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Sustainable Energy Connectivity in Central Asia

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The European Union – Turkmenistan Sustainable Energy Days

Lectures for faculty members and students of the State Energy Institute of Turkmenistan

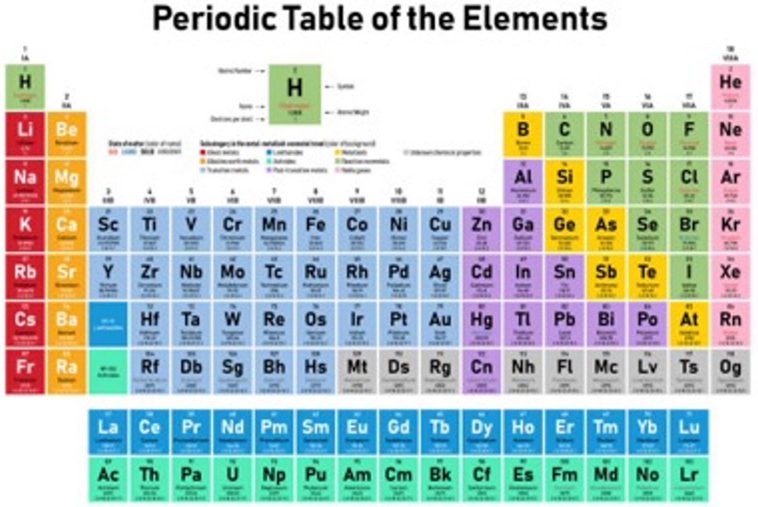
State Energy Institute of Turkmenistan, Mary, 15 December 2023

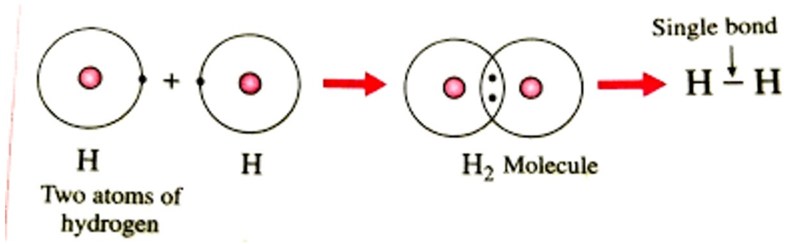
Green Hydrogen Prospects and Challenges

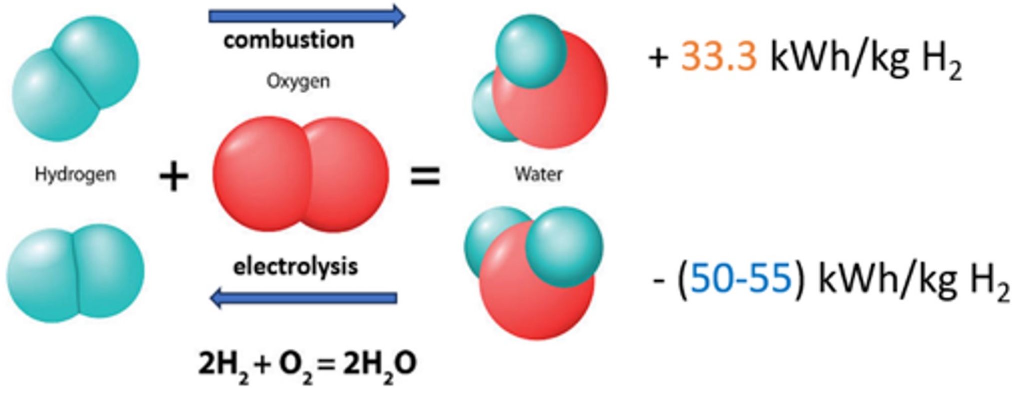
Murman Margvelashvili,
World Experience for Georgia, WEG / Ilia State University

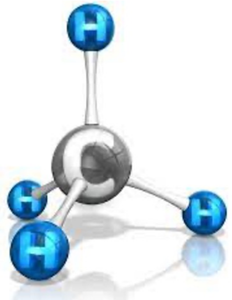
Stantec | intec | ACTED | European University Institute | Robert Schuman Centre for Advanced Studies | FSR Energy Florence School of Regulation

Hydrogen physics & chemistry









Methane CH_4 9.8 kWh/Nm^3

Hydrogen H_2 - 3 kWh/Nm^3

1/3 of volumetric energy density compared to NG

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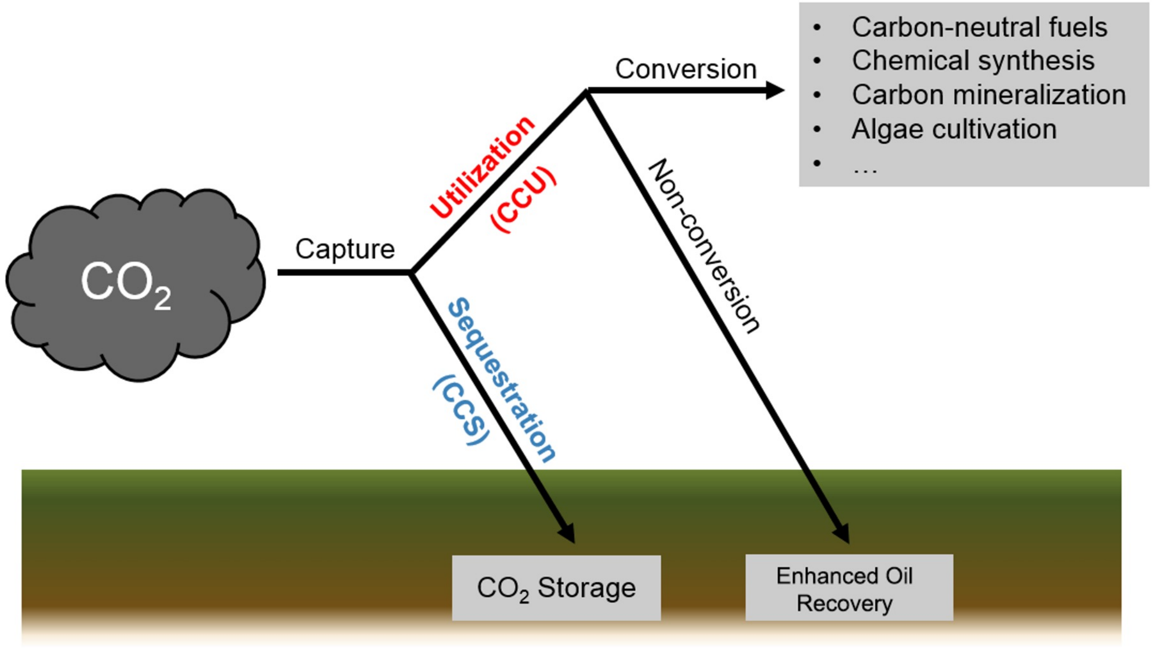
Methane Steam reforming is the main current source of hydrogen

Produced CO_2 adds to climate change Carbon Capture Utilization and Storage is needed CCUS.

Methane Steam reforming

$$CH_4 + H_2O \leftrightarrow CO + 3H_2$$
$$CO + H_2O \leftrightarrow CO_2 + H_2$$
$$CH_4 + 2H_2O \leftrightarrow CO_2 + 4H_2$$



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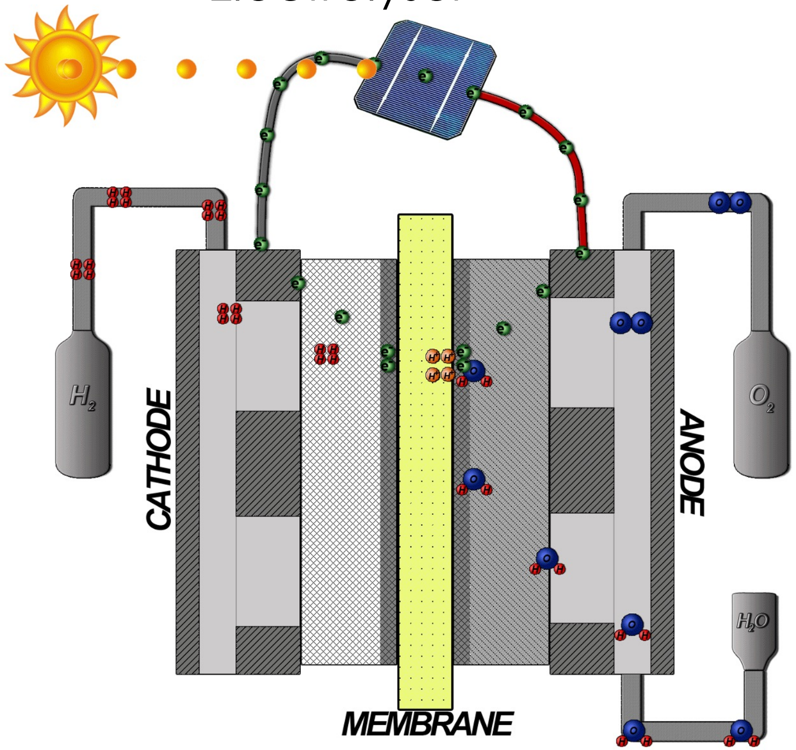
Electrolysis

PEM
Electrolyser



Alkaline
Electrolyser

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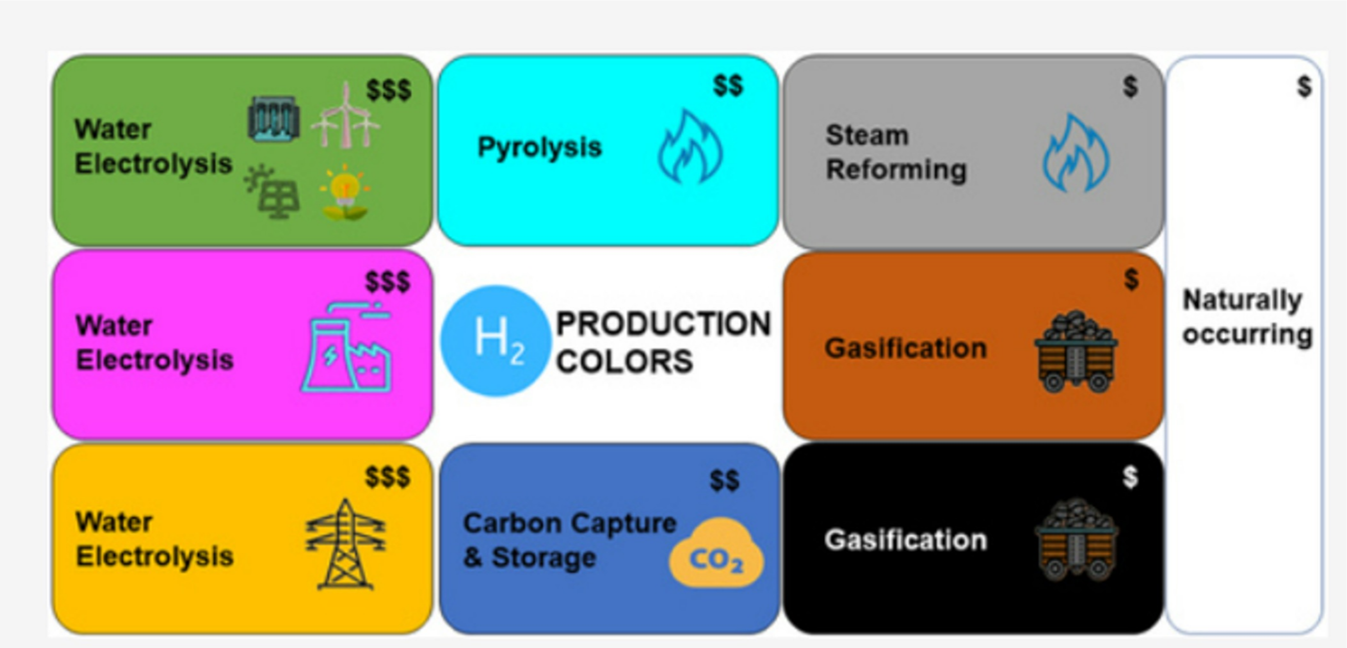
Hydrogen Production methods and hydrogen palette

Colour	Fuel	Process	Products
Brown/Black	Coal	Steam reforming or gasification	$H_2 + CO_2$ (released)
White	N/A	Naturally occurring	H_2
Grey	Natural Gas	Steam reforming	$H_2 + CO_2$ (released)
Blue	Natural Gas	Steam reforming	$H_2 + CO_2$ (% captured and stored)
Turquoise	Natural Gas	Pyrolysis	$H_2 + C$ (solid)
Red	Nuclear Power	Catalytic splitting	$H_2 + O_2$
Purple/Pink	Nuclear Power	Electrolysis	$H_2 + O_2$
Yellow	Solar Power	Electrolysis	$H_2 + O_2$
Green	Renewable Electricity	Electrolysis	$H_2 + O_2$

Source: The many colours of hydrogen | Sustainable NI



Source: Gases | Free Full-Text | The Hydrogen Color Spectrum: Techno-Economic Analysis of the Available Technologies for Hydrogen Production (mdpi.com)

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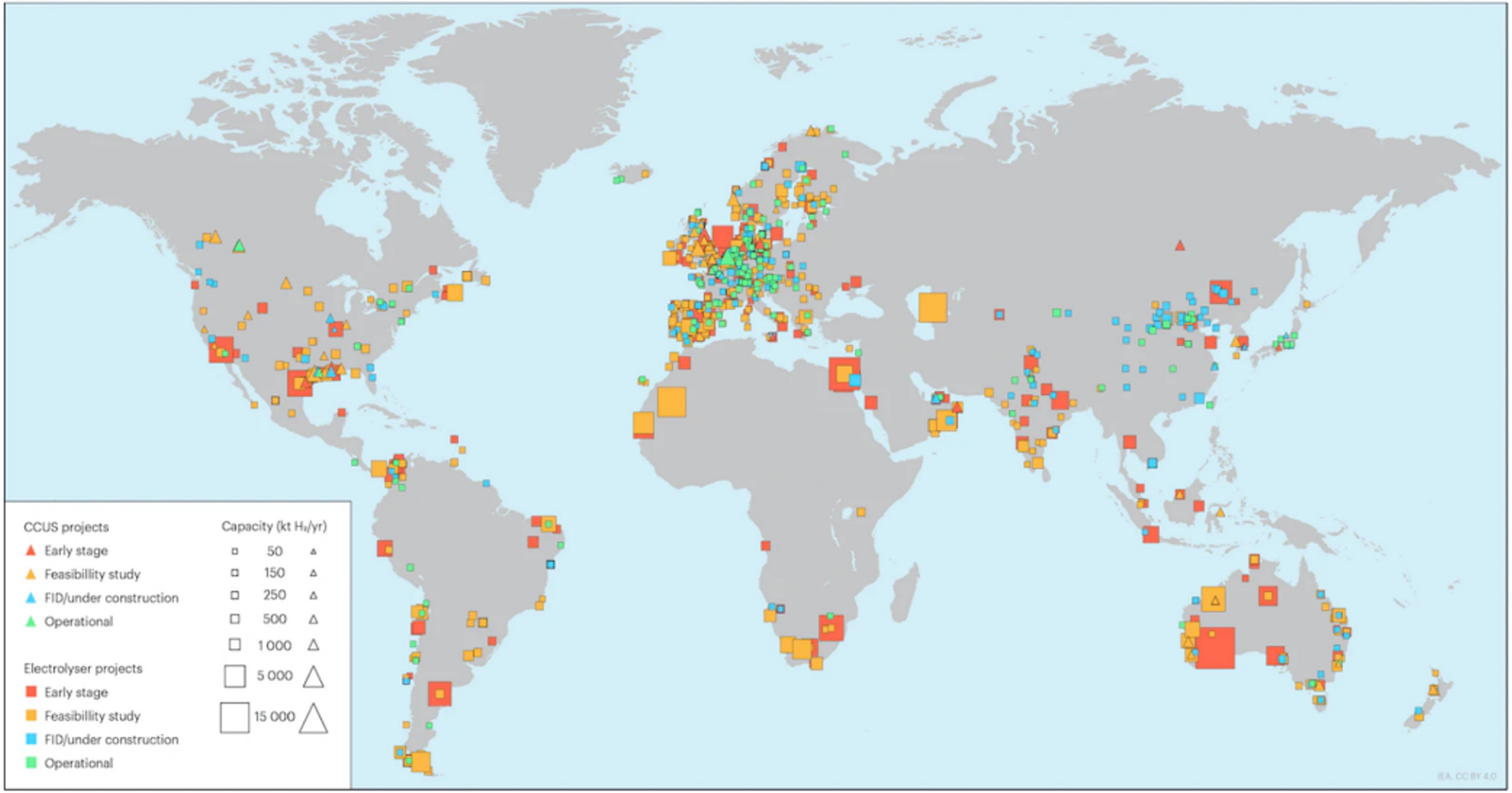
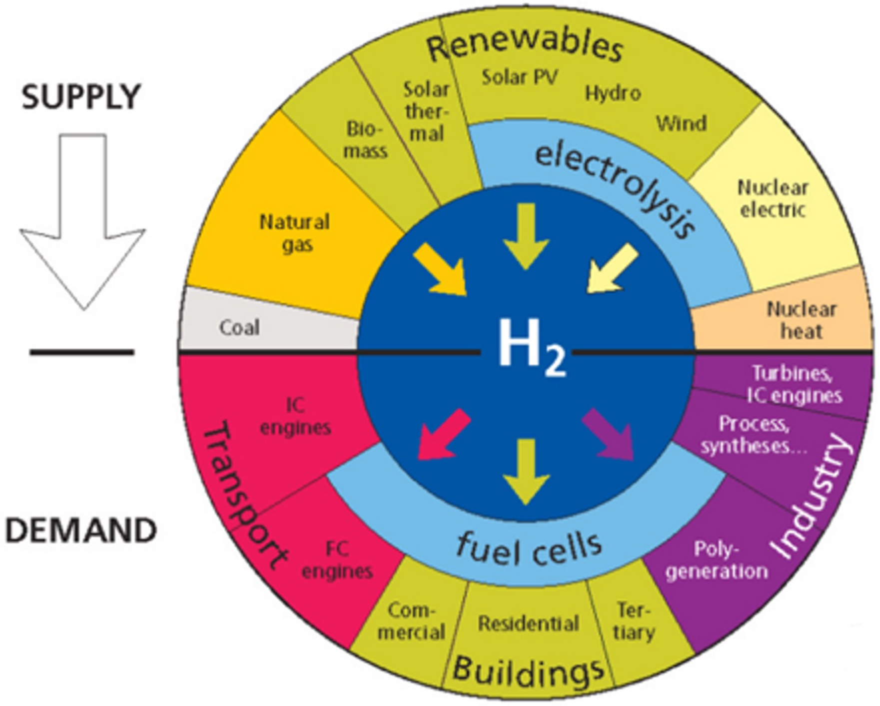
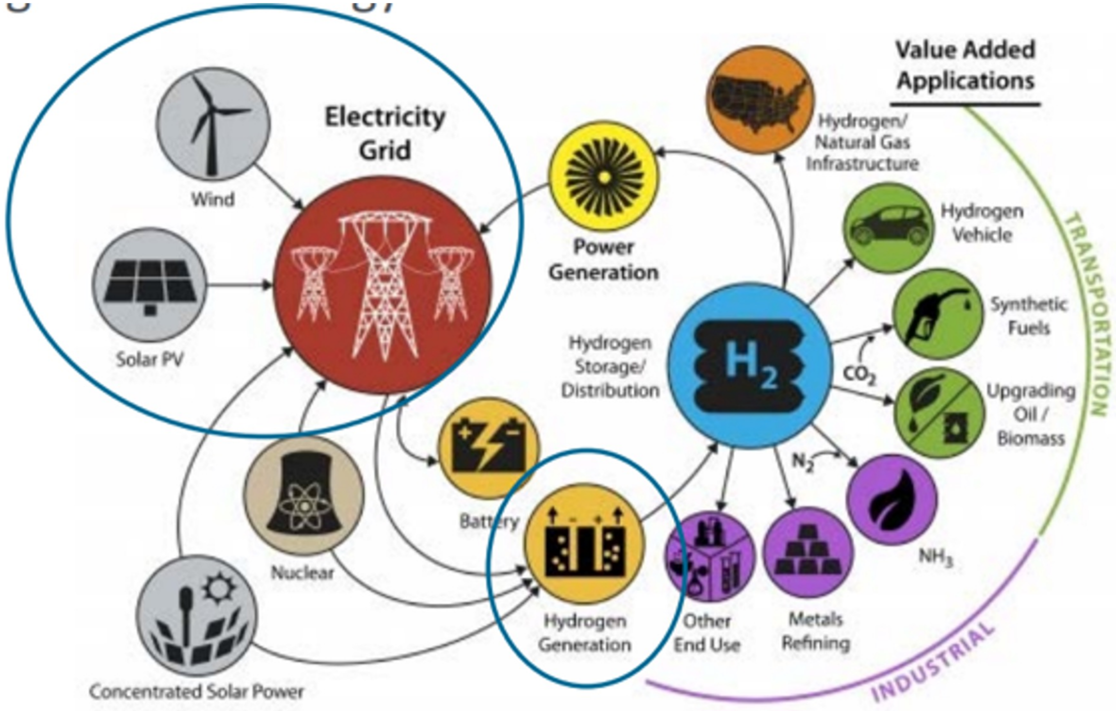
Low-Emission Hydrogen Projects Globally



Deployment of hydrogen for decarbonization a systemic task





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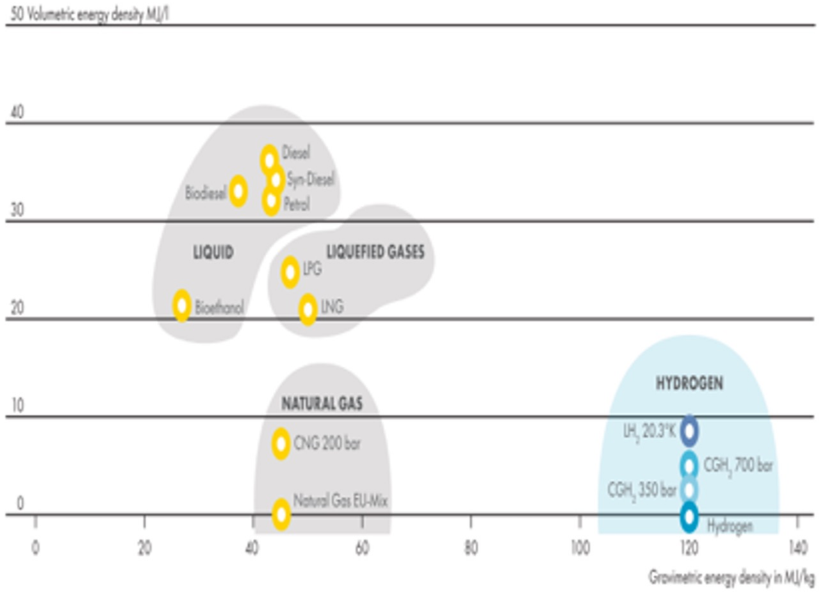
Hydrogen storage and transportation



Geological Storage (Salt caverns)

Storage of compressed hydrogen 500-700bar

Liquefied hydrogen -253^{0}C

Chemical storage - Paladium hydrid 900 times volume of H_2

Ammonia and methanol

https://hydrogeneurope.eu/sites/default/files/shell-h2-study-new.pdf

Hydrogen Transportation

COMPRESSED GAS CONTAINERS

At standard conditions (1.013 bar and 0 °C), the density of hydrogen is 0.0899 kg per cubic meter (m3). and 33 kg H 2 / m 3 at 500 bar. Target is 700 bar. TTaargen

Liquid Hydrogen transportation

Temperature -253^{0}C low pressure

Hydrogen pipelines

80-85% of methane equivalent achievable

www.ebay.com

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https://hydrogeneurope.eu/sites/default/files/shell-h2-study-new.pdf

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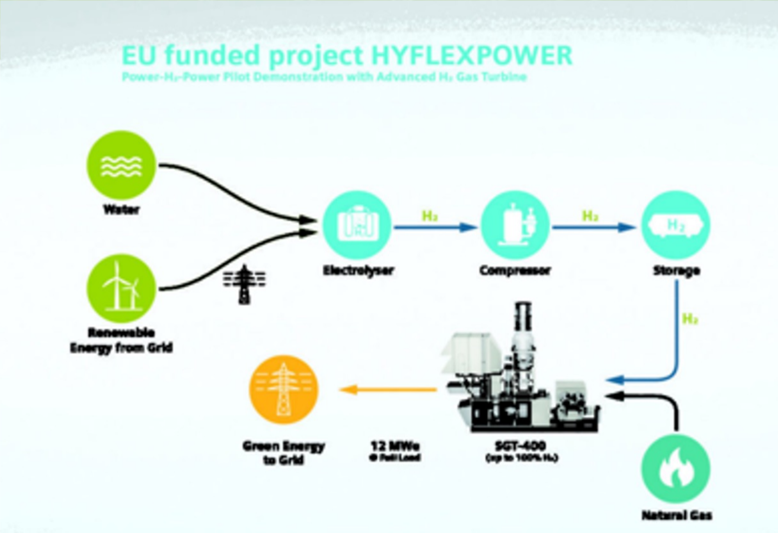
Hydrogen uses

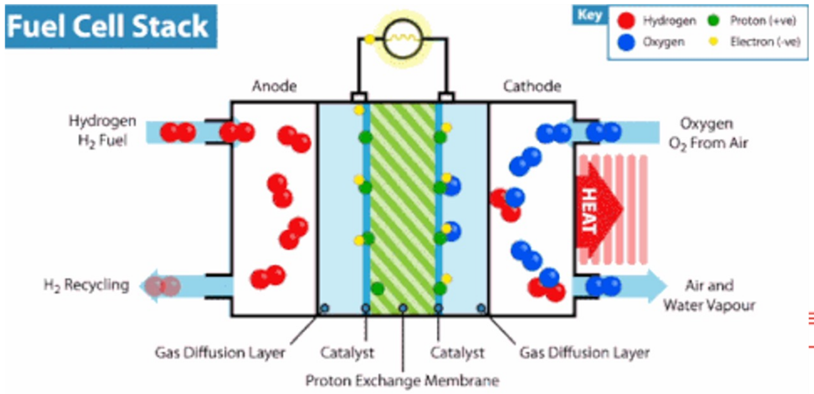


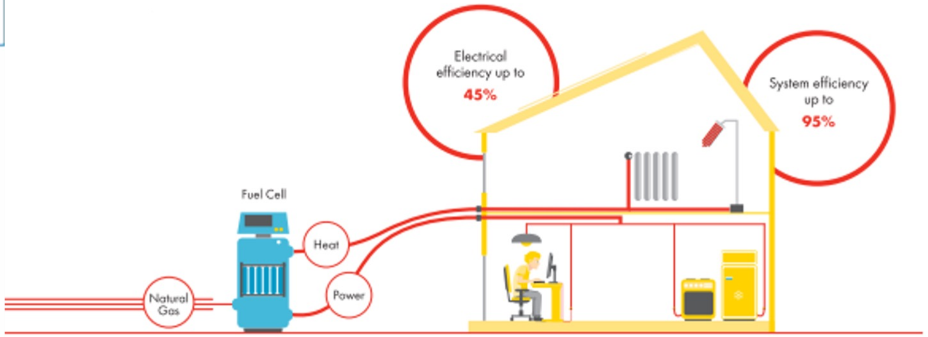
Electricity generation

•Cofiring of gas turbines and engines

Electricity and heat for homes and industries

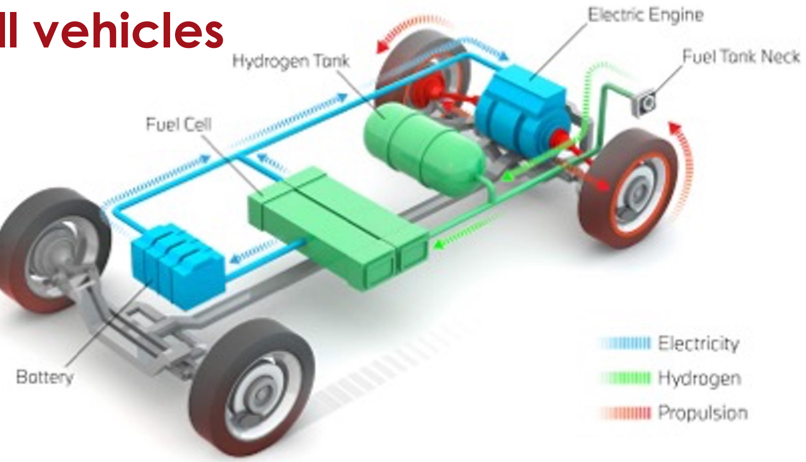
powered 1.4-MW fuel cell Germany

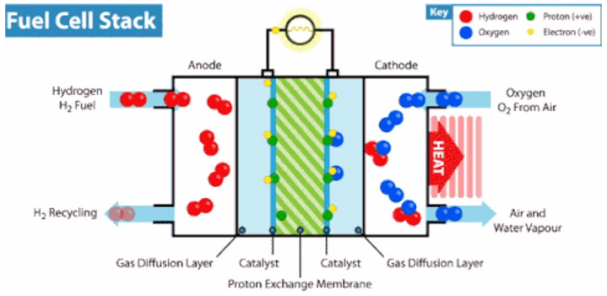




Hydrogen in Transport

Fuel Cell vehicles





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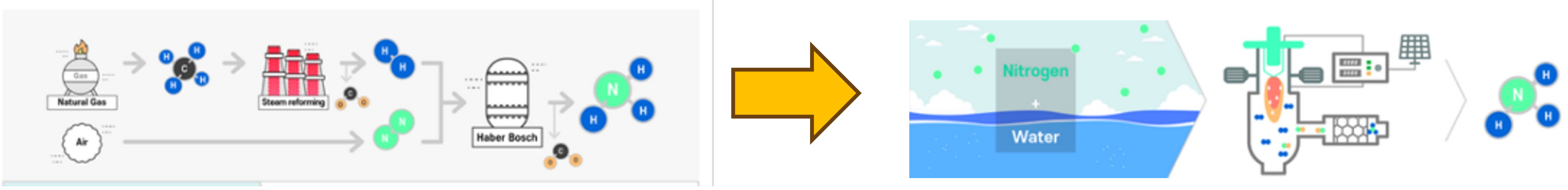
Decarbonization of Industry

Steel Industry
•DRI – Direct Iron Reduction
•Hydrogen for heat

Cement industry
•Cofiring
•Carbon capture and utilization CCU – profuction of syngas and other fuels

Refining
•Use of GH_2 for cracking the oil compound molecules

Green fertilizer industry



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Hydrogen derivatives

Ammonia

• feedstock for fertilizers - 20 million tonnes per year (Mtpa), and 195 ammonia terminals at over 120 ports.

•Cofiring in coal PPt

•Shipping fuel

•Cracking – takes 30% of energy

$$2N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Nitrogen Hydrogen Ammonia

Methanol

•Feedstock for chemical processes 15Mt/a -2021.

•Can be used as a car fuel

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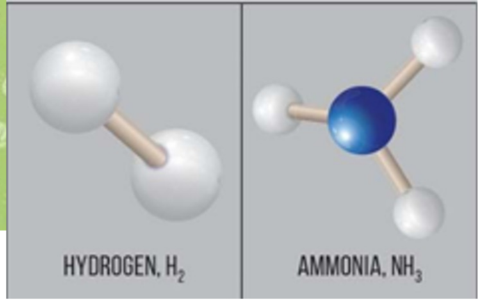
Ammonia (NH_3) a carrier for GH_2



Advantages:

High Hydrogen Content: - Ammonia contains a high percentage of hydrogen by weight (approximately 17.6%). means that a significant amount of hydrogen can be stored and transported in the form of liquid ammonia.

Easy Storage and Transportation: - Ammonia can be stored and transported at relatively low pressures and moderate temperatures. This makes it easier and safer to handle and transport over long distances.

Established Infrastructure: - There is an existing global infrastructure for ammonia production, storage, and transportation, making it a practical choice for utilizing and distributing green hydrogen at scale. This infrastructure can be repurposed for hydrogen-related applications.

Energy Density: higher energy density than liquid hydrogen. More energy can be stored and transported in the same volume.

Carbon-Free Production: - Ammonia can be completely carbon-free if produced with renewable electricity.

End-User Applications:

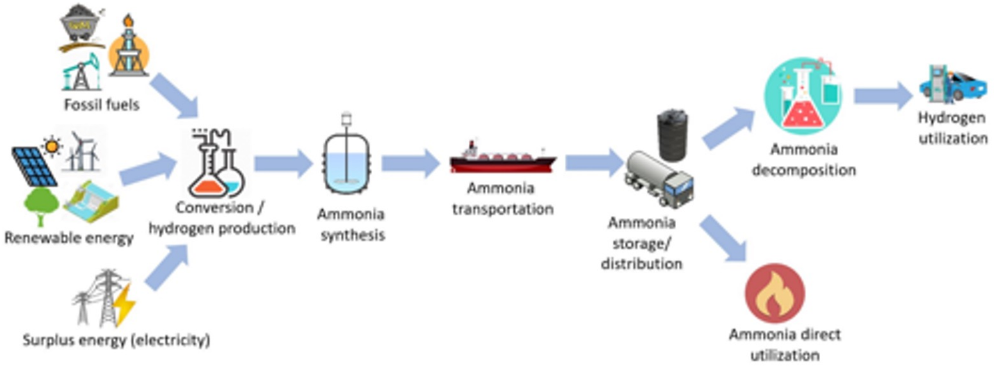
- Ammonia is widely used in agriculture applications as a feedstock for fertilizers
- Ammonia can be converted back into hydrogen through "cracking" and used for various applications, including fuel cells for electricity generation and hydrogen fueling stations for vehicles.

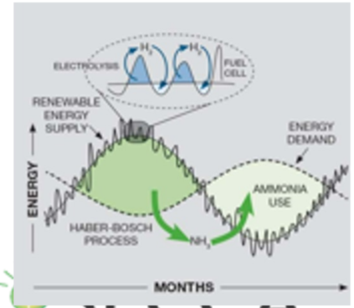
Challenges:,

Need for efficient and cost-effective cracking technologies,

Safety concerns,

Potential for nitrogen oxide emissions.





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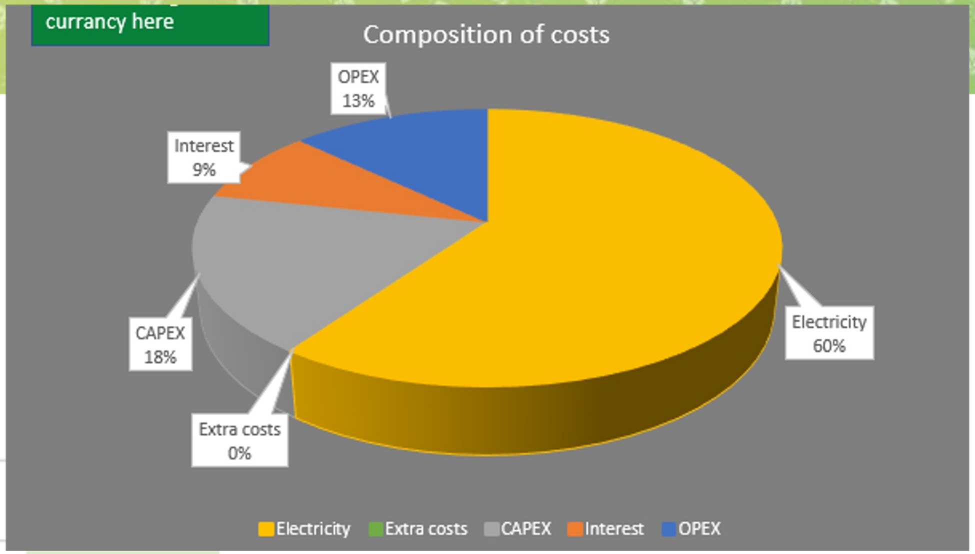
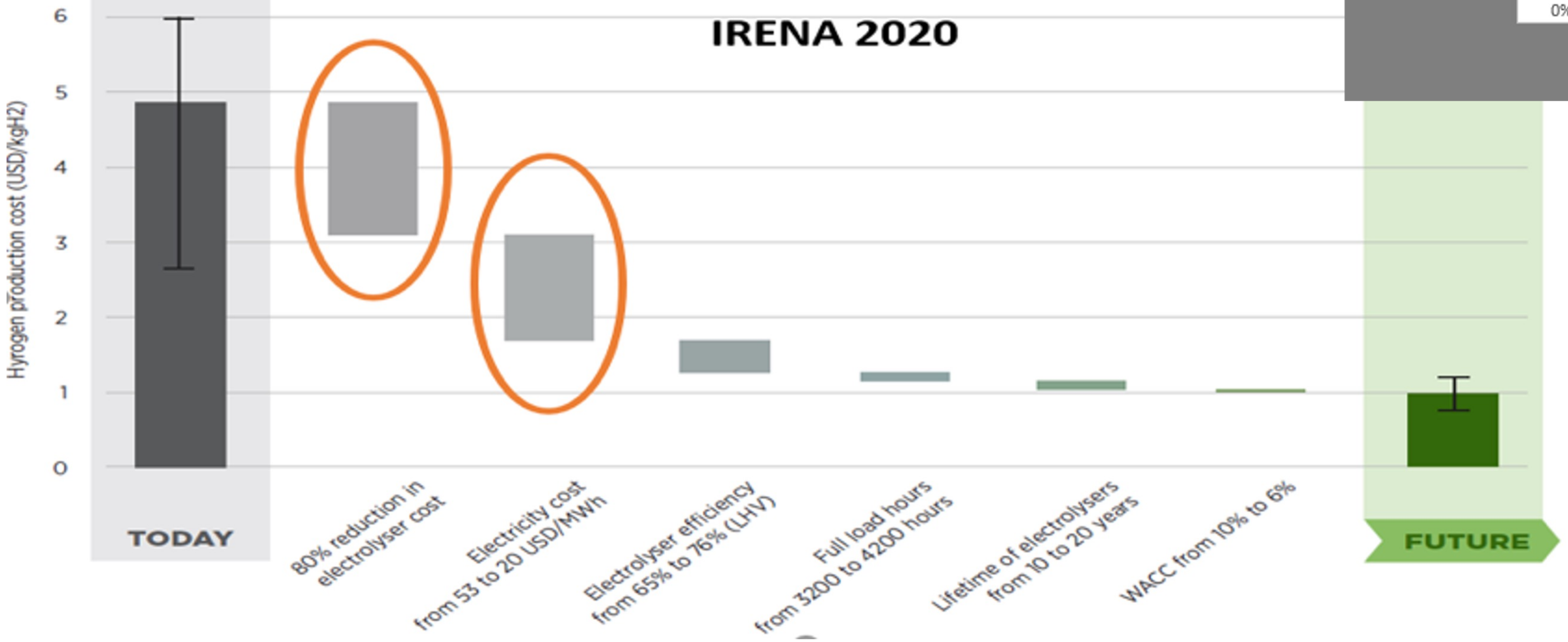
Green Hydrogen Cost



- ❖Current cost of Green hydrogen € 3-8/kg
- ❖Cost of grey hydrogen €1-2/kg
- ❖**US DoE – make $1/kg by 2030**



Source: grinix.de
Parameters:
electricity € 50/MWh
Operating time 6000h/a
Interest -3%
Depreciation – 20y.

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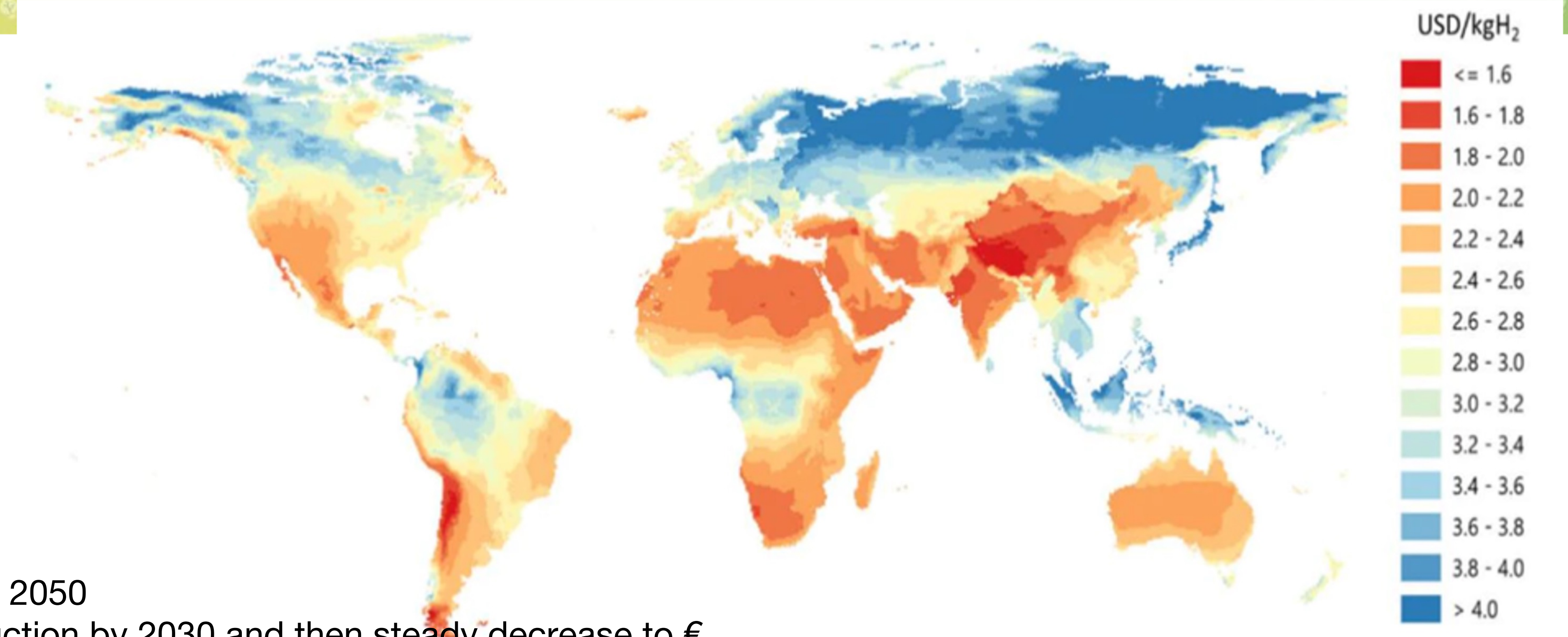
Prospective price of h_2



PWC projection 2050

- 50% cost reduction by 2030 and then steady decrease to € 1/kg rate until 2050.
- By 2050, green hydrogen production costs in some parts of the Middle East, Africa, Russia, China, the US and Australia will be in the range of €1/kilogram.

Source: Analysing the future cost of green hydrogen | PwC

https://www.iea.org/reports/the-future-of-hydrogen

Geopolitics of Hydrogen and Central Asia

SOURCE: IRENA

[The Green Hydrogen disruption: what nations, firms and investors are doing to reshape global energy - Energy Post]

[Central Asia decarbonizing the Southern Gas Corridor]
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Electrolyzers

Alcaline electrolyzers

•Proven

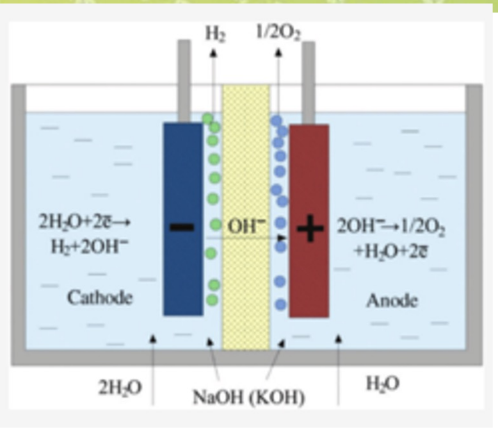
Proton Exchange Membrane PEM

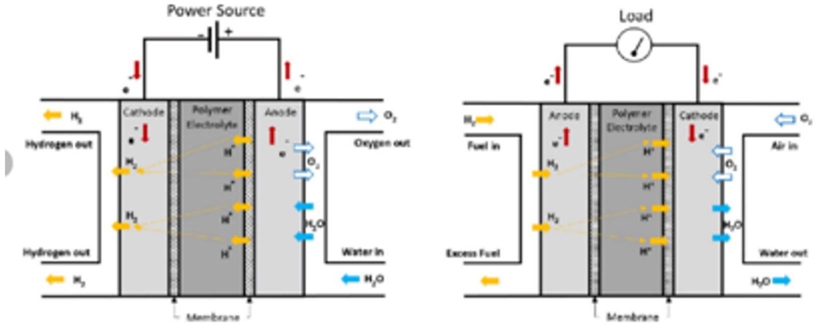
•Flexible reversible

Sodium Oxide fuel cells

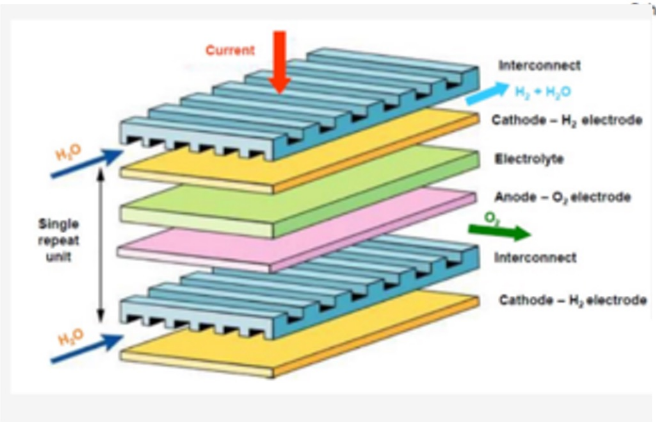
•High temperature

•Higher efficiency





hematics of PEM devices: electrolyzer (left) and fuel cell (right).



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