

Bergen Energy Lab, 10. Nov 2020

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Hydrogen 1.00794



Overview

- A bit about hydrogen
- The role of hydrogen in a zero emission future
- Presentation of planned and ongoing hydrogen projects in Norway



Figure 1.8 Global primary energy demand and energy-related CO₂ emissions, 1971-2020 300 Index (1971=100) Total primary 250 energy demand 200 Energy-related 150 CO₂ emissions 100 CO₂ intensity of 50 primary energy 1971 1980 1990 2000 2010 2020

IEA 2020. All rights reserved.

Source: Energy Technology Perspectives, International Energy Agency, Oct 2020.



Global energy supply

Oil	32 %	Bioenergy	10 %
Coal	27 %	Nuclear	5 %
Gas	22 %	Hydropower	2 %
		Sun, wind, ++	1 %

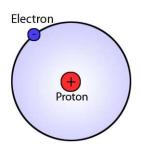


https://www.iea.org/statistics/balances/ (2016)



A bit about hydrogen

 The most common element on earth (water, hydrocarbons)



- Very reactive; hydrogen gas exist in nature only in very small quantities
- Colorless, odorless, non-toxic
- The lightest of all gases; 14 times lighter than air. Buoyancy of 20 m/s in air.

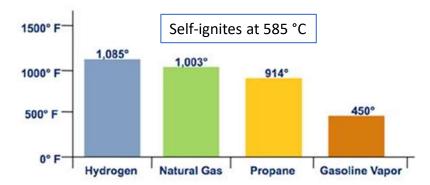
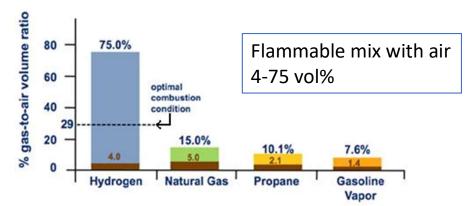


Figure 2. Auto Ignition Temperature



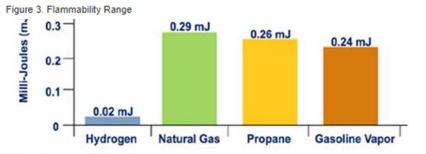


Figure 4. Minimum Ignition Energy



Is hydrogen dangerous?



SISTE: Mann i 40-årene bekreftet død

Fire in gas stationone man died All fuels are flammable.
Hydrogen has a low ignition energy and is explosive.
Hydrogen has a high buoyancy.



Hydrogen is 14 times lighter than air



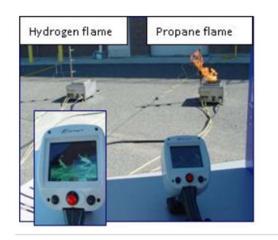


Figure 5 - Hydrogen and Propane Flames in Daylight (Photo courtesy of HAMMER)

https://h2tools.org/



Figure 6 - Hydrogen and Propane Flames at Night (Photo courtesy of ImageWorks)

It is important to understand the properties of hydrogen upon design of hydrogen equipment and facilities

Combustion of hydrogen:

Hydrogen burns rapidly, and releases large quantities of energy/heat upon combustion:

- In open spaces: a gas cloud will burn in the matter of seconds, and release water vapor
- In confined spaces: flame propagation and release of large quantities of energy/heat
 - → rapid pressure build-up/explosions



Compressed hydrogen, CH₂:

- The size of the molecule → leak through most materials
- Can cause hydrogen embrittlement
- 700 bar- private cars, 350 bar or lowerheavy duty trucks or marine applications



Liquid hydrogen, LH₂:

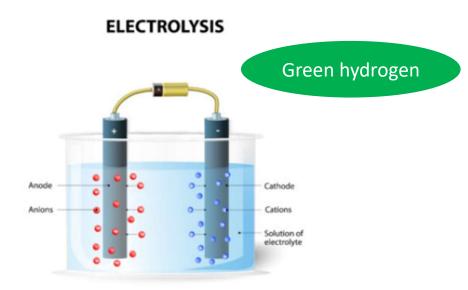
- Boiling point of hydrogen is: -253 °C
- -253 °C is technically challenging and energy demanding
- Contains 2-3 times more energy than compressed H₂



Production of hydrogen



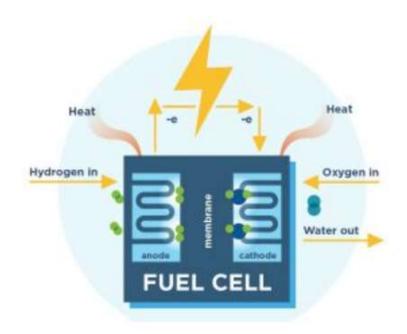
- Steam reforming of natural gas: methane and water vapor react to produce hydrogen and CO₂
- 95 % of the global H₂-production is from fossil fuels
- Most cost efficient production method:
 ~12 kr/kg H₂



- Splitting of water using electricity, to produce hydrogen and oxygen
- H₂ produced from renewable sources,
 with no emission of CO₂
- Cost of produced H₂ depends on the electricity cost: ~50 kr/kg H₂



Hydrogen as a zero emission fuel



Fuel cell- converts fuel to electric energy



- Hydrogen is converted to electricity using a fuel cell
- Zero emission, only water
- Short filling time- 3 minutes
- Longer range than batteries



Her overleveres 13 nye hydrogenbiler i en by uten offentlig fyllestasjon

Asko-ansatte i Trondheim får fylle på jobben.





ASCO launches the worlds first truck on hydrogen January 2020

Teknisk Ukeblad 3. juli 2020

https://asko.no/nyhetsarkiv/asko-lanserer-verdens-forste-hydrogendrevne-lastebil/

Hydrogen as maritime fuel

Norled is building the worlds first (?) car ferry on hydrogen

- 4 tons of liquid hydrogen
- PEM fuel cells
- 50/50 hydrogen battery
- LH₂ brought to Norway by truck
- Will be operational Sept 2021

www.tu.no 28.02.2019.



NORLED

Skal bygges av Westcon i Ølen

Velger verft før påske: Slik kan den aller første hydrogenfergen bli



Hydrogen as maritime fuel

Fast ferries

- Trøndelag municipality 2019: five consortia designed zero emission vessels, for high speed ferries from Trøndelag to Kristiansund.
- Tender for several of the fast ferry routes in Sogn og Fjordane and in Trøndelag (S&Fj autumn 2020).

Figure 24 - Design for non-emission high-speed crafts







Source: From top: LMG Marin, Flying Foil and Brødrene Aa

Source: NCE MCT report: «Norwegian future value chain for liquid hydrogen», 2019



Havila-Kystruten

- Four new ships for the Coastal Express are being build
- Will be sailing from 2021
- LNG and battery
- Save space onboard for fuel cells and hydrogen, will be installed when the technology is ready



https://www.tu.no/artikler/havila-kystruten-gjor-klar-for-hydrogen-og-brenselceller-selv-om-teknologien-ikke-er-moden-til-a-tas-i-bruk/447579?key=CY5iQgzy



Car ferry across Vestfjorden



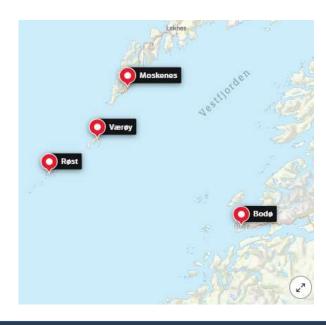
VIL SKIFTE: Regjeringen ønsker å bytte ut dagens gassdrevne ferger på Vestfjorden med hydrogendrift. Bildet viser MF Værøy på vei inn til Bodø.

FOTO: ANNELI STRAND / NRK

https://www.nrk.no/norge/regjeringen-vil-ha-hydrogendrift-pa-vestfjorden-fra-2024-1.15222286

Good news 31. Oct 2020:

- Norwegian government:
 Ferry sailing Vestfjorden will use hydrogen as a fuel
- Tender out before Christmas



«Trapped» power

Hydrogen factory will be build in Hellesylt



Geirangerfjorden. Fra 2023 vil Hellesylt Hydrogen Hub forsyne tre fergesamband med hydrogen. Fra 2026 vil fjorden være stengt for alle andre enn nullutslippsfartøy. (Folo: Per Elde/Hellesyll Hydrogen Hub)

- Hellesylt Hydrogen Hub
- Pilot-E projekt 37,6 mill
- Started in January 2020
- Consortium consisting of Flakk
 Gruppen, Hexagon Composites, Hyon,
 Tafjord (kraft), Fiskerstrand, Gexcon,
 SINTEF, Stranda municipality.
- Deliver green hydrogen within 2023
- Use of renewable «trapped» power
- 2300 tonn H₂ /year
- Deliver hydrogen to the ferries trafficking Hellesylt- Geiranger
- Geirangerfjorden: World heritage site, zero emisson from cruise ships and ferries within 2026

https://www.stranda.kommune.no/



«Trapped» power

Hydrogen factory has been built in Berlevåg in Finnmark



I Berlevåg er man i gang med å bygge hydrogenfabrikken. Forhandlinger som nå pågår avgjør om det blir ordinær produksjon, eller forsøksproduksjon når anlegget er klart på nyttåret.

2. Juli 2019: www.nrk.no



Vindkraftverket i Berlevåg er Norges mest effektive og skaper mer kraft enn det strømnettet klarer å utnytte. En ansatt i kommunen fant imidlertid en løsning.

- Wind park in Raggovidda, Finnmark
- Hydrogen production from «trapped» power
- Mitigate intermittancy of the wind park
- Varanger kraft, SINTEF and others received 50 mill NOK from EU
- HAEOLUS-project
- PEM-elektrolyzer 2,5 MW. 1 ton H₂/day.



Installert effekt
2.5MW







Produksjon

1tonn/døgn

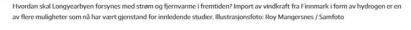
PEM-elektrolysør

I drift **2020**

Pilot hydrogen plant installed in Berlevåg

https://www.varanger-kraft.no/hydrogen-1/

http://www.haeolus.eu/



Hydrogen as energy supply to Svalbard



Production of liquid hydrogen at Mongstad

- Consortium: BKK, Equinor, Air Liquide, Norled, Wilhelmsen, Viking Cruises
- Will build liquid hydrogen factory at Mongstad
- Mix of green and blue hydrogen
- 33,5 mill NOK from Pilot-E



Her vil dei ha fabrikken som kan innleia ein drivstoffrevolusjon langs kysten. Fensfjorden i flau bris, oljeindustri og kalanlegg. Sturle Bergaas direktør frå Equinor, prosjektleiar frå BKI Bjørn Sundland og Steinar Madsen prosjektleiar for Wilhelmsen har trua på ei grønare framtid.



Wilhelmsen har planar om to slike skip som skal inn i fast rute med åtte anløp dagleg mellom Mongstad og Stavanger. Foto: Wilhelmsen

Wilhelmsen will build two new cargo ships, to run on hydrogen and fuel cells, between Mongstad and Stavanger.

