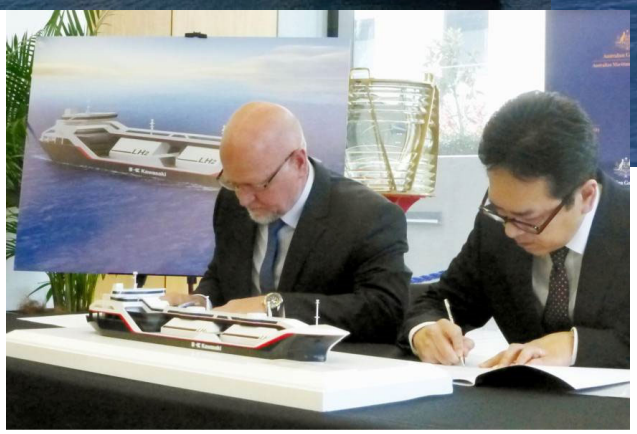


Type IV CHG tanks



(Photo)graphs courtesy of Quantum, Tuffshell, DoE, and hydrogeit

LH2, LNG and Ammonia Transport



sources: fuelcellworks.com, various

Map courtesy of Air Liquide

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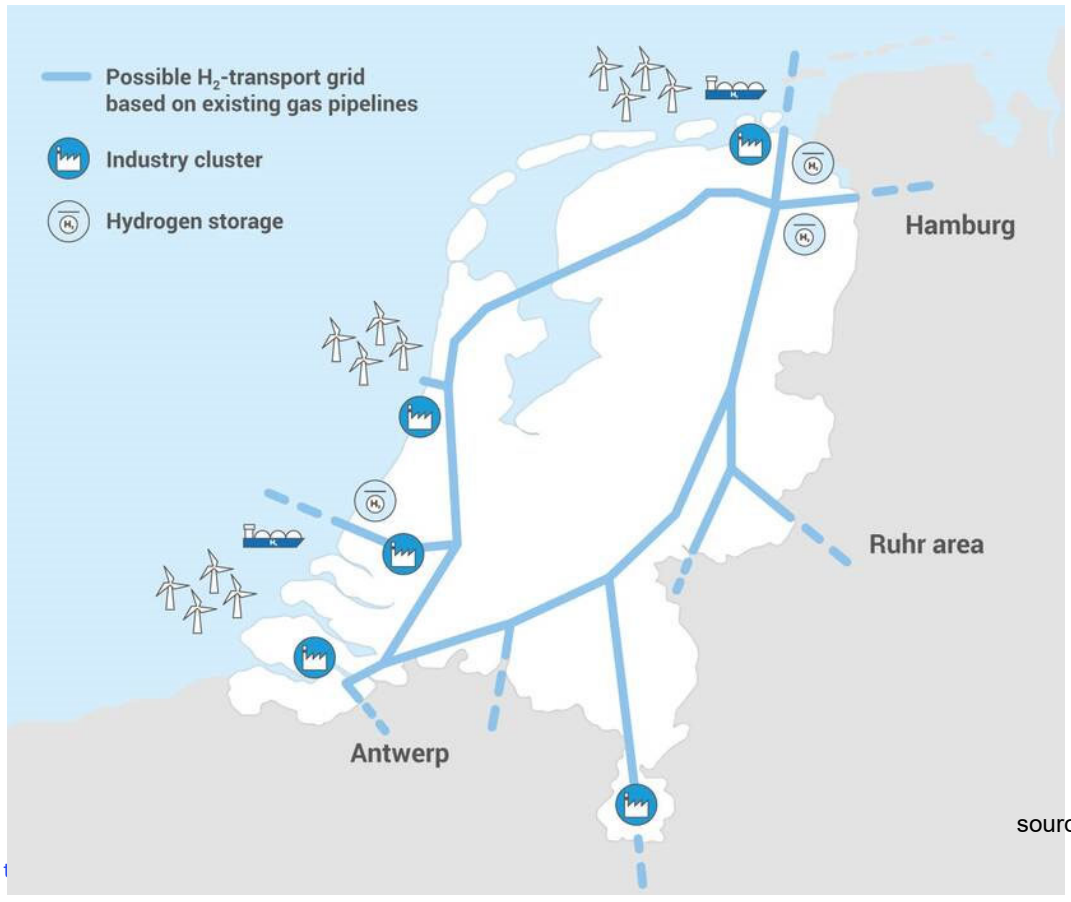
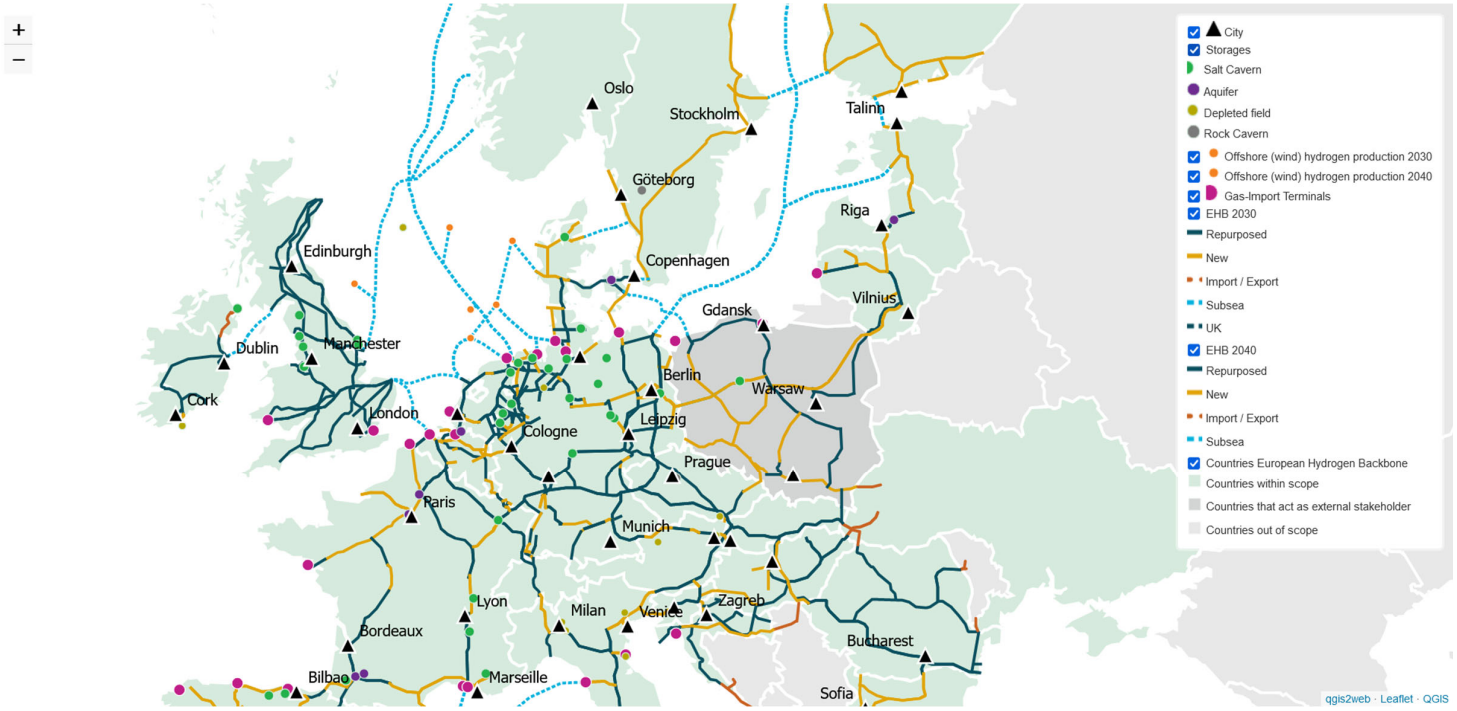
Netherlands ‚H2 Backbone' Plans 2030



source: GasUnie

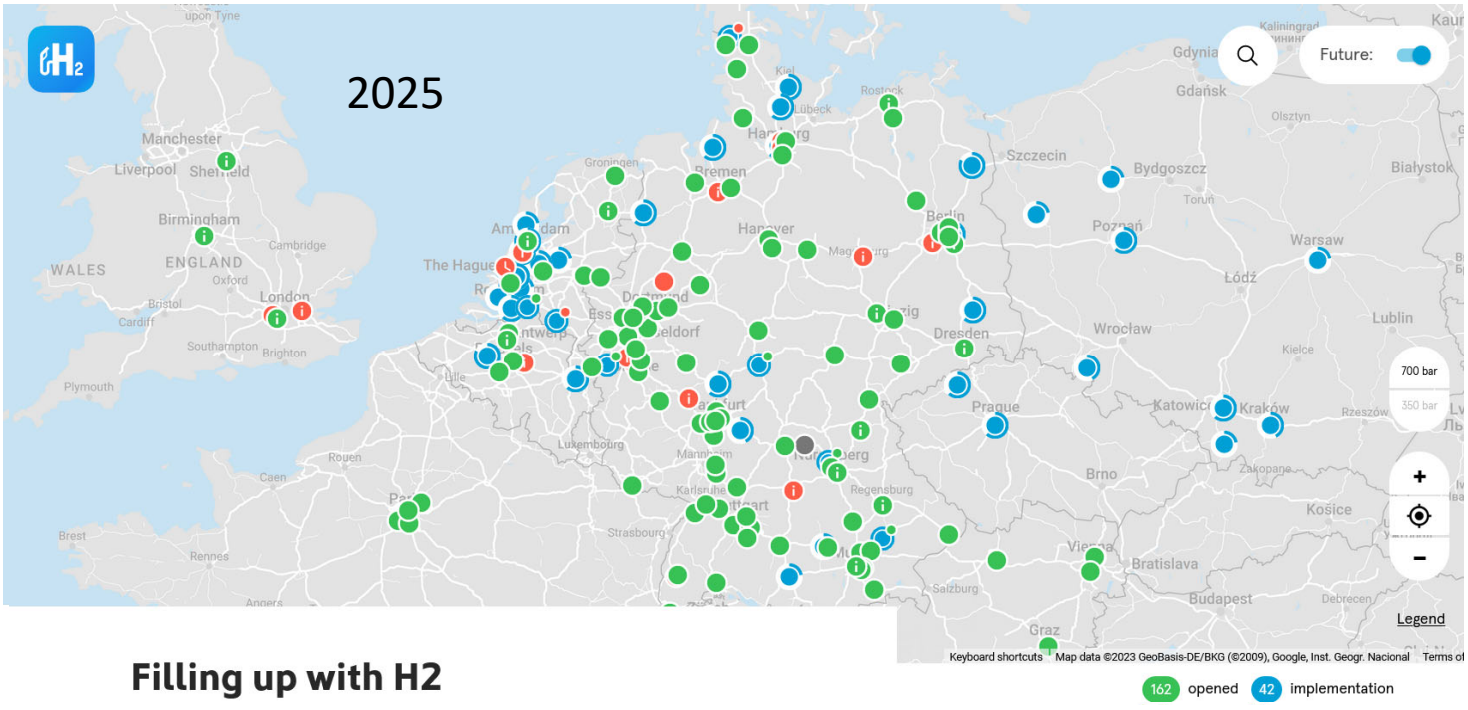
European ‚H2 Network' (backbone) Plans



source: EHB.eu

source: **NDR, Jutta Przygoda**

European Hydrogen Refuelling Stations



Filling up with H2

Source: h2.live