Hydrogen

Tech for Net Zero Knowledge Poster #4

TECH FOR NET ZERO

An introduction to hydrogen

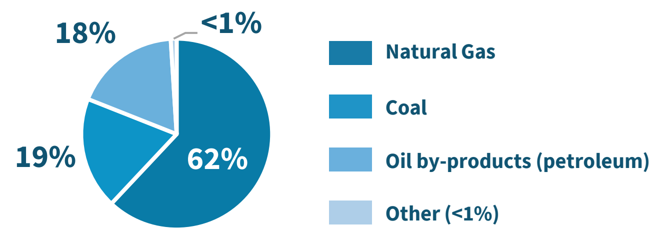
Green Hydrogen is a **clean** alternative to methane, commonly known as natural gas. The EU defines **low-emission hydrogen** as meeting a 70% GHG reduction threshold compared to fossil fuels.

Background:

On Earth, hydrogen molecules are abundant in water, plants, animals, and humans, yet as a gas it is extremely rare. *The challenge lies in producing hydrogen on a large scale to power industry and produce key derivatives.*

Today's hydrogen production

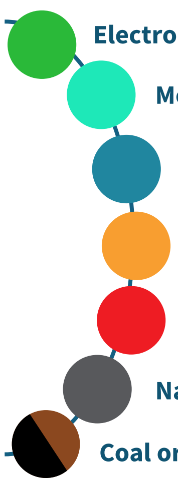
Hydrogen production reached 97 Mt in 2023, of which less than 1% was low-emissions.



Source: IEA Global Hydrogen Review (2024)

The hydrogen color code

*Hydrogen is colorless - the **color code** is used to distinguish the various **production pathways** and their **corresponding CO_2 emissions**. These labels serve as technical classification system but are not an official standard.*



Electrolysis using renewable electricity: Carbon-neutral, but relatively expensive

Methane pyrolysis: Medium carbon impact, byproduct is solid carbon instead of CO_2

Natural gas + CCS: Very high emissions combined with Carbon Capture & Storage

Electrolysis with grid electricity: Medium Emissions, in line with electricity mix

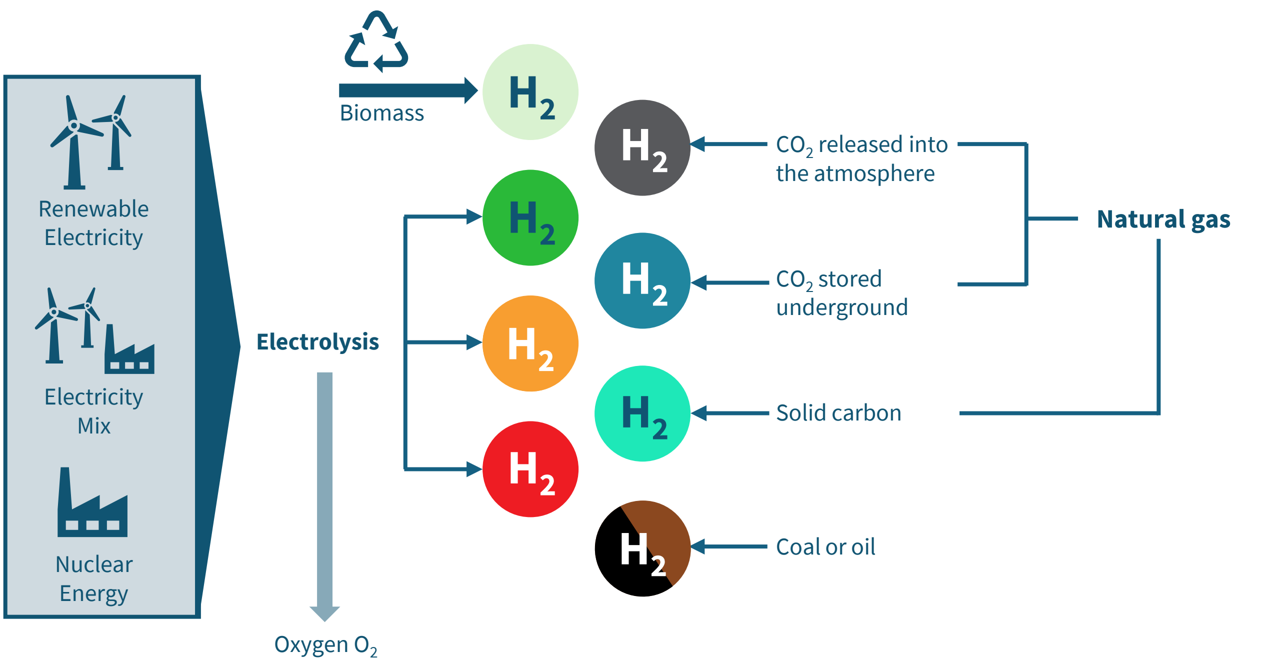
Electrolysis using nuclear energy: Low-carbon, but not renewable

Natural gas (Very high emissions, Most common today)

Coal or oil (Very high emissions)

Source: Gartner Instruments (2023); IKEM (2020)

The technology behind hydrogen



Source: emcel (2024)

Main electrolysis technologies for green hydrogen

Alkaline electrolysis (AEL)

- Mature, low-cost technology using liquid alkaline electrolyte.
- Ideal for large-scale plants; slower ramp-up and lower efficiency.
- TRL 9 with decades of operating experience.

Proton exchange membrane (PEM)

- Compact, flexible system using solid polymer membrane.
- Handles variable renewables well; higher purity H_2 and fast response.
- TRL 8–9, widely deployed commercially.

Anion exchange membrane (AEM)

- Hybrid between AEL and PEM using anion-conducting membrane.
- Potential for low-cost materials but still limited durability.
- TRL 6–7, in pilot development.

Solid oxide electrolysis (SOEC)

- High-temperature, high-efficiency ceramic technology.
- Can utilise waste heat; most efficient but complex materials.
- TRL 6–7, demonstration and early pilots.

Alongside established electrolysis technologies, groundbreaking new approaches are emerging – from artificial photosynthesis and solar-thermochemical processes to geo-inspired reactors that replicate the natural formation of hydrogen.

Sources: IEA (2022), IRENA (2020), U.S. Department of Energy (n.d.)

Policy recommendations to enable hydrogen scale-up

- **GHG-reduction quotas in transport (especially aviation and shipping)**, **a clear decarbonisation pathway for power plants**, and a **green-gas quota** can provide reliable demand signals and unlock private investment.
- **Public guarantees, long-term offtake guarantees**, and **Carbon Contracts for Difference (CCFDs)** can be effective to secure predictable revenue and attract large-scale finance.
- **Renewable energy build-out, hydrogen transport and storage networks**, and **cross-sector integration** need to be supported to avoid bottlenecks and enable system-wide deployment.

Hydrogen technologies in the Tech for Net Zero network

*All relate to green hydrogen.

Enapter develops modular AEM electrolysers that use renewable electricity and water to generate green hydrogen for applications ranging from industrial processes to backup power and mobility, positioning the company in the green hydrogen electrolysis segment.

HDF Energy Germany develops large-scale Hydrogen-to-Power plants using PEM fuel cells that convert green or low-carbon hydrogen into clean electricity, strengthening the downstream end of the green hydrogen value chain.

Hydrogenious LOHC advances the hydrogen value chain through its Liquid Organic Hydrogen Carrier technology, enabling safe, efficient, cost-effective and scalable storage and transport of hydrogen from production to end use, leveraging existing infrastructure.

ionysis provides advanced membranes and MEAs that are critical components for PEM and AEM electrolysers and fuel cells, making it a key technology enabler within the green hydrogen value chain rather than a hydrogen producer itself.

STOFF2 designs and builds zinc-based electrolysers that store renewable energy in a zinc cycle and release it as green hydrogen on demand, combining energy storage with the green hydrogen electrolysis sector.

Sunfire manufactures large-scale pressurized alkaline and solid oxide electrolysers that produce green hydrogen and syngas for industries such as chemicals, steel, and e-fuels, placing it firmly in the green hydrogen electrolysis segment.