Hydrogen Reuse

Section 1

Introduction

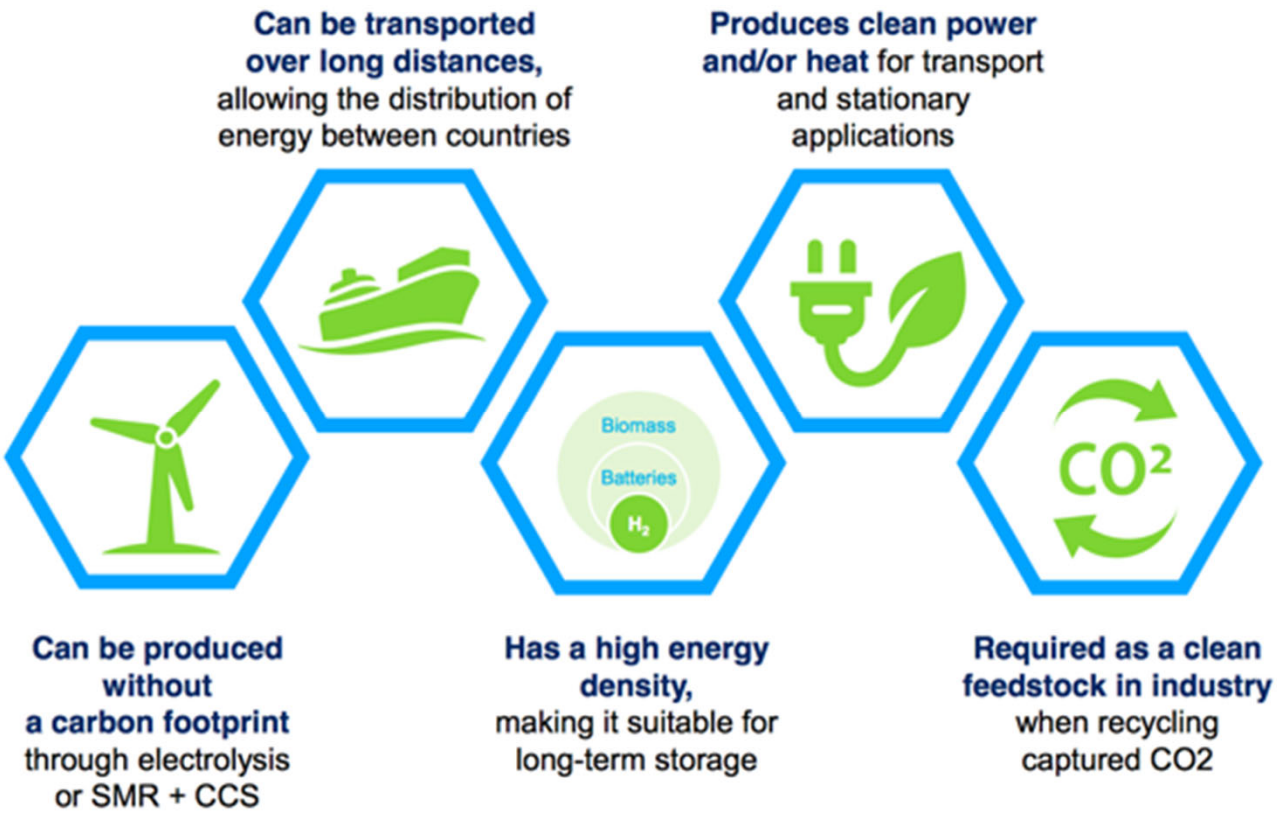
FCH EDUCATION

DTU

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Why use hydrogen as an energy carrier?

Clean
Safe
Versatile



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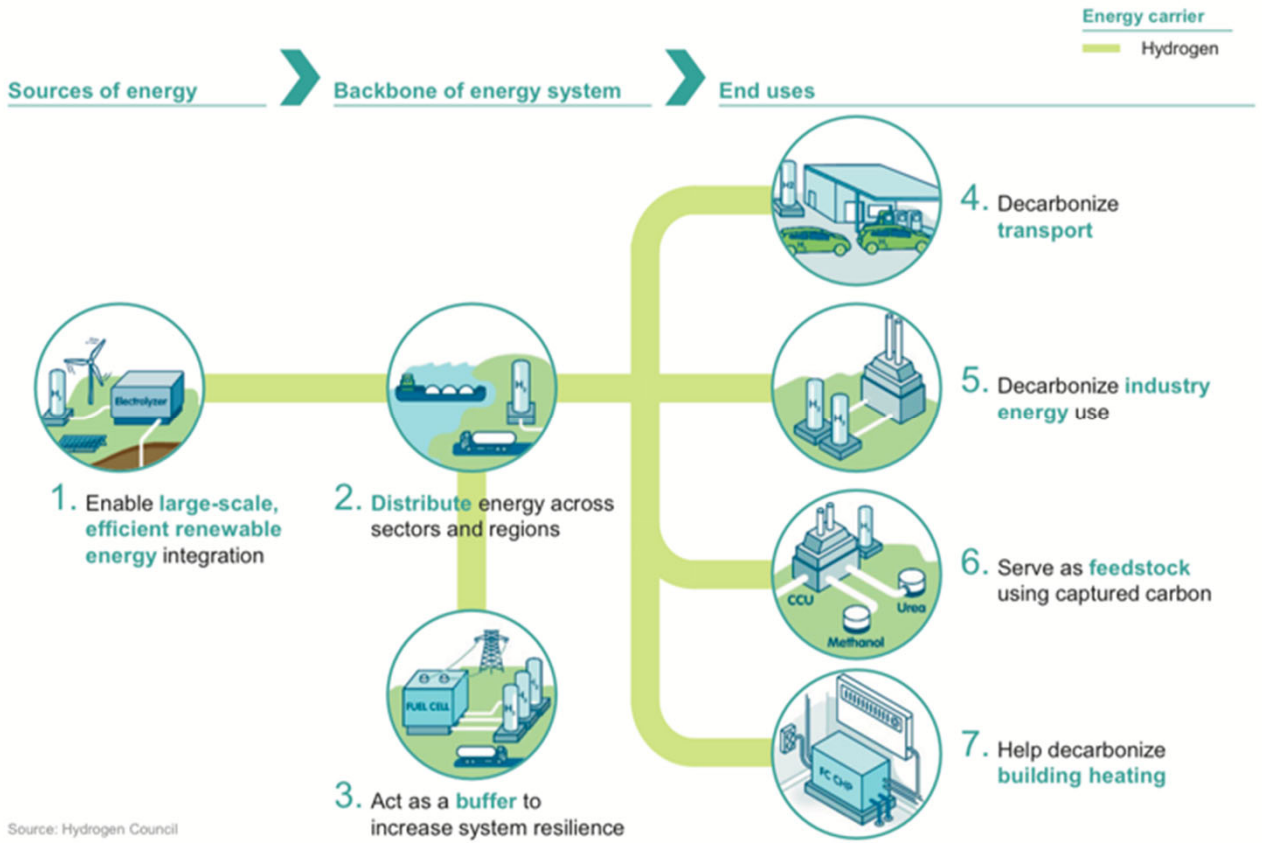
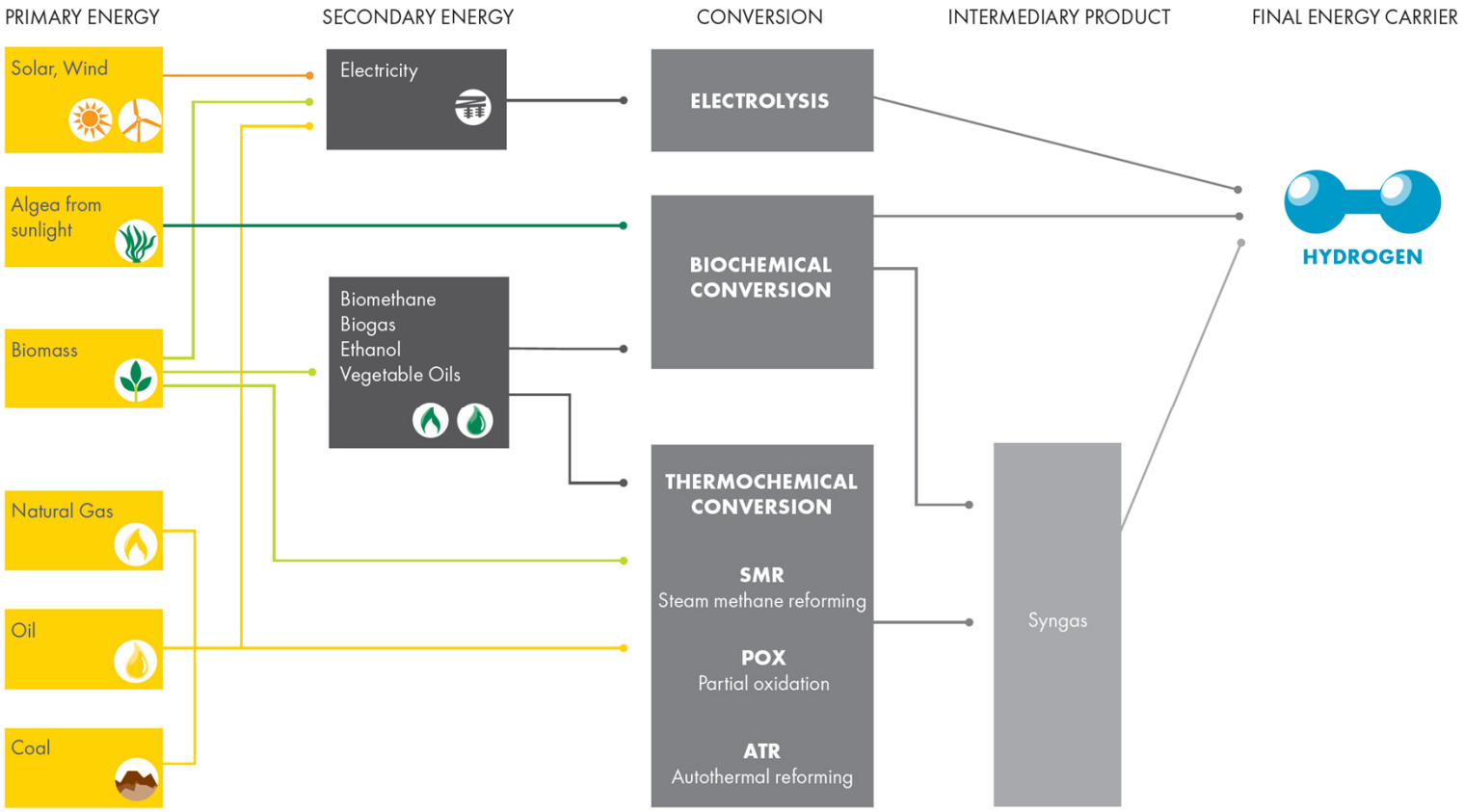
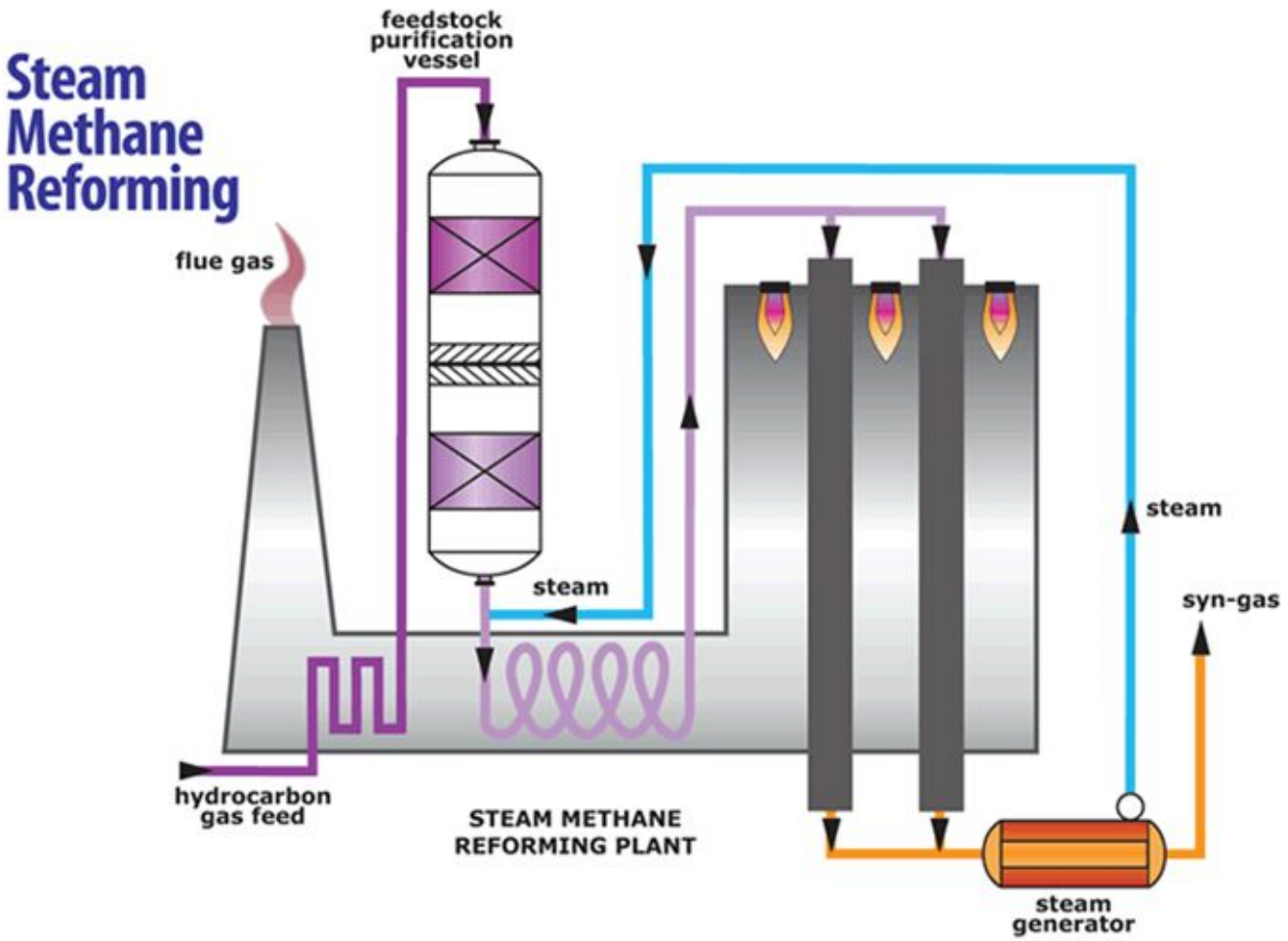
Hydrogen Europe

Hydrogen decarbonisation role



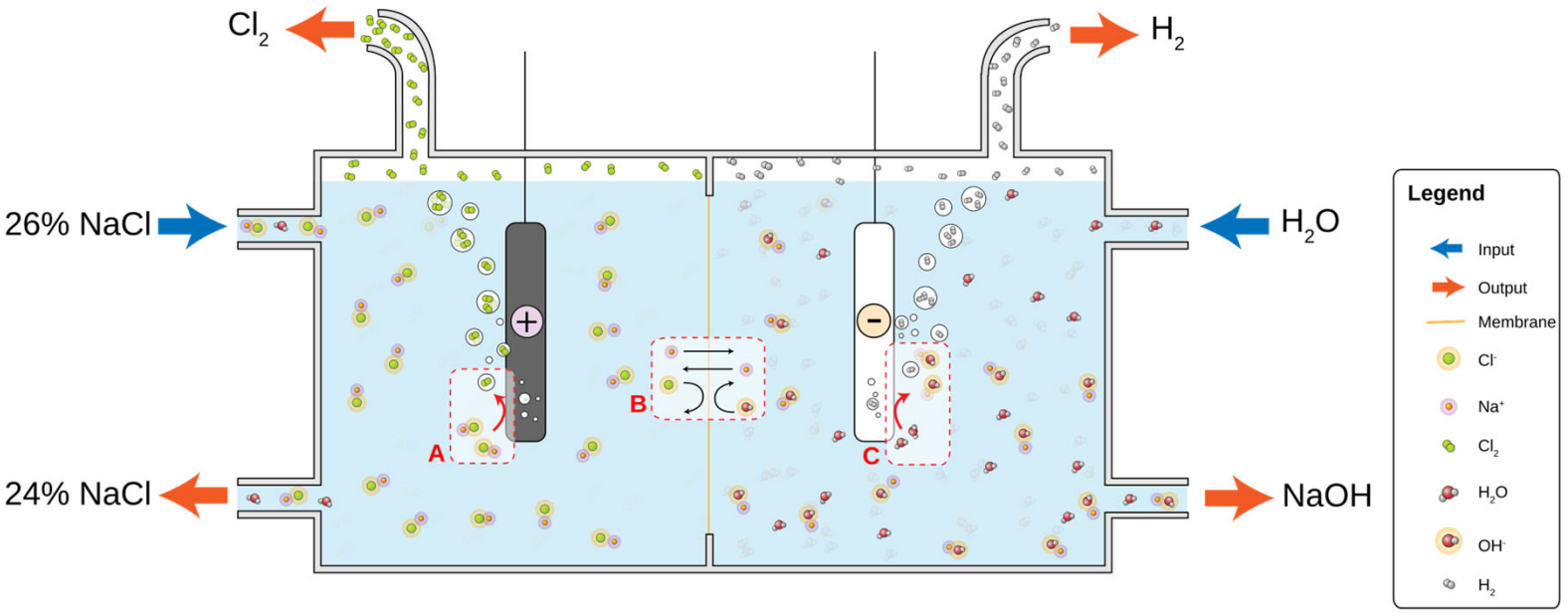
Hydrogen production routes




Steam
Methane
Reforming
feedstock
purification
vessel
flue gas
steam
steam
syn-gas
hydrocarbon
gas feed
STEAM METHANE
REFORMING PLANT
steam
generator

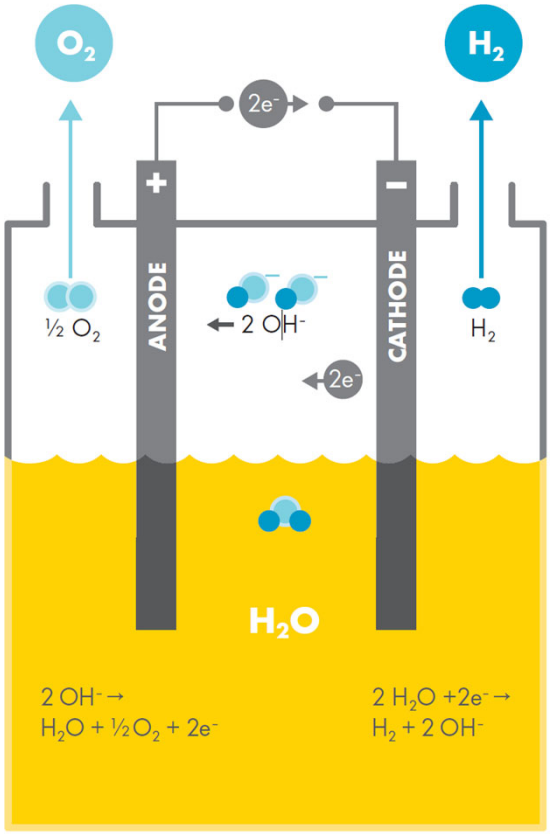
Hydrogen as a by-product

- Chlorine and NaOH production



https://en.wikipedia.org/wiki/Chloralkali_process

Hydrogen production by water electrolysis



	Temperature °C	Electrolyte	Plant size		Efficiency	Purity H_2	System costs	Lifespan	Maturity level
Alkaline Electrolysis (AE)	60 – 80	Potassium-hydroxid	0.25 – 760 Nm^3 H_2/h	1.8 – 5,300 kW	65 – 82%	99.5% – 99.9998%	1,000 – 1,200 €/kW	60,000 – 90,000 h	Commercially used in industry for the last 100 years
Proton Exchange Membrane Electrolysis (PEM)	60 – 80	Solid state membrane	0.01 – 240 Nm^3 H_2/h	0.2 – 1,150 kW	65 – 78%	99.9% - 99.9999%	1,900 – 2,300 €/kW	20,000 – 60,000 h	Commercially used for medium and small applications (<300 kW)
Anion Exchange Membrane Electrolysis (AEM)	60 – 80	Polymer membrane	0.1 – 1 Nm^3 H_2/h	0.7 – 4.5 kW	N/A	99.4%	N/A	N/A	Commercially available for limited applications
Solid Oxide Electrolysis (SOE)	700 – 900	Oxide ceramic	Until now at experimental stage in laboratories		85% (lab)	N/A	N/A	approx 1,000 h	Experimental stage

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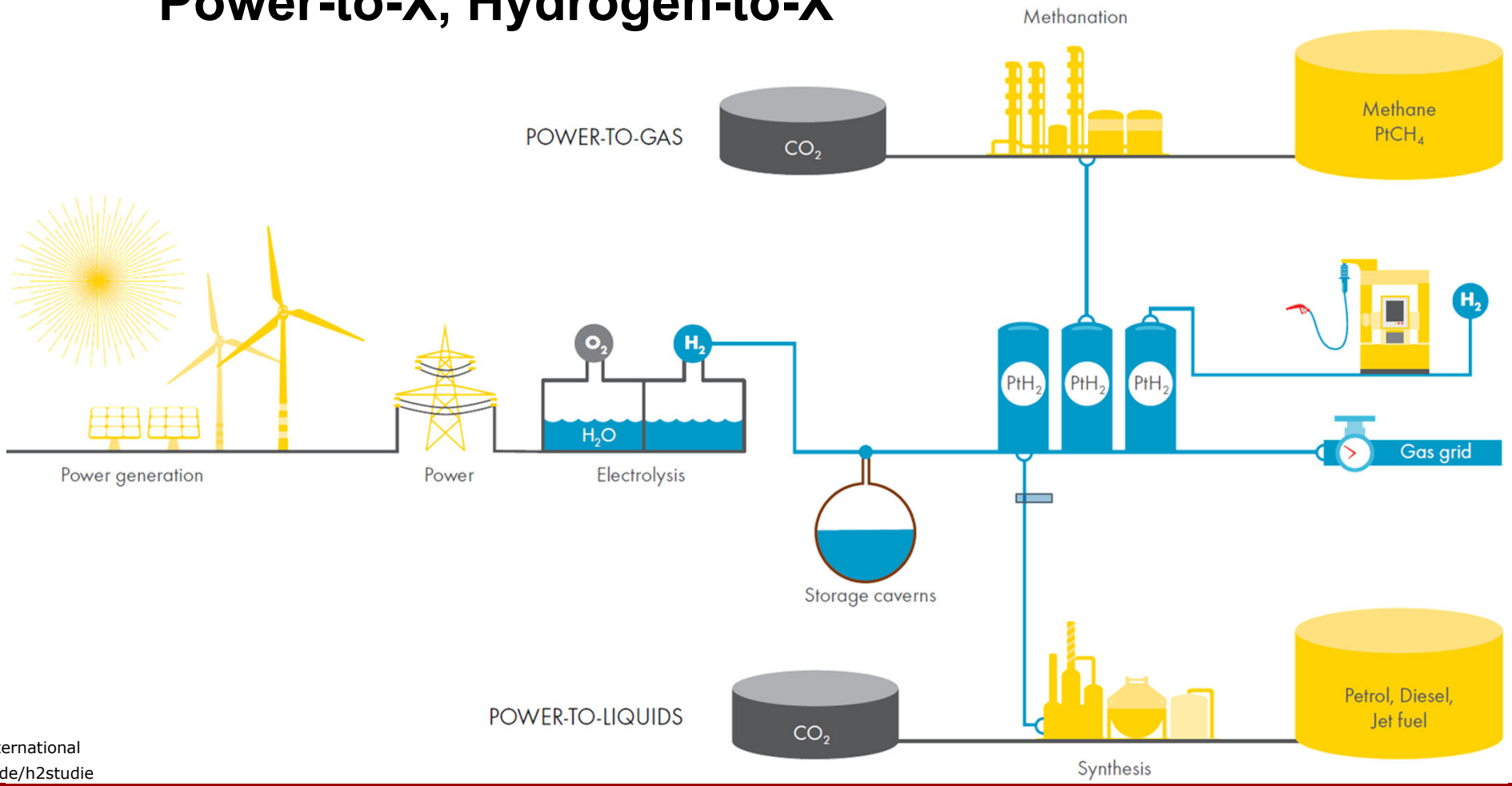
Power-to-X, Hydrogen-to-X



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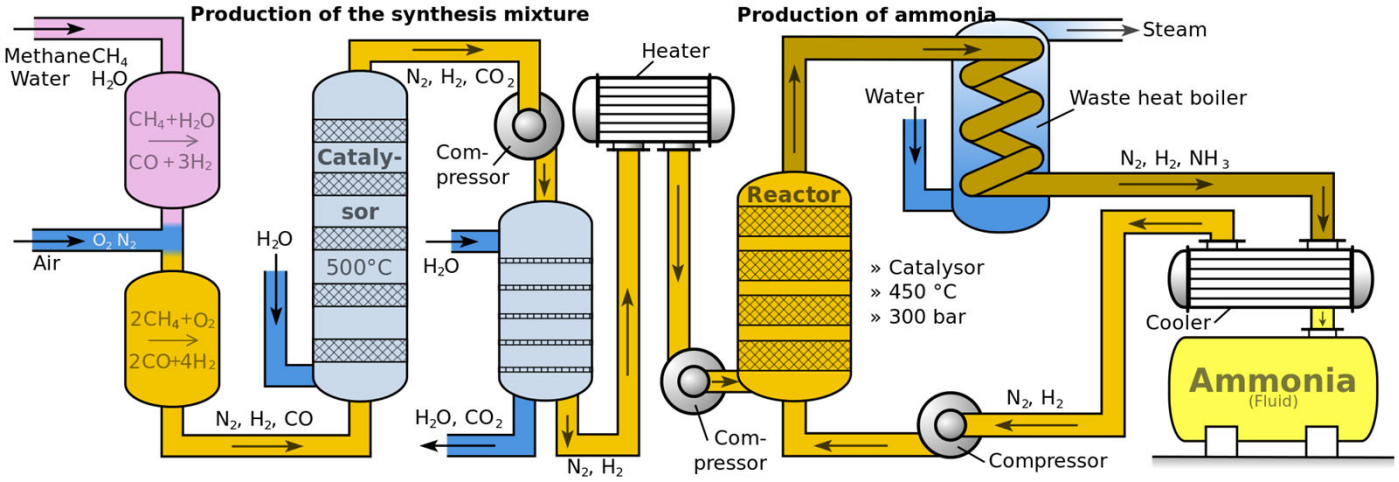
Industry/fertiliser/fuel production refining



Transport

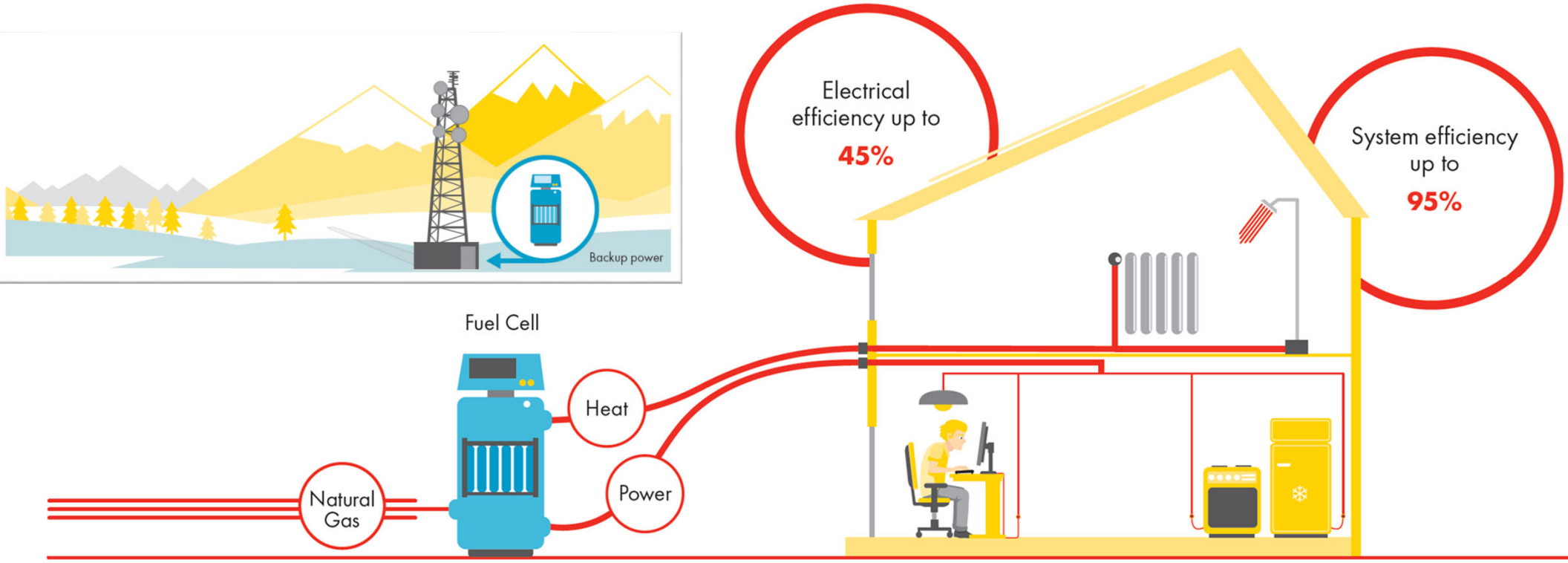
Jason Lawrence [CC BY 2.0
https://commons.wikimedia.org/wiki/File:Fuel_cell_test_bus_at_Malden_Center,_December_2016.jpg

Dr. Artur Braun CC BY-SA 4.0
https://commons.wikimedia.org/wiki/File:Hyundai_NEXO_Hydrogen_Fuel_Cell_Car_beim_Autosalon_Genf_2018_o.jpg

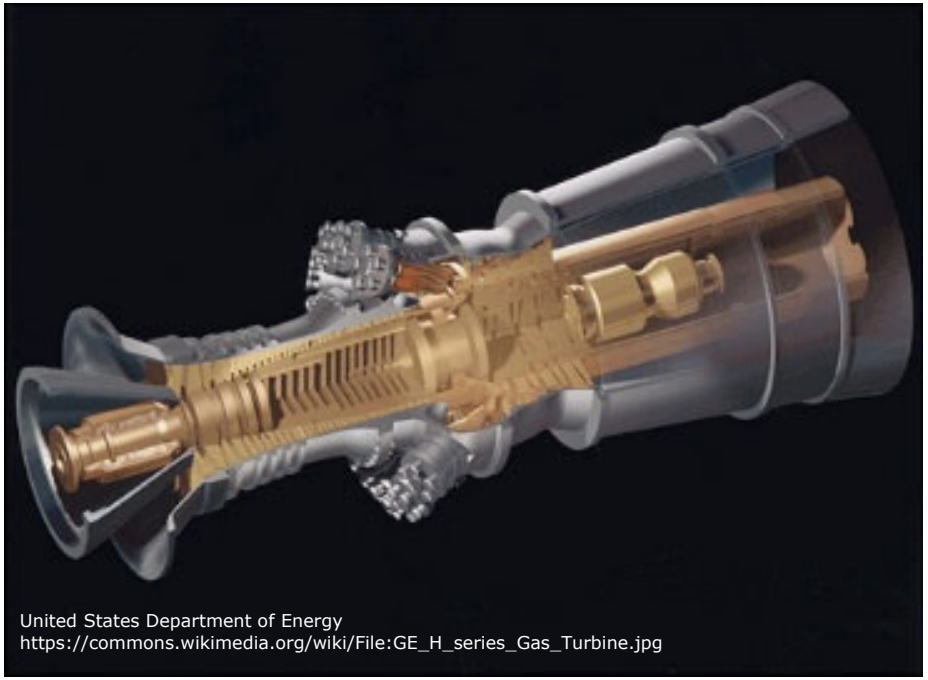
http://evtalk.co.nz/wp-content/uploads/2019/10/PastedGraphic-10.png

https://www.still.de/en-DE/company/news-press/news/detail/pioneering-use-of-hydrogen-in-intralogistics.html

Stationary electricity / energy generation

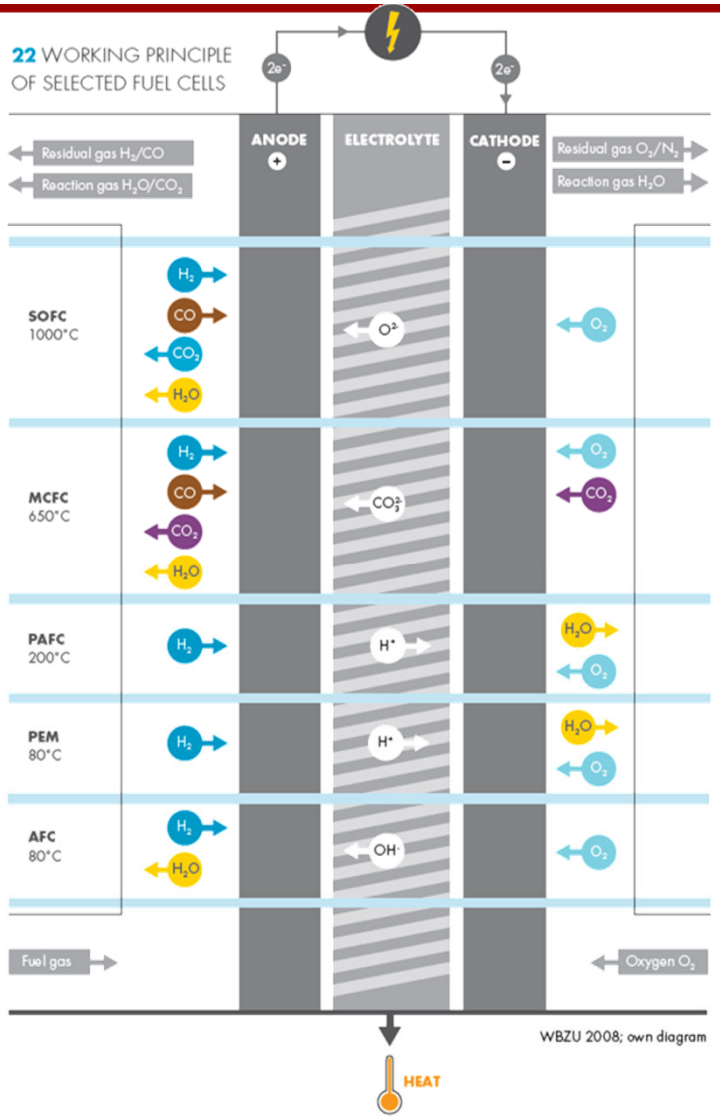


Hydrogen turbines



United States Department of Energy
https://commons.wikimedia.org/wiki/File:GE_H_series_Gas_Turbine.jpg

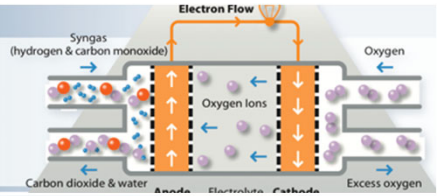
Fuel cells


22 WORKING PRINCIPLE OF SELECTED FUEL CELLS
2e⁻
2e⁻
ANODE
ELECTROLYTE
CATHODE
Residual gas H2/CO
Reaction gas H2O/CO2
Residual gas O2/N2
Reaction gas H2O
SOFC
1000°C
MCFC
650°C
PAFC
200°C
PEM
80°C
AFC
80°C
Fuel gas
Oxygen O2
WBZU 2008; own diagram
HEAT

Fuel cells

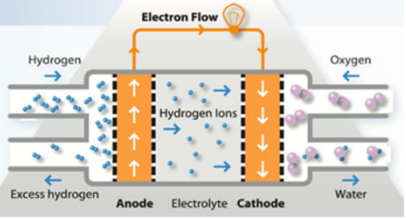
SOFC – Solid Oxide Fuel Cells

- Electrolyte: solid ceramic, such as stabilised zirconium oxide
- A precious metal catalyst is not necessary
- Can run on hydrocarbon fuels such as methane
- Operate at very high temperatures, around 800°C to 1,000°C
- Best run continuously due to the high operating temperature
- Popular in stationary power generation



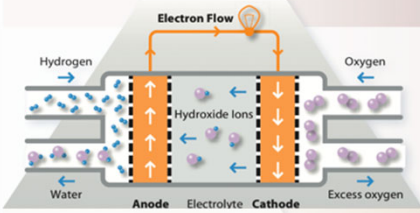
PEMFC – Proton Exchange Membrane Fuel Cells

- Electrolyte: water-based, acidic polymer membrane
- Also called polymer electrolyte membrane fuel cells
- Use a platinum-based catalyst on both electrodes
- Generally hydrogen fuelled
- Operate at relatively low temperatures (below 100°C)
- High-temperature variants use a mineral acid-based electrolyte and can operate up to 200°C.
- Electrical output can be varied, ideal for vehicles



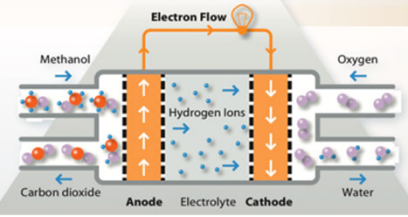
Alkaline Fuel Cells – AFC

- Electrolyte: alkaline solution such as potassium hydroxide in water
- Commonly use a nickel catalyst
- Generally fuelled with pure hydrogen and oxygen as they are very sensitive to poisoning
- Typical operating temperatures are around 70°C
- Can offer high electrical efficiencies
- Tend to have relatively large footprints
- Used on NASA shuttles throughout the space programme



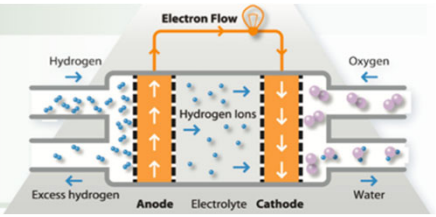
Direct Methanol Fuel Cells – DMFC

- Electrolyte: polymer membrane (like PEMFC)
- Use a platinum–ruthenium catalyst on the anode and a platinum catalyst on the cathode
- This catalyst can draw hydrogen atoms from liquid methanol, which is used as fuel instead of hydrogen, giving the cell its name.
- Operate in the range from 60°C to 130°C
- DMFC are convenient for portable power applications with outputs generally less than 250 W



PAFC – Phosphoric Acid Fuel Cells

- Electrolyte: liquid phosphoric acid in a bonded silicon carbide matrix
- Use a finely dispersed platinum catalyst on carbon
- Quite resistant to poisoning by carbon monoxide
- Operate at around 180°C
- Electrical efficiency is relatively low, but overall efficiency can be over 80% if the heat is used
- Used in stationary power generators (100 kW to 400 kW)



Source
www.fuelcelltoday.com

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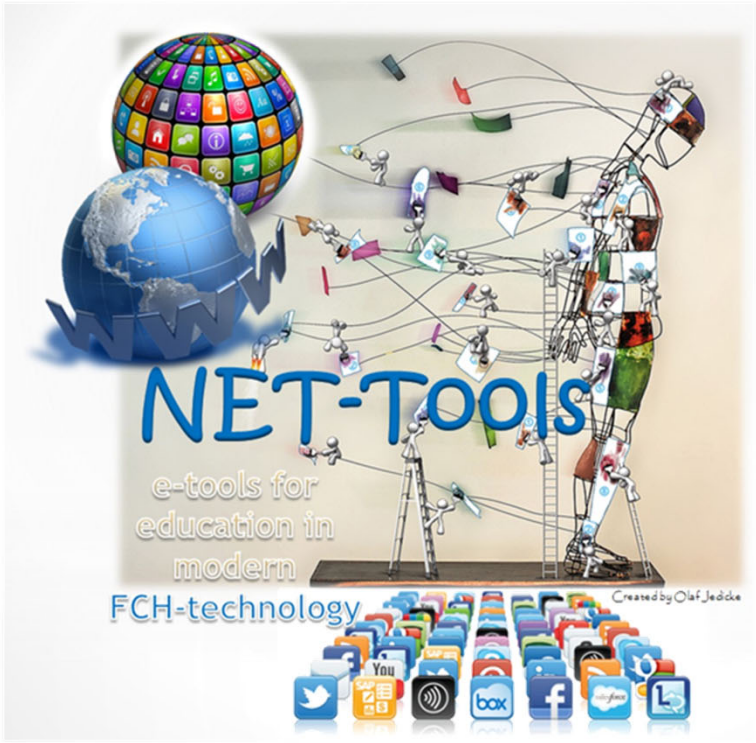

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