THE BASICS & THE GAPS

Future Cleantech Factsheet Series #6 / 2024

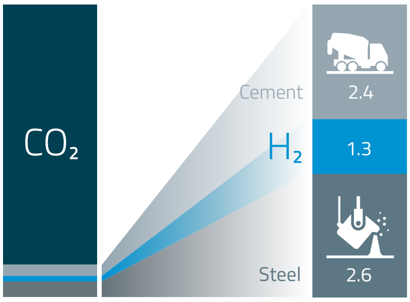
Hydrogen (H_2)

Part 1

HYDROGEN AND CLIMATE CHANGE

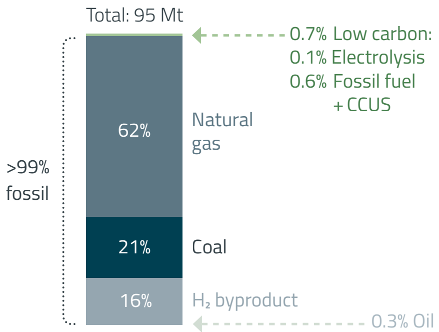
H_2 production is emissions- intensive and contributes ~2.5% to global CO_2eq emissions.

Global emissions (Gt CO_2 eq/year)
Total: 54 Gt (2022)



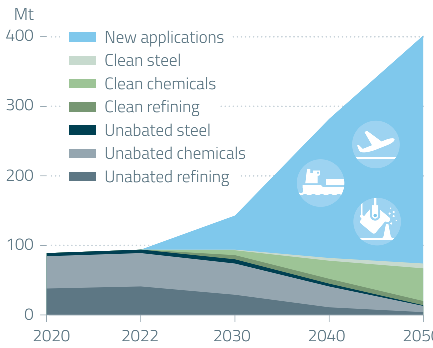
Currently, H_2 is primarily produced from fossil fuels. Low-carbon H_2 can only meet a minimal fraction of today's global demand.

Global hydrogen production by technology (Mt)



In the future, more industries beyond just refining and chemicals will require H_2.

Global hydrogen demand by sector (Mt)



THE BIG PICTURE: PRODUCTION PATHWAYS, COSTS, AND ENERGY PENALTIES

Hydrogen does not contribute to energy security because it is energy intensive to produce. Every production pathway proposed has an associated cost and energy penalty.

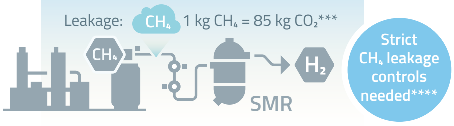
Hydrogen production pathways	Fossil		Fossil + CCS		Biogenic		Renewable
	Coal gasification	Methane SMR	Methane SMR + CCS	Coal gasification + CCS	Biogenic methane SMR	Biogenic methane SMR +CCS	H_2O electrolysis
TRL	9	9	5-9	5-9	9	7-8	5-9
Current production (%)	21	62	<0.6	<0.6	0	0	~0.1
Availability	high	high	high	high	scarce	scarce	low
LCoH* ($/kg$H_2$)	2.3 - 3.3	1 - 3	2 - 5	2.8 - 3.8	2.1**	2.8**	5 - 12
Emissions (kg CO_2/kg H_2)	15 - 30	10 - 17	3 - 9	2 - 10	1-9	-12 - -9	0.5 - 2.5
Feedstock (Kg/Kg H_2)	7.6	3.2	3.5	8.4	3.2	3.5	11
Energy (kWh/kg H_2)	60	41.5	45.5	67	41.5	45.5	55

* LCoH= Levelised Cost of Hydrogen

** No commercial application yet, subject to high uncertainty.

*** Based on a 20 year global warming potential (GWP20). Its GWP is ~30 based on a 100 year timeframe.

**** Strict methane controls requirements also apply to coal mines.

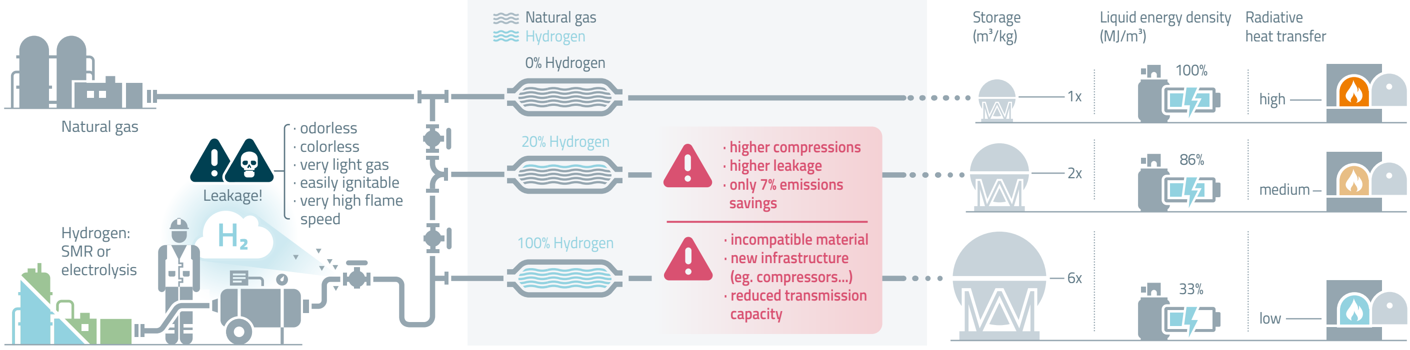


THE BIG PICTURE: HYDROGEN CHALLENGES ALONG THE VALUE CHAIN

Production and handling: Compared to natural gas, hydrogen's wider flammability range and lower ignition energy makes it more prone to explosions and fires.

Transport: Hydrogen's unique properties require new infrastructure, meaning existing natural gas pipelines will require a substantial overhaul.

End use: Hydrogen has different properties to hydrocarbon fuels and cannot be treated as a drop-in solution in all sectors.



Sources: Our World in Data (2024), IEA (2023), Rosa & Mazzotti (2022), BNEF (2023), NREL (2022), Lou et al. (2023), S&P Global (2024), Zang et al. (2024), CATF (2023), Hydrogen Science Coalition (2024), IEA (2021), Lange et al. (2023), MIT Climate Portal (2023)

Methodology and sources: fcarchitects.org/h2-factsheet-sources/

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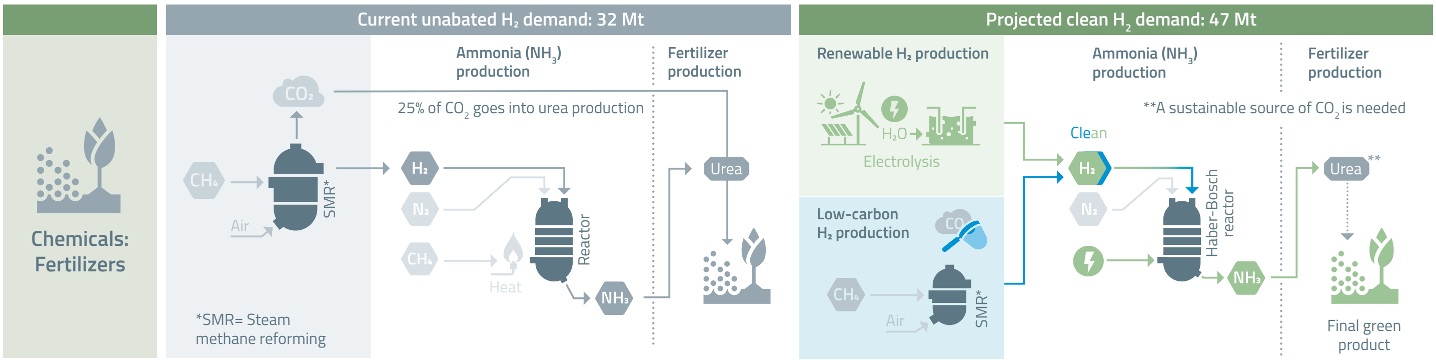
Hydrogen (H_2)

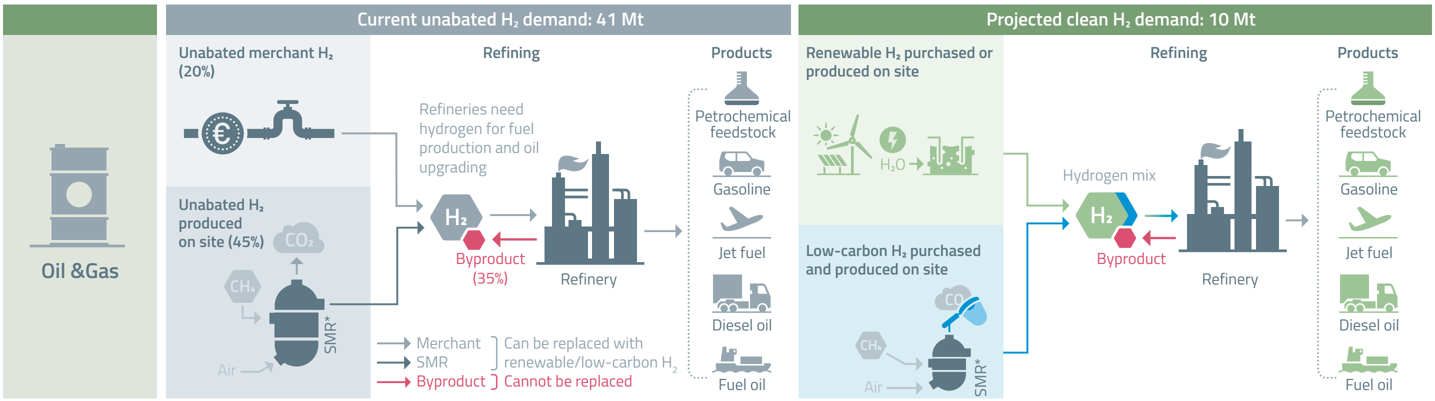
Part 2

HYDROGEN PRIORITIZATION: MAIN USE CASES FOR HYDROGEN

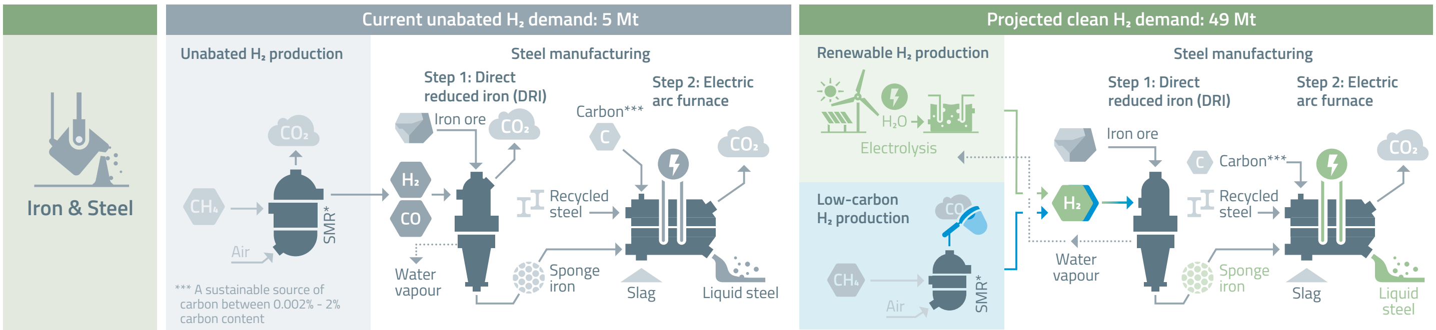
Several high-emitting sectors of the economy are or will be dependent on hydrogen. Considering that clean hydrogen will remain scarce and expensive for decades to come, the sectors outlined below should have priority access to clean hydrogen before introducing it into additional sectors.



Hydrogen is a crucial feedstock for ammonia production, the largest emitter in the chemicals sector. Currently, 400 Mt/year CO_2 is emitted from dedicated hydrogen use for ammonia. Ammonia is the precursor to most fertilizers, which about 50% of the global population is dependent on to produce food at the rates needed to sustain life.



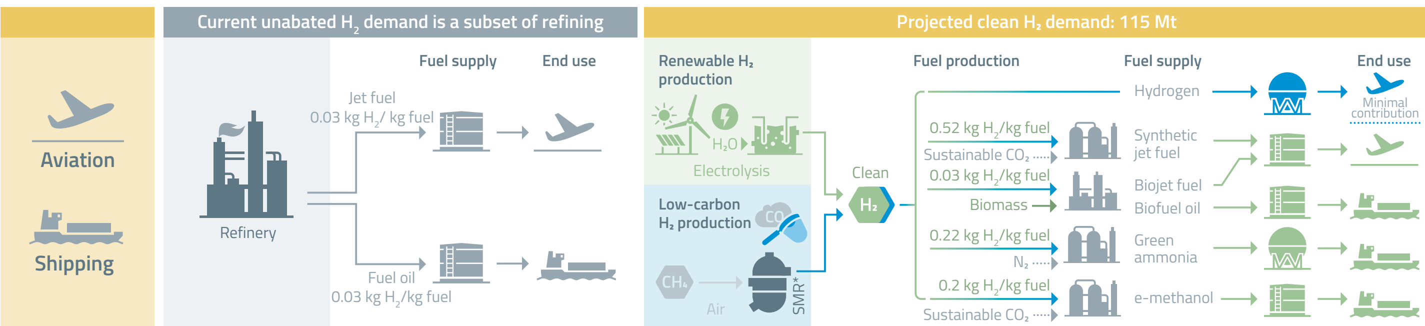
Hydrogen is a crucial feedstock that is used in many refining processes. ~380 Mt/year CO_2 is released from dedicated hydrogen use in refineries. As sectors decarbonize, reliance on oil and gas for fuel will diminish but their use in petrochemicals and asphalt will remain, necessitating the continued use of hydrogen in refineries.



Hydrogen is a promising feedstock for the production of primary steel via the DRI pathway, currently a secondary pathway in steel manufacturing. Today, steel production is a carbon-intensive industry responsible for 2.6 Gt/year or ~5% of CO_2eq emissions and dependent on coal to meet 75% of the energy and feedstock needs of the sector. Primary steel will continue to play a major role in steel production, as current scrap collection rates are at 85% and insufficient to meet the current and projected global steel demand.

HYDROGEN PRIORITIZATION: VIABLE USE CASES FOR HYDROGEN

Hard-to-abate sectors, such as long-distance shipping and aviation, will require hydrogen in some capacity to decarbonize.



Sources: IEA (2023), IEA (2021), Ding et al. (2023), Our World in Data (2017), Roland Berger (2020), Liebreich (2023), ITF (2023),The European Hydrogen Observatory (2021), Atsonios et al. (2023), Pagani et al. (2024), Sollai et al. (2023)

Methodology and sources: fcarchitects.org/h2-factsheet-sources/

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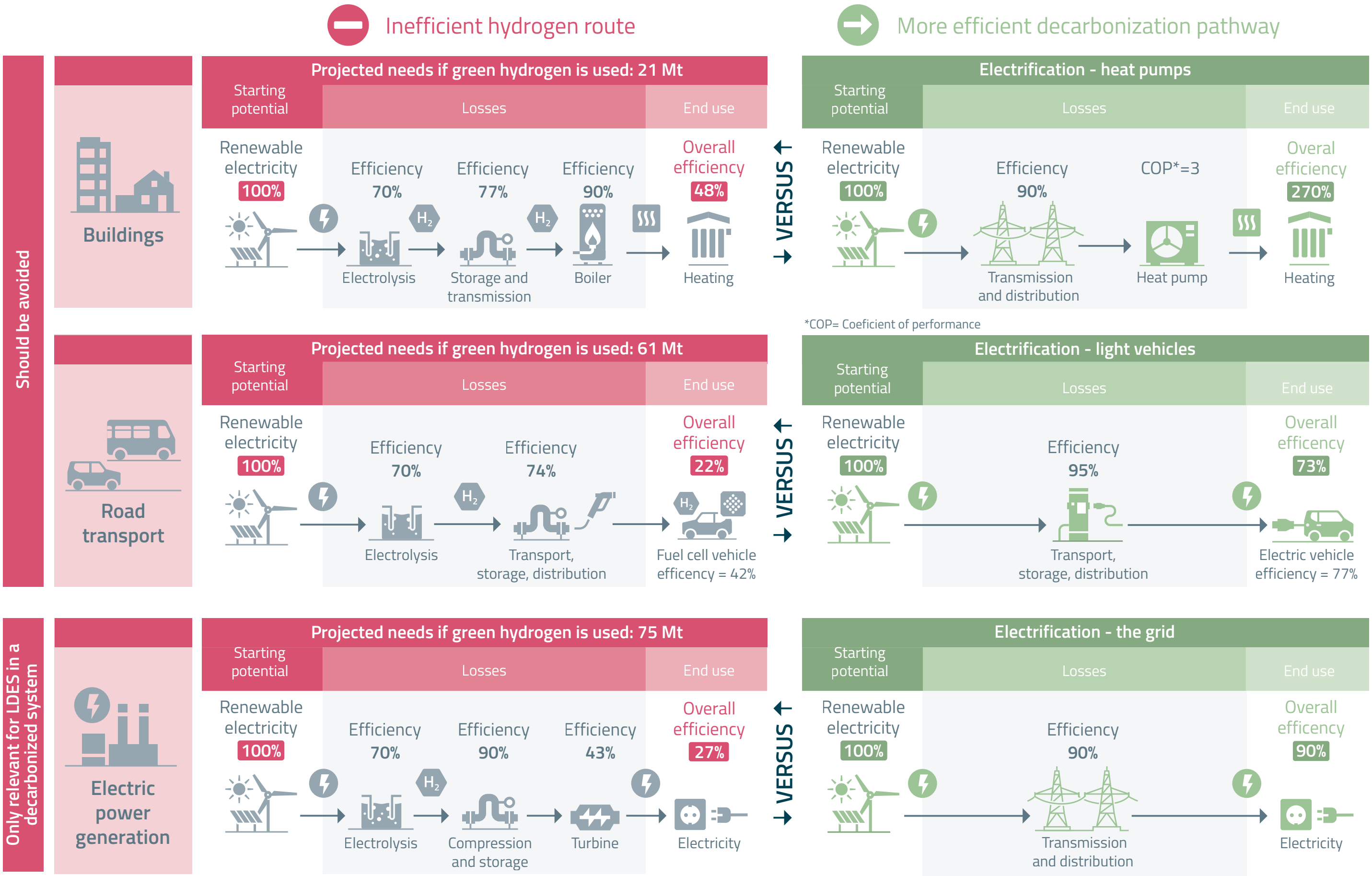
HYDROGEN PRIORITIZATION: INCOMPATIBLE SECTORS

Hydrogen should be prioritized for the sectors where it has the most effective carbon abatement potential. Sectors where direct electrification is feasible should avoid hydrogen and the significant energy losses associated with its use due to extra conversion steps.



157 Mt of additional clean hydrogen, which remains a scarce resource today, could be prioritized for hard-to-abate sectors with no alternative decarbonization solutions. Sectors such as buildings, road transport, and power generation should opt for the more efficient direct electrification route.

RECOMMENDATIONS

Invest in RD&D

Current hydrogen uses amount to 95 Mt per year, with more than 99% still produced from fossil fuels. Clean hydrogen remains a scarce and costly resource. Investing in RD&D is crucial to closing the commercialization gap and ramping up production to help meet current and future hydrogen needs.

- Increase funding in commercially viable alternative clean hydrogen production pathways to ramp-up supply for sectors with no viable alternatives.
- Invest in innovative supplementary pathways, such as thermochemical, to diversify the supply chain and reduce dependence on renewable electricity for electrolysis.
- Accelerate RD&D, investment, and scaling in hydrogen sourcing, infrastructure, and storage to overcome upstream challenges and avoid bottlenecks in supply for indispensable sectors as demand rises.

Decarbonize current hydrogen uses

Current essential hydrogen uses lead to 1.3 Gt of emissions annually and must be decarbonized first before branching into novel hydrogen uses. Clean hydrogen's critical role in facilitating emissions reductions in sectors such as refining, chemicals, and steel must be prioritized.

- Implement a facts-based allocation of scarce resources, such as renewable electricity and green hydrogen, which are subject to cross-sectoral competition.
- Ramp-up renewable electricity deployment, including novel sources such as geothermal, to eliminate bottlenecks and drive down green hydrogen costs.
- Consider low-carbon hydrogen from natural gas with CCUS as a supplement to renewable hydrogen in the short-to-medium term, only if strong methane leak controls are implemented.

Prioritize hard-to-abate sectors

Hydrogen should be positioned as a decarbonization enabler for hard-to-abate sectors alongside its role as an indispensable industrial feedstock. Hydrogen will play a key role in sectors where direct electrification is not a viable decarbonization option, such as aviation and shipping.

- Develop clear national strategies with guiderails for clean hydrogen deployment that prioritize hard-to-abate sectors dependent on hydrogen for decarbonization.
- Close the commercialization gap through dedicated funding, Contracts for Difference, incentives, and permitting for hydrogen and alternative fuels projects.
- Provide long-term visibility for hydrogen and alternative fuels through targets with effective mechanisms to eliminate uncertainty over decarbonization pathways and stimulate off-take agreements.

Abandon incompatible sectors

Science-based guiderails are needed to prevent precious and scarce renewable electricity from being inherently lost in the production and use of hydrogen in sectors where other more effective and efficient decarbonization strategies, such as direct electrification, can be deployed.

- Remove incompatible sectors such as road transport, power generation, and buildings from hydrogen strategies, as they lead to ineffective allocation of public funds.
- Avoid technology openness strategies in sectors where direct electrification is the most efficient, cost-effective, and environmentally-friendly solution.
- Raise awareness with all stakeholders on the limited availability of renewable hydrogen and the challenges in its sourcing, transportation, and storage, necessitating the need to restrict its use to hard-to-abate sectors.