KEROGREEN Winter school

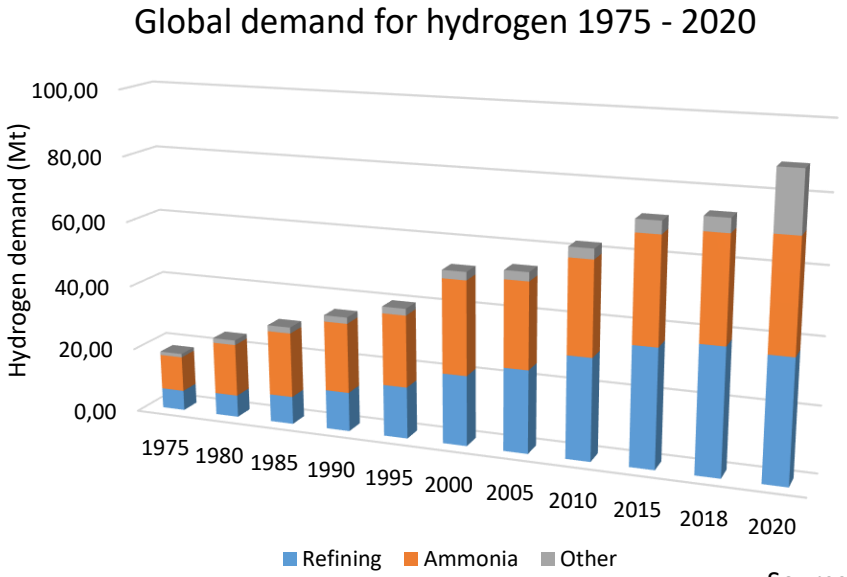
State-of-the-art and future mapping of electrolyser technologies

14/02/2022 VTT – beyond the obvious

Current hydrogen demand and production

- The global hydrogen demand in 2020 was estimated to be **88.5 Mt**
- Currently the major part of the hydrogen is utilized in **refining** and **ammonia** industries
- Hydrogen production is based on fossil fuels, namely **natural gas** (76 %) and **coal** (23 %) resulting to annual 900 Mt CO_2 emissions

IEA Hydrogen



Source: IEA

Future ambitions for electrolyser capacities

- Within last three years European Union and several nations have released their **hydrogen strategies**
- According to strategies, the total electrolysis capacity by 2030 is around **40 GW in Europe**, which is in line with the EU's own strategy
- There is also high interest and actions for electrolyser capacity increase in Asia and in Americas

H_2 strategies

	Country and release year (electrolysis capacity target by 2030 if mentioned)
Europe	EU 2020 (40 GW) France 2018 (6.5 GW) Germany 2020 (5 GW) Spain 2020 (4 GW) Portugal 2020 (2 – 2.5 GW) The Neatherlands (3 – 4 GW) Italy 2020 (5 GW) Norway 2020 United Kingdom (5 GW) Sweden (5 GW) Hungary 2021 (240 MW) Poland 2021 (2 GW) Belgium 2021 Slovakia 2021
Asia	Japan 2019 Australia 2019 South Korea 2020 China 2021 (100 GW) Uzbekistan 2021
Americas	Canada 2020 Chile 2020 (25 GW)
Rest of the world	-

Electrolysis projects

- Electrolysis total capacity is rapidly increasing and system sizes are simultaneously growing

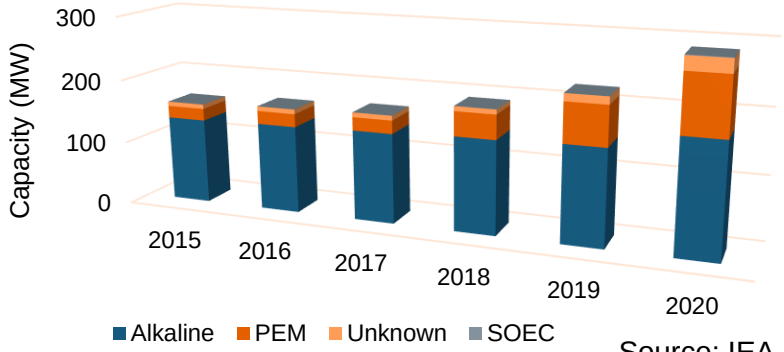
bp to decarbonise Rotterdam refinery with 250MW hydrogen plant
H2-view

'Enormous demand makes 10GW AquaVentus green hydrogen plan very likely to get built' Rechargenews

German industrial conglomerate Thyssenkrupp wins contract from Air Products for 2GW electrolysis plant at $500bn Neom future city showcase
Rechargenews

300MW electrolyser set to be coupled for hydrogen production in Denmark as HySynergy project begins phase II H2-view

Global installed electrolysis capacity by technology



Source: IEA

Yara and Linde Engineering agree to build a 24 MW green hydrogen demonstration plant in Norway. Both companies aim to achieve a significant carbon dioxide reduction in the production of fertilizers in Norway Yara

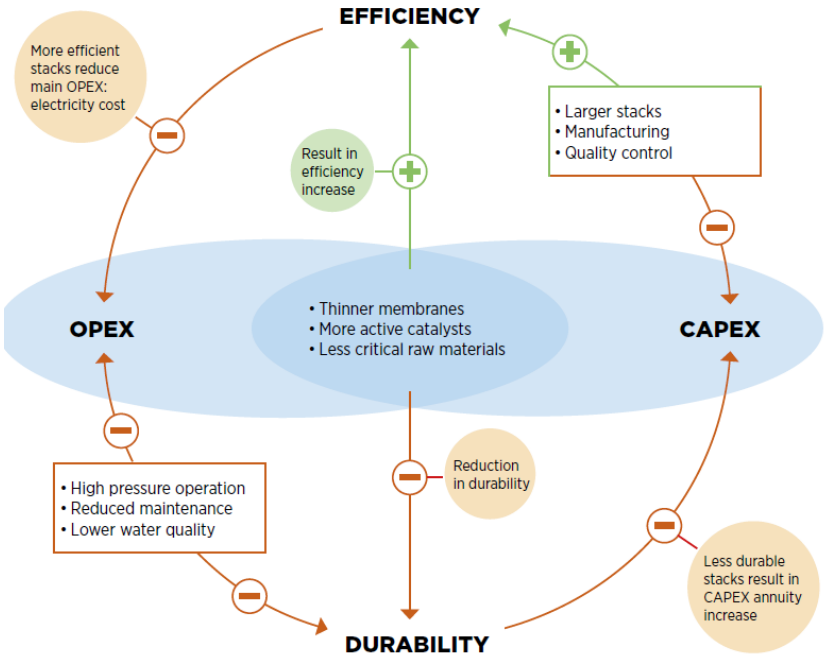
JANUARY 28, 2022

Commercial water electrolyser systems

- There are four types of water electrolyser technologies commercially available
  - **Alkaline (AEC)**
  - **Polymer electrolyte membrane (PEM)**
  - Solid oxide electrolysis cell (SOEC)
  - Anion exchange membrane (AEM)

- Alkaline and PEM electrolyser system key performance indicators (KPIs)
  - Investment costs
  - Efficiency
  - Stack lifetime (durability)

IRENA 2020



Selected alkaline and PEM electrolyser KPIs

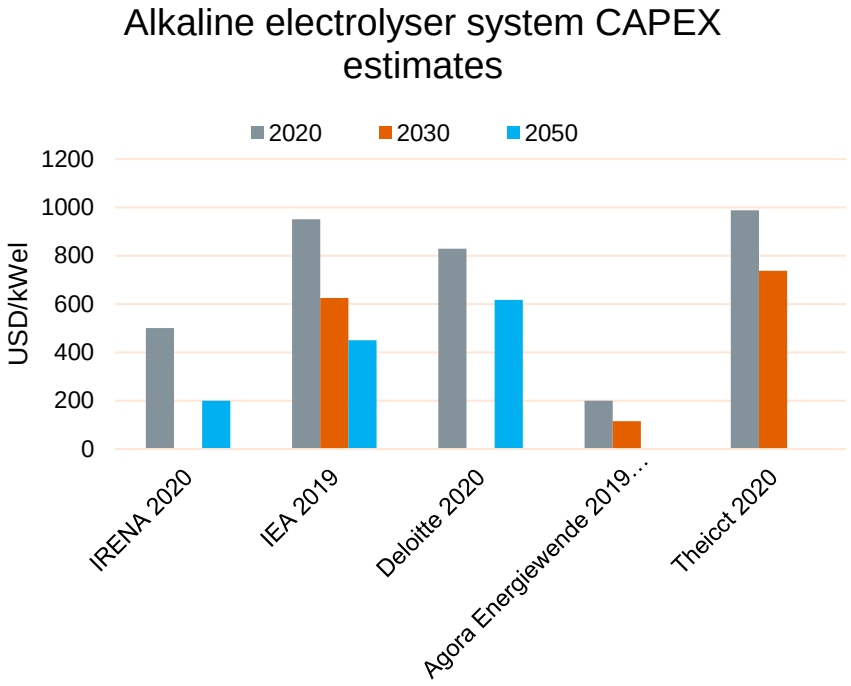
AEC

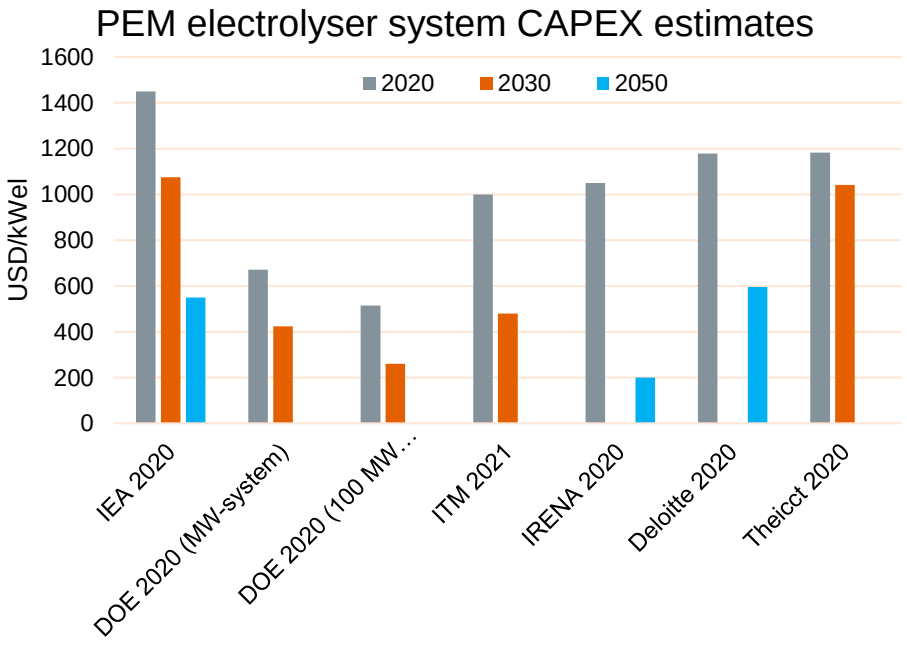
Parameter	Unit	State-of-the-art
System efficiency	kWh/kg_{H2}	52 – 56
Stack efficiency	kWh/kg_{H2}	46 – 52
Stack lifetime	Hours	57 500 – 82 500
Load level range	% of nominal level	15 – 100

PEM

Parameter	Unit	State-of-the-art
System efficiency	kWh/kg_{H2}	50 – 65
Stack efficiency	kWh/kg_{H2}	48 - 50
Stack lifetime	Hours	35 000 – 82 500
Load level range	% of nominal level	5 – 100

Alkaline and PEM electrolyser investment cost estimations





Western electrolyser manufacturers

Company	Country	Technology	Production capacity
McPhy	France	Alkaline	300 MW/a 1 000 MW/a planned
Nel hydrogen	Norway	Alkaline	500 MW/a potential to 2 000 MW/a
thyssenkrupp nucera	Germany	Alkaline	1 000 MW/a 5000 MW/a planned
Green Hydrogen Systems	Denmark	Alkaline	75 MW/a 400 MW/a by 2023 planned
John Cockerill	Belgium	Alkaline	200 MW/a 1 000 MW/a planned
Cummins (Hydrogenics)	Canada	Alkaline/PEM	PEM: 500 MW/a potential to 1 000 MW/a
GTT/Elogen (Areva H2Gen)	France	PEM	160 stacks and 40 electrolysers
Siemens Energy	Germany	PEM	250 MW/a 1 000 MW/a planned
MAN Energy (H-TEC Systems)	Germany	PEM	N/A
ITM Power	United Kingdom	PEM	1 000 MW/a (UK) Future: 1 500 MW/a (UK) + 2 500 MW/a (overseas)
NEL (Proton On-Site)	USA	PEM	> 50 MW/a
Plug Power (Giner elx)	USA	PEM	500 MW/a
Sunfire (IHT)	Germany	SOE/Alkaline (IHT)	Alkaline: 500 MW/a by 2023 1 000 MW/a planned
Haldor Topsoe	Denmark	SOE	500 MW/a by 2023 potential to 5 000 MW/a
Enapter	Germany	AEM	1 200 units/a x100 production planned 2022

Thanks for your attention and is there any questions?

beyond
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