MOU1

Isabel François

Hydrogen

Cogen cursus 29 aug 2023

WaterstofNet

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Outline

- Hydrogen characteristics
- Production – transport- storage of hydrogen
- Applications
- Policy context Europe-Belgium- Flanders

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Dia 1

MOU1 Kleur wijzigen of afbeeldingen invoegen?

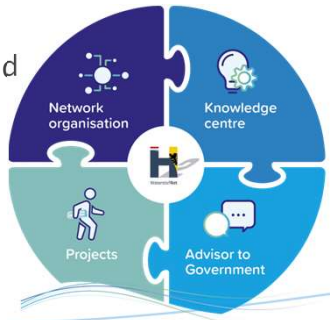
1. Selecteer op het tabblad Ontwerpen de optie Achtergrond opmaken.
2. Selecteer Afbeelding uit bestand of Vullen met effen kleur.

of
1. Rechtermuisknop
2. Achtergrond opmaken
3. Opvullen met afbeeldingen of Vullen met effen kleur.

Microsoft Office User; 28/09/2020

WaterstofNet

- Start 2009
- Project organisation located in Turnhout and Helmond (NL)
- Focus on projects and roadmaps
- Collaboration with industry, knowledge institutes and governments
- Hands-on experience:
  - 5y exploitation & maintenance H2 refuelling station Helmond
  - Facilitation demonstration projects
  - Mobile H2 station



WaterstofNet coordinates the "Waterstof Industrie Cluster"

In BE/NL

Hydrogen, main characteristics

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Hydrogen: basics

- Symbol H (1 proton/1electron) molecule H_2
- More than 90% of all atoms in the universe is hydrogen
- On earth, almost always connected to other materials:
  - oxygen (O_2) water
  - carbon (C) methane (CH_4), C_2H_6,….
  - …..

So, H_2 has to be produced, it is an energy carrier, not an energy source

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However….

NEWS

White hydrogen from soil may be inexhaustible source of energy

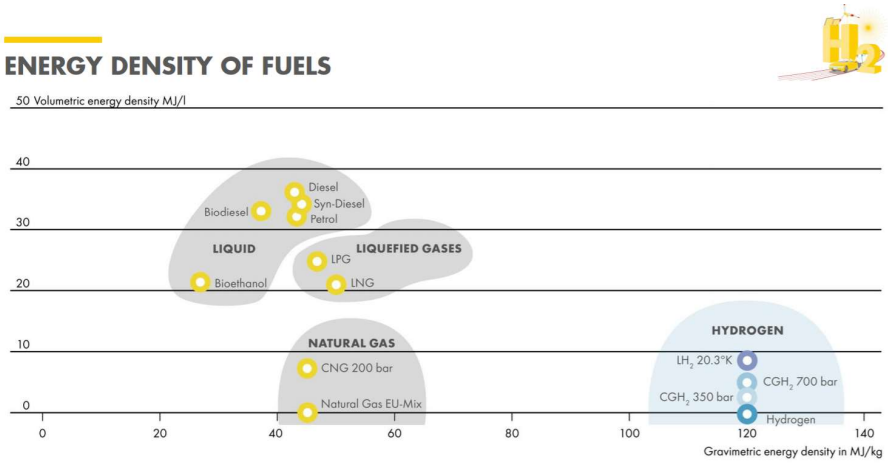
Like Comment Mar 14, 2023 134 views

Source: Change, Inc

Copyright ChangeInc

We already knew about gray, blue and green hydrogen, but now it turns out there is also such a thing as white or natural hydrogen. That just comes from the ground, just like natural gas. According to preliminary American research, it could provide half of all the world's hydrogen needs until the year 2100 and beyond: hundreds of millions of tons per year. Initial studies have begun in Africa and the Americas.

H2 properties: Energy density



High per unit of mass => advantage (for mobile applications) compared to batteries

Low per unit of volume => store under high pressure (80-350-700bar) or in liquid form (-253°C)

Production & transport & storage

Hydrogen 'colours'

Transport tube trailer & pipelines

Storage small scale and large scale

Technologies

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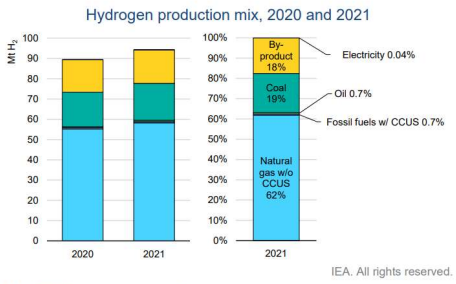
Production methods

- Production method defines the 'colour' of hydrogen: grey, blue, green, turquoise
- Worldwide & Belgium: mostly grey hydrogen via SMR (from fossil fuels)
- Sustainable H2: electrolysis, byproduct H2 or fossile source with CO_2 capture, pyrolysis



Note: CCUS = carbon capture, utilisation and storage.

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Steam Methane Reforming (incl. CCS)

Reforming hydrogen

= 90-95% of worldwide production

Steam-Methane Reforming Reaction

$CH_4 + H_2O$ (+heat) → $CO + 3H_2$

Water-Gas Shift Reaction

$CO + H_2O \rightarrow CO_2 + H_2$ (+small amount of heat)

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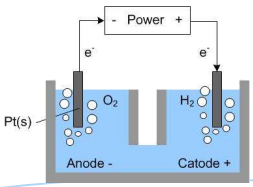
Water-electrolysis

$$H_2O \rightarrow \frac{1}{2}O_2 + H_2$$

With supply of electricity

- PEM, Alkaline, Solid oxide electrolysis
- Efficiency conversion electricity to H2:
  - Average 70% (30% energy loss to heat)
  - Recent new technologies up to 85%



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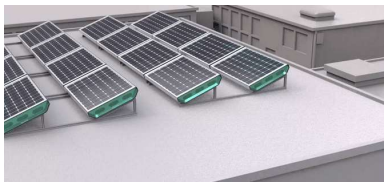
Direct conversion sunlight → hydrogen (e.g. KU-Leuven)

- Hydrogen produced in solar panel
- Use of water from the air
- Cheaper material than electrolysis

- http://solhyd.org/nl/



'Photo-electrolysis'

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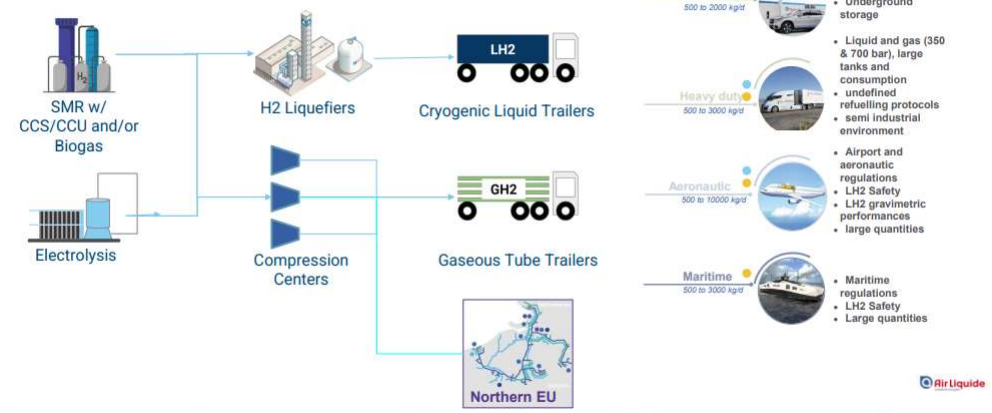
Transport of hydrogen

A quick snapchat on the supply chain...



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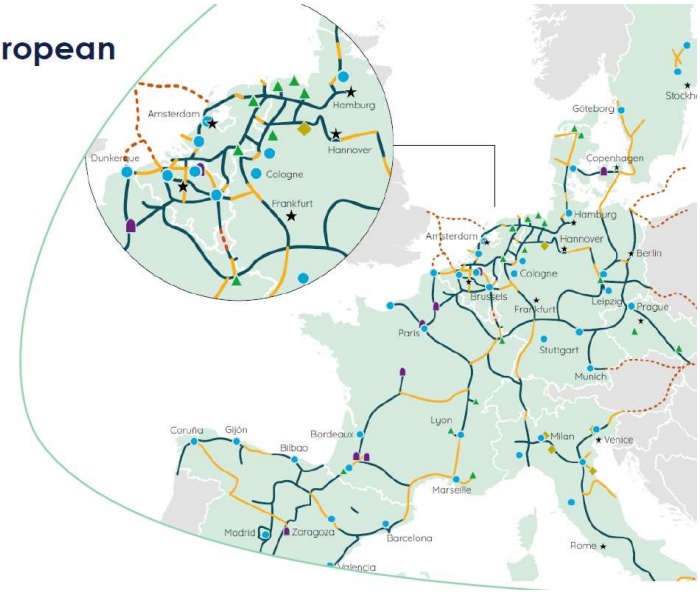
Transport in pipelines

- H2NG (Mix H2 and natural gas) in natural gas infrastructure
- Pure H2 in natural gas infrastructure
- Dedicated / New H2 pipelines

Integrated into the European hydrogen backbone



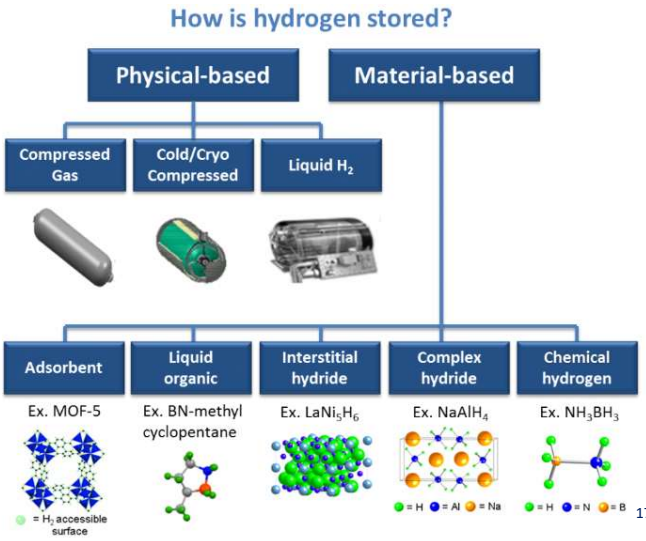
Small Scale Hydrogen Storage

Hydrogen can be stored in its pure form as

- Compressed gas
- Cold compressed
- Liquid hydrogen

Or it can be stored in compound materials, such as

- Ammonia
- Methanol
- ……



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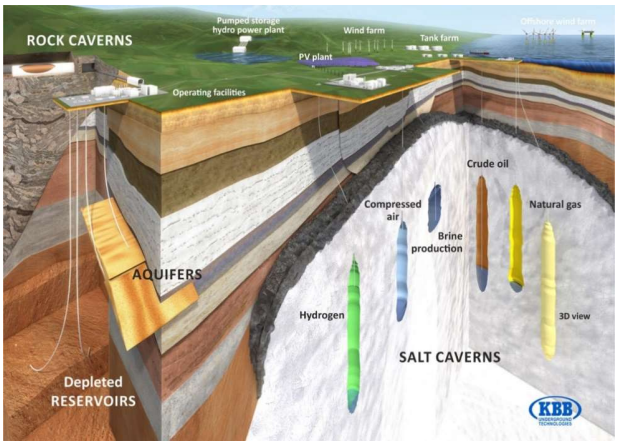
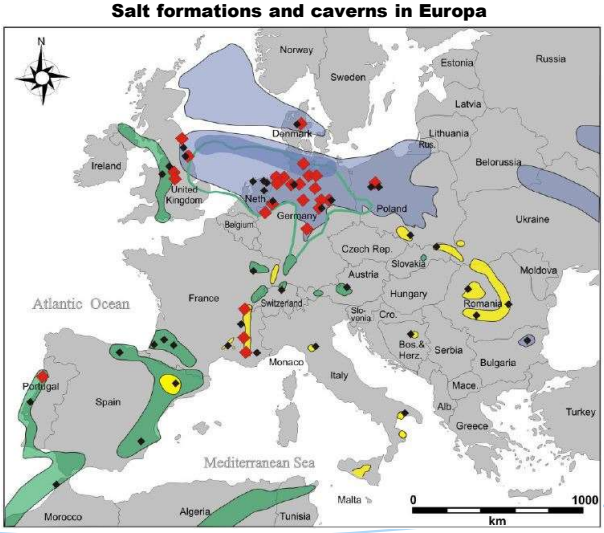
Large Scale Hydrogen Storage

Hydrogen storage in Salt Caverns



Salt formations and caverns in Europa



1 salt cavern can contains 6,000 ton hydrogen; Equivalence of 17 million Tesla Power walls

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Applications of hydrogen

Industry, transport & built environment

Technologies

WaterstofNet

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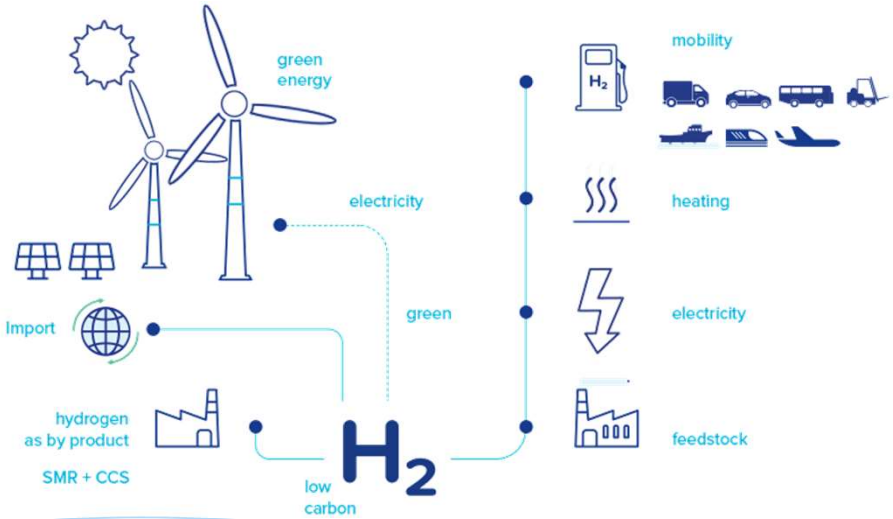
Applications of hydrogen



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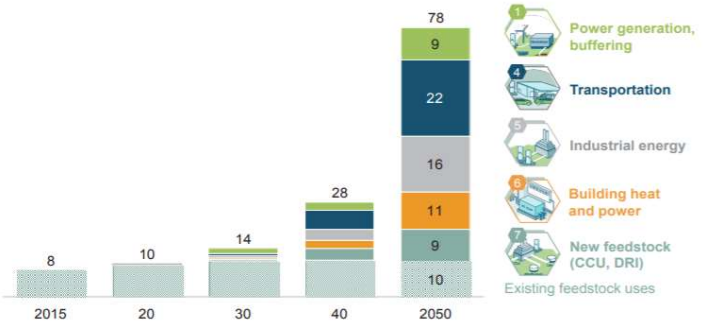
Scenario's for growing hydrogen….

Exhibit 5: Hydrogen demand could increase 10-fold by 2050

Global energy demand supplied with hydrogen, EJ

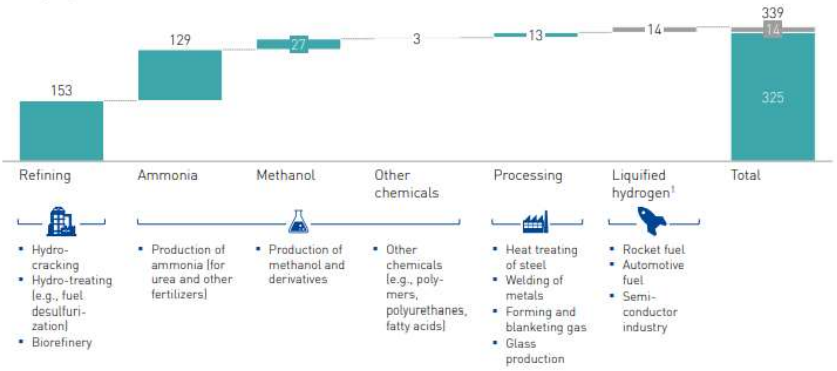


SOURCE: Hydrogen Council

Hydrogen in industry today

EXHIBIT 17: USE OF HYDROGEN TODAY

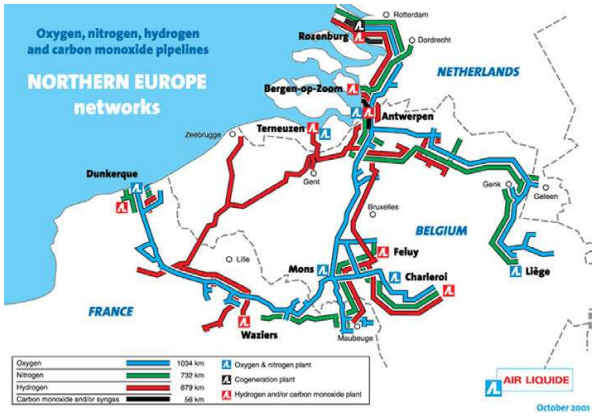
Total hydrogen use in the EU, in TWh



1 Counted in transportation segment

Source: Hydrogen Roadmap Europe, FCH-JU, 2019

The largest H2 network in EU is in …Belgium



Clean Hydrogen in industry - future

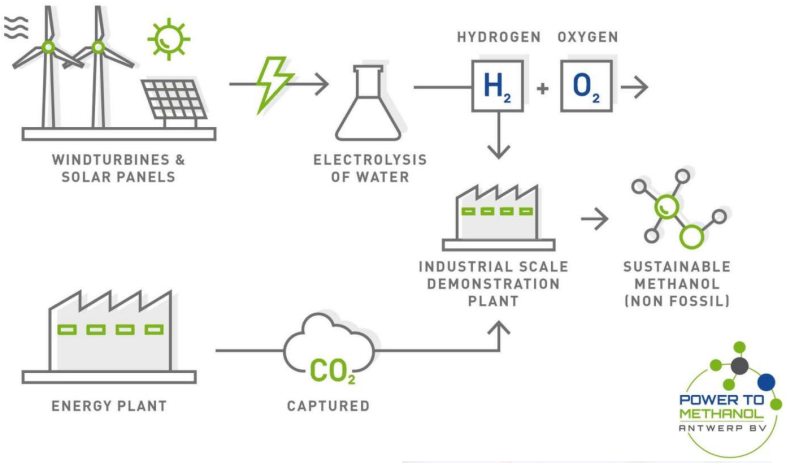
Replacement (drop-in) of (fossile) H2 in existing applications/processes

New applications of H2

- Heat (mid/high grade), replacing natural gas
- Steel production, replacing cokes
- Feedstock for chemicals or synthetic fuels based on H2 and recycled CO2.

Pilot projects in refinery (RefHyne Shell/ITM Germany), steel (H2future Sweden), methanol (CRI Iceland.)

Example projects in BE



https://powertomethanolantwerp.com/

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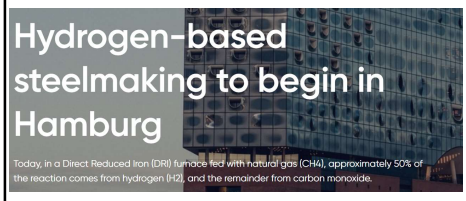
Steel production

Blast furnaces: replace part of cokes by H2

DRI process: replace natural gas by 100% H2



Manufacturing News

ArcelorMittal to build DRI and electric furnaces in Gent

By **Stainless Steel World Publisher** - October 7, 2021

ArcelorMittal announced that it has signed a letter of intent with the Governments of Belgium and Flanders, supporting a €1.1bn project to build a 2.5 million-tonne direct reduced iron (DRI) plant at its site in Gent, as well as two new electric furnaces.

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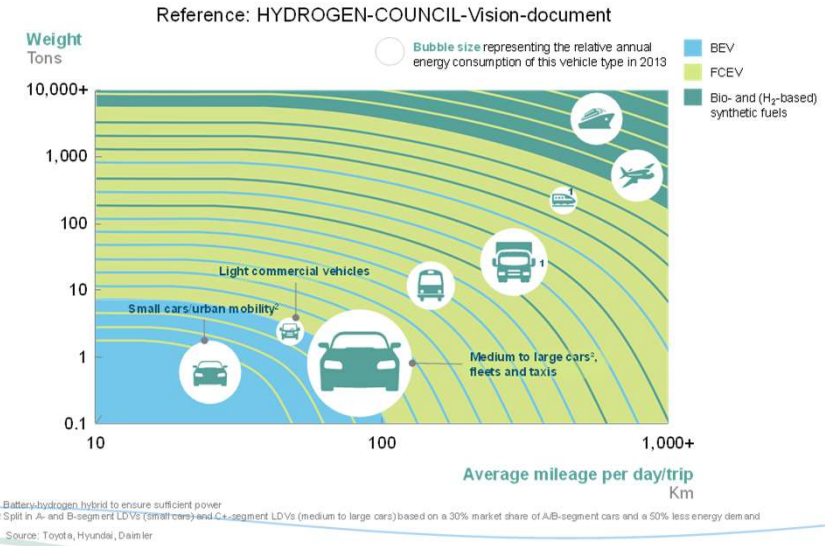
Hydrogen in transport applications

Different technologies are complementary!



Source:
Hydrogen Roadmap Europe, FCH-JU, 2019

Hydrogen in transport applications

ROAD

- Large passenger vehicles with long-ranges (e.g. taxi-fleets)
- Public transport regional buses
  - ✓ Centralised, dedicated infrastructure → high equipment utilization
  - ✓ Fast filling => Operational flexibility
- Heavy-duty trucks
  - ✓ Fast filling => Operational flexibility
  - ✓ Available payload ↔ BEVs: weight and payload penalty

- Status: cars and buses "commercially available"; trucks in development @ major OEM's (Volvo, Iveco, MAN, Nikola…)

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Hydrogen in transport applications

RAIL

- Zero-emission alternative for Diesel trains

WATER

- Ferry's/ Inland barges for limited distance
- Seaships: high density fuel needed (loss of payload)

  → Liquid hydrogen or H2 carrier (ammonia)

- Status: pilots

Example projects

https://www.alstom.com/solutions/rolling-stock/coradia-ilinttm-worlds-1st-hydrogen-powered-train

Hydroville Antwerp (CMB)

Hydrotug Port of Antwerp (2022)

Future Proof Shipping

Hydrogen in transport applications

AIR

- EU flights → H2 combustion in gas turbines / fuel cells / liquid hydrogen tanks
  - Status: R&D phase
- Intercontinental flights → high energy density required
  - Synthetic kerosene → admix in fossil kerosene during transition period

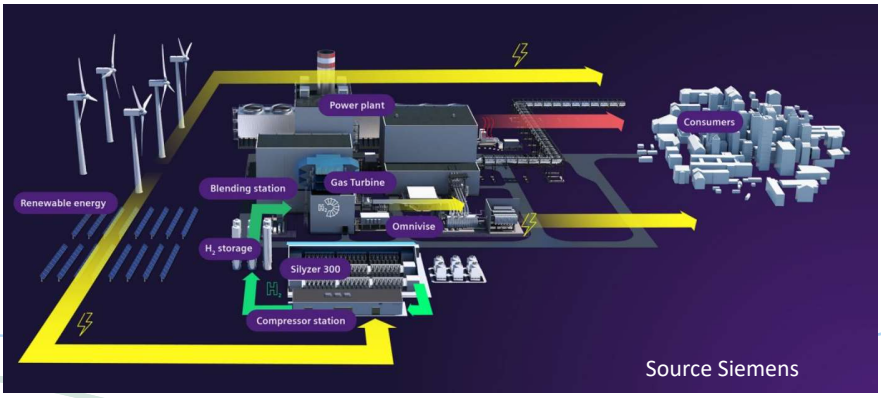
https://www.airbus.com/innovation/zero-emission/hydrogen/zeroe.html

Planned 2035

- Synthetic kerosine: recent announcement Synkero in Amsterdam port, production as of 2027

Hydrogen in power & heating

- Turbines/ CHP on hydrogen (combustion)
- Fuel cells
- CCGT - power plants to operate on H2?

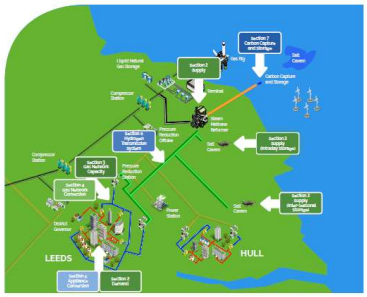


Source Siemens

Hydrogen in built environment

Central production

- Hydrogen imported via gas grid from central source; transport & distribution via gas grid

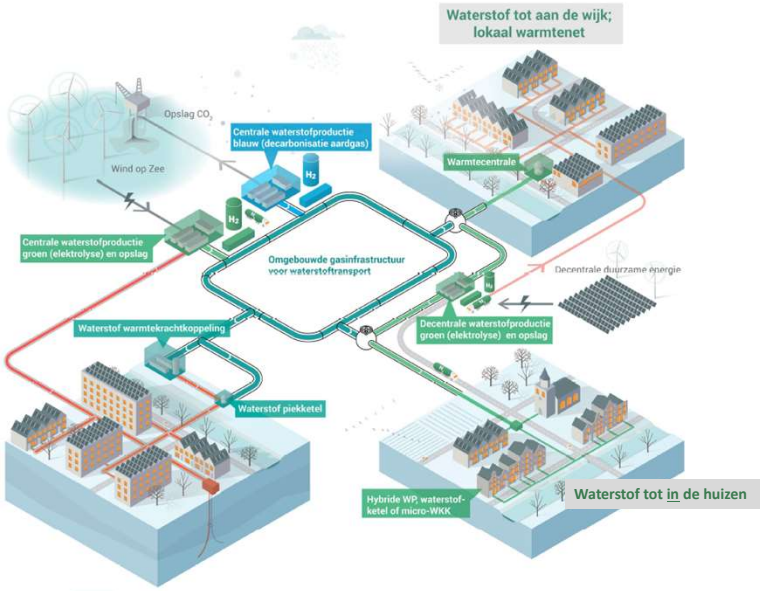


H21 project in Leeds

Local production

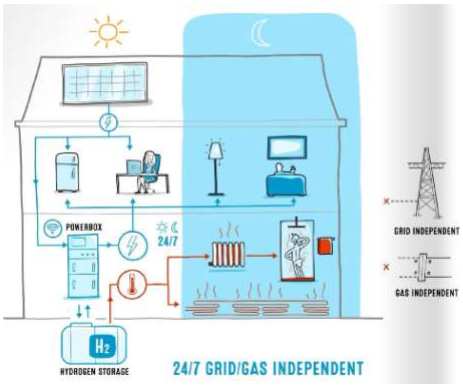
- Hydrogen is **produced in/close to** the building from onsite produced energy (solar)

Waterstof aangevoerd via gasnet uit centrale bron



Opslag van lokaal geproduceerde elektriciteit

- Opslag van lokaal geproduceerde energie (PV) in waterstof; re-elektrificatie met WKK/brandstofcel



Source:
Solenco power

Omzetting waterstof naar stroom en warmte

Gebruik in gebouwen

- Waterstof gas boiler
- WKK gebaseerd op brandstofcel of verbrandingsmotor
- Hybride warmtepomp (elektrische warmtepomp met extra boiler op H2 voor piekvraag)

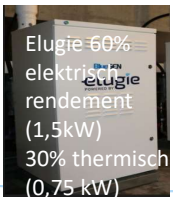
µ-WKK op waterstof, verschillende types

- Verbrandingstechnologie
  - Minder zuivere waterstof nodig
  - Flexibiliteit naar brandstof
  - Lagere elektrische efficiëntie, meer warmte
  - Uitstoot Nox?
  - Levensduur

- PEM-brandstofcel
  - Zuivere waterstof nodig
  - Lage temperatuur => flexibel aan/uit
  - Lagere elektrische efficiëntie , meer warmte
  - Nul uitstoot

Vandaag werken de brandstofcel modellen altijd op aardgas.
Lokale SMR nodig om H2 te onttrekken aan methaan

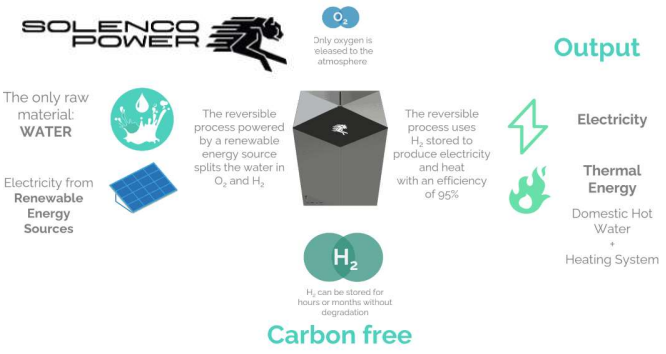
- SOFC (Solid Oxide brandstofcel)
  - Hoge temperatuur => continue operatie
  - Verschillende brandstoffen mogelijk
  - Hogere elektrische efficiëntie
  - Nul uitstoot



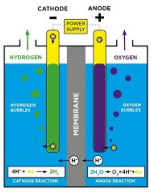
Omzetting elektriciteit → waterstof → stroom en warmte

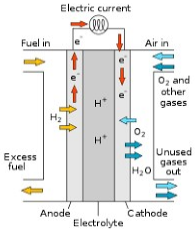
Gebruik in gebouwen

- Aparte componenten:
  Elektrolyse of waterstofpanelen
  + brandstofcel of ICE-WKK
- All-in-one oplossingen
  - Reversibele brandstofcel



Technologies

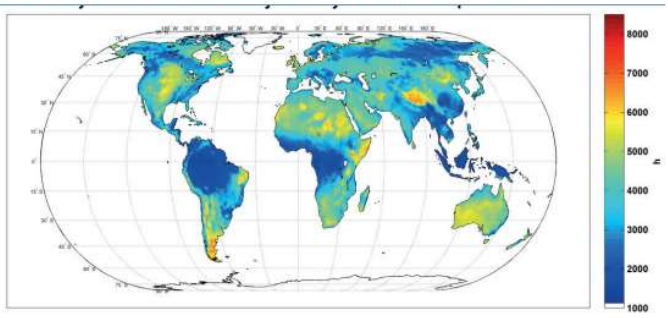




Electrolysers | Fuel Cells | Engines | Boilers

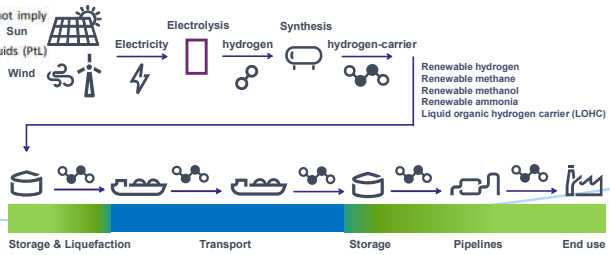
Transport of renewable electricity from regions with ideal conditions

Figure 8. Hybrid solar and wind full load hours adjusted by critical overlap in 2005



Disclaimer: The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Source: Adapted and based on Fasihi, Bogdanov and Breyer (2016), "Techno-Economic Assessment of Power-to-Liquids (PtL) Fuels Production and Global Trading Based on Hybrid PV-Wind Power Plants".



Source: Renewable Energy for Industry, IEA 2017

H2 Policy context Europe

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Hydrogen developments in Brussels

The EU hydrogen ambition has significantly increased in the last three years

Hydrogen Europe

2020

European Hydrogen Strategy

- Ambition of producing of 1 Mt by 2024 and 10 Mt of renewable hydrogen by 2030
- Ambition of 40 GW_{LHV} of electrolyzers by 2030 (56-62 GW_{el})

2021

Fit for 55
Hydrogen and Decarbonised Gas Package

Fit for 55

- Numerous legislative initiatives
  - Industry target (50%)
  - General industry demand ~3.3 Mt[1]
  - RFNBOs in transport (2.6%[2])
  - General transport demand~ 3.4 Mt[1]
  - Others

Hydrogen and decarbonised gas package

- Gas regulation
- Gas directive

2022

RePowerEU

- Raising the Fit for 55 ambition
- Targets of 10 Mt of domestic renewable H2 production and 10 Mt of imports
- Industry target (50%=>75%)
- General industry demand 3.3=>8.3 Mt[1])
- RFNBOs in transport (2.6%=>5%)
- General transport demand (3.4=>6.4 Mt[1])
- CCfD
- Hydrogen Valleys
- IPCEI acceleration
- Developing European hydrogen grid (H2 in TEN-E)
- 3 import corridors
- Other support mechanisms

1 According to European Commission PRIMES model

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Renewable Energy Directive (RED III): targets on H2 use

EU institutions reach agreement on RED III - key implications for hydrogen March 31, 2023

- 42% RFNBO in 2030 in industry, 60% in 2035
- 1 % RFNBO in 2030 in transport,

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Bedankt voor uw aandacht!
Thank you for your attention!

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