Analysing future demand, supply, and transport of hydrogen

European Hydrogen Backbone

Webinar, 15 June 2021

A cooperation with Gas for Climate

Webinar programme

01 **Welcome & introduction by Daniel Muthmann |** 10min
Coordinator of EHB and Head of corporate development, strategy, policy and communication at OGE

02 **Statement by EU Commissioner Ms. Kadri Simson |** 10 min
European Commissioner for Energy

03 **Assessing European hydrogen demand and supply, and looking at the options for storage and transport**

- Demand analysis: presentation by Guidehouse | 10 min
  Statement by ThyssenKrupp | 4 min
- Supply analysis: presentation by Guidehouse | 10 min
  Statement by ITM Power | 4 min
- Underground storage of hydrogen
  Presentation by GIE | 14 min
- Transport infrastructure: presentation by Guidehouse | 10 min
  Statement by North Sea Wind Power Hub | 4 min

04 **Q&A** | 15 min
Close by Daniel Muthmann

01

Welcome & Introduction by Daniel Muthmann

Coordinator of EHB and
Head of corporate development, strategy, policy and communication at OGE

Welcome & Introduction

Who we are

European Hydrogen Backbone

- 23 European gas TSOs
- Covering 19 EU Member States plus the United Kingdom and Switzerland

Current study complements the April 2021 European Hydrogen Backbone maps

The updated European Hydrogen backbone maps show a vision for

39,700 km hydrogen pipeline infrastructure

In **21** countries by 2040

almost **70%** of which is based on repurposed existing natural gas pipelines

At an average cost of **€0.11-0.21 per kg**

European Hydrogen Backbone initiative 2021, supported by Guidehouse

Hydrogen Backbone is essential for a European hydrogen market

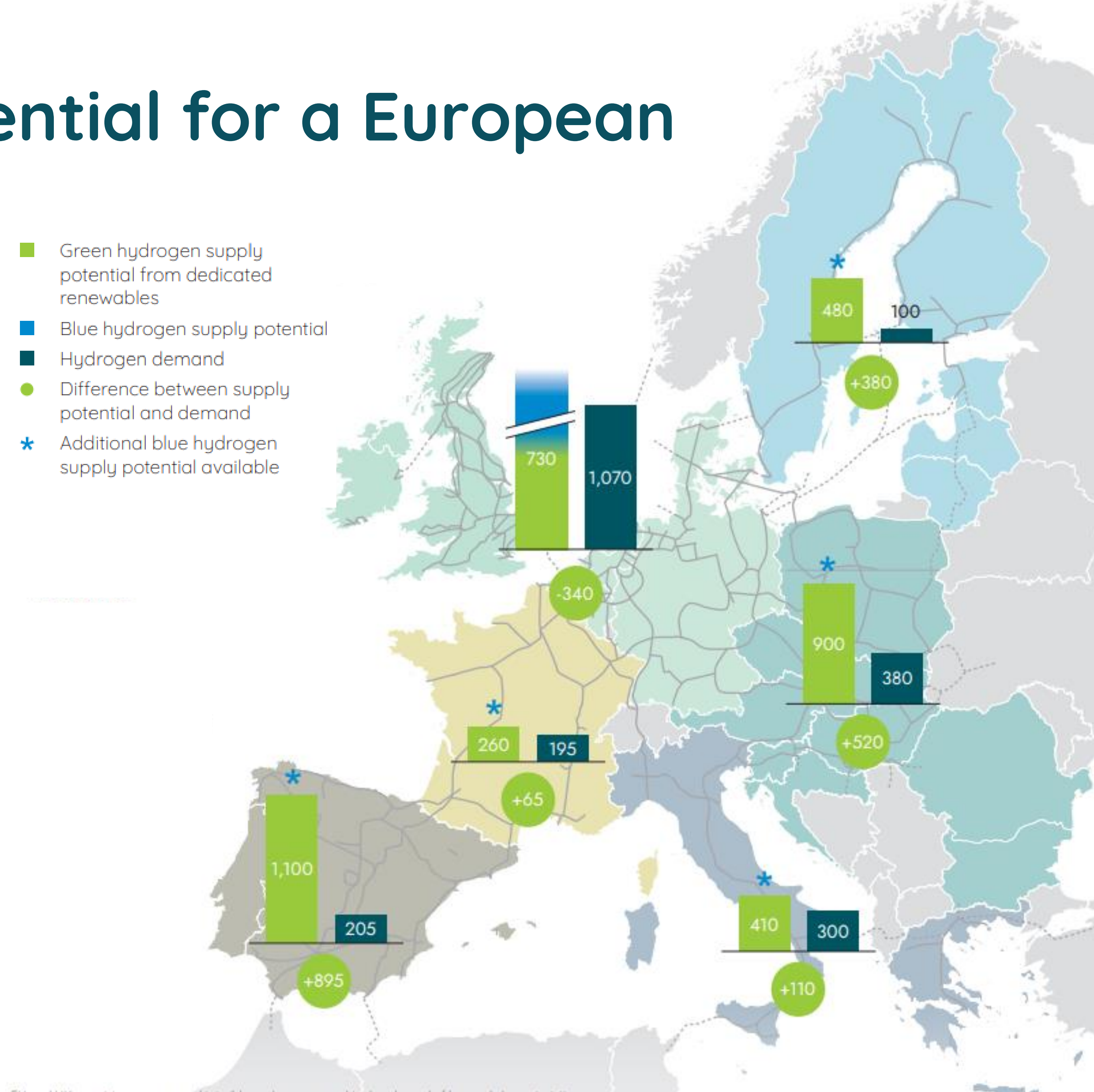
Hydrogen is crucial in meeting Europe's climate targets. By 2050, **demand** will be ~2,300 TWh, or 20-25% of final energy demand

Domestic European green and blue hydrogen **supply** potential at affordable cost exceed projected hydrogen demand

Neighbouring regions can be attractive partners

Hydrogen network needed to bridge regional differences in hydrogen supply and demand and to connect Europe to neighbouring regions with abundant supply potential

Pipelines are the most cost-efficient option for long-distance, high volume transport



EU and UK countries are grouped into 6 based on geographical and supply/demand characteristics: North Sea, Baltic Sea, Central & Eastern Europe, South East Europe, Portugal & Spain, and France.

02

Statement by European Commissioner for Energy Ms. Kadri Simson

03a

European hydrogen demand

Daan Peters
Guidehouse

Hydrogen is crucial to Europe's transformation into a climate-neutral continent by mid-century

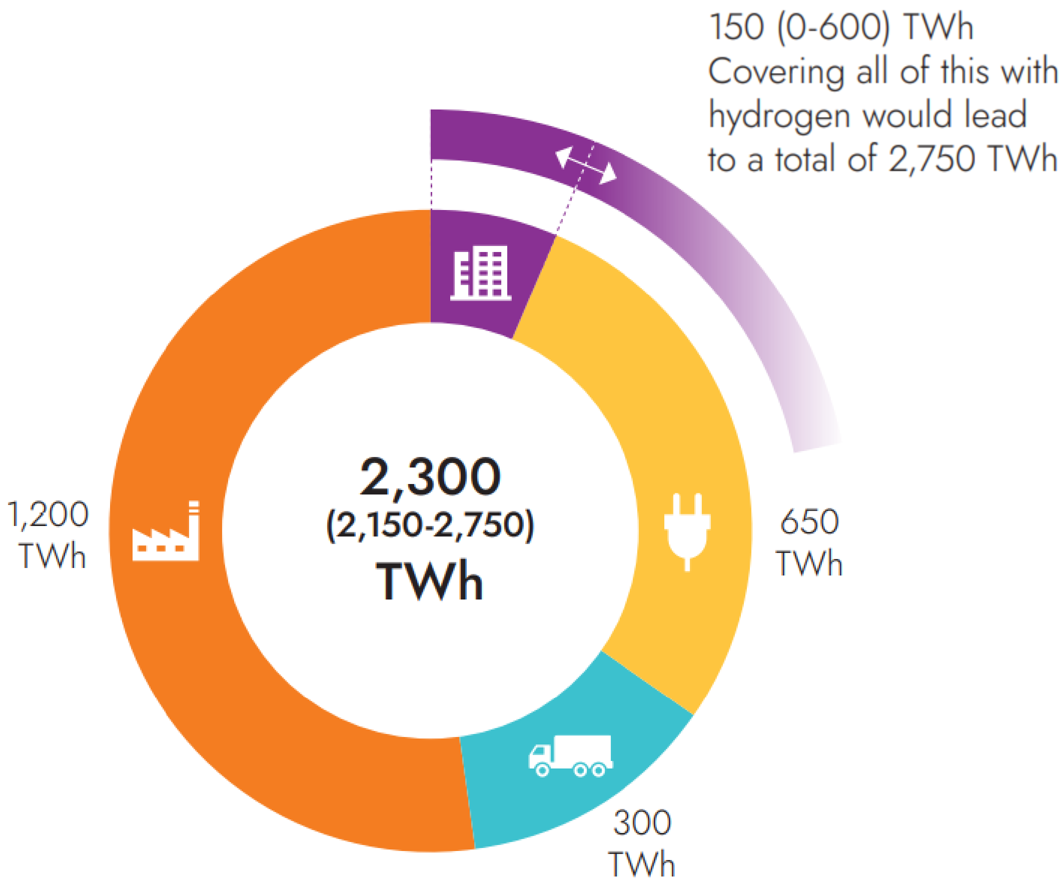
The EU and UK hydrogen demand is estimated to be **2,300 (2,150-2,750) TWh**, corresponding to **20-25%** of EU and UK final energy consumption, by 2050.

Green and blue hydrogen are crucial for **industrial** decarbonisation, particularly for iron & steel, ammonia, and fuel production**.**

Hydrogen can cost-effectively integrate and provide deep resilience to the highly electrified net-zero energy system of the future by providing **dispatchable power** and long-duration storage.

In **transport**, next to electrification and biofuels, there is a clear role hydrogen as a fuel and in the production of hydrogen-derived fuels for heavy road transport and aviation.

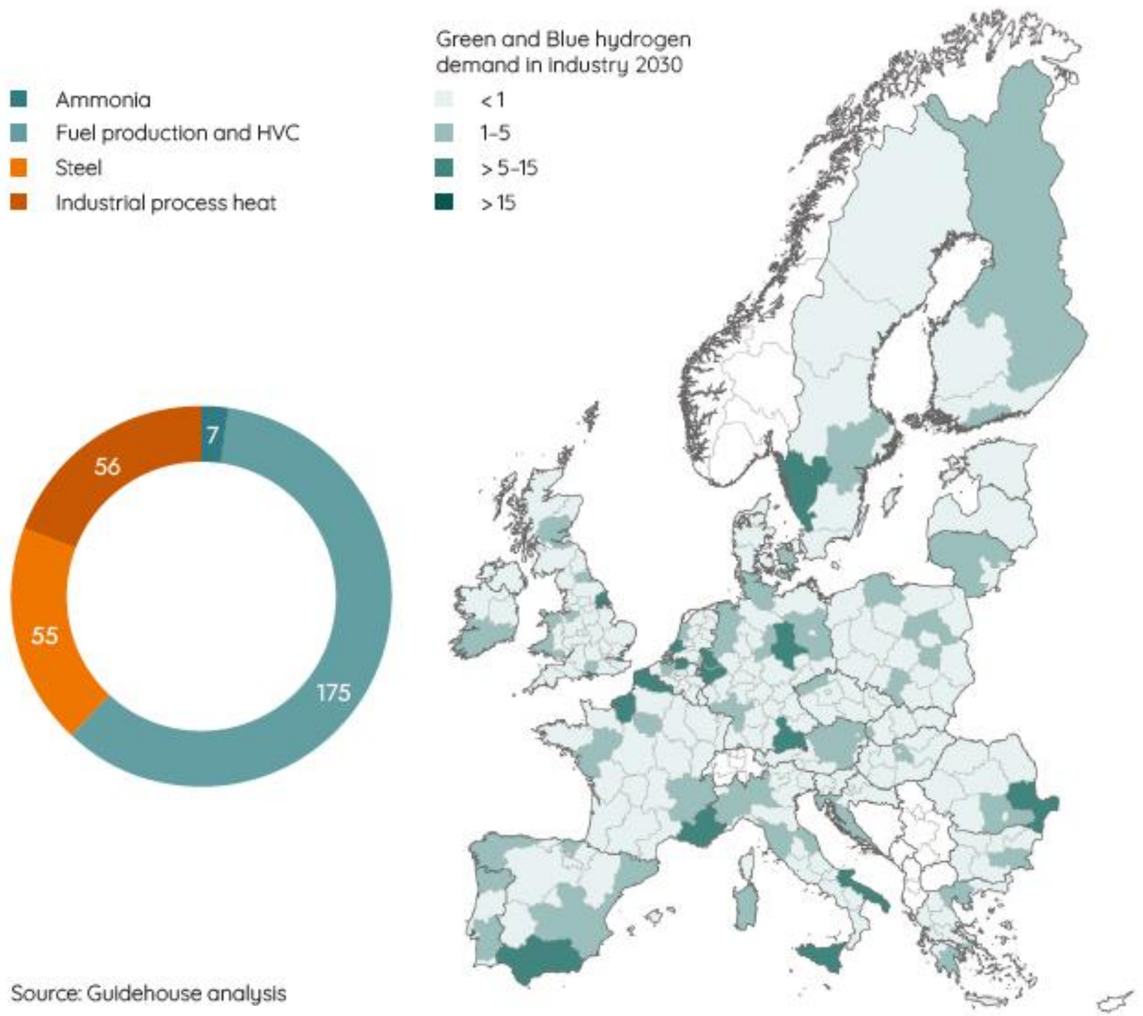
Under an accelerated renovation scenario, gas demand in the building stock will be around 600 TWh. This demand could be met with biomethane and hydrogen. Under the assumptions of this study around 150 TWh of hydrogen would be used in **buildings**.



Note: Figures are expressed in TWh/year in 2050. As a result of the chosen methodology, incl. technology assumptions, demand figures represented in this infographic may differ from other (national) decarbonisation scenarios.
Source: Guidehouse analysis.

Hydrogen is instrumental to the decarbonisation of the industry sector

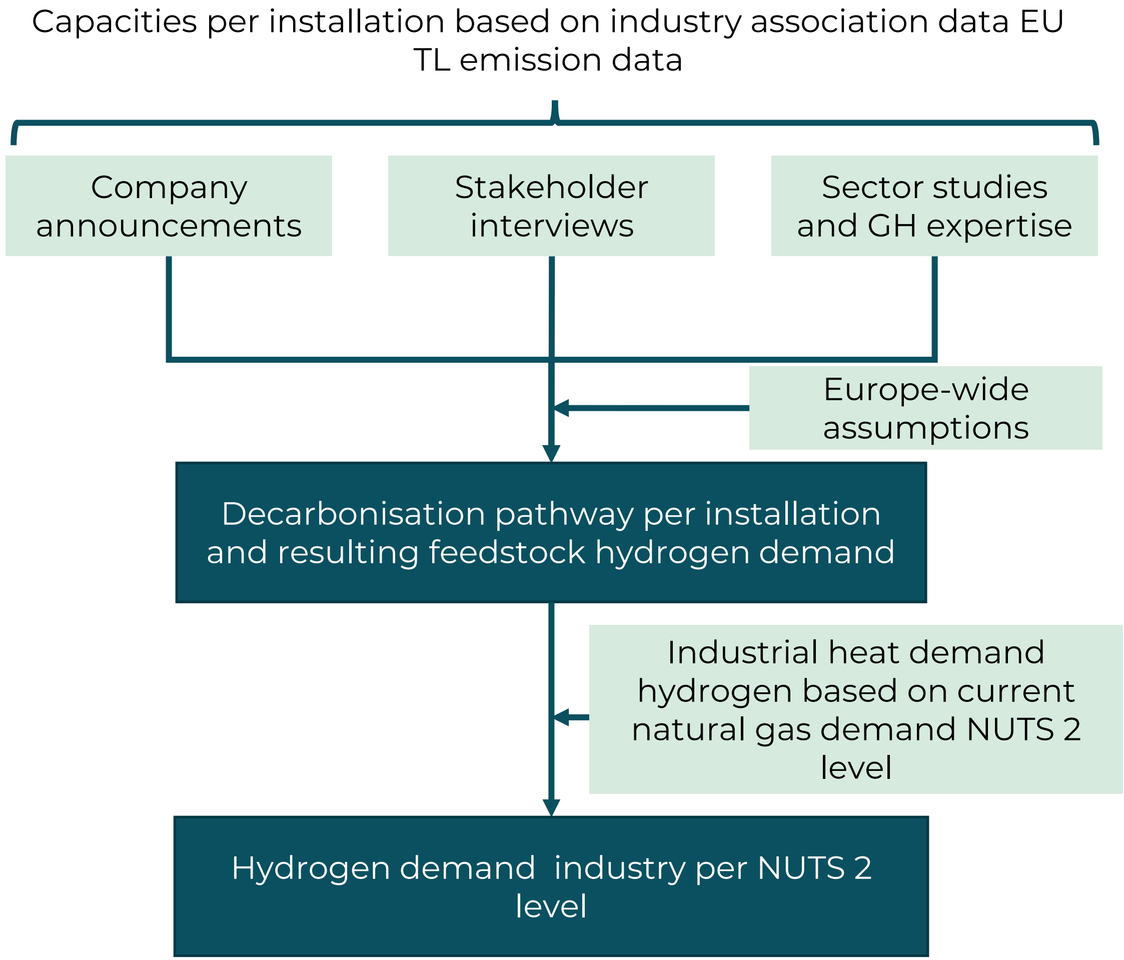
- Green and blue hydrogen are crucial in our industrial decarbonisation pathway.
- Particularly relevant for these industries:
  - Chemicals (fertilizers and high-value chemicals)
  - Iron and steel
  - Fuel production
- By 2050, approximately **1,200 TWh** of annual hydrogen demand is expected in the EU+UK



Figures are expressed in TWh/year in 2050. As a result of the chosen methodology, demand figures represented in this infographic may differ from other (national) decarbonization scenarios.
Source: Guidehouse analysis.

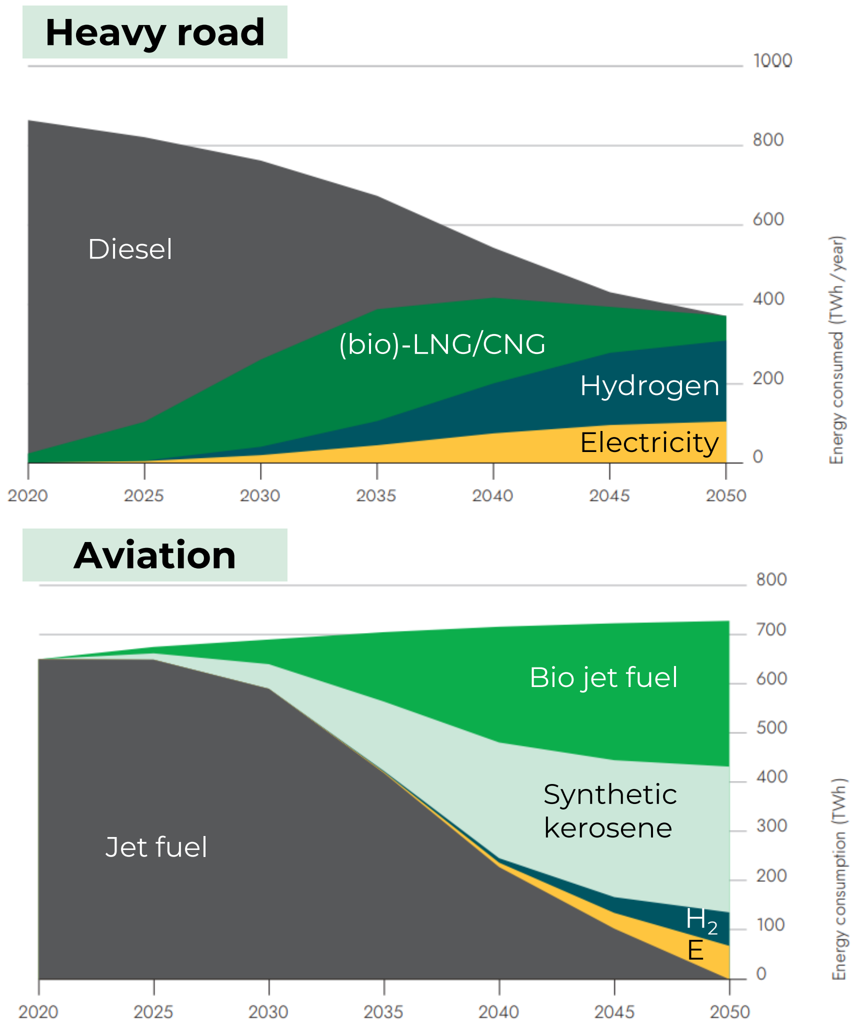
Industrial hydrogen demand based on bottom-up analysis with installation specific pathways

- Analysis of **300+ industrial installations** in the four focus sectors accounting for **30-40% of industrial emissions**, with industrial heat covering most of the remaining emissions
- **Scope:** EU+ UK
- **Years:** 2030, 2040, 2050
- Sectors included for **feedstock hydrogen demand:**
  - Ammonia
  - High Value Chemicals
  - Fuel production
  - Iron & steel
- **Relocation** within Europe, increase of imports and country specificities **not included**
- **Fuel production** includes hydrogenation, fuels for aviation and HVCs, assumed to be located at **current refineries**



Hydrogen is a promising option to help decarbonise heavy road transport and aviation

- Hydrogen as transport fuel can be about **300 TWh** per year in 2050
- In heavy road transport, **hydrogen fuel cells** are expected to power **55% of trucks** and **25% of buses** by 2050
  - Over time, fuel stations will need to converted to supply hydrogen & a hydrogen infrastructure will need to supply these stations
- The main use of hydrogen in **aviation** is anticipated to be as feedstock in fuel production, shown under industrial demand in this study
  - Synthetic and bio kerosene are each expected to power 40% of aircrafts by 2050
  - Current research and development, company announcements, and policy indicate that hydrogen aircrafts can take to the air for short-haul trips over the coming decades. **Hydrogen** is expected to make up **10%** of aviation fuel demand by 2050



Source: Guidehouse analysis

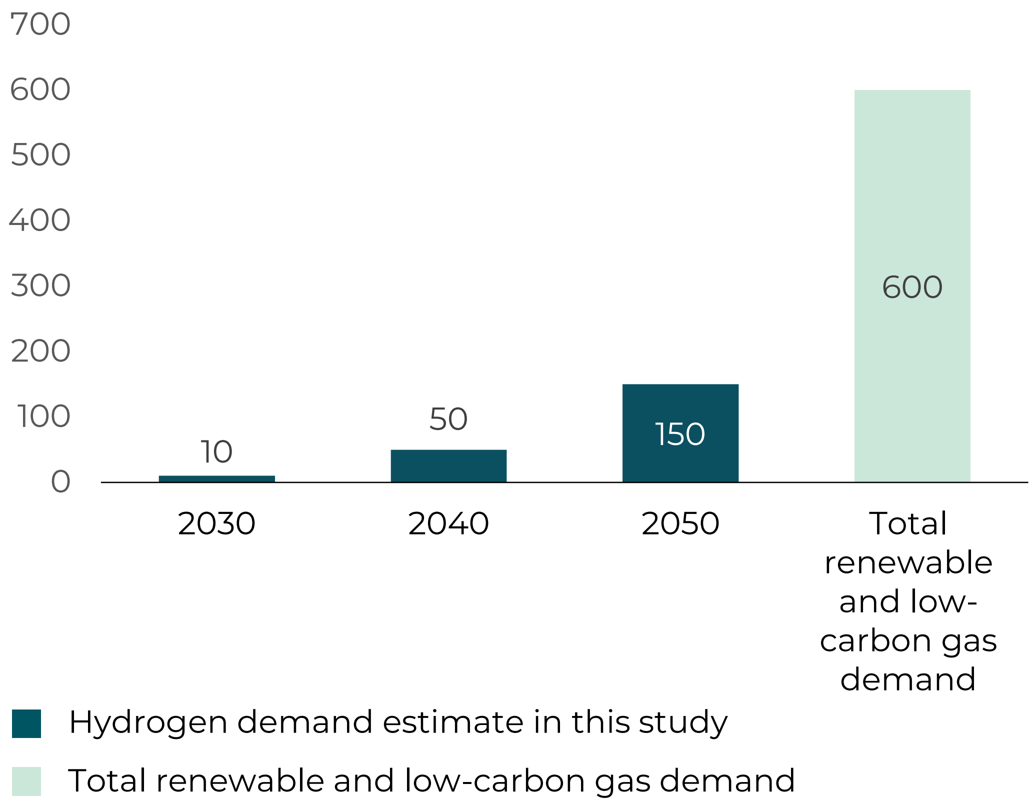
Hydrogen demand in buildings

- Heating in buildings will be decarbonised using a range of technologies with significant regional variations.

- This study assumes Europe-wide accelerated renovation rates and **hybrid heating** systems in existing homes with a gas connection and in 30% of district heating.
- Such hybrid systems use electricity (in a heat pump) and, for peak supply, renewable or low-carbon gas

- Under these assumptions, annual renewable and low-carbon gas demand in buildings will be around **600 TWh** in 2050
- Assuming a scale-up of biomethane as in previous Gas for Climate studies, annual hydrogen demand would be around **150 TWh**

Hydrogen and low-carbon gas demand for buildings in EU+UK (TWh/year)



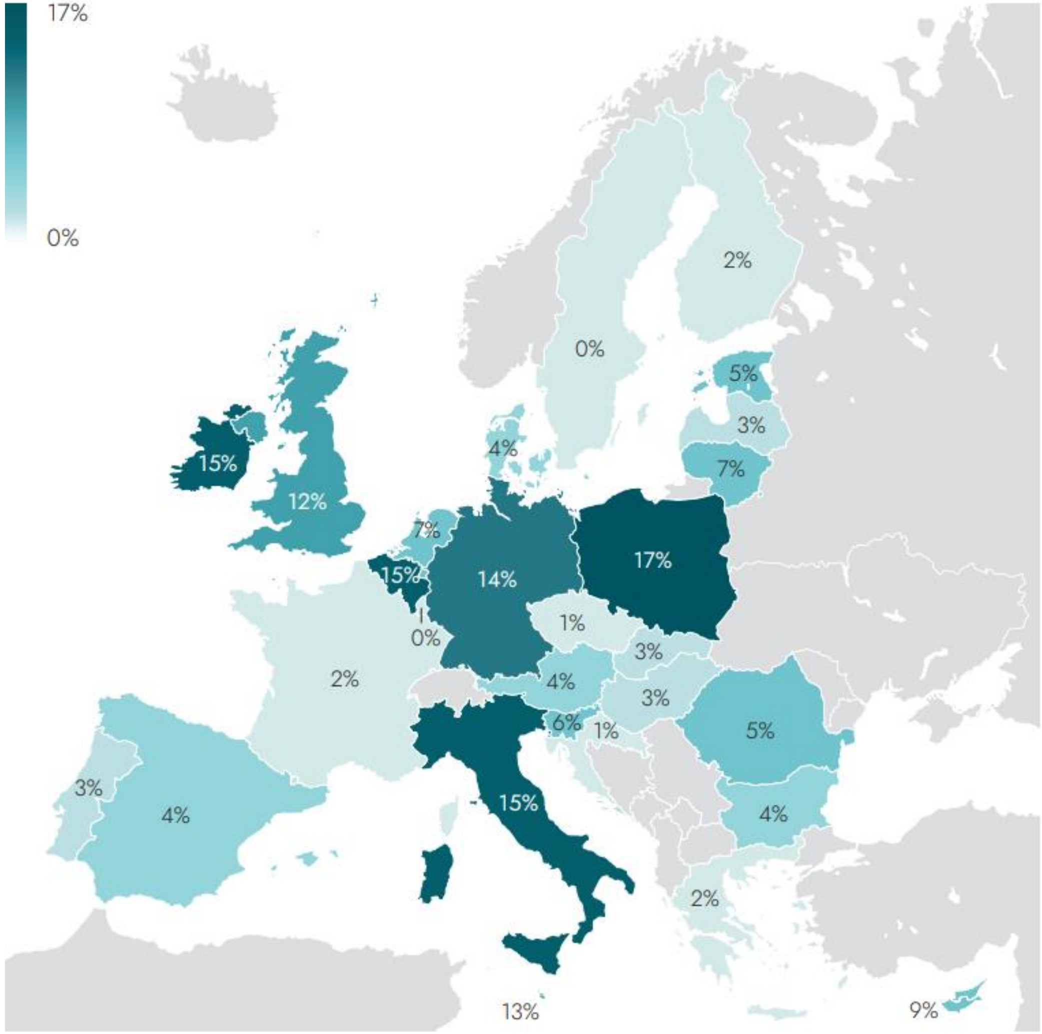
Source: Guidehouse analysis

Hydrogen can provide needed flexibility to the power sector

- Compared to other flexible power options, hydrogen is particularly appealing for **long-duration storage**
  - Can be supplied and stored in large quantities for relatively low investment costs
- Hydrogen can **cost-effectively** help integrate variable renewable sources and provide **deep resilience** to the highly electrified net-zero energy system (and economy) of the future.

	2030	2040	2050
Hydrogen demand	12 TWh	301 TWh	626 TWh
Fraction of electricity generated from hydrogen	1 %	3 %	7 %

Source: Guidehouse analysis



Fraction of hydrogen generated electricity of total country electricity generation in 2050 (%)

03a

European hydrogen demand

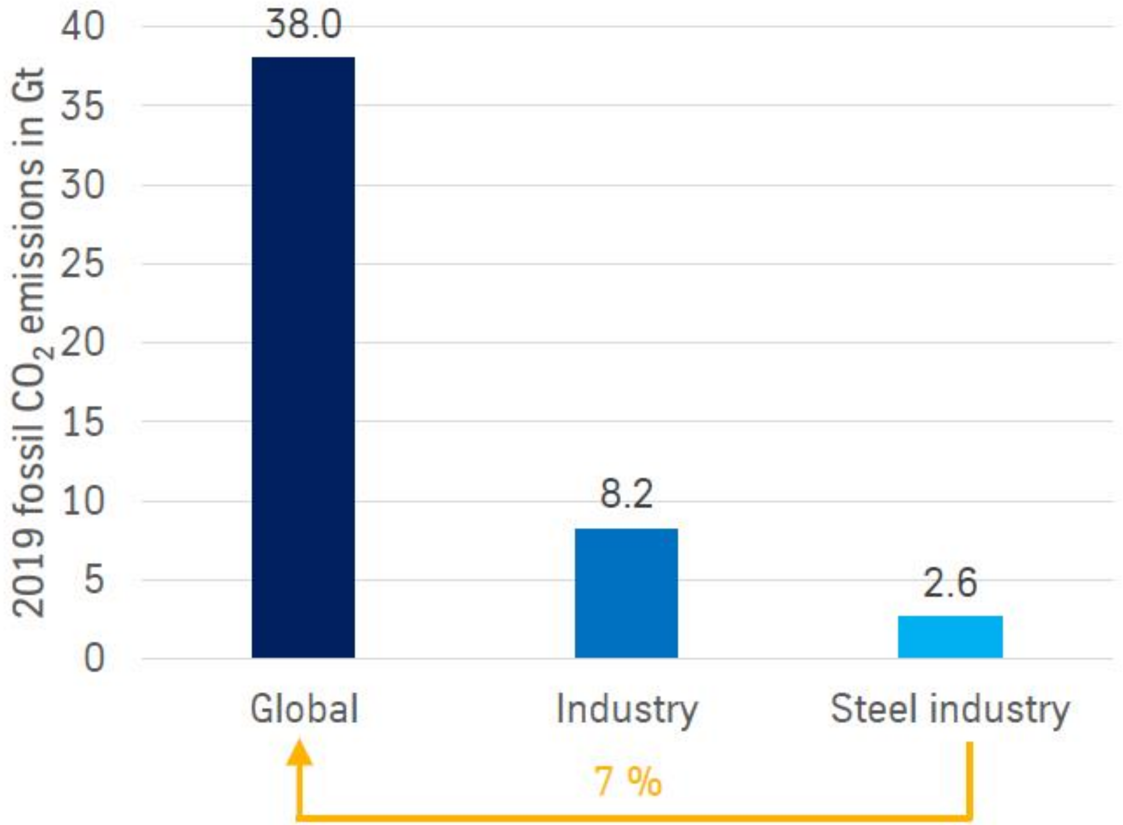
Statement by Thyssenkrupp

Dr. Markus Schöffel,
Manager Hydrogen
Transformation

On the importance of the European Hydrogen Backbone for the decarbonization of the steel industry

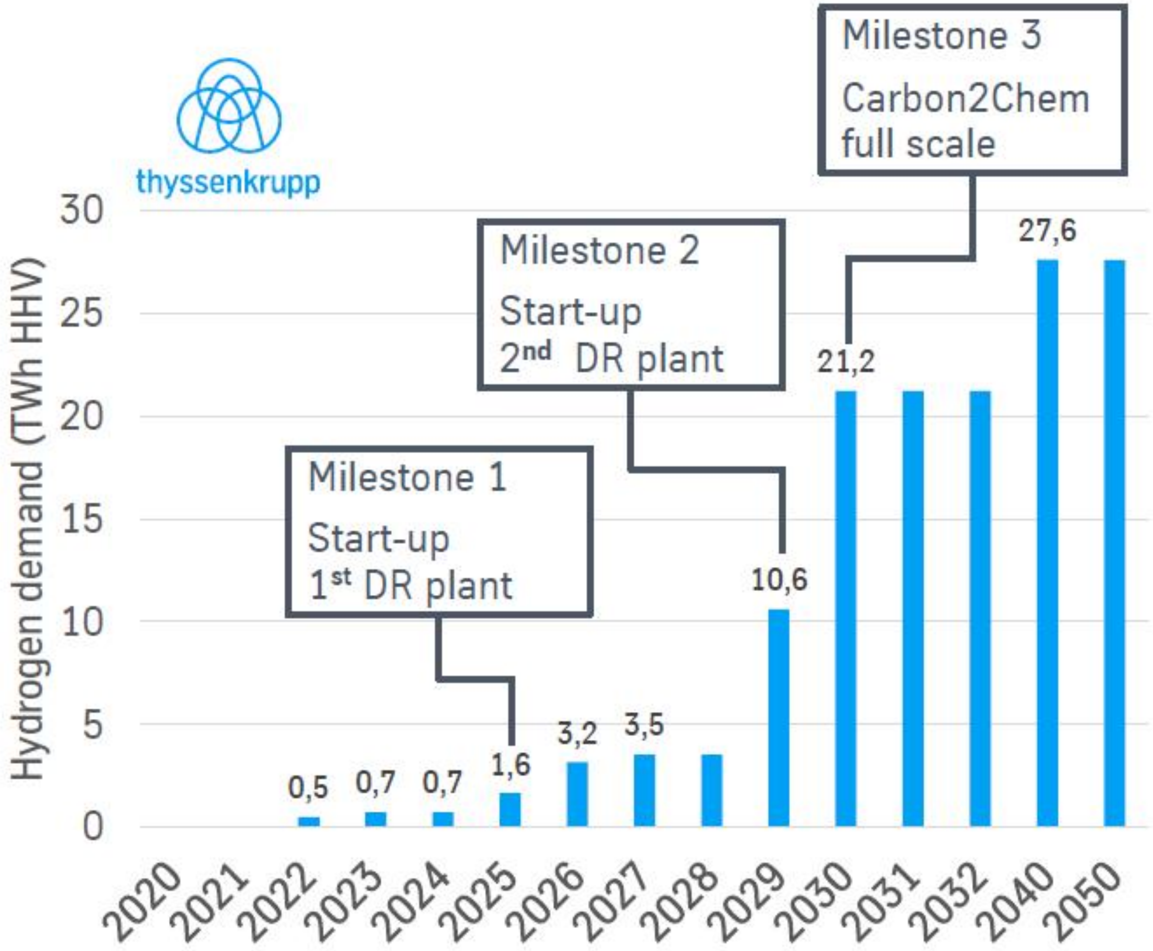
June 15th, 2021 | Dr. Markus Schöffel, Manager Hydrogen Transformation | Center for Decarbonization | thyssenkrupp Steel Europe AG

The steel industry offers the potential to fulfill the Paris agreement



Sources:
https://edgar.jrc.ec.europa.eu/climate_change
https://www.iea.org/data-and-statistics/charts/direct-co2-emissions-in-the-iron-and-steel-sector-by-scenario-2019-2050

tk SE's transformation to climate neutrality requires significant amounts of hydrogen



Notice: For comparison, LHV is 85 % of HHV.

The European Hydrogen Backbone provides connection between supply and demand

Eemshaven (NL)

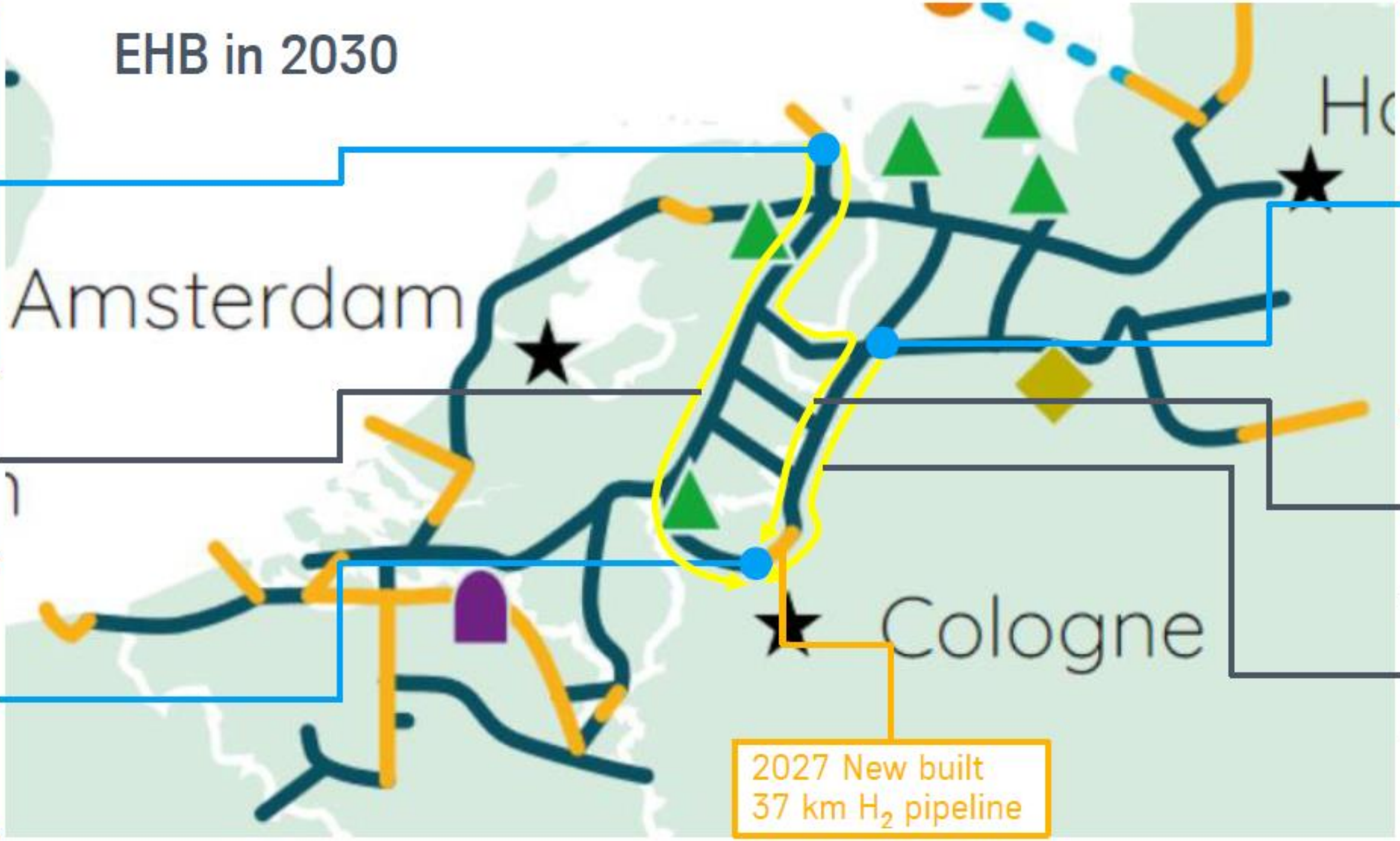
H2morrow steel

2.7 GW blue H_2 production

2030 Connection Eemshaven-Duisburg via Elten/Zevenaar

Duisburg (DE)

thyssenkrupp



Lingen (DE)

GETH2 Nukleus

Initial 100 MW green H_2 production, scale up to 2 GW possible

2027 Connection Eemshaven-Duisburg via Vlieghuis

2022 Connection Lingen-Ruhr area, 2027 to Duisburg

2027 New built 37 km H_2 pipeline

Source: https://gasforclimate2050.eu/sdm_downloads/extending-the-european-hydrogen-backbone/

03b

European hydrogen supply

Kees van der Leun
Guidehouse

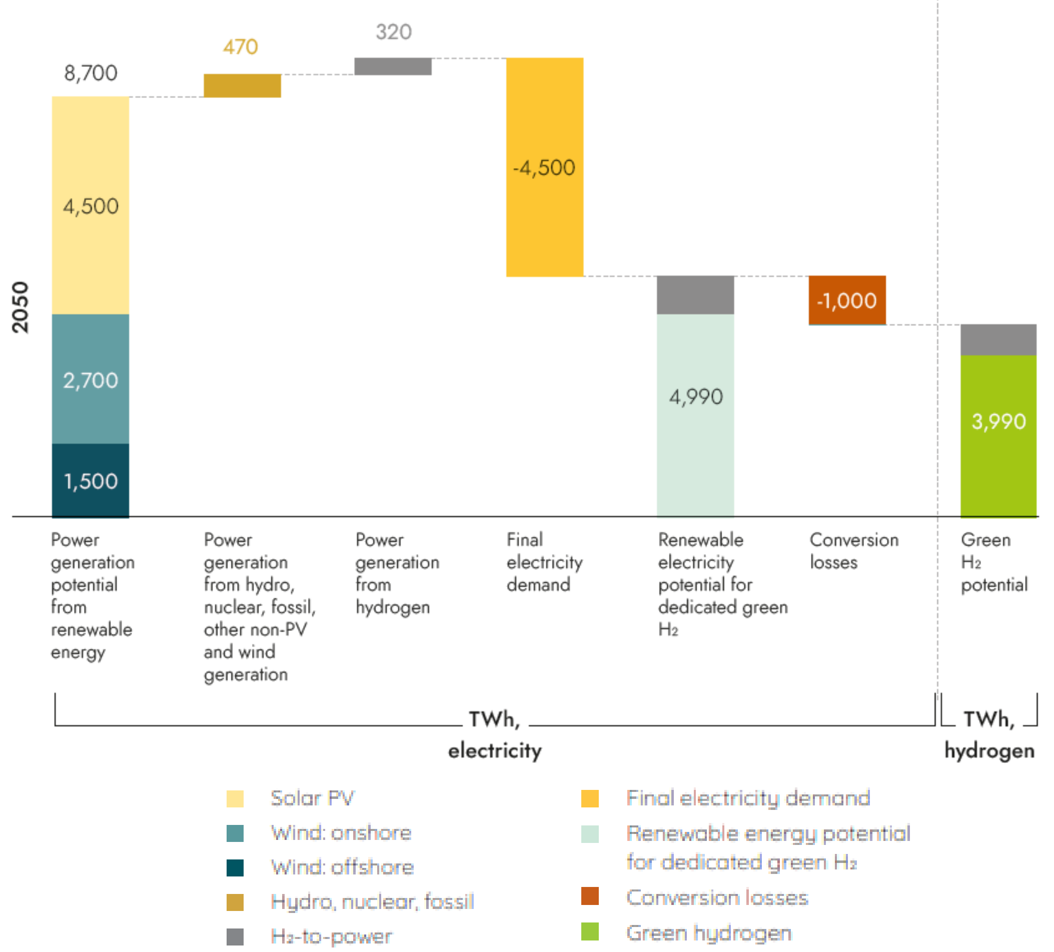
Domestically produced green hydrogen is sufficient to meet European demand, plus additional large potential for blue hydrogen

EU and UK **green hydrogen supply potential** from dedicated renewables is estimated to be 450 TWh in 2030, 2,100 TWh in 2040 and 4,000 TWh in 2050

- Taking into account growing demand for direct electricity, land availability, environmental regulations, and installation rates
- Total realistic land availability for renewables by 2050 adds up about 1.1% of total EU+UK land mass
- Rapid, vast expansion of wind & solar capacity, beyond what is needed for direct electricity, is required to reach green hydrogen supply potentials
- Achieving the supply potentials is subject to public acceptance of renewables

Europe can also produce large quantities of **blue hydrogen:**

- Enabling quick start to the use of hydrogen to drive emission reductions and accelerate the pace of the transition
- Supply is virtually **unlimited:** natural gas supply and CO_2 storage potential far exceed forecasted hydrogen demand



Source: Guidehouse analysis based on data from EC-JRC's ENSPRESO database and Wind Europe

Vast potential for competitively priced green hydrogen in EU & UK

By 2040 and 2050 **green hydrogen supply** in Europe:

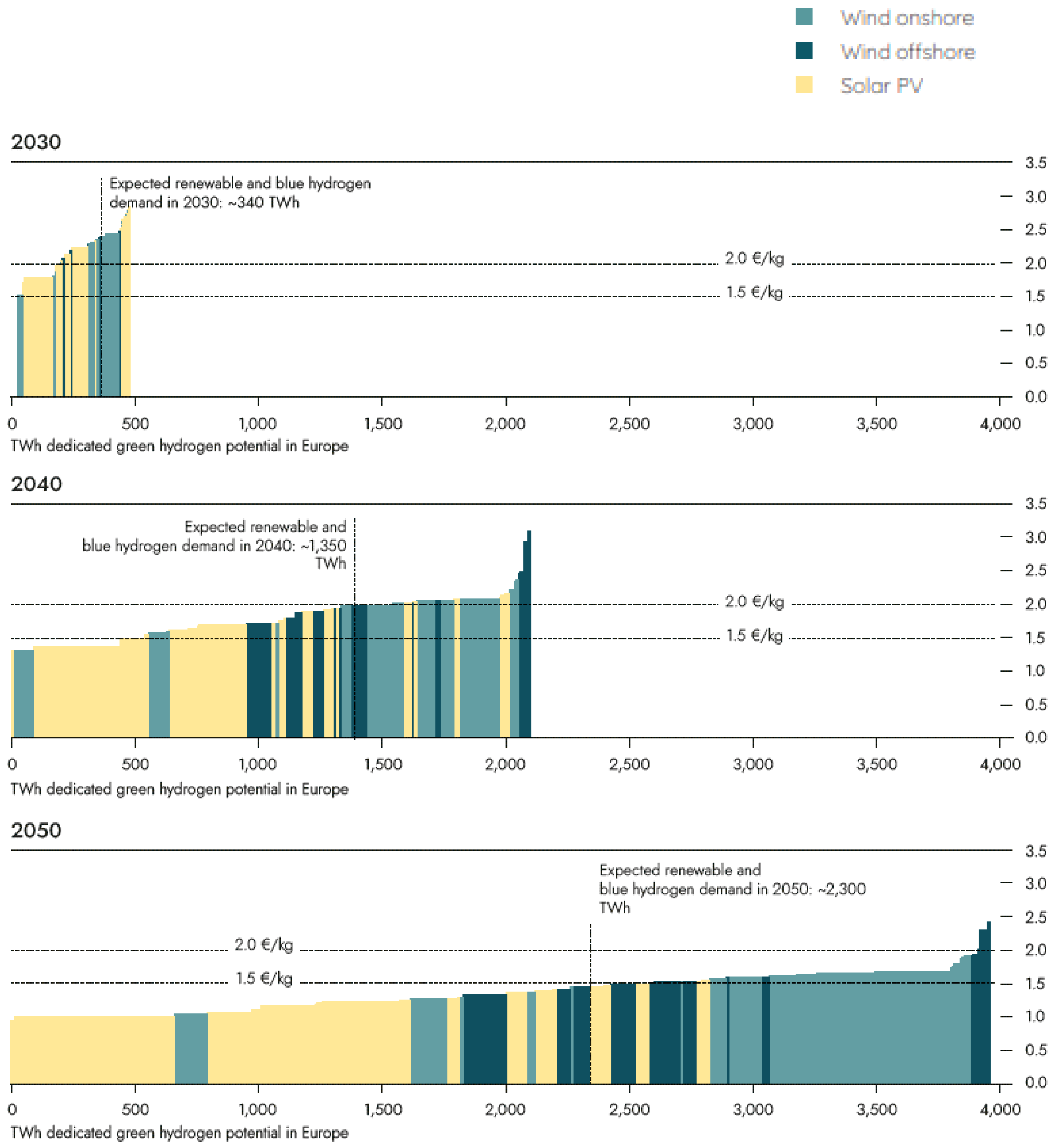
- Sufficient to meet projected European hydrogen demand in all sectors
- Cost competitive with grey hydrogen and other fossil alternatives

2050 green hydrogen **costs:**

- All 4,000 TWh potential green hydrogen: <2.0 €/kg
- Up to 2,400 TWh: <1.5 €/kg
- 500 TWh: <1.0 €/kg

This means that with growing CO_2-prices there's an emerging prospect for green and blue hydrogen production without the need for subsidies.

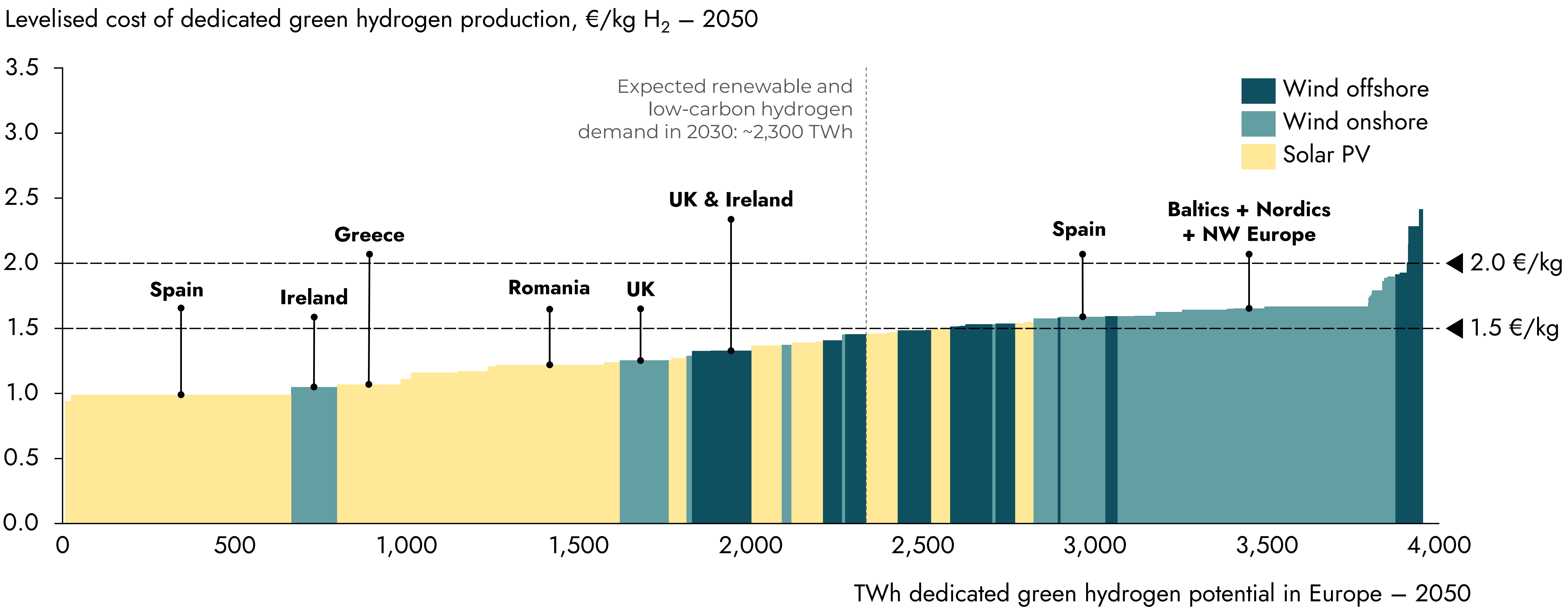
Supplying projected 2050 hydrogen demand of 2,150-2,750 TWh requires ~2,900-3,800 TWh of dedicated renewable electricity



Source: Guidehouse analysis based on data from EC-JRC's ENSPRESO, BNEF, TYNDP, and Wind Europe

Supply analysis – Green hydrogen production within EU+UK

Zooming in on the 2050 green hydrogen supply potential

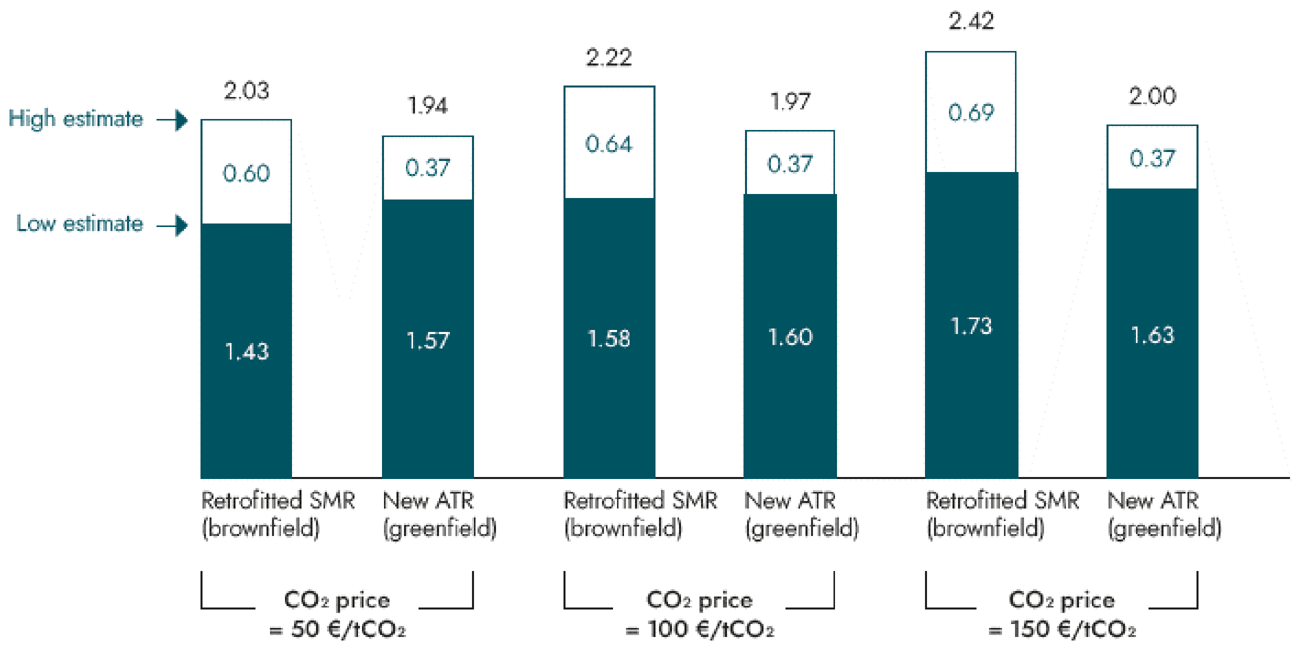


Source: Guidehouse analysis based on data from EC-JRC's ENSPRESO database, TYNDP, and Wind Europe

Blue hydrogen can accelerate emission reductions and can be scaled up quickly

- Europe also has a large potential to produce blue hydrogen
  - Supply is virtually unlimited as natural gas supply and CO2 storage potential exceed the total foreseen hydrogen demand
- Blue hydrogen can drive quick emission reductions
  - This holds especially in the market's ramp-up phase (2030) in the absence of the mature fully interconnected EHB
- Blue hydrogen production costs are expected to be 1.4-2.0 €/kg at a CO_2-price of 50 €/tCO_2 in 2030
  - Beyond 2030, deployment of new blue hydrogen projects will face increasing competition from more widely available green hydrogen at lower costs
- Projects announced to date add up to 230 TWh by 2030 and 380 TWh by 2035 and onwards
  - 70% of these volumes stem from the UK and the Netherlands

Blue hydrogen production cost (2030), in €/kg H_2

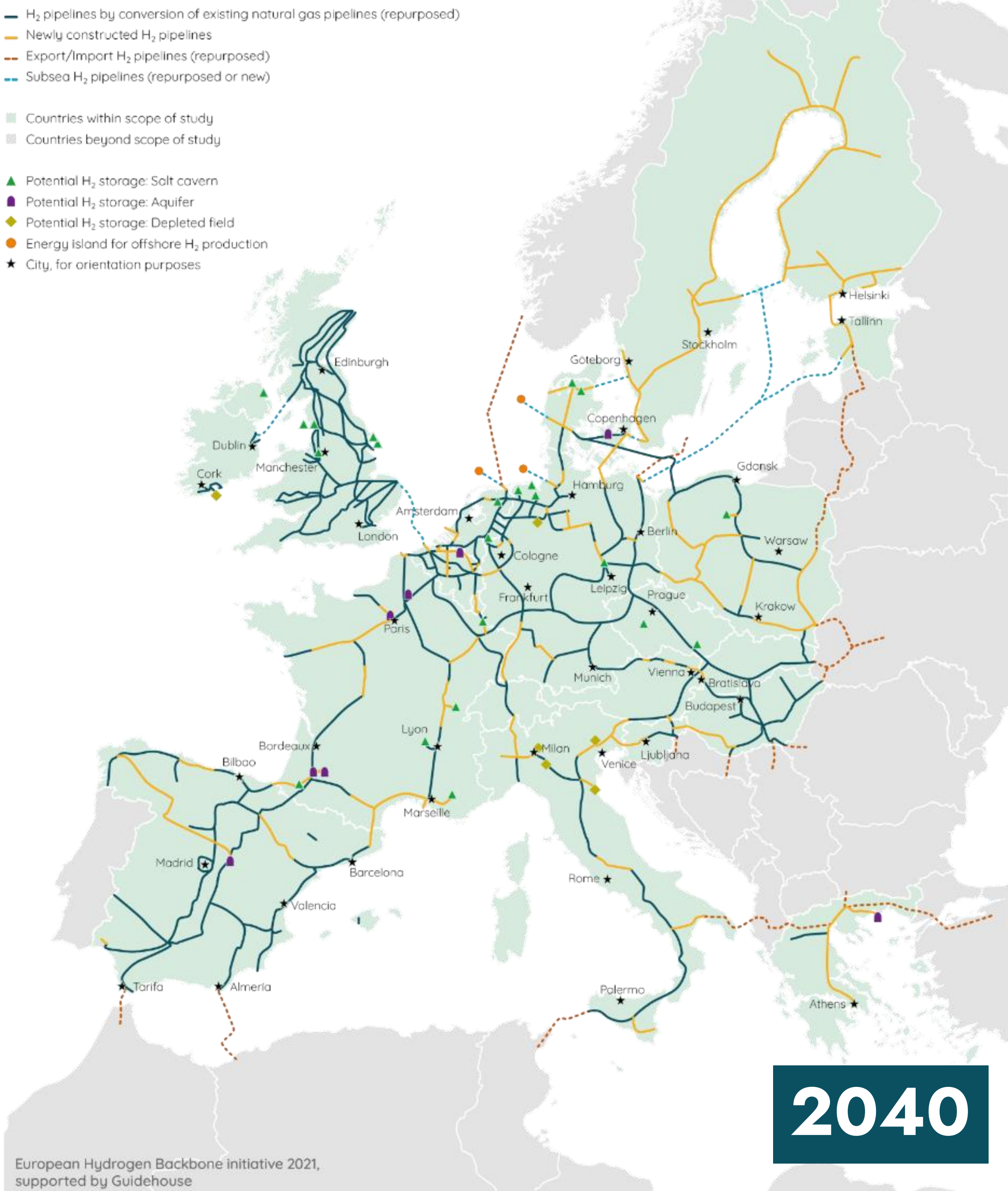


Natural gas feedstock prices are assumed to be 20 €/MWh across all cases.[165]

Source: Guidehouse analysis based on data from H-Vision project in Rotterdam

Hydrogen imports from neighbouring countries can complement domestic EU+UK production

- In addition to domestic EU+UK supply**, favourable economics of pipeline transport** allow cost-competitive imports from neighbouring regions
  - Abundant natural resources and physical proximity drive favourable economics of these imports
- Major potential green hydrogen **supply regions** outside of EU+UK such as North Africa and Ukraine.
  - This can be at a competitive cost, e.g. solar green hydrogen from Morocco, Algeria, and Tunisia could reach the EHB at a cost of around 1 €/kgH_2 by 2050.
- Blue hydrogen from **natural gas producing countries** (e.g. Norway, Russia) are also an option
- It should be ensured that both domestic and imported hydrogen is produced sustainably with high greenhouse gas saving.



03b

European hydrogen supply

Statement by ITM Power

Dr. Graham Cooley, CEO

ITM POWER
Energy Storage | Clean Fuel

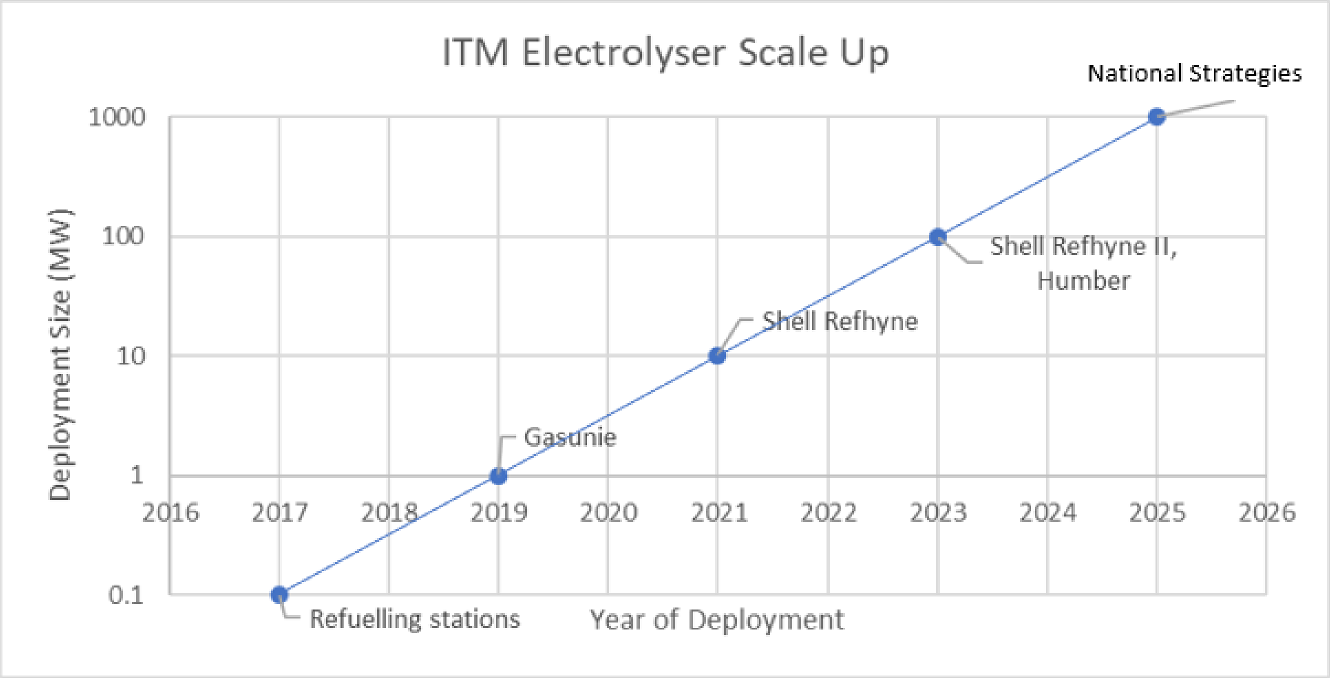
ITM Power | European Hydrogen Backbone

15th June 2021

Dr Graham Cooley, CEO

Delivering to emerging GW demand

- Project scale is growing rapidly
- Project scale increases 10x every two years
- Fully automating core elements of product
- Planning production capacity will be critical



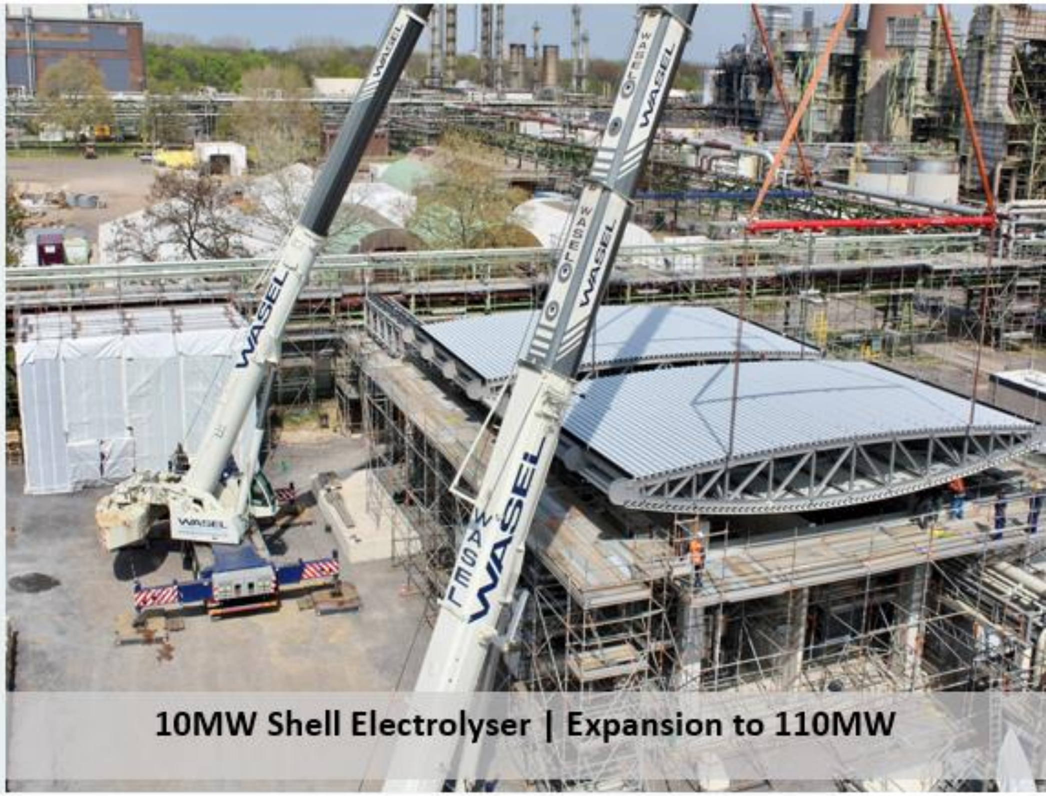
International Energy Agency

"Global electrolyser capacity of 3,585GW needed by 2050 to achieve net-zero" | ~130GW pa

ITM POWER
Energy Storage | Clean Fuel

Achieving a GW Scale European Electrolyser Market:

- EU has first mover advantage in terms of strategy
- Incentives need to be realized and defrayed
- Execution is now vital
- Policy stability will encourage long term investment



10MW Shell Electrolyser | Expansion to 110MW

iea
International Energy Agency

"Global electrolyser capacity of 3,585GW needed by 2050 to achieve net-zero" | ~130GW pa

03c

Underground storage of hydrogen, by GIE

Dr. Axel Wietfeld, GSE President
Francisco P. de la Flor, GIE Board Member

Gas Infrastructure Europe

Picturing the value of underground gas storage to the European hydrogen system

Gas Infrastructure Europe

Dr Axel Wietfeld
GSE President

Francisco de la Flor
GIE System Operations & Development Area Sponsor

About this study

What will be the role of underground storage in the future hydrogen and energy system?

About Gas Infrastructure Europe (GIE)

- EU association of gas infrastructure operators active in **storage** (GSE), **transmission** (GTE) & **regasification** (GLE)
- Supporting the development of the hydrogen economy with the **existing gas infrastructure** and the development of **innovative projects**

Why this study?

- Discussion starter on the **role of underground storage** in future hydrogen and energy system
- **Connected** to the envisioned developments in the **European Hydrogen Backbone**
- First-order **estimation of the storage needs**
- Summaries of **hydrogen storage suitability** for all the 4 main storage types

The role of underground storage

Ultimate objective

Design and operate an energy system (electrons and molecules) that meets net-zero GHG emissions by 2050, at the lowest cost to society and with a high degree of security

Large scale, underground hydrogen storage is indispensable to the European hydrogen market and will become a key part of the decarbonised energy system

System value

Enables **efficient planning and use of infrastructure** (electricity, hydrogen)

Adds **flexibility** to the system, reduces needs to overbuild production, transmission capacities vis-à-vis expected demand

Market value

Lowers the final cost of hydrogen for end users as storage reduces price on both short-term (hourly, daily volatility) and seasonal time scales

Insurance value

Provides **backup for extreme events,** e.g., infrastructure failure, extreme weather or demand, etc.

Gas Infrastructure Europe

Early market stage – up to 2030

Up to 2030, most demand will likely be concentrated around hydrogen valleys managing their supply mostly locally. Underground storage will be an integral part of these valleys, helping to improve their economics

Supply, demand and storage

- The **hydrogen supply** profile will be both variable (green H_2) and flat (blue H_2)
- The **hydrogen demand** profile will be mostly flat (e.g. industrial feedstock, synthetic fuels for transport)
- This will result in a **flexibility need** to match these profiles
- Underground hydrogen storage can provide the needed flexibility by **storing over-supply** and **withdrawing at times of under-supply**

Developments up to 2030

- **At first** - **Hydrogen valleys** will pop-up in areas with aggregated demand
- **Some storage sites** will be repurposed, possibly new ones developed, **improving the economics of the hydrogen valleys**
- **Later - the European Hydrogen Backbone** will begin to interconnect the first valleys creating **hydrogen regions**, both intra-country and cross-border

Later market stage – after 2030

After 2030, hydrogen supply and demand will grow and hydrogen hubs will evolve into an interconnected hydrogen network, as shown by the European Hydrogen Backbone initiative

Supply, demand and storage

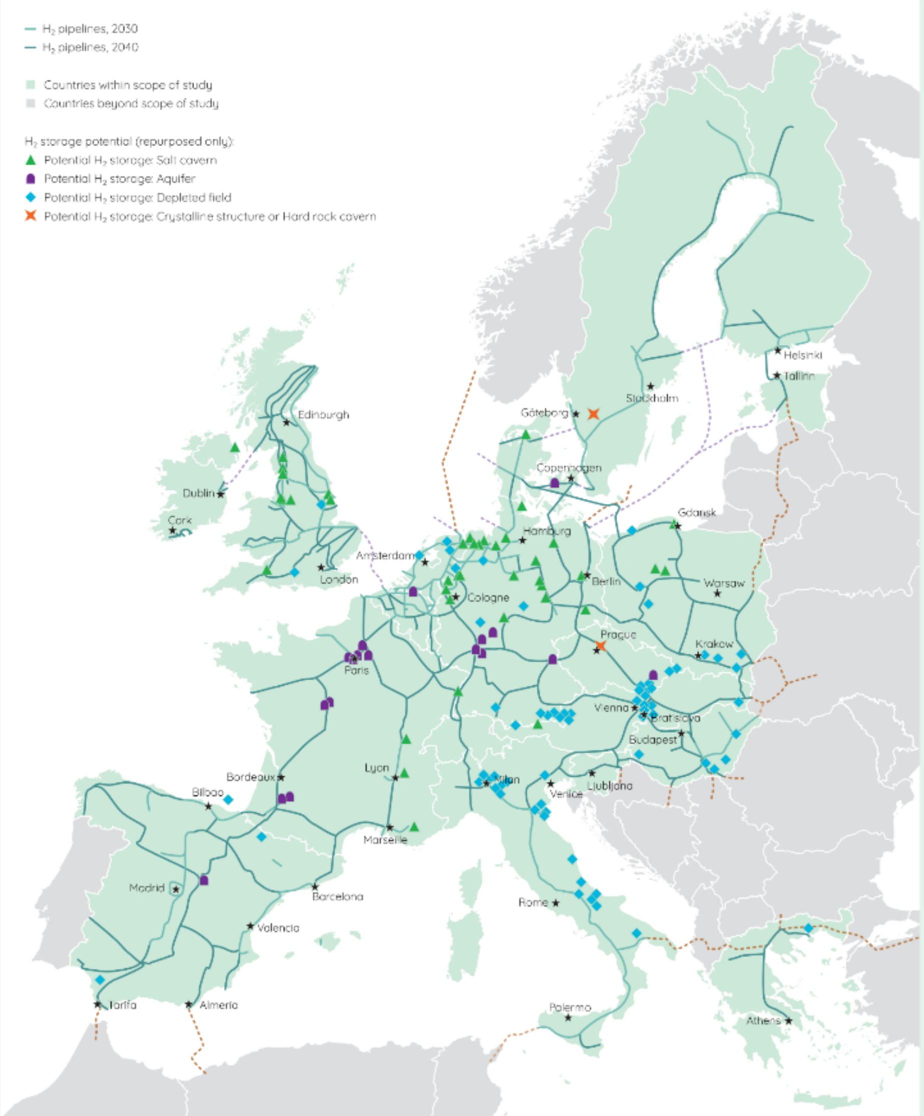
- Hydrogen could expand its use to the **power** sector to support advancing **integration of RES-E**, to meet **demand peaks** created by residual load
- Hydrogen could also be used in **heating directly** (hybrid heat pumps), or **indirectly** (district heating)
- This will **alter the demand profile for hydrogen**, peaking requires flexibility, heating large volumes (seasonal storage)

Developments after 2030

- **More** underground **storages** will be **repurposed** as well as **new ones** developed
- Hydrogen **regions** will be **interconnected into a pan-European hydrogen infrastructure** that will allow to use storages further away from hydrogen supply and demand

The European Hydrogen Backbone and underground hydrogen storage analysis for 2030–2050 (repurposing potential)

Gas Infrastructure Europe



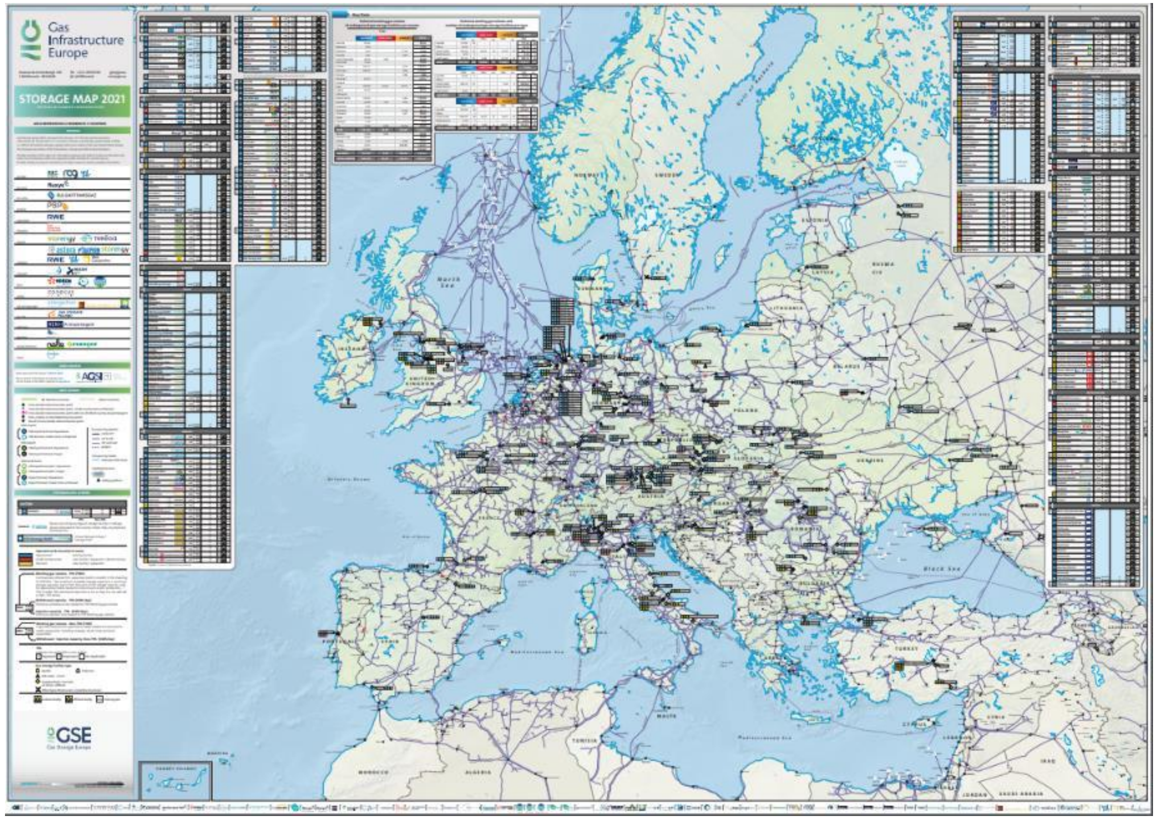
European Hydrogen Backbone initiative and Gas Infrastructure Europe 2021, supported by Guidehouse

Transparency tools

GIE has successfully developed storage-related transparency initiatives such as the storage transparency platform AGSI+ and will release an updated 2021 storage map (printed and interactive versions) in the coming weeks.

AGSI+

Storage Transparency Platform



Gas Infrastructure Europe

Next steps

Our first estimates show a H_2 storage capacity need of:
70 TWh H_2 by 2030
450 TWh H_2 by 2050

Repurposing takes between **1-7 years.**

Development of **new** sites between **3-10 years.**

We need to get started now

System storage operators have **assets suitable** for the hydrogen market.

Many of them have already **started to investigate** the feasibility of their assets to be **repurposed.**

SSOs will have a key role

A **clear business case** and **regulatory environment** is required to allow for repurposing and development of new underground hydrogen storages.

Business case and regulatory environment need to exist

Download the report here

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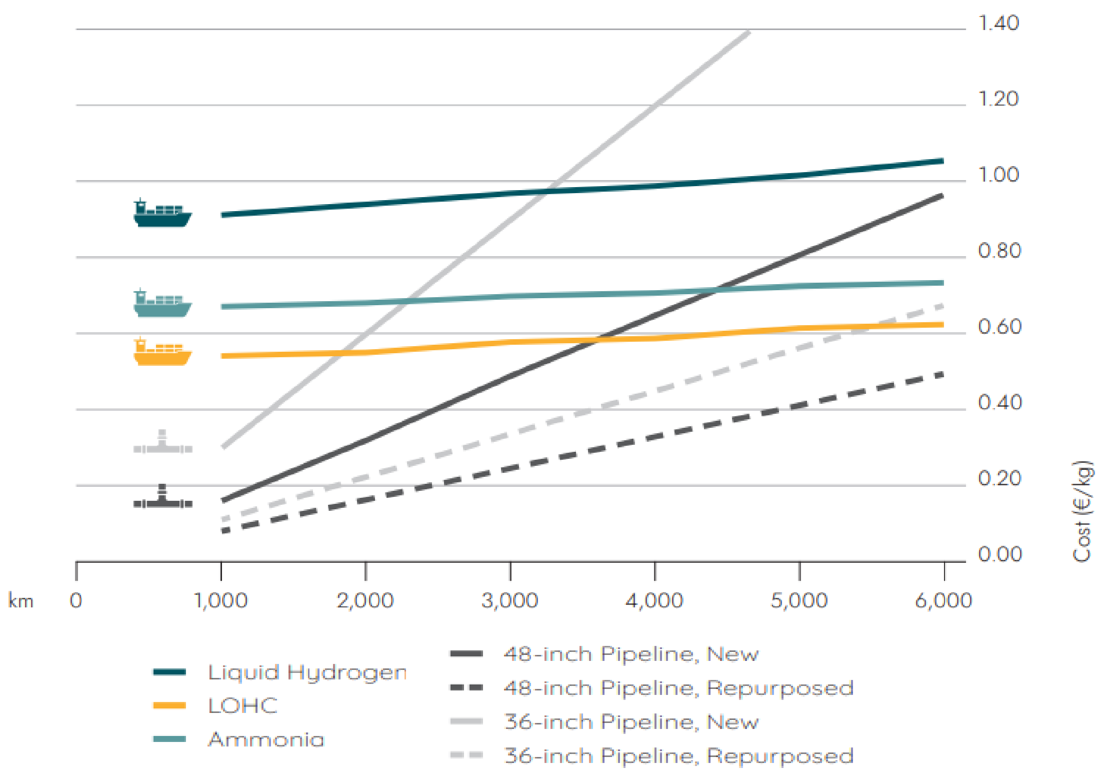
03d

Hydrogen transport, by pipeline and by ship

Anthony Wang
Guidehouse

Hydrogen pipelines are the most cost-efficient option for long-distance, high volume transport

Cost comparison of hydrogen transport options over various distances [€/kg]



Source: Guidehouse analysis with input from TSOs.

Key messages

1. **Pipeline transport, at 0.11-0.21 € per kg per 1,000 km[1]**, outcompetes shipping on a cost basis for all reasonable distances within Europe and neighbouring regions

2. Shipping transport methods have **high fixed costs**, related to conversion and reconversion installations and losses, and in some cases the carrier chemical costs
   - Ship transport is **3-5 times** more expensive compared to pipelines when considering imports from North Africa & Saudi Arabia (2,000-3,000 km)
   - Ship transport costs from Australia (16,000 km) are around 1.0 €/kg of H_2

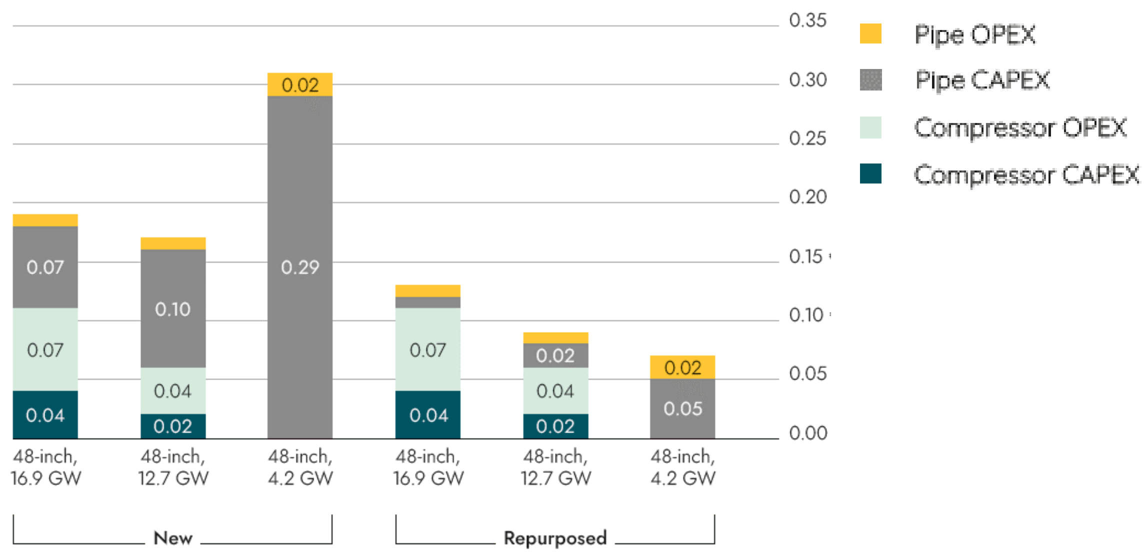
3. **Cost-efficient** hydrogen transport by pipeline gives neighbouring regions a strong advantage over imports from other continents

[1] Volume and length weighted average across the full EHB network

Pipeline and shipping transport options have very different cost structures

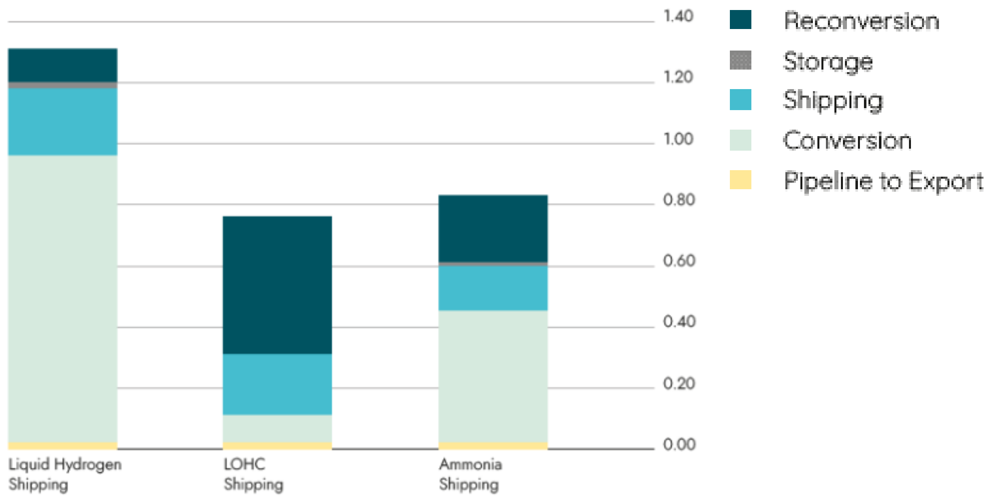
Pipelines: driven by pipeline and compression costs

Breakdown of levelised cost of new and repurposed pipelines at different operating capacities [€/kg/1,000km]



Shipping: driven by (re)conversion costs

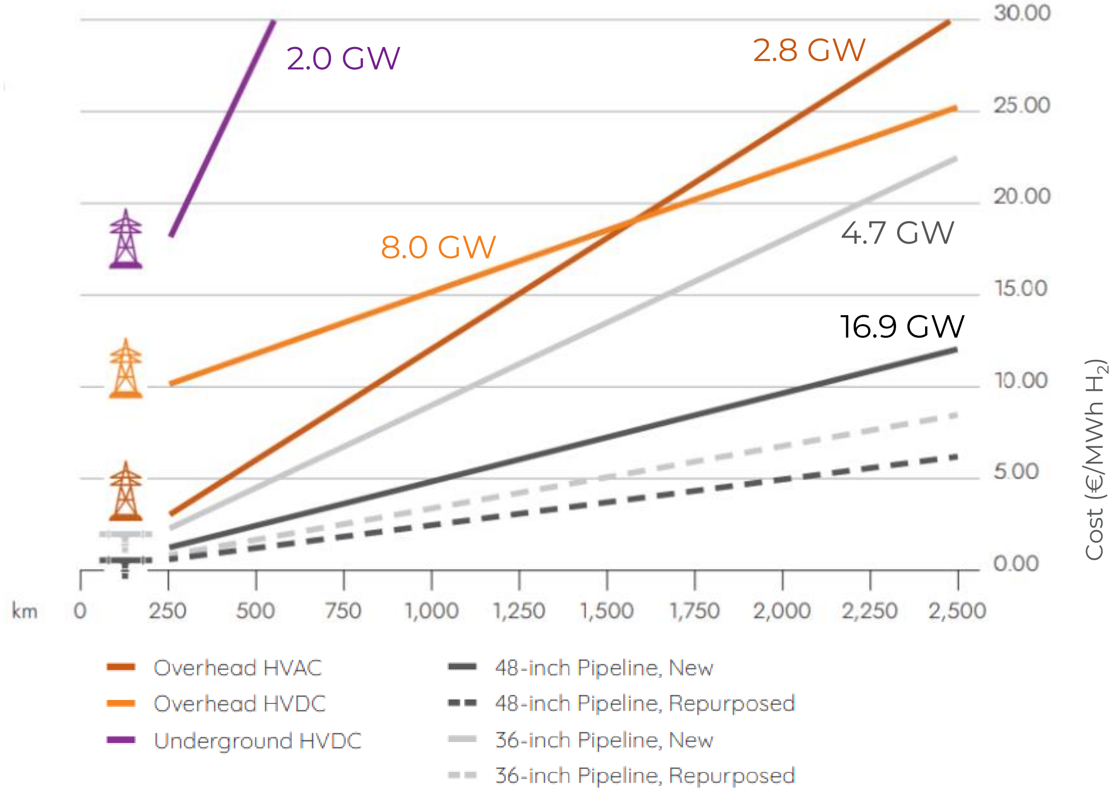
Breakdown of levelised cost of hydrogen transport by ship as liquid hydrogen, LOHC, and ammonia [€/kg/10,000km]



Source: Guidehouse analysis with input from TSOs.

Hydrogen infrastructure & electricity networks have complementary strengths in long-distance transport

Cost comparison of onshore hydrogen transport options over various distances [€/MWh H_2]



Source: Guidehouse analysis with input from TSOs.

Key messages

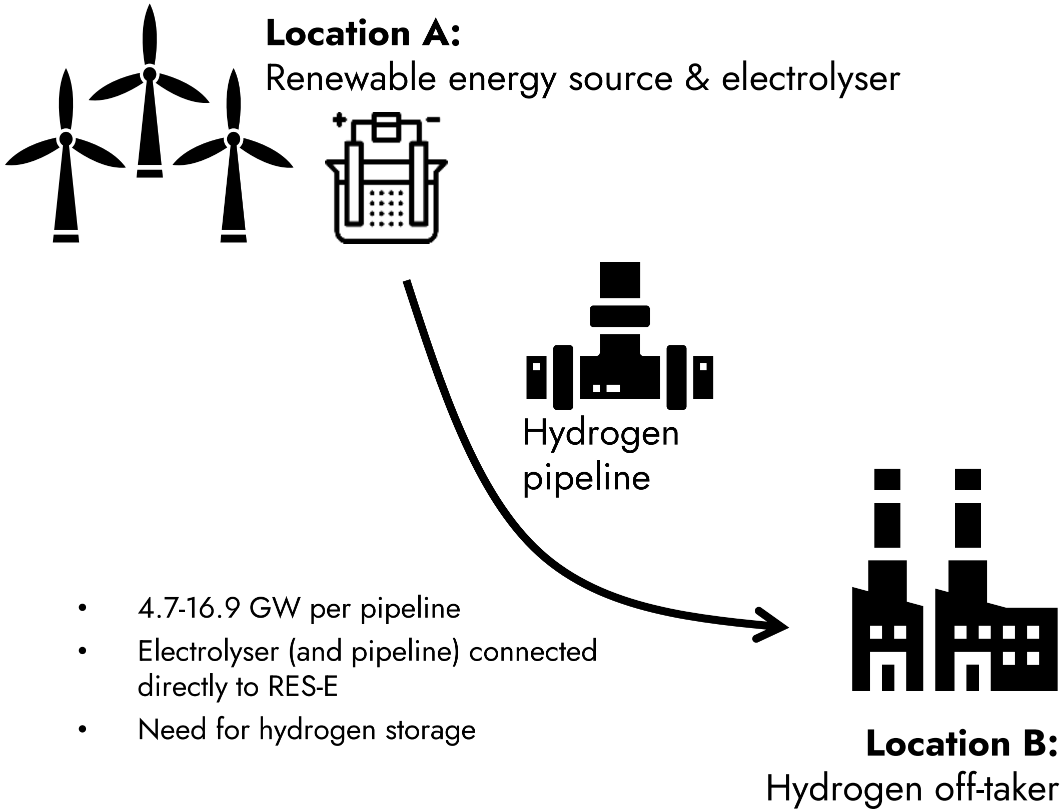
1. For high-volume transport of energy when the desired end product is hydrogen, underground **pipelines are up to 4 times** more cost-effective than overhead power lines per MWh of energy transported – both for newly built and repurposed pipelines, excluding storage costs
2. A **48-inch** underground hydrogen pipeline (size currently used for natural gas) can transport the same amount of energy as ~**7** overhead transmission lines
3. Cost estimates are sensitive to:
   1. Desired end-use energy carrier
   2. Renewable energy supply characteristics
   3. Availability and cost of storage

Consideration between gas and electricity transport is not only an economic question but also one of **societal acceptance**

Hydrogen transport

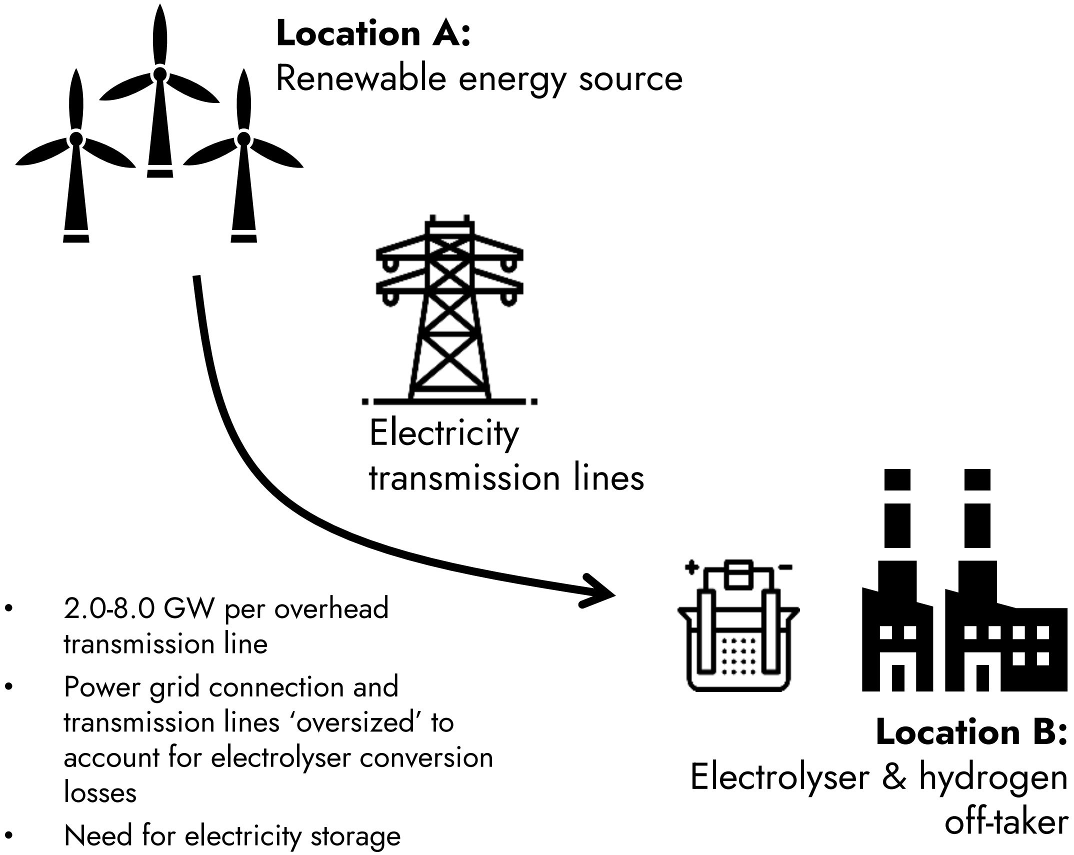
Considerations for onshore transport of hydrogen from dedicated renewable energy sources

Situation 1: Transport by pipeline



- 4.7-16.9 GW per pipeline
- Electrolyser (and pipeline) connected directly to RES-E
- Need for hydrogen storage

Situation 2: Transport by power line



- 2.0-8.0 GW per overhead transmission line
- Power grid connection and transmission lines ‘oversized’ to account for electrolyser conversion losses
- Need for electricity storage

Source: Guidehouse analysis with input from TSOs.

03d

Hydrogen transport

Statement by
North Sea Wind Power Hub
Michiel Müller, programme director

Vision NSWPH Consortium

- To reach climate neutrality in 2050, significant (300 GW) offshore wind capacity needs to be built
- We consider it our social responsibility to pro-actively facilitate affordable and secure connection and integration of this vast amount of energy
- This requires a series of hub-and-spoke projects, with the ambition to realise the first hub in the early 2030s

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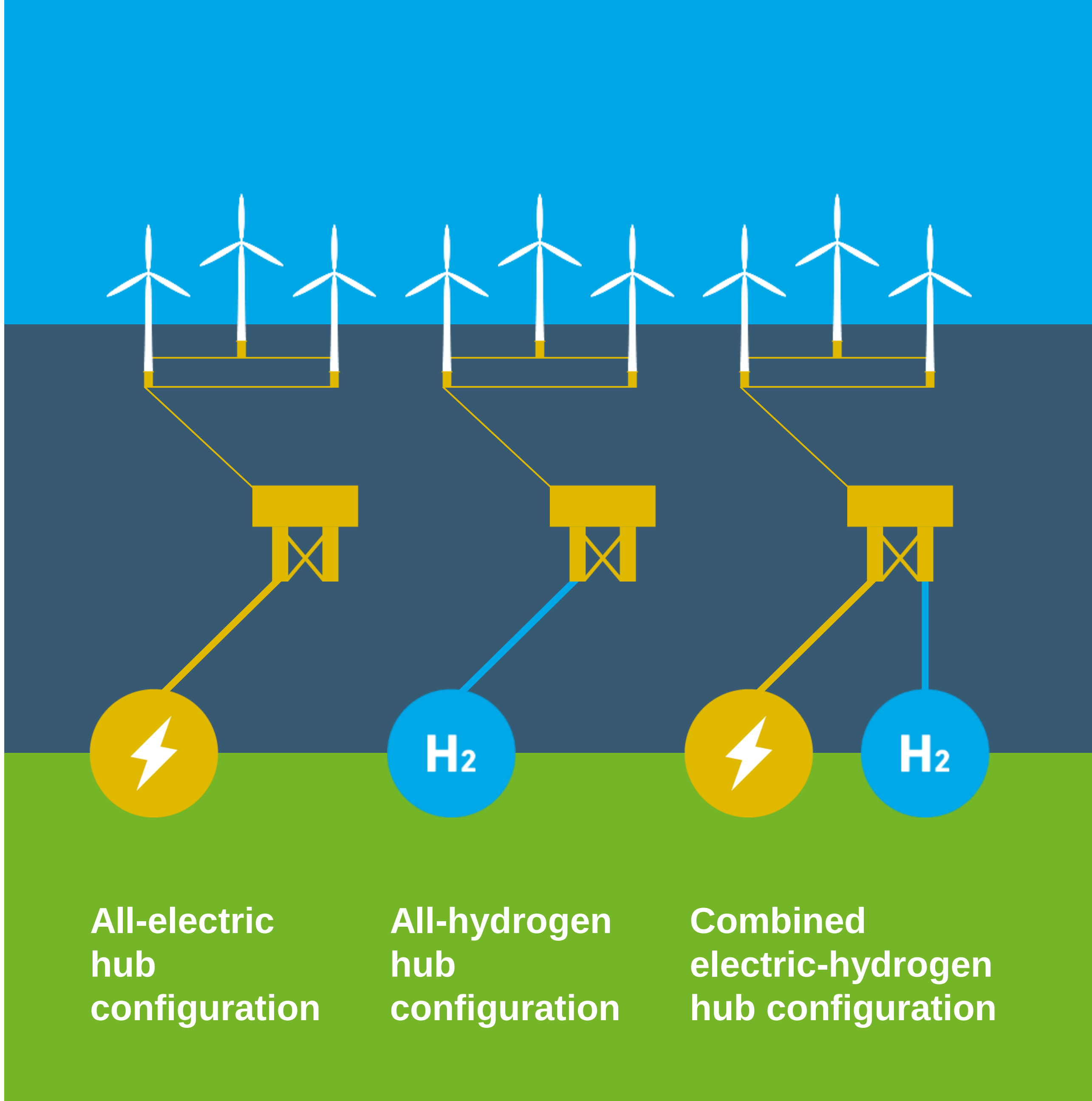
System Integration, insights

- The future power system requires large amounts of flexibility
- Hydrogen can play a vital role in cost efficiently integrating large volumes of offshore wind energy
- Further integration of energy sectors is a necessity and lowers total system costs
- Domestic green hydrogen production plays a key role in cost effective system integration



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Questions & Answers

For more information

Download the report here.

For more information contact the EHB member organisations or send an email to:
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