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the Netherlands

The International Perspective on Clean Hydrogen

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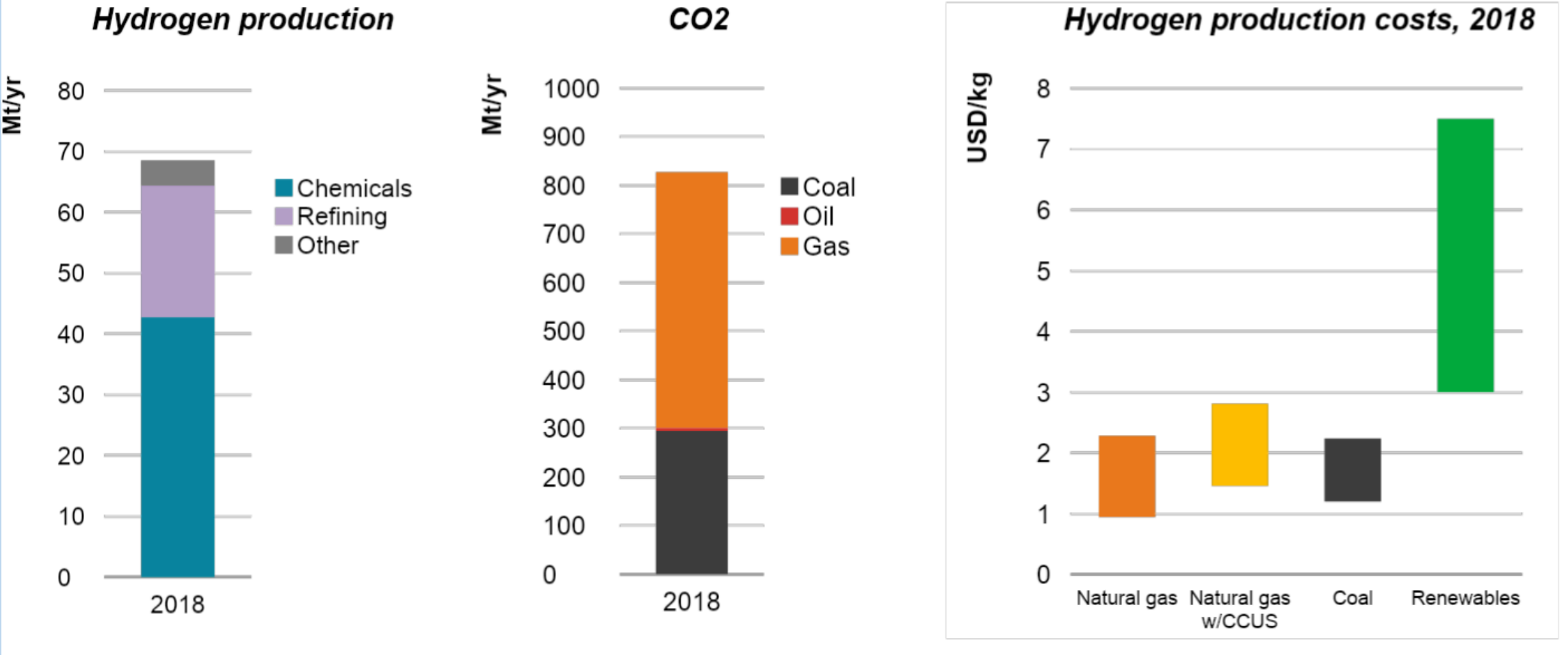


Hydrogen – A common *element* of our energy future?

- 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.



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.



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Hydrogen Production with CO₂ Capture is Coming Online

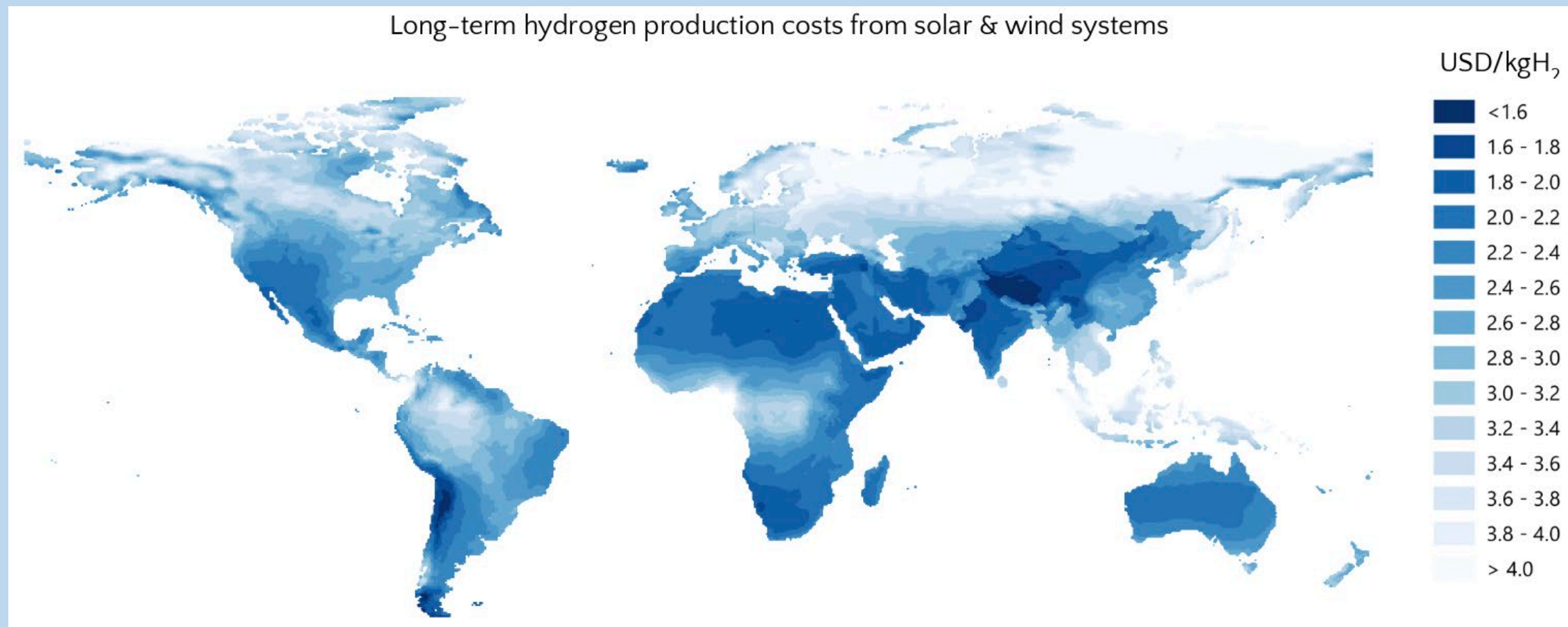


Low-carbon hydrogen from fossil fuels is produced at commercial scale today, with more plants planned. It is an opportunity to reduce emissions from refining and industry.

Source: IEA



Renewables Hydrogen Costs are Set to Decline

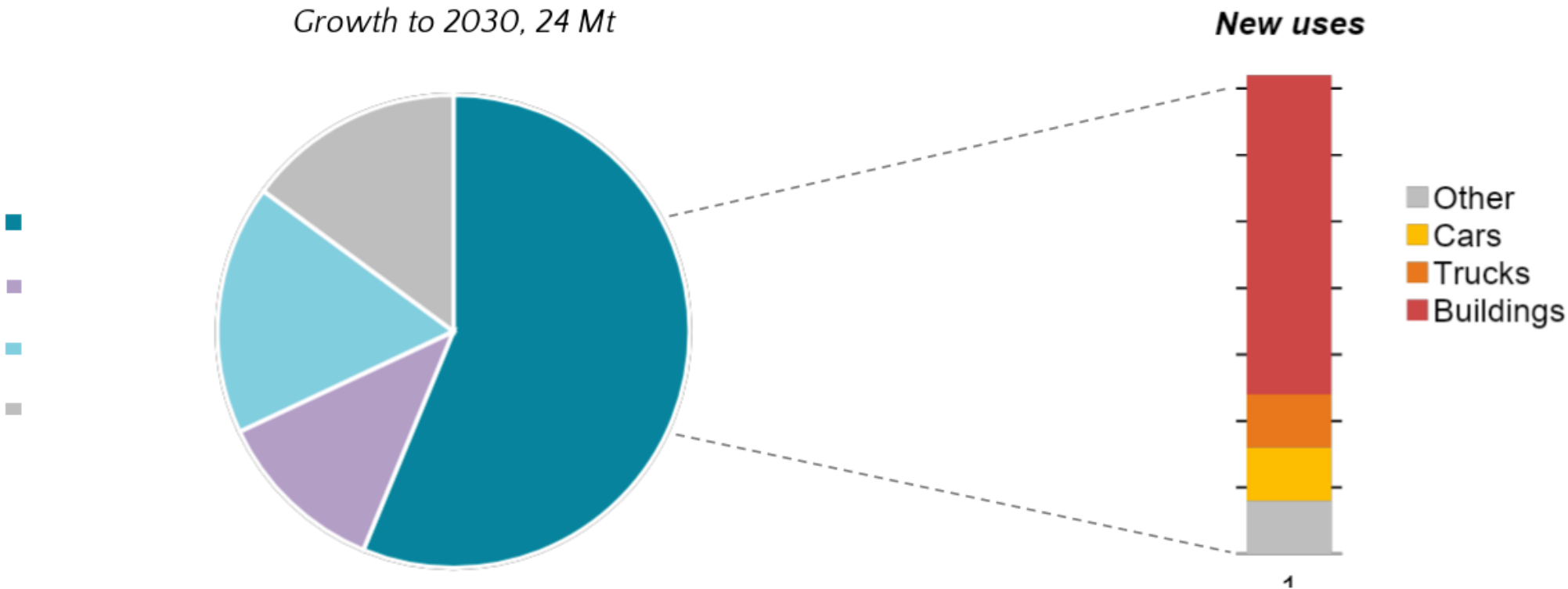


The declining costs of solar PV and wind could make them a low-cost source for hydrogen production in regions with favourable resource conditions.



The Challenge to 2030: Expand Hydrogen Beyond Existing Applications

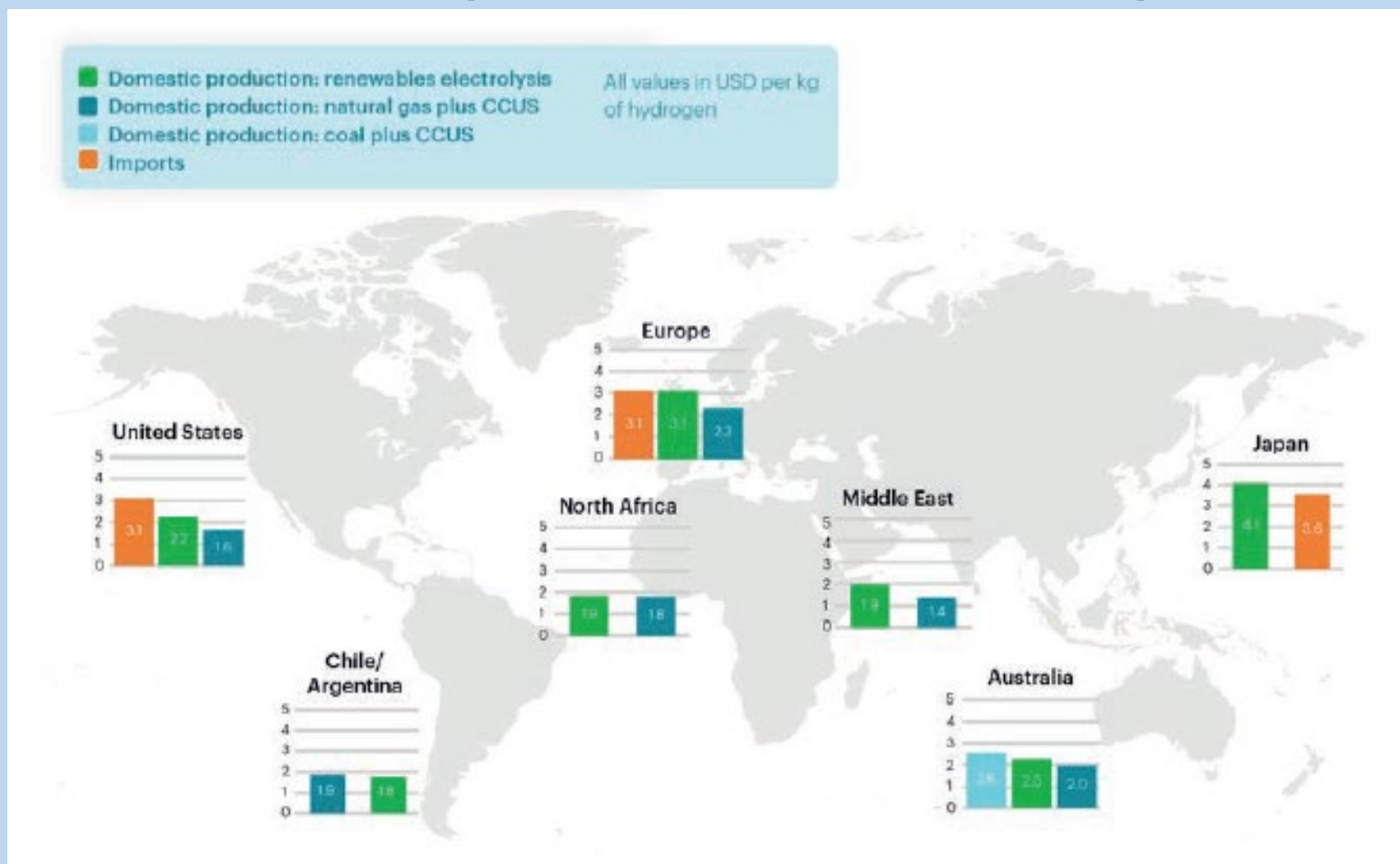
Growth in hydrogen use based on announced policies, 2018-2030



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.



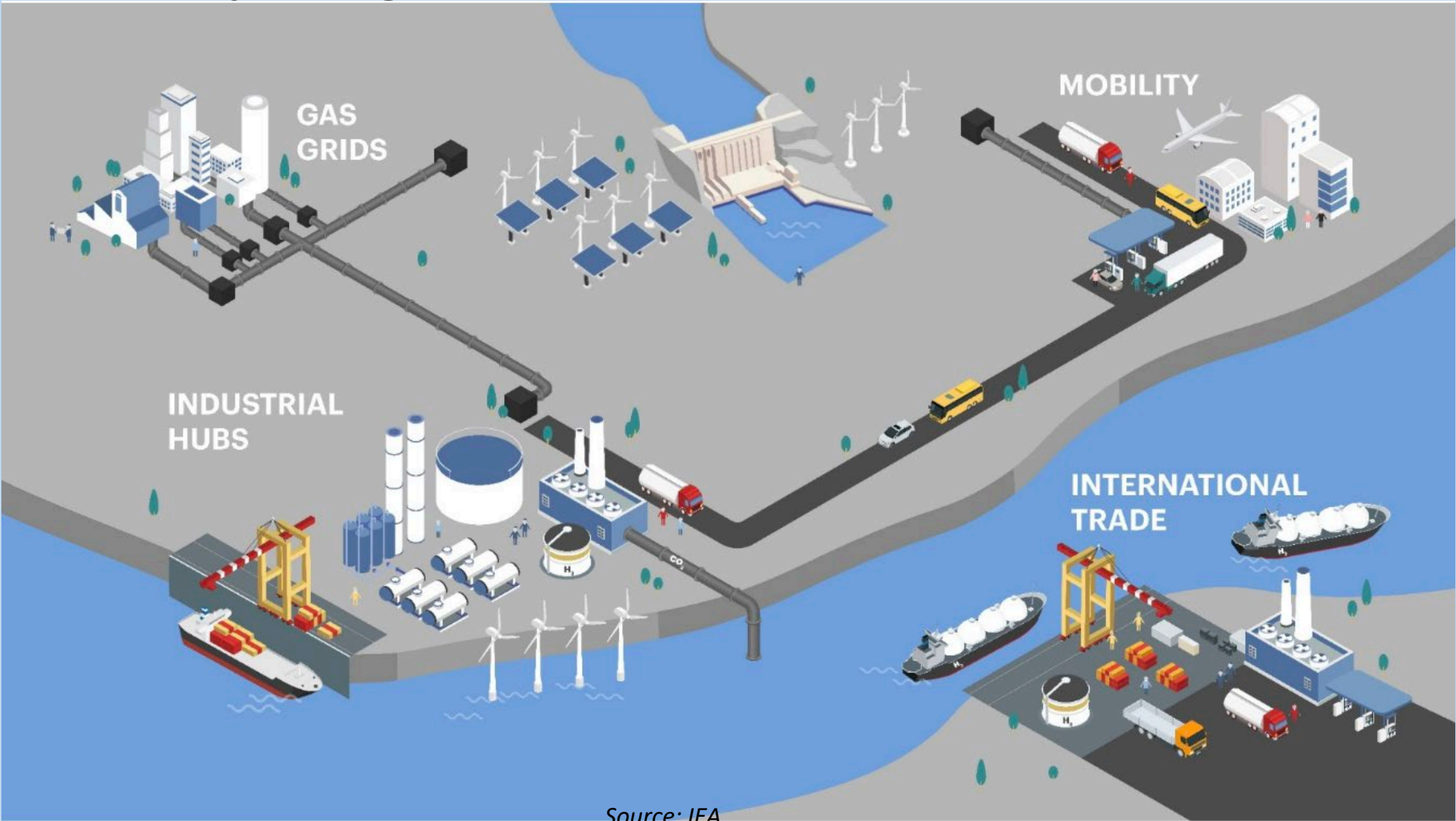
Routes for hydrogen trading with long-term costs compared to domestic production



Envisaged import market requires international cooperation

Source: IEA

Four Key Opportunities for Scaling up Hydrogen to 2030



Source: IEA

Moving towards 2030 and 2050 with hydrogen

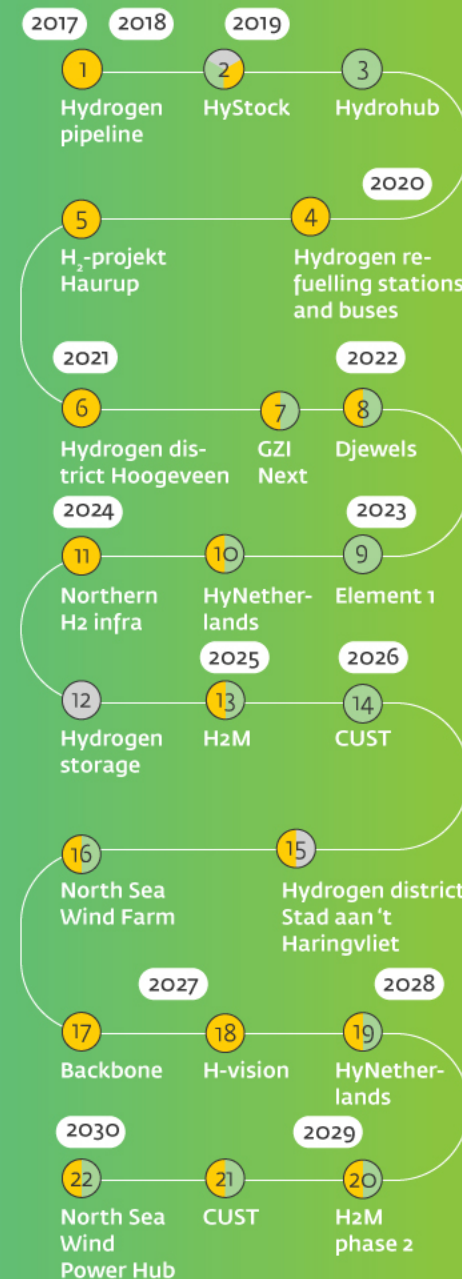
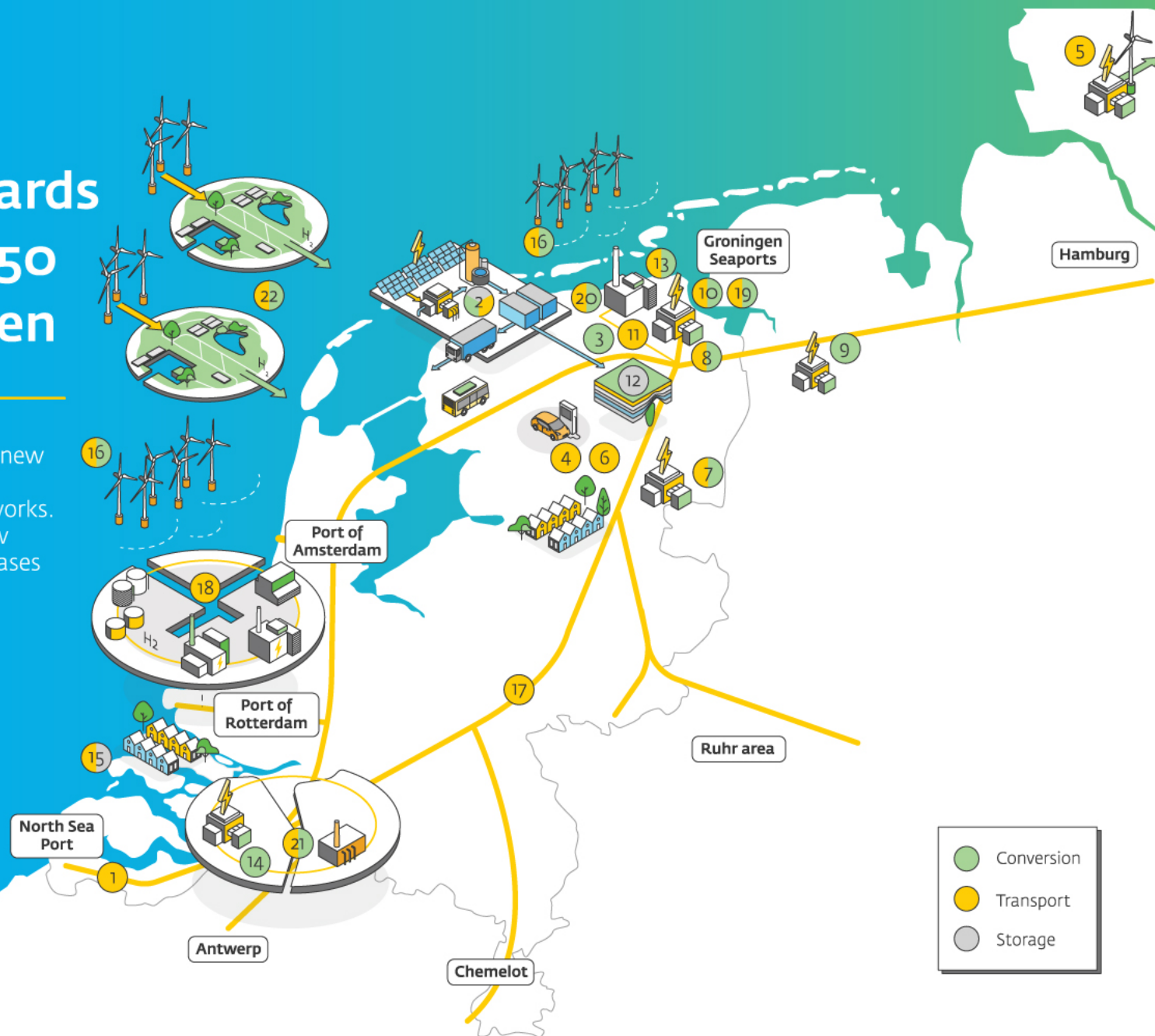
The energy transition requires new forms of infrastructure and intelligent use of existing networks. Gasunie wants to invest in new infrastructure for renewable gases such as hydrogen.

2016 Paris Agreement:

Global warming set at a max. 2°C. This requires CO₂-reduction in the Netherlands of:

- 40-50% in 2030
- 85-100% in 2050

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



- Building heating
- Power generation
- Production
- Mobility
- Feedstock
- Distribution
- Storage

H2 FC TRUCKS

TOYOTA Shell

ups Air Liquide

KENWORTH & Others

CENTURION - CAVERN - ENERGY FLEXIBILITY

Cadent inovyn

storengy & Others

H2 FC TRUCKS FLEET

Shell Air Liquide & Others

MAGNUM H2 POWER PLANT

VATTENFALL gasunie equinor

HYNET & H21 HEATING UK

JM Johnson Matthey Inspiring science, enhancing life

Progressive energy Northern Gas Networks equinor Cadent

NORTHERN LIGHTS

CO₂ transportation & storage

equinor Shell TOTAL

HYBRIT - STEEL CO₂ FREE

SSAB LKAB

VATTENFALL

H2 FC TRAINS

LNVG THE LINDE GROUP

ALSTOM & Others

H2 MOBILITY ENERGY NETWORK

Air Liquide KOGAS nel

HYUNDAI & Others

H2 MOBILITY

Air Liquide HONDA Iwatani

JAPAN H₂ MOBILITY JHyM

JXTG Nippon Oil & Energy & Others

LH2 SUPPLY CHAIN

Kawasaki Iwatani

Marubeni Shell & Others

GREEN H2 PROD FOR AMMONIA

YARA & Others

X Foreseen CO₂ abatement of project at scale (Mt)

SOME KEY ON GOING LARGE « FLAGSHIP » PROJECTS



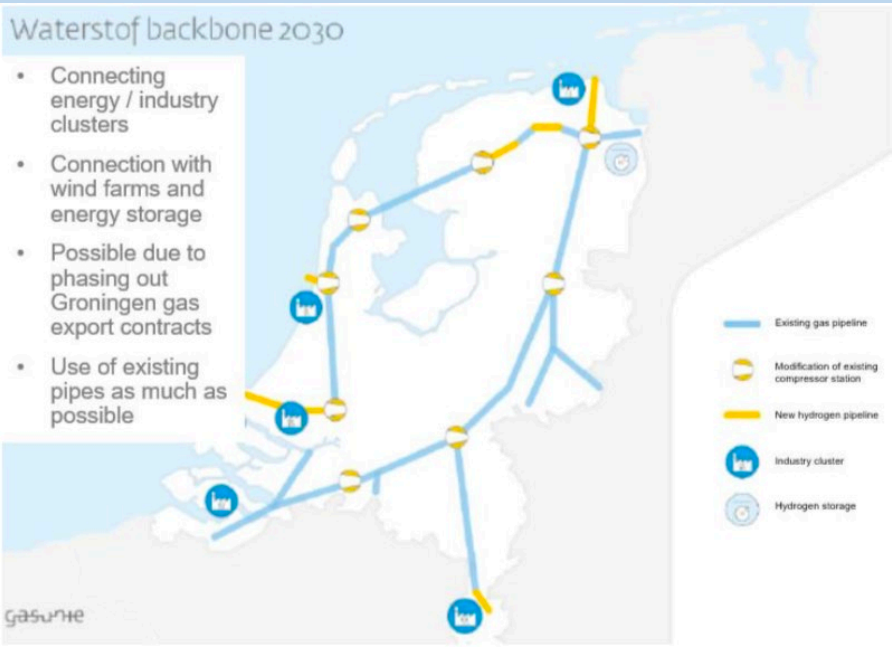
Full List of Flagship Projects – *as of* *2019.01.24*

1. Centurion Large-Scale Electrolysis Project, UK
2. Fukushima Renewable H₂ Project, Japan
3. Acorn (Aberdeenshire) Clean H₂ production, UK
4. Hydrogen to Magnum (H₂M), 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 H₂ Supply Chain Project, Japan and Australia
11. H2 Mobility Deutschland
12. HyNet H₂ Project, South Korea
13. JHyM (H₂ 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 H₂ Tanks (FORCE), France
20. Ene-Farm Flagship Project, Japan
21. Green H₂ Production & Conversion to Green Ammonia, Australia
22. Reallabor GreenHydroChem Project, Germany
23. HYBRIT fossil-free steel production, Sweden

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



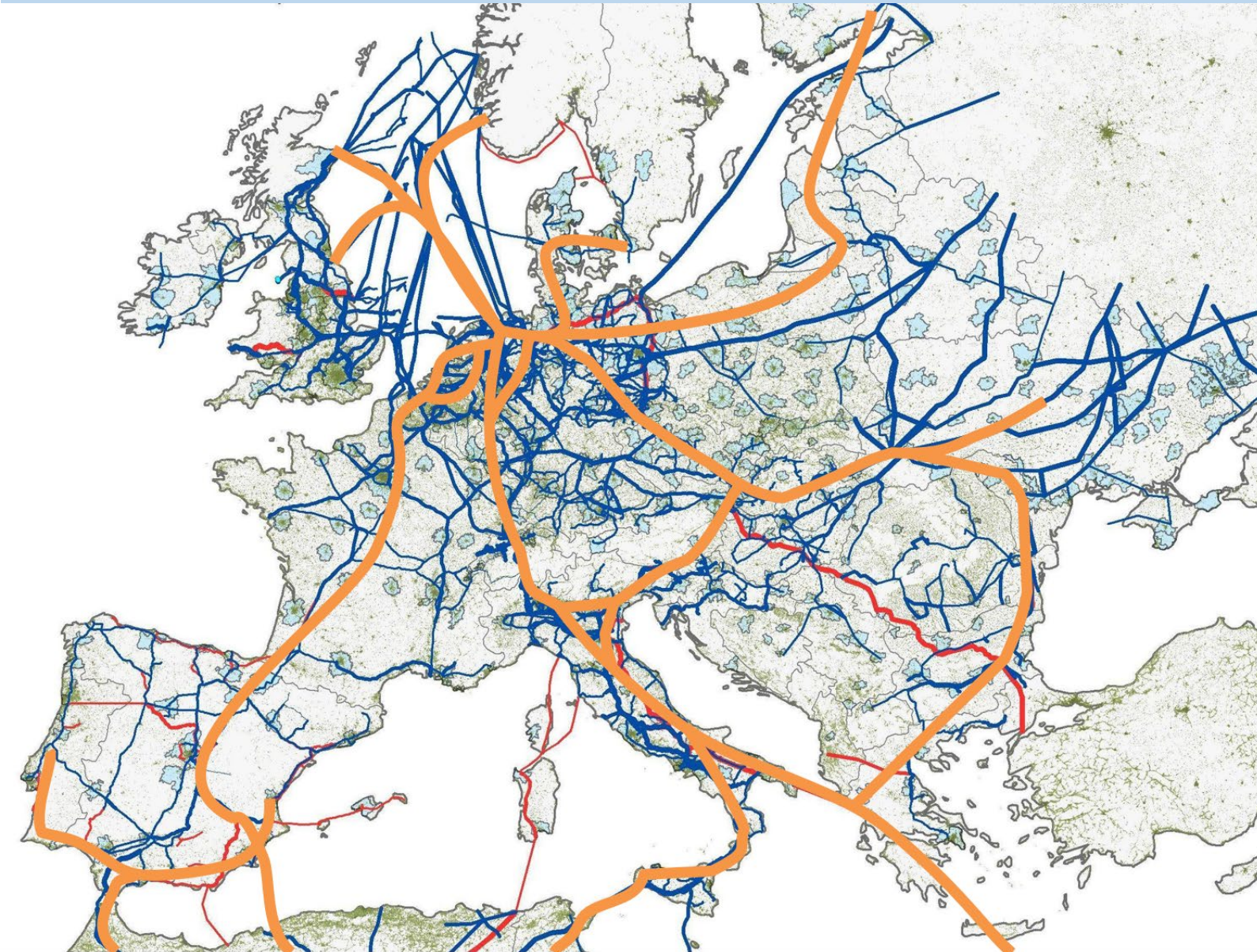
European Hydrogen Infrastructure

- 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



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European Hydrogen Backbone





Key Elements of EU Hydrogen Strategy

- EU Hydrogen strategy in 2020 (priority new EC)
- Ambitious targets for clean hydrogen market: blending in gas grids (5-10% 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)



European Commission: The European Green Deal

- Strategy for smart sector integration (mid-2020)
- Decarbonisation of gas sector
- Review of regulatory framework energy infrastructure (incl. TEN-E)
- 1st commercial applications of breakthrough technologies like clean hydrogen & fuel cells in key industrial sectors by 2030
- IPCEI projects for new innovative value chains (like clean hydrogen)
- Clear pathway from 2025 onwards towards zero-emission mobility (TEN-T, Alternative Fuels Infrastructure Directive)