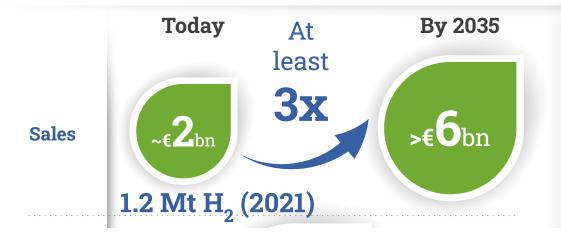


We think BIG for hydrogen



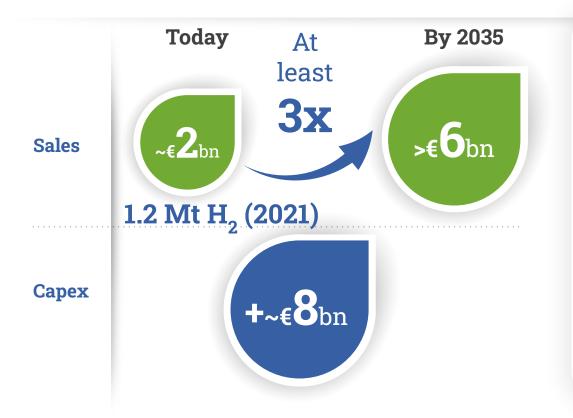
Capturing demand:

- Low Carbon + Renewable H₂ offer
- New H₂ industrial applications
- Carbon Capture as a service
- H₂ mobility

Capturing additional value by decreasing customers CO₂ footprint

> (a) Including a confirmed capacity of 1 GW still under construction

We think BIG for hydrogen



Capturing demand:

- Low Carbon + Renewable H₂ offer
- New H₂ industrial applications
- Carbon Capture as a service
- H_2 mobility

Capturing additional value by decreasing customers CO₂ footprint

Investment in:

- CO₂ Capture plants
- Electrolyzers
 - IEMENS
 - Air Liquide SIEMENS CONCIOY
- Supply chain for mobility
- Takeovers

(a) Including a confirmed capacity of 1 GW still under construction

Why hydrogen release?

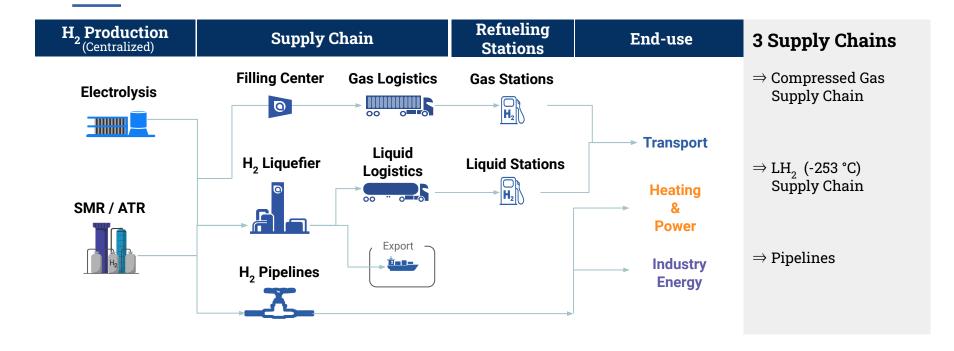
Disclaimer

Within the context a plausible scenario informed by current knowledge, the following is meant to provide <u>rough orders of magnitude</u> of what *could be* the **potential impact** of hydrogen released into the atmosphere following the deployment of the hydrogen economy.

It aims at giving **conservative figures** to evaluate whether **hydrogen released** as a result of **the hydrogen economy deployment** actually represents **a significant potential contribution** to climate change or not.

Context

Supply Chain Organization



Production

H, release into the atmosphere



Electrolysis



SMR / ATR



Today

Under Development/Mature

- \Rightarrow ~0.2% of the production:

 - Venting, H_2 in O_2 Dryers Regeneration
 - Leakages etc

Mature

- \Rightarrow Well optimised
- \Rightarrow Very low losses of 10⁻⁴ % of the production

Target 2030

Mature

- \Rightarrow Very low losses: ~0.03% of the production:
 - Venting H2 in O2 (reduced crossover)
 - Improved Dryers Regeneration
 - New techno for leakage detection

Mature

⇒ No significant changes expected

Supply Chains: Gas, Liquid & Pipeline

H, release into the atmosphere

Supply Chain

Filling Center

Gas Logistics





H₂ Liquefier



H₂ Pipelines



Today

Mature

- \Rightarrow Very low losses of <1% of the delivered hvdrogen:
 - Trailer hose purging
 - Other losses including leakages on fittings, valves, etc

Under Development

- \Rightarrow Release ~10% of the delivered hydrogen:
 - Liquefaction: Maintenance, Start-up, absorber regeneration, boil-off,
 - Boil-off: transfill operation, long "sitting time"
 - Purging
 - Other losses including leakages
 - Very low loading of supply chain in market initiation phase

Optimisation required for the economic viability of LH, logistic

Mature

- ⇒ Very low losses of ~1% of the delivered hvdrogen:
 - Pipeline maintenance and modifications
 - Compressors on the pipeline network
 - Other losses including leakages

Target 2030

Mature

- ⇒ No significant changes expected
 - Improved leakage detection and mitigation

Mature

- ⇒Release ~2% of the delivered hydrogen:
 - Boil-off-recycling at the liquefier,
 - Improved trailer loading/unloading methods
 - Higher logistic intensity⇒ shorter "sitting time" for LH2 in the supply chain

Mature

- ⇒ Very low losses of <0.7% of the delivered hvdrogen
 - Improved leakage detection and mitigation



Refueling Stations

H, release into the atmosphere

Refueling Stations

Gas Stations



Liquid Stations



Today

Under Development/Mature

- \Rightarrow ~3% of the delivered H_a:
 - Purging: Heat exchanger, hoses (dispenser, trailer)
 - Compressor membrane loss
 - Commissioning, buffer inspection, leakages etc.

Under Development

- \Rightarrow ~8.5% of the delivered hydrogen:
 - Purging: dispenser hose
 - Boil-off stationary (pump & storage) & dynamic (pump)
 - Commissioning, buffer inspection, leakages etc.

Optimisation required for the economic viability of LH, logistic

Target 2030

Mature

- \Rightarrow ~2% of the delivered hydrogen
 - New optimized standards for the inspection (eg acoustic)

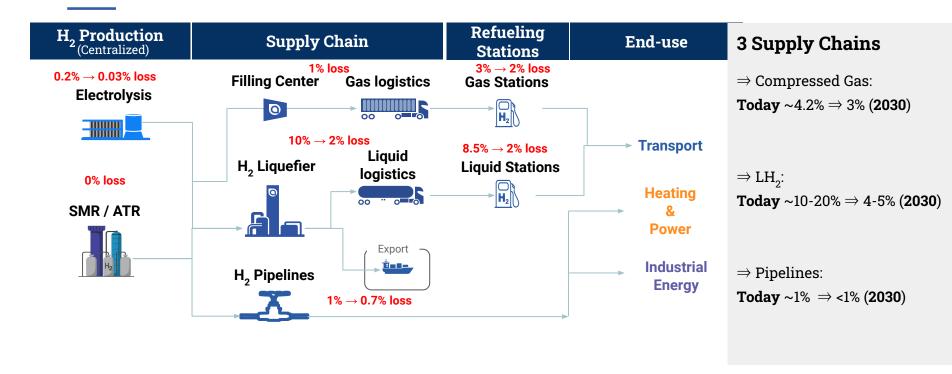
Mature

- \Rightarrow ~2% of the delivered hydrogen:
 - Technology improvement
 - Procedures optimisation
 - Higher logistic intensity ⇒ Shorter "sitting time" for LH2 at HRS



Summary on releases:

*H*₂ release into the atmosphere



Summary: Global View

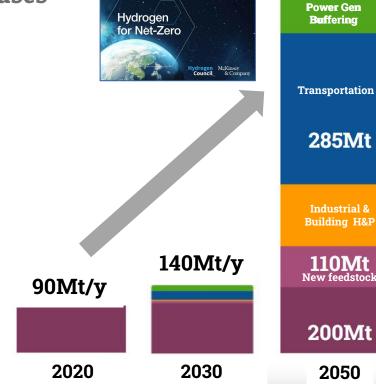
 ${\it Global}~{\it H_2}~{\it Budget}~{\it vs}~{\it H_2}~{\it Production}~\&~{\it Releases}$

Assumptions (2030 \Rightarrow 2050)

Transportation (70/30 LH2/GH2) 4%/3% All other markets <1%

| H ₂ Release (Mt/y) | 2020 | 2030 | 2050 |
|----------------------------------------------|------|------|-------|
| Power Gen Buffering | | 0.2 | 0.5 |
| Transportation | 0.02 | 0.2 | 10.5 |
| Industrial & Building H&P | | 0.1 | 8.0 |
| Industry Feedstock, Chemicals, Refineries | 1.1 | 0.7 | 1.5 |
| Total H ₂ Release (Mt/y) | ~1.1 | ~1.2 | ~13.3 |

~1% (90 Mt) ~1% (140 Mt)



Atmospheric Impacts of Hydrogen as an Energy Carrier, Center for International Climate and Environmental Research (CICERO), Oslo, 2020

660Mt/y

~2% (660 Mt)

% of Produced

Global Hydrogen Budget 2008-2017, Global Carbon Project, Yang et al., 2022

Summary: Takeaway Points

H₂ release values

- represent rough orders of magnitude aiming at giving conservative values.
- o release values due to the deployment of hydrogen economy would be around 13 Mt/y in 2050.
- of ~13 Mt/y represent a limited quantity compared to the 2020 sources of 73 to 107 Mt/y.
- should decline with time
 - due to methane and NMVOCs decrease \Rightarrow Less H₂ from the photochemical production.
 - due to decline of the fossil fuel use.

Funding Opportunity Announcements (EU and US) published recently to further investigate $\rm H_2$ release topic



Thank you

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