

Global Hydrogen Trends and Opportunities

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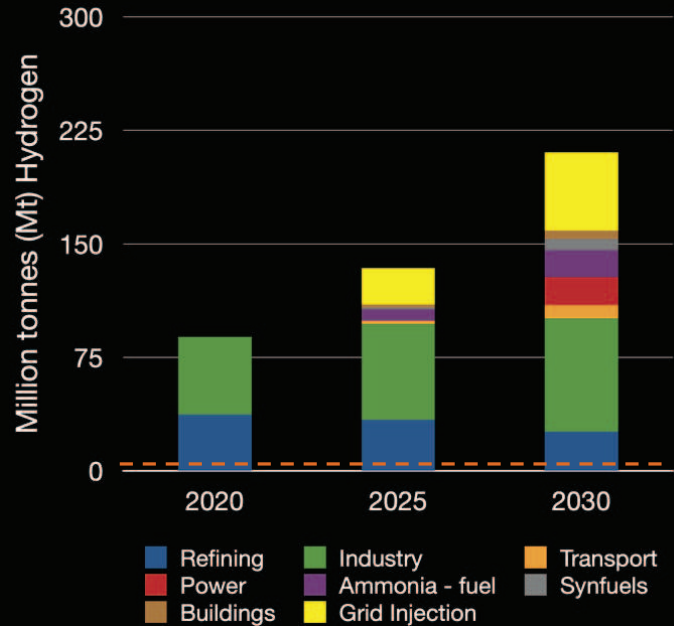
Background

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Hydrogen is increasingly being considered a key decarbonization tool

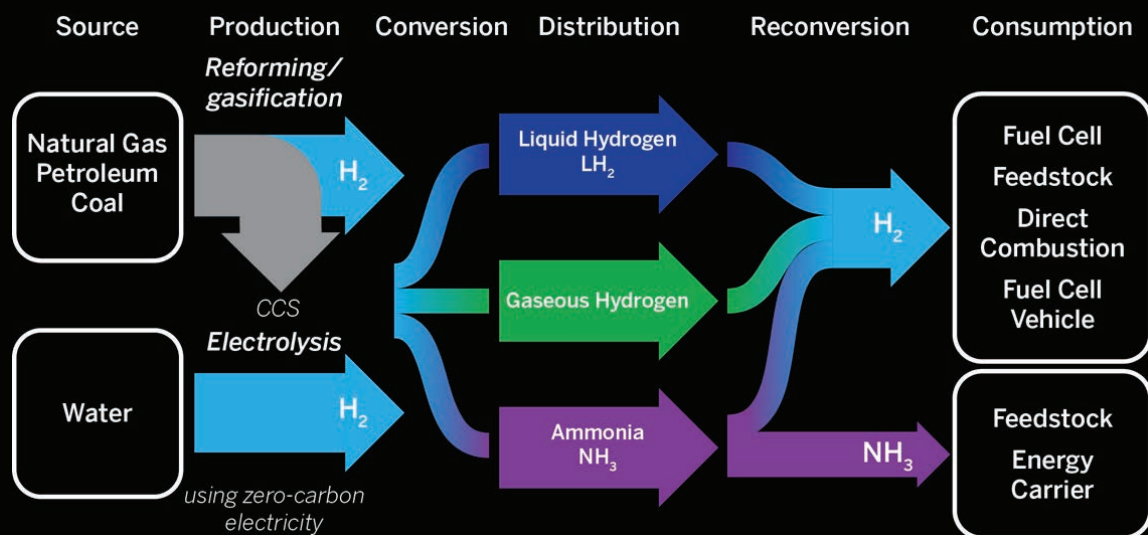
- Hydrogen (H_2) releases no greenhouse gases when used
- Can serve as a fuel, feedstock, or energy carrier
- Potential emission reduction applications across many sectors (industrial, transportation, electricity)

Global hydrogen demand by sector in the IEA Net Zero Scenario



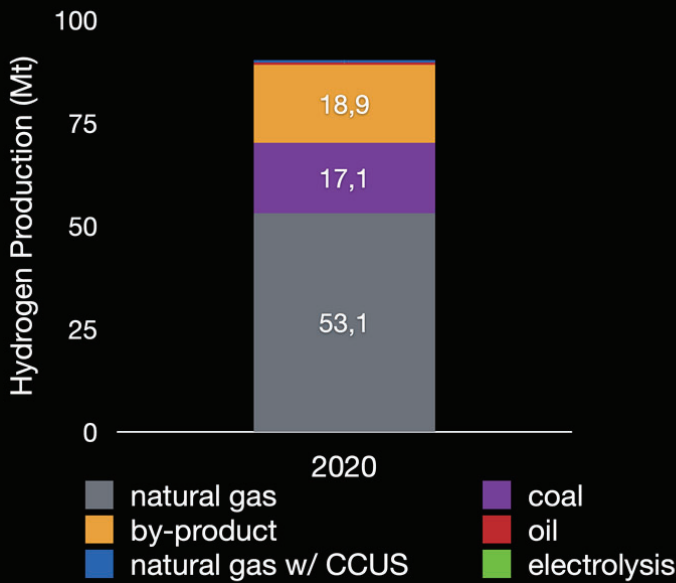
2020 TX H_2 production: 3 Mt/year

Energy usage and emissions across the hydrogen supply chain are an important consideration for its use



Hydrogen supply chain may look like some version of this - illustrative of different supply chain components

Current hydrogen production methods emit greenhouse gases



- 59% of global hydrogen produced by steam methane reforming (SMR) of natural gas → ~9 kg CO₂/kg H₂
- 19% of global hydrogen produced from gasification of coal → ~19 kg CO₂/kg H₂
- Only 0.7% of global hydrogen production from steam methane reforming of natural gas with carbon capture and storage (CCUS) → ~0.9 - 3.6 kg CO₂/kg H₂
- Negligible production of hydrogen from electrolysis

Hydrogen production coded by 'color' misses some key considerations

Steam Methane Reforming (SMR) of Natural Gas 'Grey Hydrogen'

- Splits methane (CH₄) to produce H₂ with a by-product of CO₂
- ~9 kg CO₂/kg H₂ (at point of production)
- Must also consider upstream emissions
- Continued reliance on fossil fuel feedstocks
- ~95% of US hydrogen production

Steam Methane Reforming (SMR) of Natural Gas with CCUS 'Blue Hydrogen'

- Adds carbon capture and storage (CCUS) to SMR
- ~0.9 - 3.6 kg CO₂/kg H₂ (depending on capture rates)
- Must also consider upstream emissions
- Continued reliance on fossil fuel feedstocks

Electrolysis with Renewable Electricity 'Green Hydrogen'

- Uses electricity to split water (H₂O) into H₂ and O₂
- Lifecycle emissions are dependent on electricity emissions
- Renewable electricity use yields zero-carbon hydrogen
- Negligible amount of global production currently

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"Trends and Recent Activity - Hydrogen Energy Projects"