Introduction to Hydrogen Economy

Hydrogen uses
(source Thesis by María Hanako Olmedilla Ishishi)

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Hydrogen as fuel in engines

Hydrogen can be used as fuel in **combustion engines, turbines and fuel cells**

Hydrogen in Internal combustion engines (ICE)

- Can be used as direct or secondary fuel
- Reduces the pollution particles released compared to fossil fuels, but also lowers the output power of the engine
- Hydrogen ICE has some disadvantages that need to be addressed, such as discontinuity in the combustion process, the difference in operation and fuel distribution, high level of NO_X released and less power produced
- The methods of supplying hydrogen into ICE are carburation, manifold injection and direct injection
- The performance and efficiency of hydrogen as fuel varies between engine types (gasoline, LPG, diesel engines)

Hydrogen as fuel in engines

Hydrogen in gas turbines

- The use of hydrogen gas in turbines can potentially reduce the CO_2 emissions to zero (target by 2030)
- Two technologies are being developed: Dry Low Emission (DLE) combustion and Non-DLE Combustion
  - DLE reduces the NO_X emissions as the combustion temperature is low. The system requires advanced control of flame temperature and chemicals.
  - Non-DLE uses either diffusion flames or partially premixed flames. The use of diffusion flames requires a diluent (N_2, steam or water) to control NO_x emissions.

Hydrogen and fuel cells

- The operation principle is the opposite of an electrolyzer
- Fuel cell types: Solid Oxide Fuel Cell (SOFC), Protone Exchange Membrane Fuel Cell (PEMFC), Phosphoric Acid Fuel Cell (PAFC), Molten Carbonate Fuel Cell (MCFC), Direct Methanol Fuel Cell (DMFC), Alkaline Fuel Cell (AFC). They differ in which electrolyte is used, as well as their operating temperature, electrical efficiency and power output.

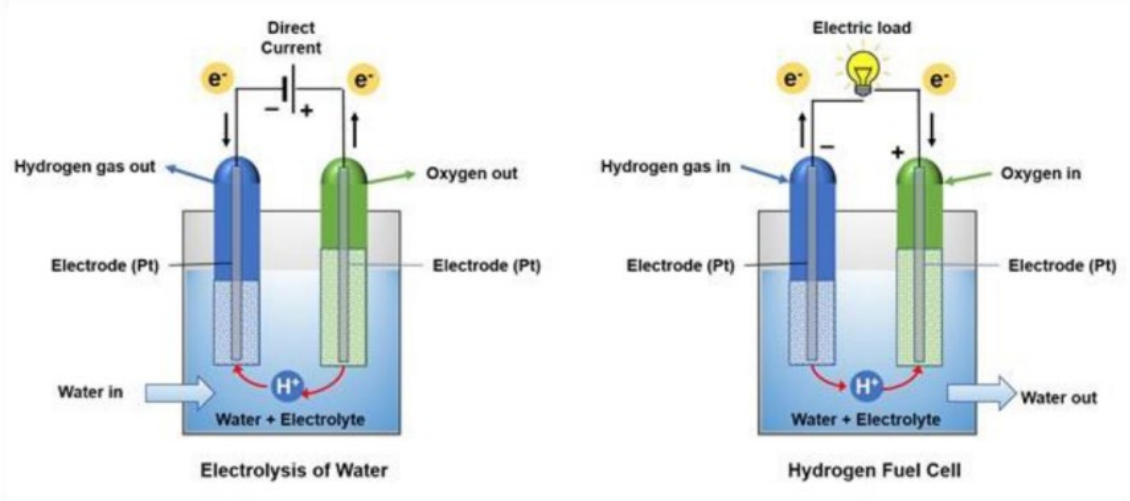

Figure 2: Water electrolyzer (left) and hydrogen fuel cell (right) [6]

Power-to-X

- Renewable energy is electricity, and the power supply has big fluctuations
- The surplus energy from solar, wind or water can be converted into another energy carrier and stored for later use
    - This conversion is called power-to-x
- Power-to-x technologies allow the decoupling of the energy sector with other industries
- Applications: power-to-gas (methane, ammonia, syngas), power-to-liquid (methanol, liquid hydrogen), power-to-heat

Hydrogen applications in transport, power generation, industry and buildings

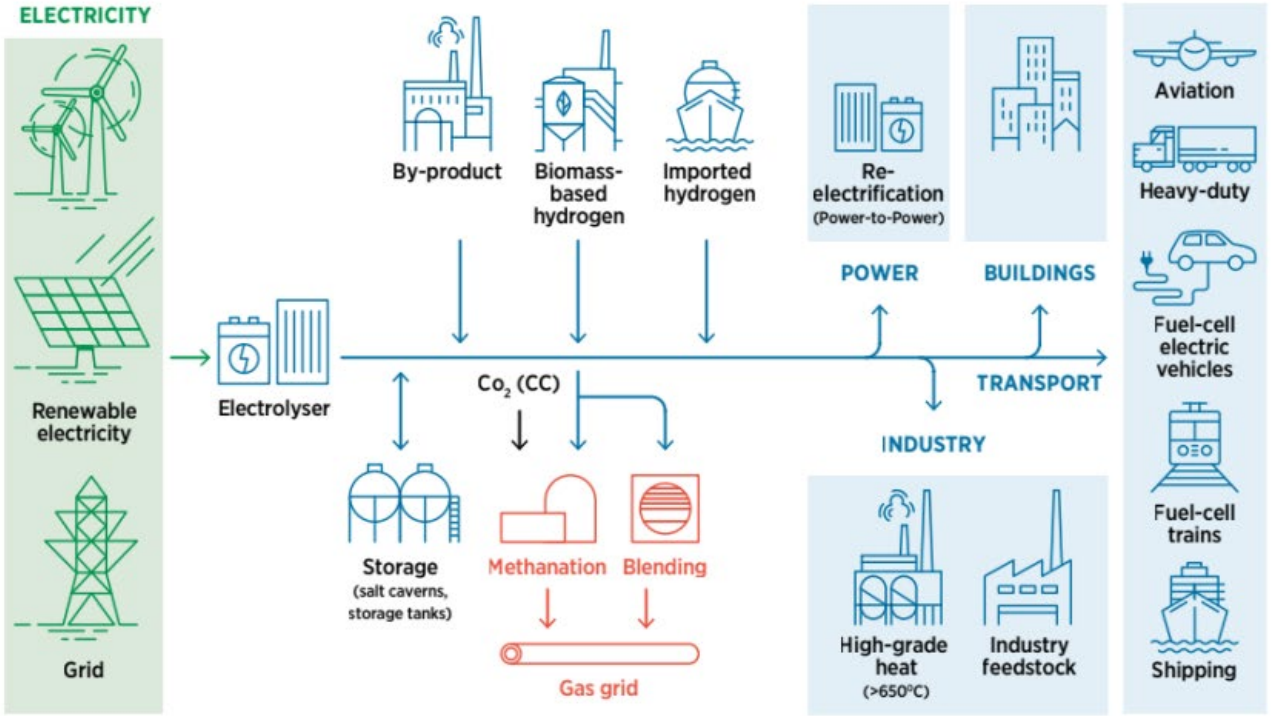

Figure 19: Hydrogen integration in the end-use of variable renewable energies [165]

Hydrogen uses today and future prospects

Traditional and new applications of hydrogen

Source: Global Hydrogen Review 2023

- Hydrogen is widely used today in refining, the chemical industry, the steel industry and for special applications in other industries.
- Hydrogen can also be used in a wide range of other applications, as a feedstock or reducing agent, and also as a fuel.
    - Hydrogen has not been used at scale in these applications, either due to its lack of competitiveness with incumbent fossil fuels and with other low-emission technology alternatives or because end-use technologies have not reached commercial maturity.
    - However, decarbonisation efforts are expected to prompt hydrogen use in some of these new applications, particularly in sectors where emissions are hard to abate and other low-emission technologies are unavailable or very difficult to implement.

Traditional and new applications of hydrogen

Source: Global Hydrogen Review 2023

Traditional applications include

- refining,
- feedstock to produce ammonia, methanol and other chemicals,
- reducing agent to produce direct reduced iron (DRI) using fossil-based synthetic gas,
- use of hydrogen in electronics, glassmaking or metal processing (these sectors use very small quantities of hydrogen).

Potential new applications include

- use of hydrogen as a reducing agent in 100%-hydrogen DRI (direct reduced iron),
- transport,
- production of hydrogen-based fuels (such as ammonia or synthetic hydrocarbons),
- biofuels upgrading,
- high-temperature heating in industry,
- electricity storage and generation,
- other applications in which hydrogen use is expected to be very small due to the existence of more efficient low-emission alternatives.

The clean hydrogen market 2050

By 2050, the clean hydrogen market is expected to reach annual revenue of €3 trillion because of its value in decarbonizing the world's largest and most difficult-to abate industries, including fertilizer, steel, maritime and aviation.

Source: Clean Hydrogen Strategy for Finland

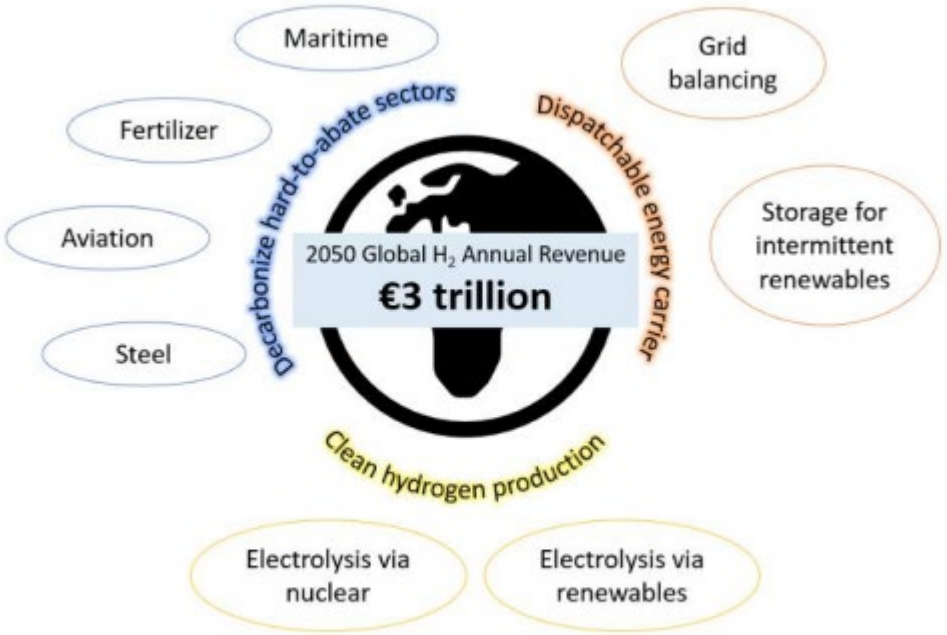

Figure 4: Revenue of global hydrogen market [6]