European Hydrogen Observatory

Hydrogen 101 Factsheets

Introduction to hydrogen

September 2023

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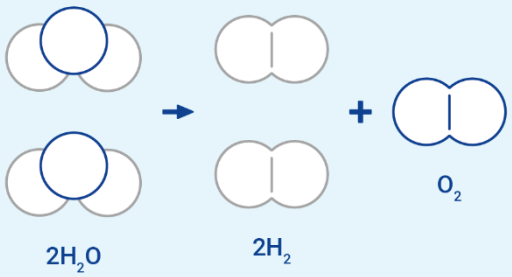
DID YOU KNOW?

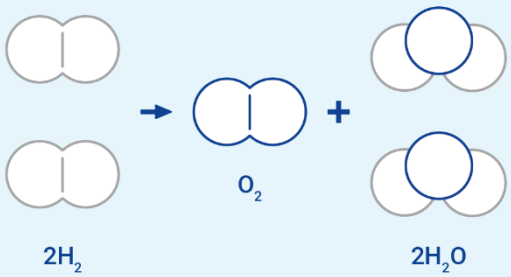
- **Hydrogen is the most abundant element in our universe**, making up about 75% of its total mass. On Earth, **naturally occurring hydrogen gas is found in very small quantities**. Instead, most hydrogen atoms are bound to other atoms – for example, water is a molecule containing hydrogen and oxygen atoms.

- Since it takes energy to separate hydrogen from these other atoms, it is an **energy carrier and <u>not</u> an energy source.**

- Hydrogen has the potential to be a **clean energy carrier**. It can, for example, be produced from water using renewable energy sources. To release this stored energy, it can be oxidised, resulting again into water to close the cycle.



Producing hydrogen: Hydrogen can be produced by splitting up water molecules through a process called 'electrolysis'.



Consuming hydrogen fuel: When Hydrogen fuel is oxidised in a fuel cell, it returns to water.

- Hydrogen has very **high energy for its weight**, which is why it is used as a rocket fuel and in fuel cells to produce energy on some spacecraft. However, it has a **very low energy for its volume**, requiring the development of advanced storage methods that have potential for higher energy density.

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A BRIEF HISTORY OF THE USE OF HYDROGEN AS A FUEL

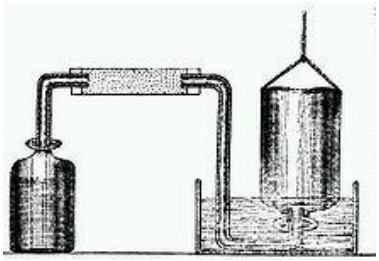
Although clean hydrogen is a relatively new field, the discovery and applications of hydrogen – including hydrogen as a fuel – stretch back over centuries. This factsheet highlights some of the key events in this history.

16th and 17th century

First written records on hydrogen production by experiments involving metals and acids.

18th century

Hydrogen was recognised as a distinct element by Henry Cavendish



19th century

Electrolysis was used to split water, leading to the construction of a water electrolysis unit to generate hydrogen for French military airships by the end of the century

Early versions of fuel cells and fuel batteries were developed.

The first combustion engines were developed using a fuel containing hydrogen gas.

Hydrogen was used to power city lighting networks.

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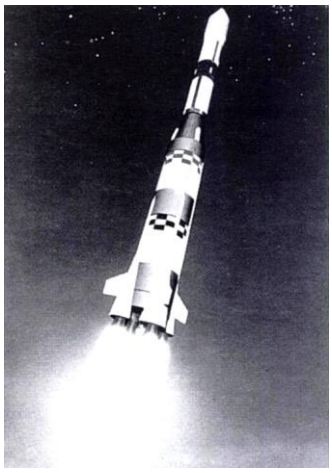
1966

General Motors release 'Electrovan', the first hydrogen fuel cell car ever produced.

1970s

Liquid hydrogen fuel is developed for the Ariane rocket by the European Space Agency.



1998

Iceland declared its intention to transform into a hydrogen economy.

2004

The EU launches the Hydrogen and Fuel Cell Technology Platform to reduce the dependence of the EU on oil and contribute to sustainable development; it is the precursor of the Clean Hydrogen Partnership.

2008

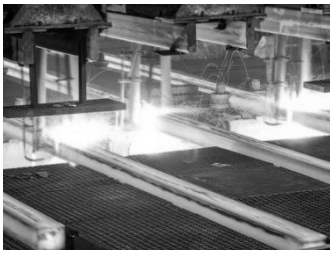
The EU launches the Strategic Energy Technology (SET) plan, which includes a focus on hydrogen as a key technology for decarbonisation.

2022

The first hydrogen fuel cell-powered train fleet was deployed in Lower Saxony in Germany.

2023

H2 Green Steel started production at Europe's first green steel plant in Boden, Northern Sweden

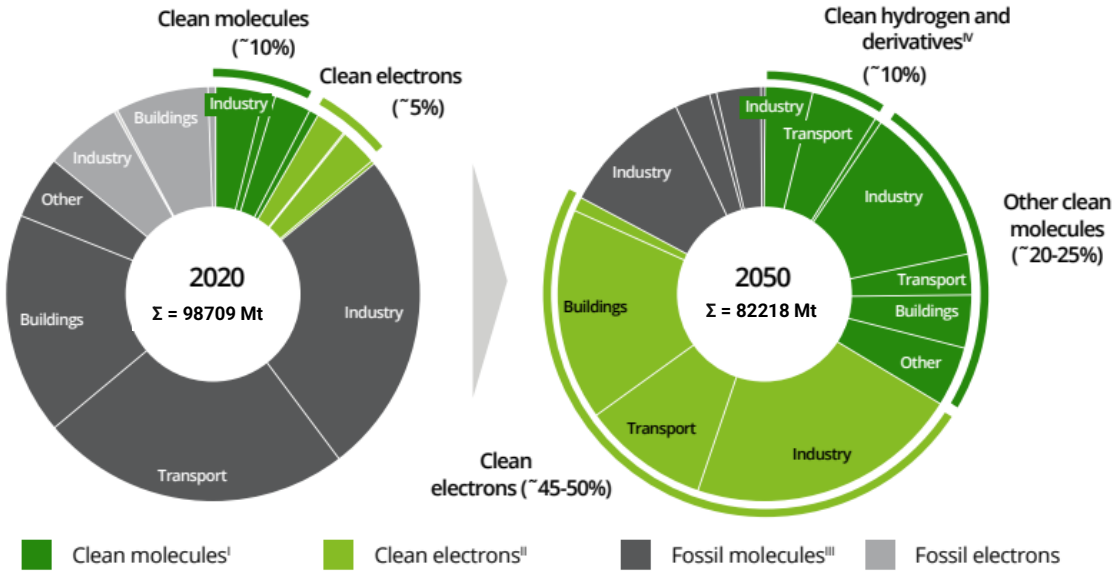


THE ROLE OF HYDROGEN IN DELIVERING NET ZERO

Electrification will be key to delivering **Net Zero** – but it won't be possible or technically feasible in all sectors. Clean molecule-based energy carriers including hydrogen and hydrogen derivatives provide an alternative to electrification in hard-to-abate sectors, for instance in primary steel production or long-distance heavy transport.

As illustrated below, in the **Net Zero Emissions by 2050 scenario**, based on data from the International Energy Agency (IEA), **clean hydrogen and hydrogen derivatives** are expected to deliver about **10%** of total energy consumption worldwide. Other **clean molecules** such as biofuels contribute to fulfilling **20 to 25%** of the demand for clean energy.

The aggregated energy per source and application in the 2050 energy mix



Notes: Includes energy carriers used as fuel, as well as feedstock in industry (e.g., naphtha in petrochemicals, natural gas in ammonia production); I) Incl. hydrogen, biofuels, heat and fossil fuels with CCUS; II) Incl. electricity production from renewables, and natural gas with CCUS / coal with CCUS; III) Fossil molecules that remain in 2050 are used where carbon is embodied in the product such as plastics and in sectors where low-carbon technology options are scarce (i.e., primarily oil in industrial applications); IV) Incl. hydrogen derivatives such as ammonia, methanol, and Sustainable Aviation Fuel (SAF). Note that industry and transport do not make up 100% of the projected future demand for hydrogen and derivatives;

Source: Deloitte research based on IEA data: World Energy Outlook 2022 – Analysis - IEA; Net Zero by 2050 – Analysis - IEA

As illustrated in the above figure, **heavy industries** (in particular, **steel**, ammonia, methanol, and fuel refining) and the **transport sector** (in particular heavy-duty road freight, international shipping, and aviation) are expected to account for most of the future demand for clean hydrogen. However, these will not account for the total demand for clean energy. In fact, **other areas** such as the **building or transport** sectors are expected to account for a significant amount of the demand for clean hydrogen and other clean molecules including energy produced using carbon capture technologies.