Framställning och användning av vätgas

Göran Lindbergh, Institutionen för kemiteknik, KTH

Vätgasens roll i framtidens energisystem, SNS, 2021-06-21

”Hydrogen is the rockstar of the energy system”

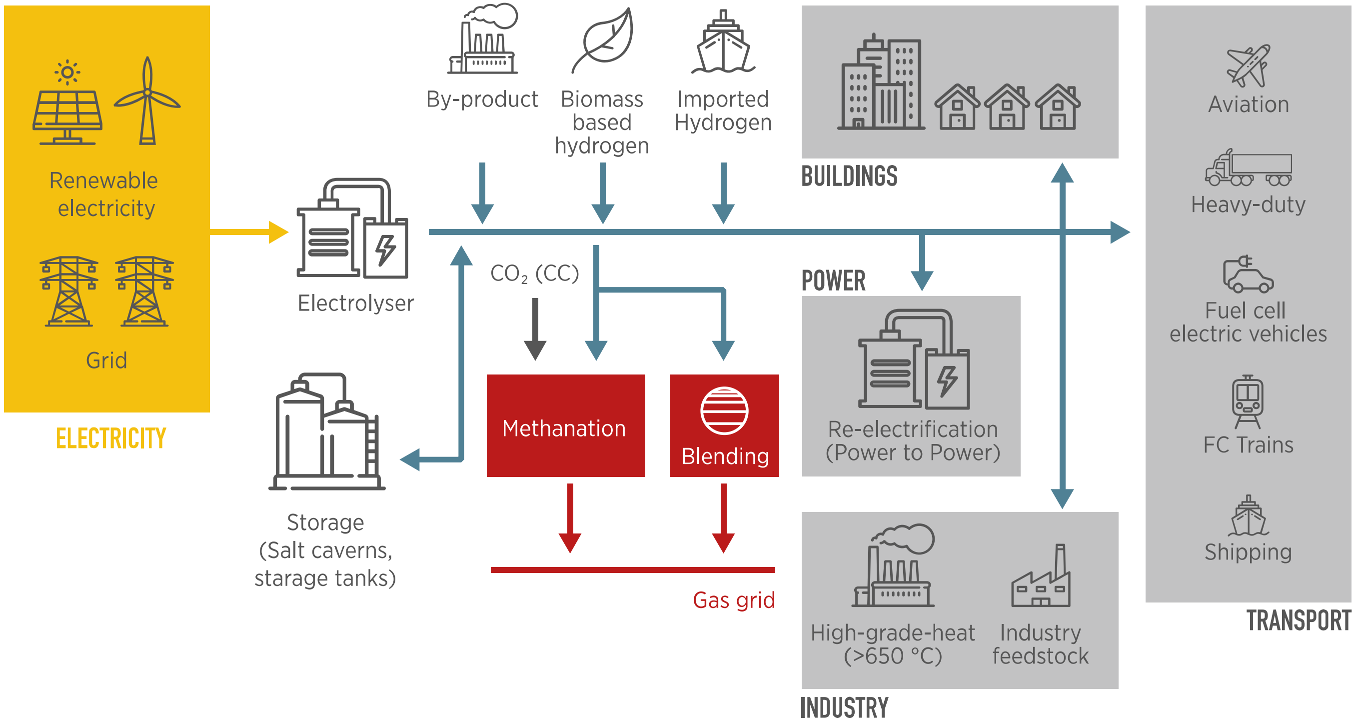
”Just four years from now, we want [to] have at least **6 gigawatts of renewable hydrogen** electrolysers installed in Europe. That is 6 times what is in place today. And **for 2030, our target is to have a capacity of at least 40 gigawatts**.”

Executive Vice-President for the European Green Deal
Mr. Frans Timmermans

8 July 2020

In January 2021, the Swedish Energy Agency was commissioned by the Swedish Government to develop a national strategy for hydrogen and electrofuels in the energy system.

Hydrogen facilitating the integration of renewable energy



IRENA (2018), Hydrogen from renewable power: Technology outlook for the energy transition

The colours of hydrogen

Different methods of producing hydrogen emit different amounts of CO_2:

- Green hydrogen is produced by the electrolysis of water. Only electricity from renewable energies is used.
- Blue hydrogen is produced by natural gas steam reforming. The CO_2 formed is not released into the atmosphere but is directly stored (CCS = carbon capture and storage).
- Grey hydrogen is obtained by steam reforming fossil fuels such as coal or natural gas. The CO_2 generated is released unused into the atmosphere.

Hydrogen produced by electrolysis in Sweden

Chlor-alkali: ~60 miljon tonne/yr Cl_2 globally
Chlorate: ~4 million ton/år $NaClO_3$ globally
Anode reaction: $2Cl^- \rightarrow Cl_2 + 2e^-$
Only 89% of the produced hydrogen is used (Europa 2019)

Hydrogen produced by electrolysis in Sweden (chlorine + chlorate)	Thousand tonne H_2/yr	TWh/yr
Cl_2	3,5	0,3
$NaClO_3$ + $KClO_3$	8,7	0,7
Total	**12,2**	**1,0**

- Stenungsund:
  ca 123 000 tonne Cl_2/yr
- Stockvik:
  ca 50 000 tonne $NaClO_3$/yr
- Alby:
  ca 15 000 ton $KClO_3$/yr and 90 000 tonne $NaClO_3$/yr
- 80 kWh/kg hydrogen
  (water electrolysis 50-55 kWh/kg hydrogen)

Från Industry-Review-2019_2020, Eurochlor

Production, use and storage of hydrogen (PUSH) – SSF Agenda 2030 Research Centre

Hydrogen will besides electricity become “the main energy vector that enables a zero-emission Europe”.

Our main goals in the centre:

- To address scientific and technical hurdles impeding the widespread use of hydrogen in sustainable energy systems
- Combining activities on production, storage and distribution, and use of hydrogen
- Obtaining synergetic effects by integration of hydrogen into the existing energy and transport systems

In collaboration with Chalmers, Lund University, Umeå University and RISE

Hydrogen production using electrolysis

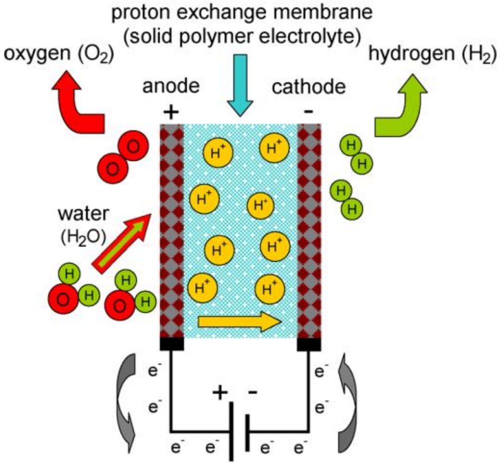
By courtesy of StatoilHydro

Anode reaction:
$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

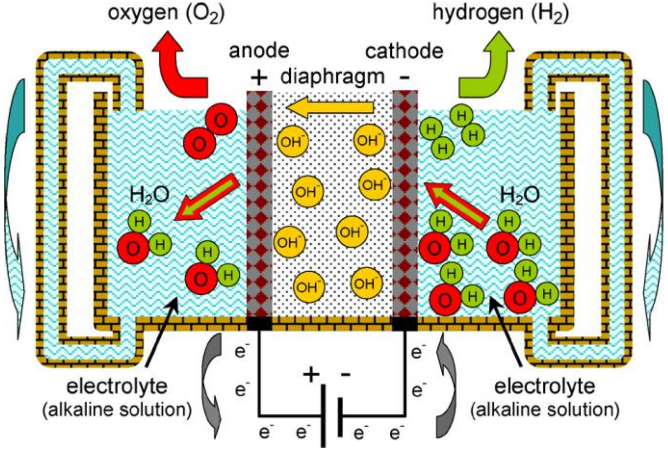
Cathode reaction:
$4H_2O + 4e^- \rightarrow 2H_2 + 4OH^-$

Electrolyte: 25 % KOH, 80 °C

Alkaline electrolysis cell (AEC)



Proton exchange membrane electrolysis cell (PEMEC)



Proceedings of the IEEE, vol. 100, no. 2, pp. 410-426, Feb. 2012

Advantages of the anion exchange membrane electrolysis cell (AEMEC)

	AEC	PEMEC	AEMEC
Use of non-noble electrode materials	+		+
Load variability		+	+
High current density operation (>10 kA/m^2)		+	+
Differential pressure hydrogen and oxygen sides		+	+
Low cell voltage		+	+
High-purity gases produced		+	+
Well-established mature technology	+		

AEMEC is a hybrid between alkaline electrolysis cell (AEC) and proton exchange membrane electrolysis cell (PEMEC).

Hydrogen storage and distribution

Large-scale and widespread storage of H_2 presents a challenge:
one kilogram of H_2 occupies over 11 m^3 at 1 bar pressure.

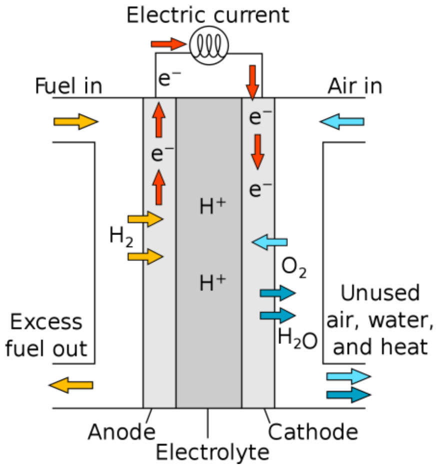
H_2 storage technologies to overcome this challenge:

- Pure H_2 as a compressed gas at around 700 bar, the current standard in fuel cell electric vehicles
- Condensed liquid form, a very energy-intensive process (up to one third of the H_2 energy content) and stored at extremely low temperature (boiling point -253 °C)
- Liquid chemical H_2 storage
  - Liquid organic hydrogen carriers (LOHCs), liquid in both hydrogenated and dehydrogenated form, e.g. methylcyclohexane/toluene
  - Gaseous in their dehydrogenated form, e.g. ammonia or methanol

Hydrogen conversion in fuel cells

Common international targets for proton exchange membrane fuel cells (PEMFC):
- Peak power efficiency of 55–65 %
- Durability of 5000 h
- Operating temperatures of 90-95 °C
- Cold starts from -40 °C
- Cost target of $40/kW

Our target is to operate at higher temperature (above 100 °C):
- External cooling becomes easier
- Enhanced catalytic activity
- Simpler water management
- Accelerated rate of degradation?



Thank you for your attention!

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