Advanced Energy Solutions

Fundamentals of Hydrogen Technology

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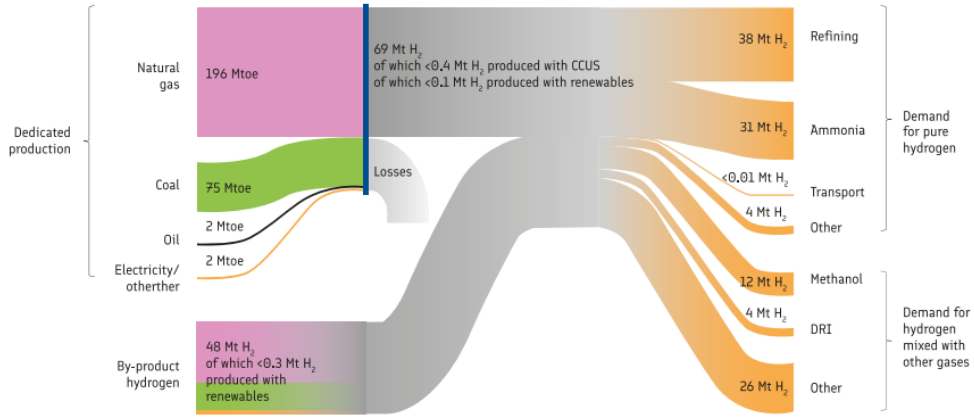
Contents

- Where hydrogen is currently used and where it could be used in the future?
- How hydrogen is produced and should be produced?
- Why hydrogen is an important topic?

Hydrogen economy

- Indirect electrification of industry and transport, reduction of CO_2 emissions
- Hydrogen must be produced with small CO_2 emissions
- Enables sector coupling (electricity, heat, energy storage, transport, industry, etc.)
- Currently hydrogen is mainly used in oil refineries and to produce ammonia and methanol
- Example applications for clean hydrogen
  - Replace fossil hydrogen
  - Indirect electrification of industry (eg. steel manufacturing)
  - Synthetic fuels and biofuels
- Currently 99% of hydrogen is produced from fossil sources



P2X

- Conversion of electricity to chemicals (X refers to hydrogen, ammonia, methane, methanol, jet fuel, diesel, protein, etc.)
- Enables coupling of electricity network, heat network, energy storage, transport fuels and industrial applications
- Hydrogen production by electrolysis is a key step in most P2X applications

Large investments

Air Products announce $5 billion renewable hydrogen to ammonia project in Saudi Arabia

DATE POSTED: **16TH AUG 2020**

Green hydrogen: ITM Power's new gigafactory will cut costs of electrolysers by almost 40%

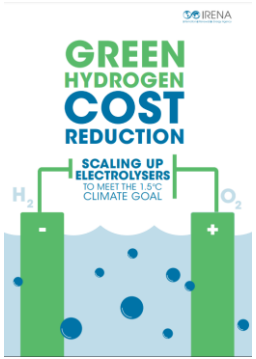
Feb 02, 2021

Endesa wants to invest €2.9bn in 23 hydrogen projects

Nel to slash cost of electrolysers by 75%, with green hydrogen at same price as fossil H2 by 2025

12 March 2020

Neste sets an ambitious target for carbon neutral production by 2035



European Commission Unveils its Hydrogen Strategy

By FuelCellsWorks | July 8, 2020 | *8 min read* (1465 words)

By 2024 at least 6 GW of electrolyser capacity installed
By 2030 at least 40 GW of electrolyser capacity installed

Lots of public support

28 May 2021, 12:48 Edgar Meza

Germany invests 8 billion euros in 62 EU-backed hydrogen projects

Press release

UK government launches plan for a world-leading hydrogen economy

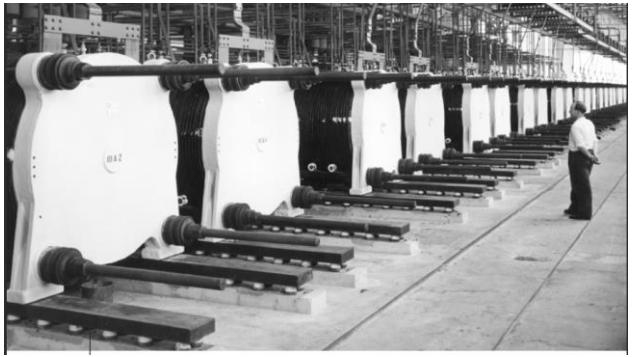
First-ever vision to kick start world-leading hydrogen economy set to support over 9,000 UK jobs and unlock £4 billion investment by 2030.

OVERVIEW OF THE FRENCH HYDROGEN MARKET

To face the challenges of ecological transition and climate emergency, the French State plans to develop low-carbon and renewable hydrogen and their industrial, energy and mobility uses. The core objective, enacted into law, is to have 20-40% of total hydrogen and industrial hydrogen consumption sourced from low-carbon and renewable hydrogen by 2030. Pursuant to the government's Multi-Annual Energy

To support the development of low-carbon and renewable hydrogen, the French State will invest €7bn by

SHELL OPENS EUROPE'S LARGEST PEM ELECTROLYSER



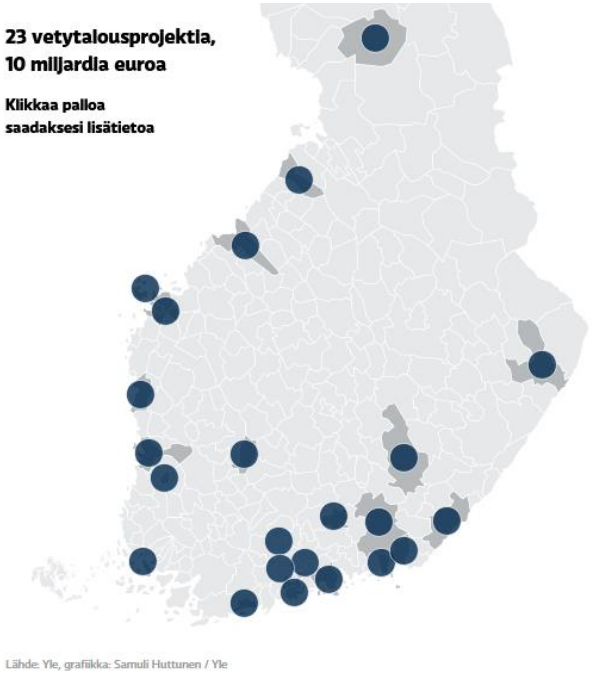
Dedicated hydrogen production in Finland

Company	Plant/site	Annual hydrogen production in recent years		Maximum annual hydrogen production		Hydrogen production process	Use of hydrogen
		t/a	GWh/a	t/a	GWh/a		
Neste Oyj	Kilpilahti oil refinery	~104 000 (2019)	~3 400 (2019)	120 000	4 000	SR (natural gas, refinery gas)	Oil refining (hydrocracking, hydrotreating.)
Oy Linde Gas Ab	Kilpilahti oil refinery	~16 000 (2019)	~520 (2019)	35 000	1 170	SR (natural gas)	Oil refining (hydrocracking, hydrotreating.)
UPM Biofuels	Lappeenranta Biodiesel plant	-	-	7 800	260	SR (natural gas)	Hydrogen treatment of tall oil to produce liquid biofuels
Terrafame Oy	Sotkamo nickel mine	~4 500 (2018–2019)	~128	5 000	167	SR (propane)	Production of H_2S which is used for precipitation of metals as sulphides
Solvay Chemicals Finland Oy	Voikkaa, H_2O_2 plant	~6 000 (2018)	~200	6 100	203	SR (natural gas)	Hydrogen peroxide production
Eastman Chemical Company	Oulu, Formic acid plant (+Kemira H_2O_2 plant)	<<5 250 (2019)	<<175 (2019)	5 250	175	POX (heavy fuel oil)	H_2 from partial oxidation of heavy fuel oil and LNG is delivered to Kemira Chemicals for production of hydrogen peroxide while CO is used to synthesize formic acid by Eastman
Oy Linde Gas Ab	Harjavalta Industrial park	1 143–1 420 (2010–2013)	38-47.3 (2010–2013)	1 500	50	LNG	Boliden & Norilsk Nickel : Cu and Ni chemical and metal production
Oy Linde Gas Ab	Hämeenlinna, SSAB	225	7.5	790	26	SR (natural gas)	Prevention of the oxidation of the steel products at high tempetures
Oy Woikoski Ab	Kokkola, Industrial Park	-	-	1 450	48	Electrolysis	Freeport Cobalt: reduction of cobalt

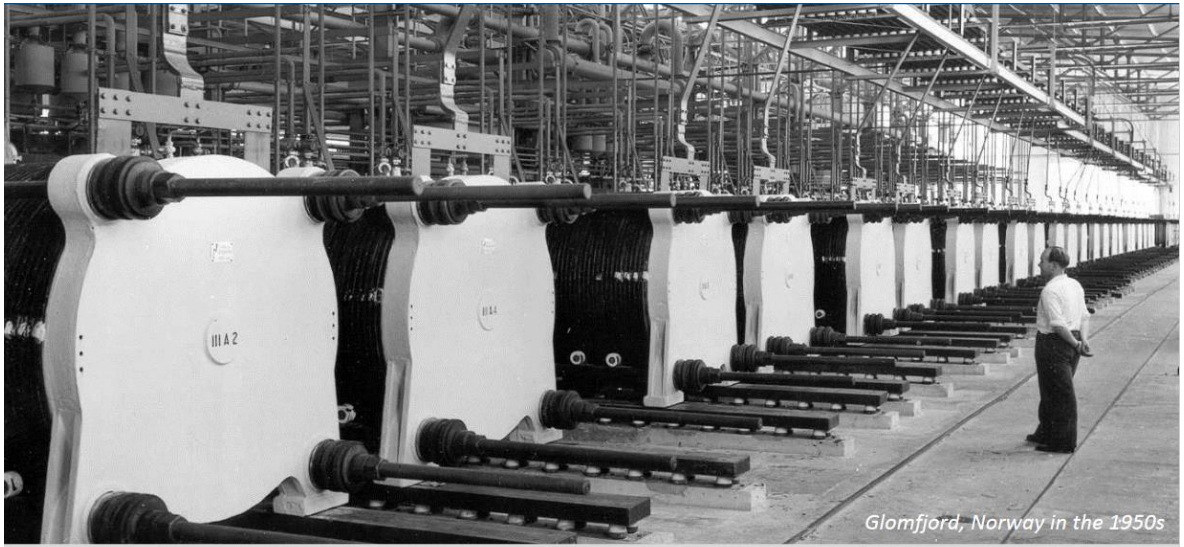
- ~150000 t/a
- Kilpilahti dominates
- GHG emissions 1.2 Mt, ~2% of Finland's emissions
- Replacing this with electrolysis would require 7-8 TWh electricity (~8% Finland's annual electricity production)

New projects in Finland

- 30+ hydrogen related projects/ideas, total investment costs >10 billion euros
- Neste oil refinery
- Green steel
- Ammonia
- Synthetic methane
- Etc.



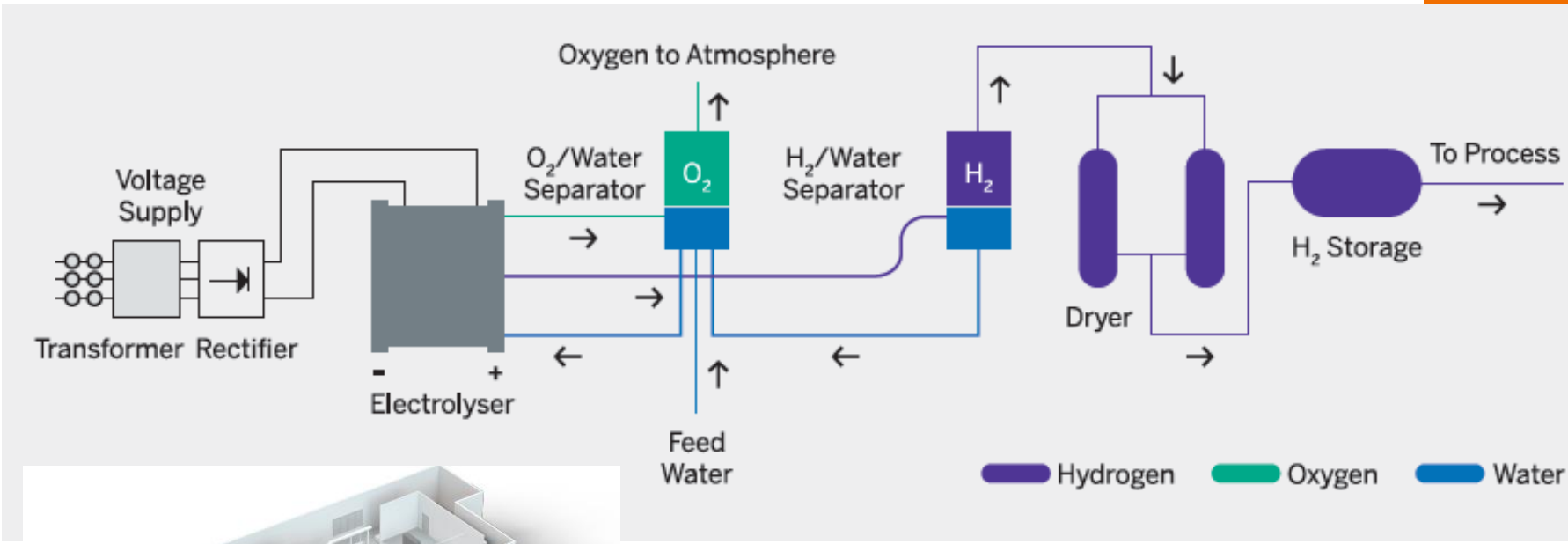
PEM, alkaline ja SOEC electrolyzers

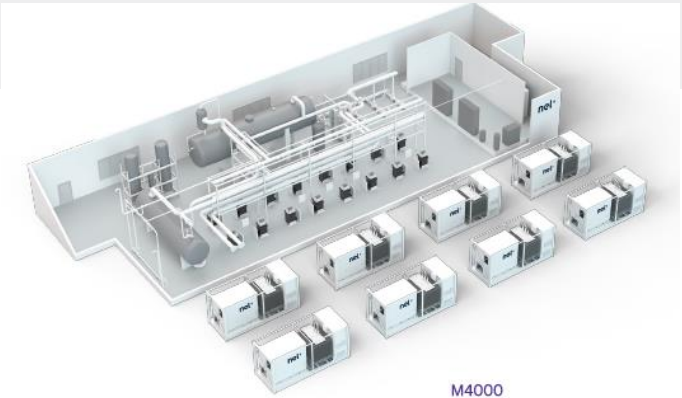


World's largest hydrogen electrolyser plant – **135 MW / 30,000 Nm3/h**

- Electrolyzers are used to split **water** into **hydrogen** and oxygen with **electricity**
- Three main technologies, differences in maturity, power consumption, size, cost, power ramp rates, etc.

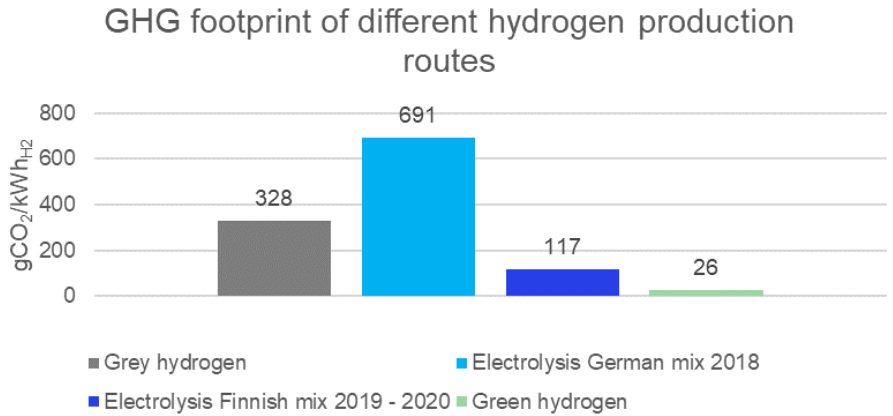
NEL's PEM electrolyzer





Emissions of hydrogen production

- **Globally ~99% of hydrogen is produced from fossil sources**
- **Hydrogen production via water electrolysis needs large amounts of renewable energy capacity**
- **Current electricity grid mixes may result in higher GHG footprint than fossil-based routes, low-CO_2 electricity needed!**



Why now?

- Reduction of GHG emissions (international agreements, national targets, companies' targets)
- Increased capacity and decreased cost of renewable electricity production
- Regulation
- Public support: RRF, Innovation Fund, investment support etc.
- Self-sufficiency, security of supply

Possibilities and reguirements for hydrogen economy

- Hydrogen enables to decrease emissions of industry and transport sectors
- Fossil hydrogen can be replaced with green hydrogen
- Lots of new possibilities that will increase hydrogen consumption in the future: steel manufacturing, HD fuel cell vehicles, synthetic fuels (synthetic methane, ammonia, liquid fuels)
- Lots of low-cost, low-emission electricity is needed. Also large capacity transmission network.
- Sector coupling improves profitability (heat, reserve and balance markets, oxygen, etc.)
- Manufacturing capacity of electrolyzers must increase significantly

Thank you very much!

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