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The Netherlands Perspective on Clean Hydrogen

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Ministry of Economic Affairs and Climate Policy The Netherlands

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Hydrogen – A common *element* of our energy future?

- Momentum currently behind hydrogen is unprecedented, with more and more policies, projects, and plans by governments and companies in all parts of the world
- Hydrogen can help overcome many difficult energy challenges
  - ***Integrate more renewables***, including by enhancing storage options and tapping their full potential
  - ***Decarbonise hard-to-abate sectors*** – steel, chemicals, trucks, ships, and planes
  - ***Enhance energy security*** by diversifying the fuel mix and providing flexibility to balance grids
- But there are challenges: ***costs*** need to fall; ***infrastructure*** needs to be developed; ***cleaner hydrogen*** is needed; and ***regulatory barriers*** persist.

Source: IEA

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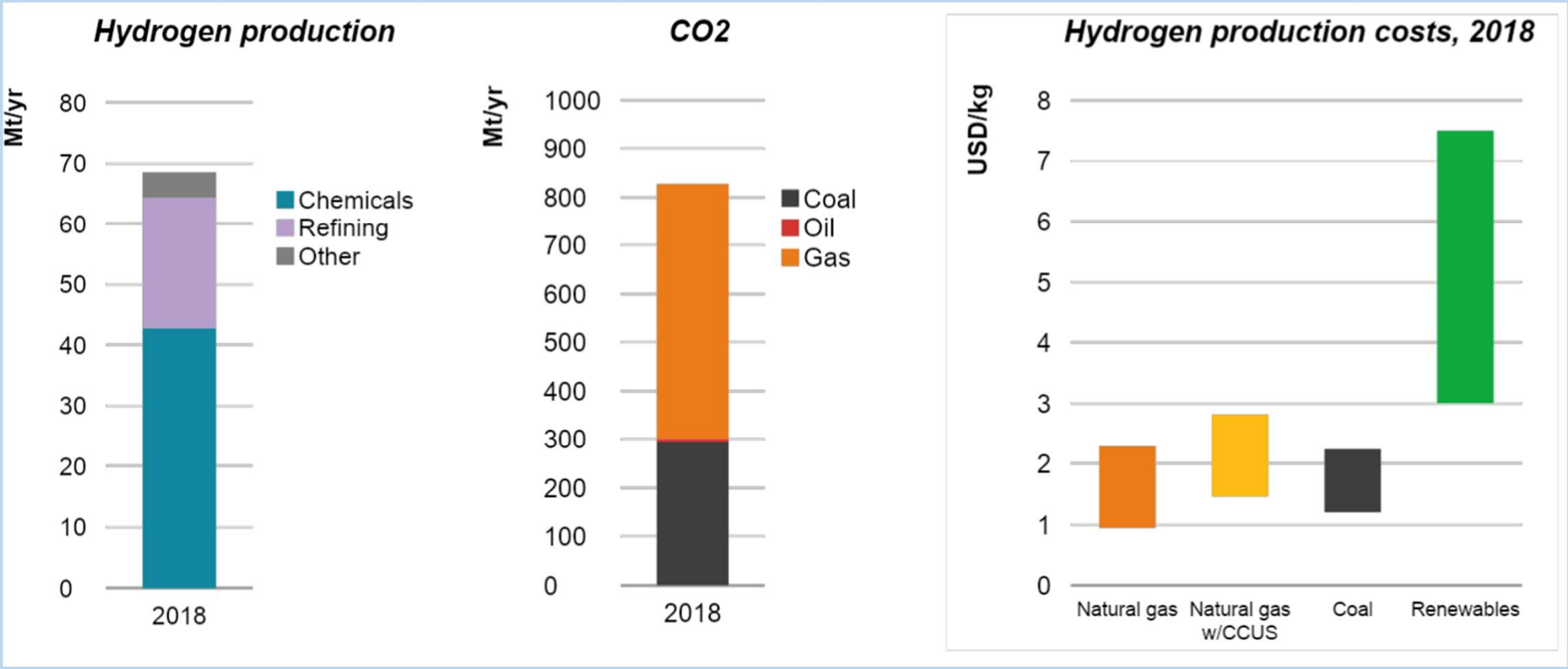
Hydrogen is Already Part of the Energy Mix



Dedicated hydrogen production is concentrated in very few sectors today, and virtually all of it is produced using fossil fuels, as a result of favourable economics.

Source: IEA

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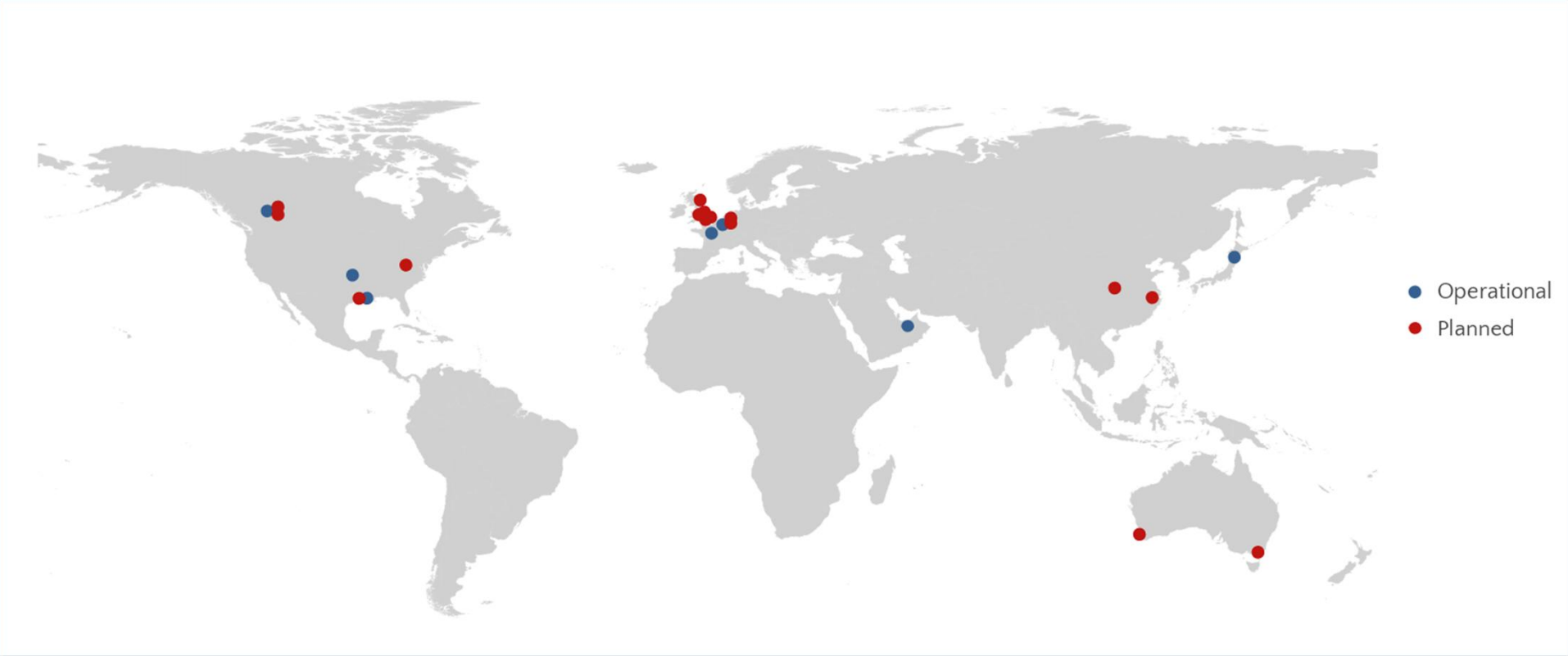
Hydrogen Production with CO_2 Capture is Coming Online



Low-carbon hydrogen from fossil fuels is produced at commercial scale today, with more plants planned. It is an opportunity to reduce emissions from refining and industry.

Source: IEA

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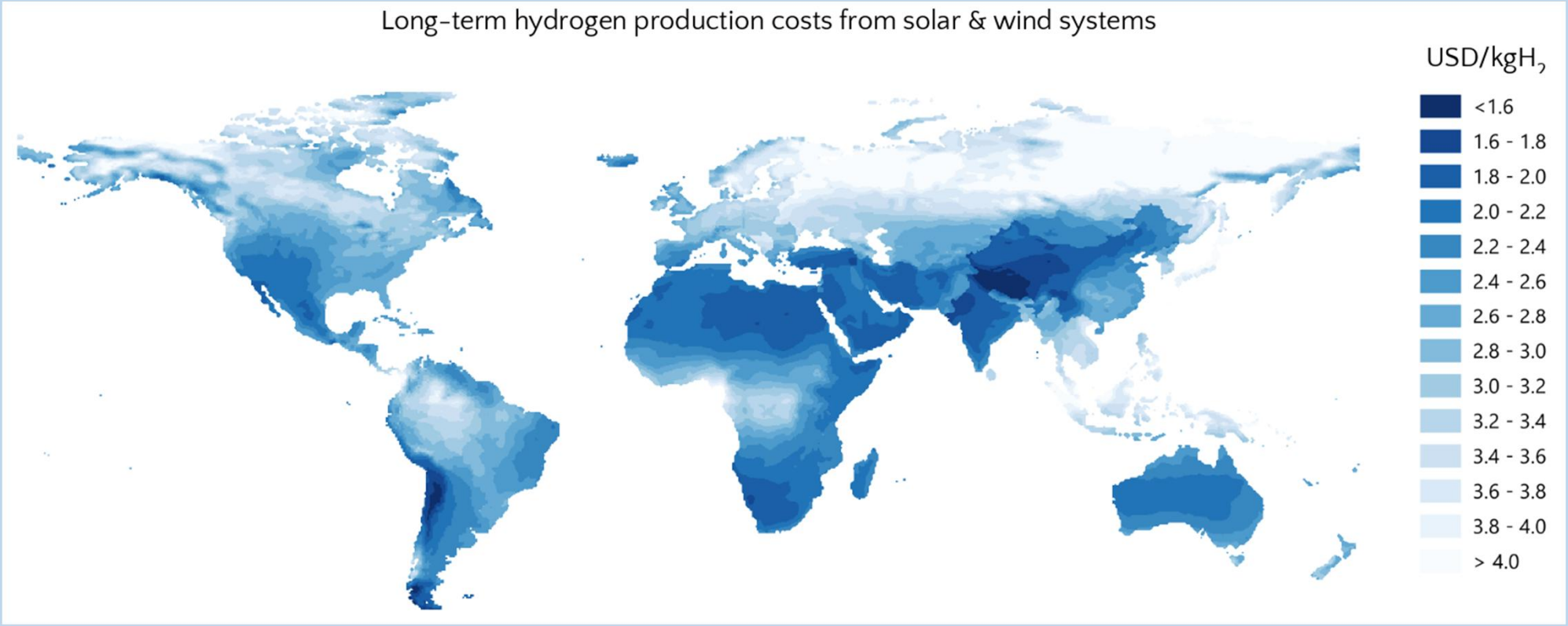
Renewables Hydrogen Costs are Set to Decline



The declining costs of solar PV and wind could make them a low-cost source for hydrogen production in regions with favourable resource conditions.

Source: IEA

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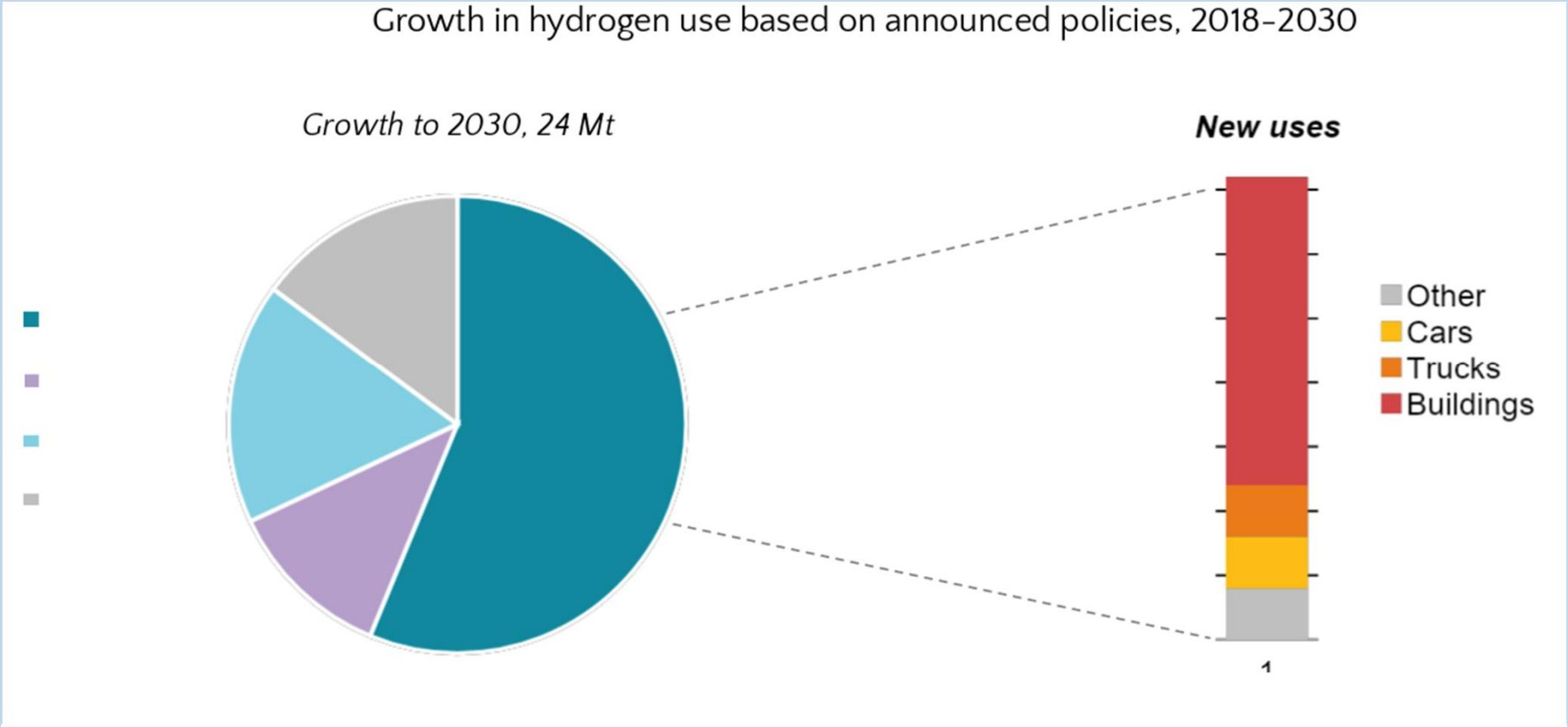
The Challenge to 2030: Expand Hydrogen Beyond Existing Applications



Dependable demand from current industrial applications can be used to boost clean hydrogen production; policies and industry targets suggest increasing use in other sectors, but ambition needs to increase.

Source: IEA

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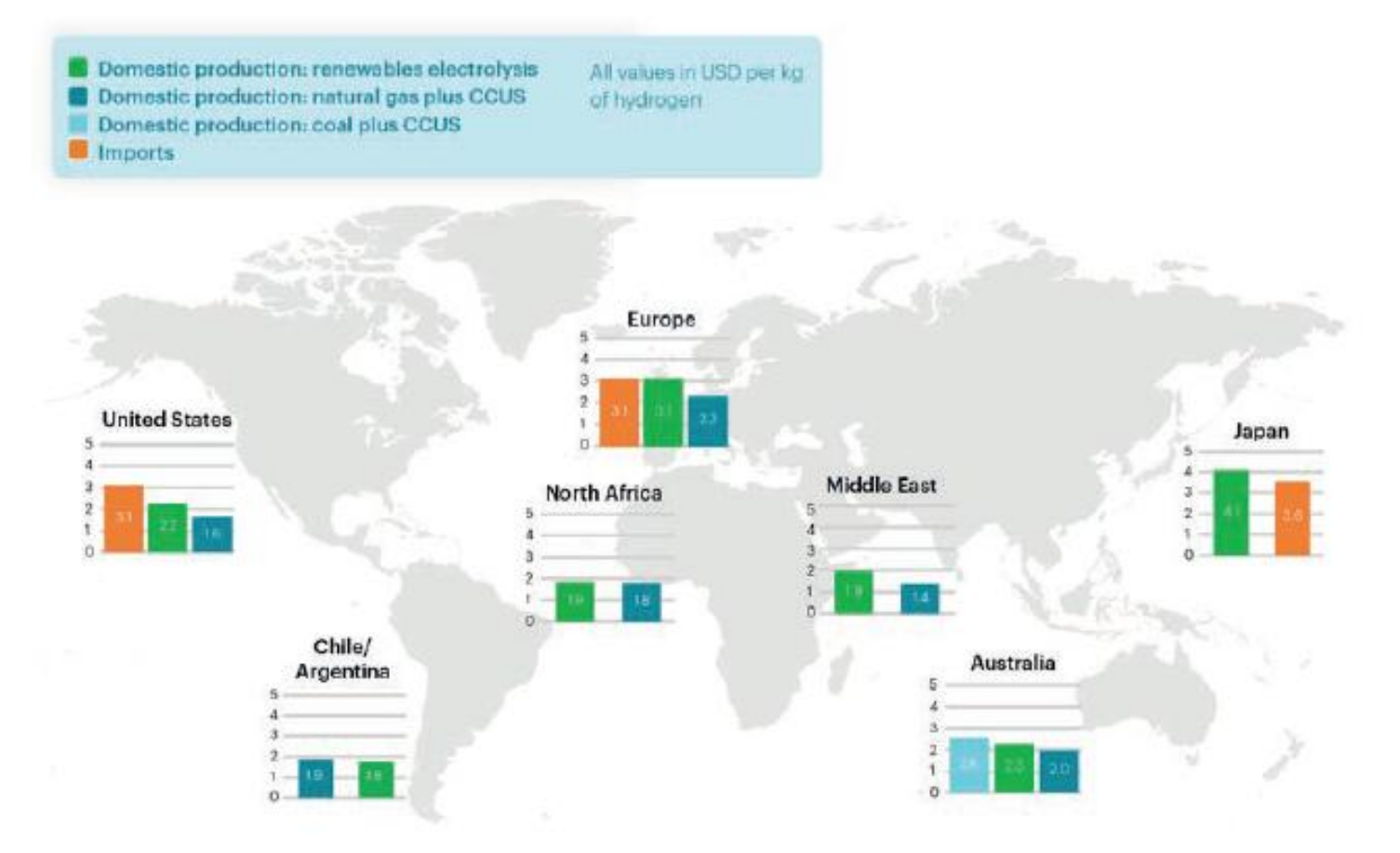
Routes for hydrogen trading with long-term costs compared to domestic production



Envisaged import market requires international cooperation

Source: IEA

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Preliminary Priorities R, D&D (work in progress)

- GW scale electrolysis in 2030
- New applications clean hydrogen in industry in 2030
- Backbone infrastructure clean hydrogen in 2030, incl storage
- Pilots clean hydrogen in built environment 2025
- Flexible power plants on clean hydrogen 2030
- Offshore electrolysis pilots
- Import modalities clean hydrogen
- Participation in IEA, FCH-JU, IPHE, CEM, HEM, Mission Innovation etc.

Source: IEA

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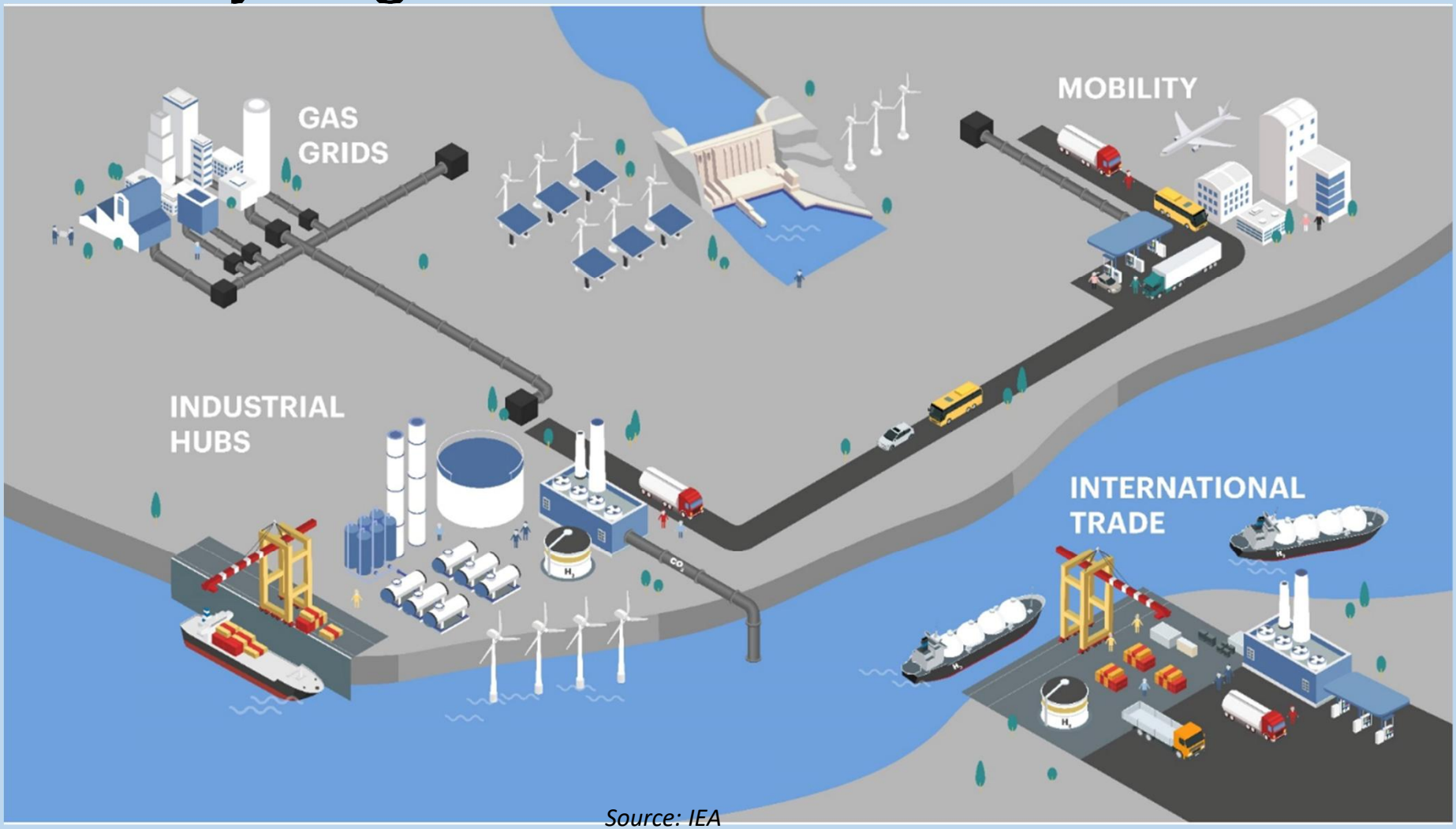
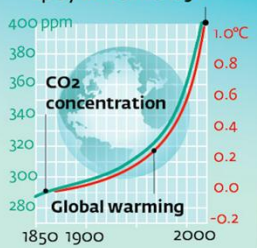
Four Key Opportunities for Scaling up Hydrogen to 2030



Source: IEA

Moving towards 2030 and 2050 with hydrogen

The earth has warmed up by 1.1°C since 1850



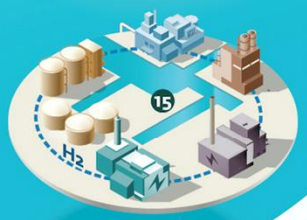
If we do nothing the global temperature will rise by another 4° C by 2100

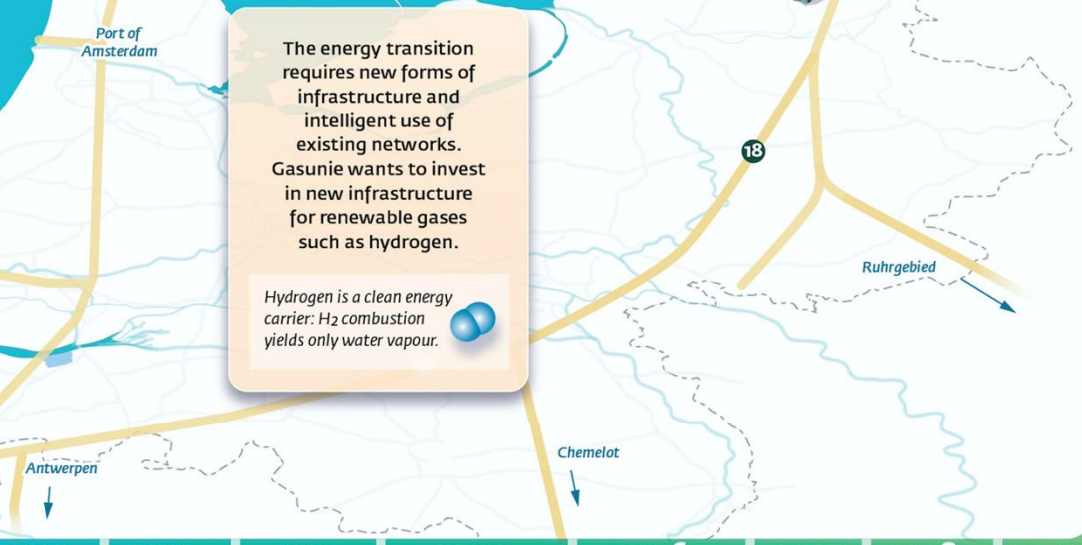
22 April 2016
Paris Agreement
Global warming set at a max. 2°C. This requires **CO2-reductions** in the Netherlands of:
- **40-50%** by 2030
- **85-100%** by 2050

Hydrogen as a fuel and as a raw material can help to achieve CO2-reduction targets

Hydrogen pipeline
Linking hydrogen industries in Zeeland and the Delta region

Pilot project HyStock
Converting solar energy into hydrogen in Zuidwending





The energy transition requires new forms of infrastructure and intelligent use of existing networks. Gasunie wants to invest in new infrastructure for renewable gases such as hydrogen.

Hydrogen is a clean energy carrier: H_2 combustion yields only water vapour.

- X Conversion
- X Transport
- X Storage

19 North Sea Wind Power Hub
An island where power from offshore wind farms is partially converted into hydrogen that is piped onshore

National hydrogen transport network
H2-pipeline network links major industrial areas Eemshaven, Ijmuiden, Rotterdam, Chemelot, Zeeland and the Ruhr area

17 Further deployment H2 - and CO2 network Zeeland

2015 2016 2017 2018 2030 2031 2032 2033 2034 2035

1 **2**

2019
3 Wind turbine generating hydrogen

2020
4 ISPT Hydrohub 1 MW test centre
5 Hydrogen refuelling station network North of the Netherlands
6 20 H2 buses Province of Groningen

2021
7 GZI Next Hydrogen plant including a hydrogen fuel station

2022
8 20-40 MW Electrolyser Green power into H2. 100 MW in 2024
9 Element 1 Gasunie / TenneT / Thyssengas power-to-gas pilot

2023
10 Green hydrogen value chain with Engie: towards a 100 MW electrolyser

2024
11 Hydrogen storage in salt caverns

2025
12 Magnum power station First turbine on hydrogen (± 700,000 households)
13 100 MW Electrolyser

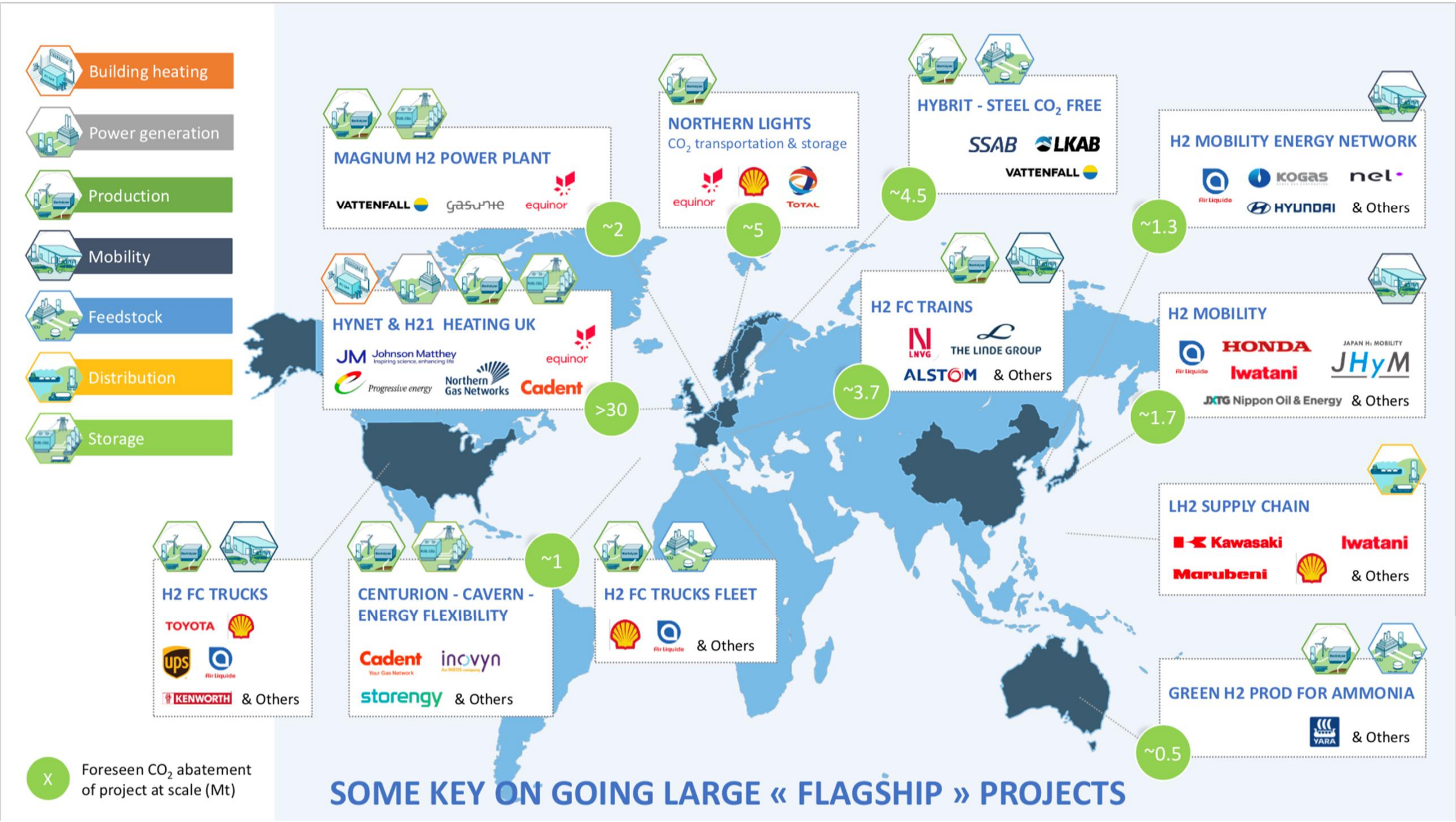
2026
14 IJmuiden Ver Wind farm, possible onshore electrolysis
15 h-vision Large-scale switch to hydrogen for power stations and chemical processes. Capture and storage of CO2

2027

2028
16 Magnum power station All three turbines on hydrogen: > 2 million homes supplied with power

2029

gasunie


Building heating
Power generation
Production
Mobility
Feedstock
Distribution
Storage
MAGNUM H2 POWER PLANT
VATTENFALL
gasunie
equinor
~2
NORTHERN LIGHTS
CO2 transportation & storage
equinor
TOTAL
~5
HYBRIT - STEEL CO2 FREE
SSAB
LKAB
VATTENFALL
~4.5
H2 MOBILITY ENERGY NETWORK
Air Liquide
KOGAS
nel
HYUNDAI
& Others
~1.3
HYNET & H21 HEATING UK
JM Johnson Matthey
equinor
Progressive energy
Northern Gas Networks
Cadent
>30
H2 FC TRAINS
LNVG
THE LINDE GROUP
ALSTOM
& Others
~3.7
H2 MOBILITY
Air Liquide
HONDA
Iwatani
JAPAN H2 MOBILITY
JHyM
JXTG Nippon Oil & Energy
& Others
~1.7
LH2 SUPPLY CHAIN
Kawasaki
Iwatani
Marubeni
& Others
H2 FC TRUCKS
TOYOTA
ups
Air Liquide
KENWORTH
& Others
CENTURION - CAVERN - ENERGY FLEXIBILITY
Cadent
inovyn
storengy
& Others
~1
H2 FC TRUCKS FLEET
Air Liquide
& Others
GREEN H2 PROD FOR AMMONIA
YARA
& Others
~0.5
X
Foreseen CO2 abatement of project at scale (Mt)
SOME KEY ON GOING LARGE « FLAGSHIP » PROJECTS

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Full List of Flagship Projects – *as of 2019.01.24*

1. Centurion Large-Scale Electrolysis Project, UK
2. Fukushima Renewable H_2 Project, Japan
3. Acorn (Aberdeenshire) Clean H_2 production, UK
4. Hydrogen to Magnum (H_2M), Netherlands and Norway
5. Northern Lights: CO2 transportation & storage project, Norway
6. HyNet Northwest Project, UK
7. HyNetherlands Project, Netherlands
8. H-Vision Project, Netherlands
9. H21 NoE Project, UK
10. Liquefied H_2 Supply Chain Project, Japan and Australia
11. H2 Mobility Deutschland
12. HyNet H_2 Project, South Korea
13. JHyM (H_2 Mobility) Flagship Project, Japan
14. Hype Taxi Fleet, France & EU
15. Zero Emission Valley Project, France
16. Pan-European Fleet of Trucks
17. Fleet of Trucks in California
18. FC Train Project, Germany
19. Low Cost Carbon Fiber for H_2 Tanks (FORCE), France
20. Ene-Farm Flagship Project, Japan
21. Green H_2 Production & Conversion to Green Ammonia, Australia
22. Reallabor GreenHydroChem Project, Germany
23. HYBRIT fossil-free steel production, Sweden

Source: IEA

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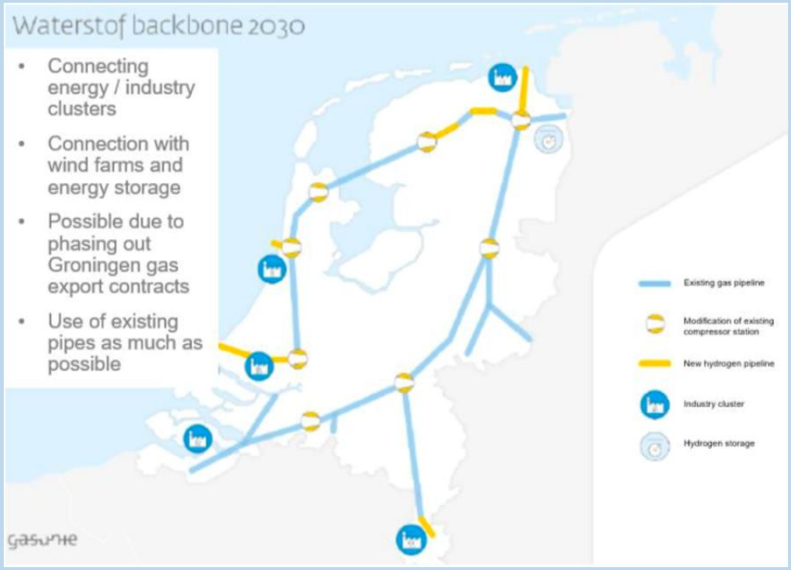
Infrastructure Initiatives

Large-scale offshore wind integration beyond 2030



Creating hydrogen backbone through partial conversion of existing natural gas network

Exploring an integrated energy infrastructure including electricity, hydrogen, and methane

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European Hydrogen Infrastructure

- Unlock the offshore-onshore wind resources in North Europe
- Unlock the solar and wind resources in South Europe
- Unlock the solar and wind resources in Northern Africa

- Connect to large scale hydrogen storage, e.g. salt caverns

- Supply chemical, petrochemical and steel plants
- Supply electricity balancing plants
- Supply hydrogen fuelling infrastructure
- Supply regional hydrogen distribution grids

TU Delft Delft University of Technology

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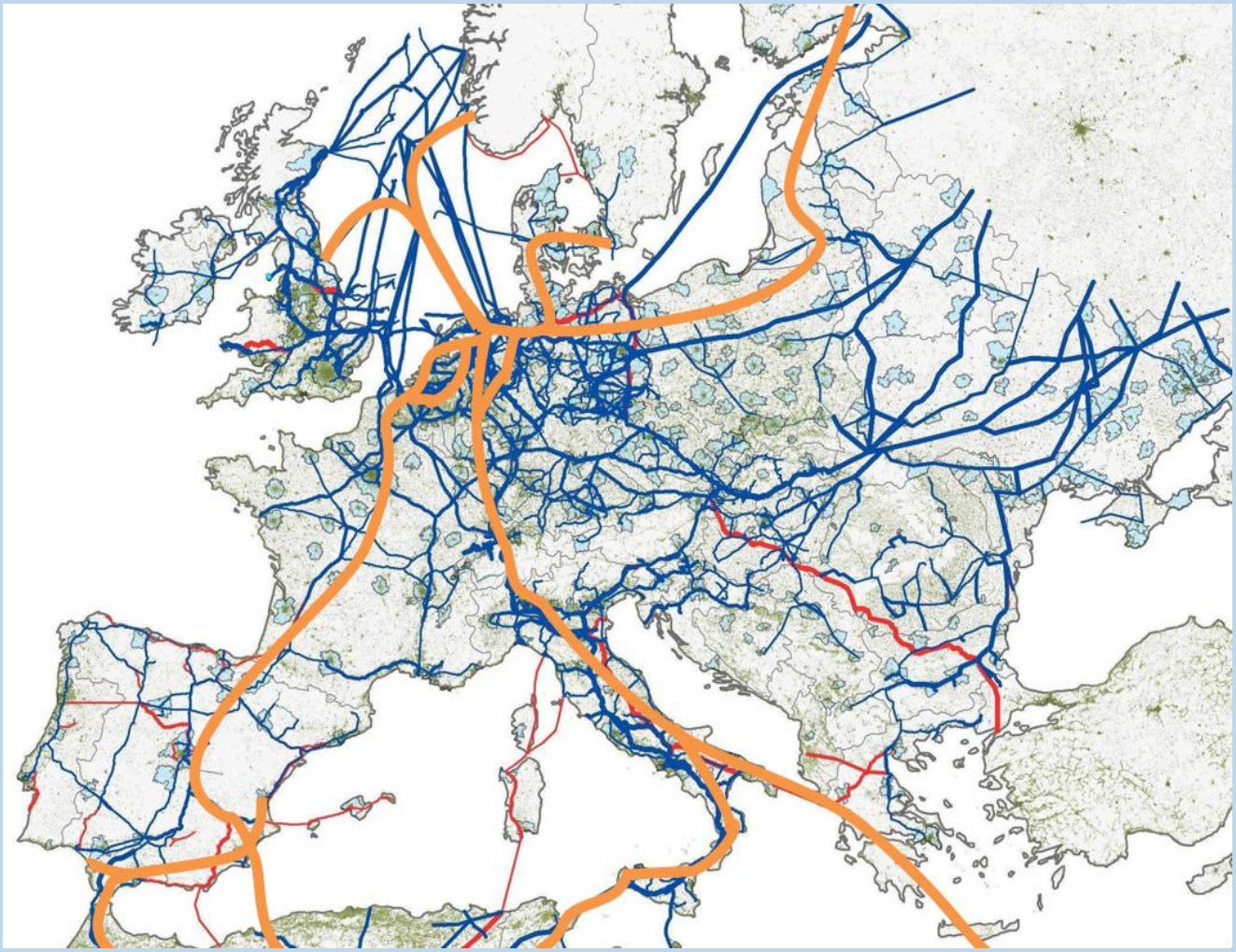
European Hydrogen Backbone



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Key Elements of EU Hydrogen Strategy

- EU Hydrogen strategy in 2020 (priority new EC)
- Ambitious targets for clean hydrogen market: blending in gas grids (10% gas replaced by clean hydrogen in 2030), transport
- Common standards, guarantees of origin (CertifyHY), flexible and hybrid market regulation
- Build strong EU presence in clean hydrogen value chain
- Boost EU clean hydrogen R&D (Mission Innovation)

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Growing International H_2 Momentum

- G20 Energy & Environment Ministerial 15/16 June 2019:
  'Ministers will step up existing international efforts to unlock the potential of hydrogen as a clean, reliable and secure source of energy...'. Focus on R&D, cost reduction, regulation & standards.

- EU Energy Council 25 June 2019:
  'Calls on the European Commission to undertake an analysis of sector coupling and sector integration technologies, including the production of hydrogen, in particular with regards to regulatory and market barriers and based on this analysis explore possible initiatives regarding the efficient integration and deployment of such technologies and energy carriers'.

- Global Action Agenda Hydrogen Energy Ministerial 25 September 2019:

  Global aspirational goals, R&D/technology, regulation, codes & standards, supply chains, H_2 trading