JM

Johnson Matthey
Inspiring science, enhancing life

How hydrogen can help us to achieve Net Zero?

13th April, 2021

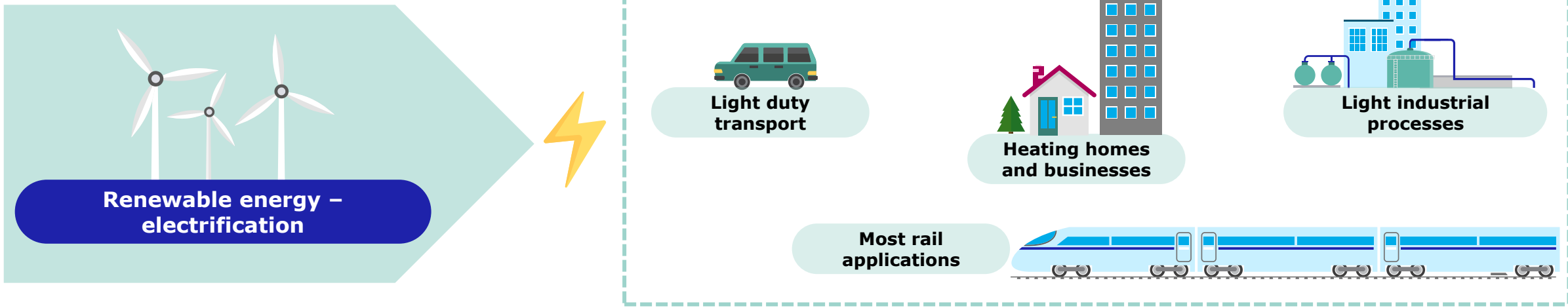
Sam French

The move to net zero is accelerating: “building back greener”

Source: Energy and Climate Intelligence Unit, December 2020.

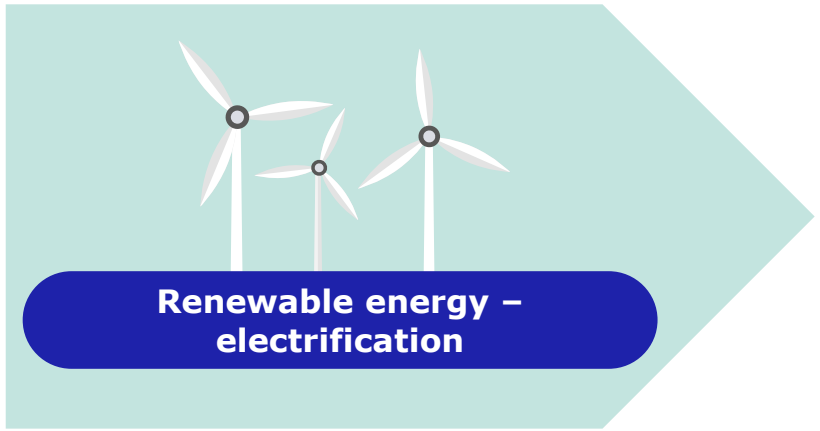
Clean electricity will play a critical role in decarbonisation

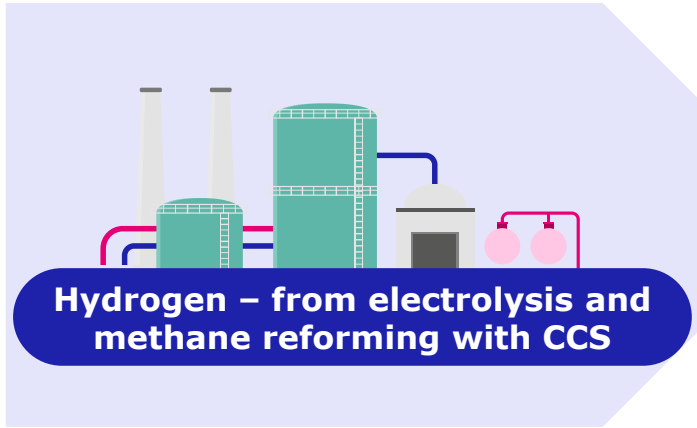
We should use renewables to electrify what makes sense – it's often the most energy efficient route



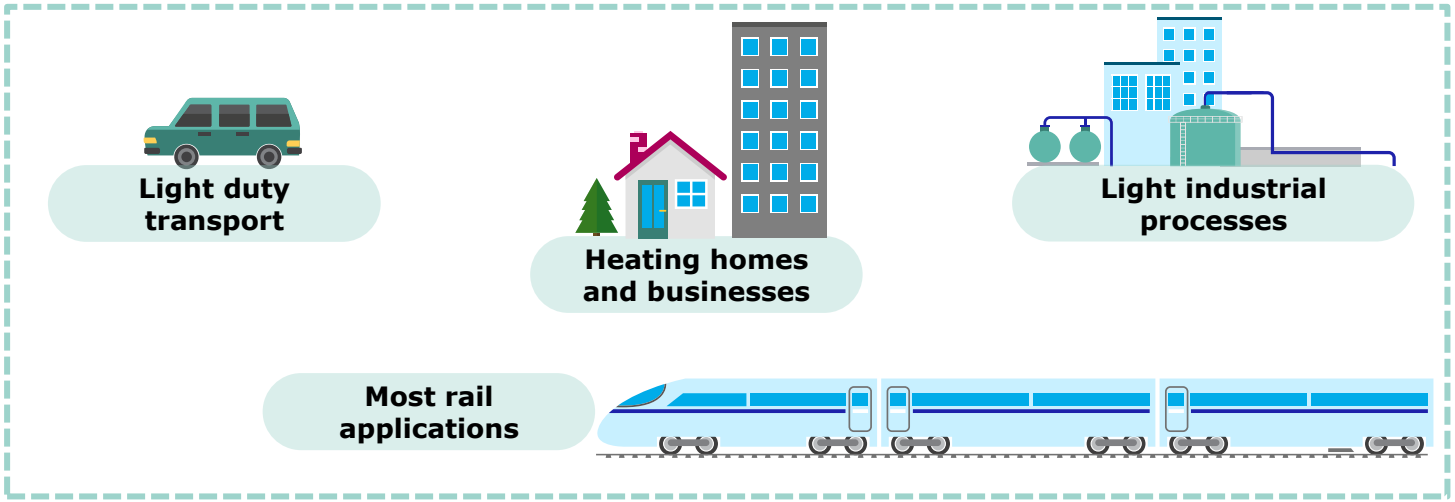
Clean hydrogen will play a critical role in decarbonisation

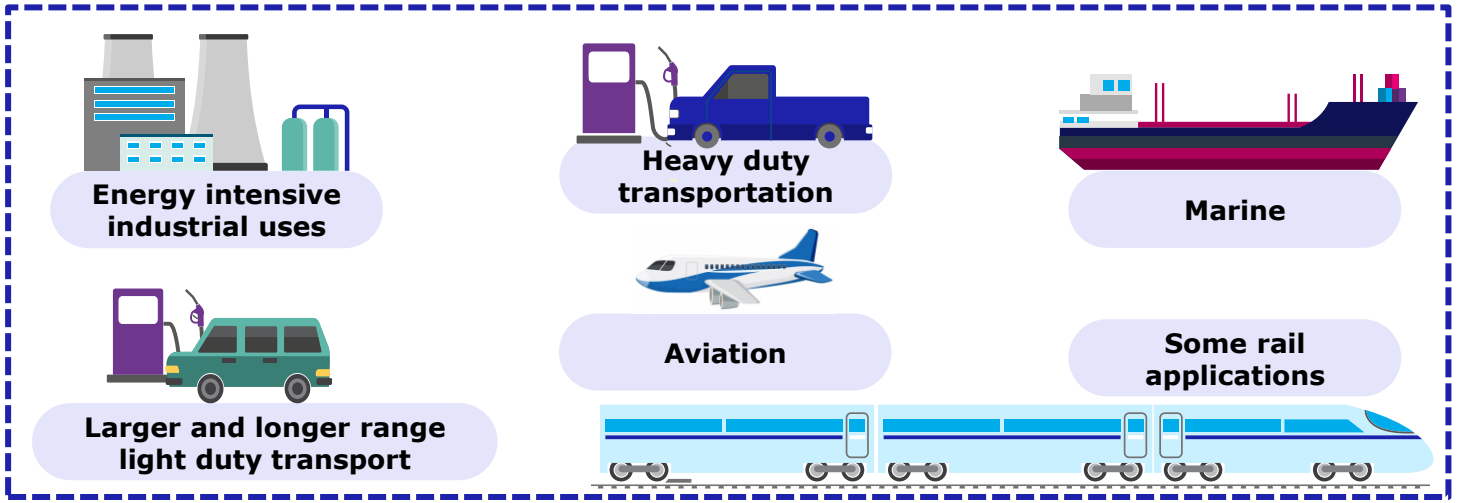
Particularly in hard-to-abate sectors. Hydrogen is transitioning from a chemical feedstock into an energy vector – storing and transporting renewable energy for a range of applications





H_2

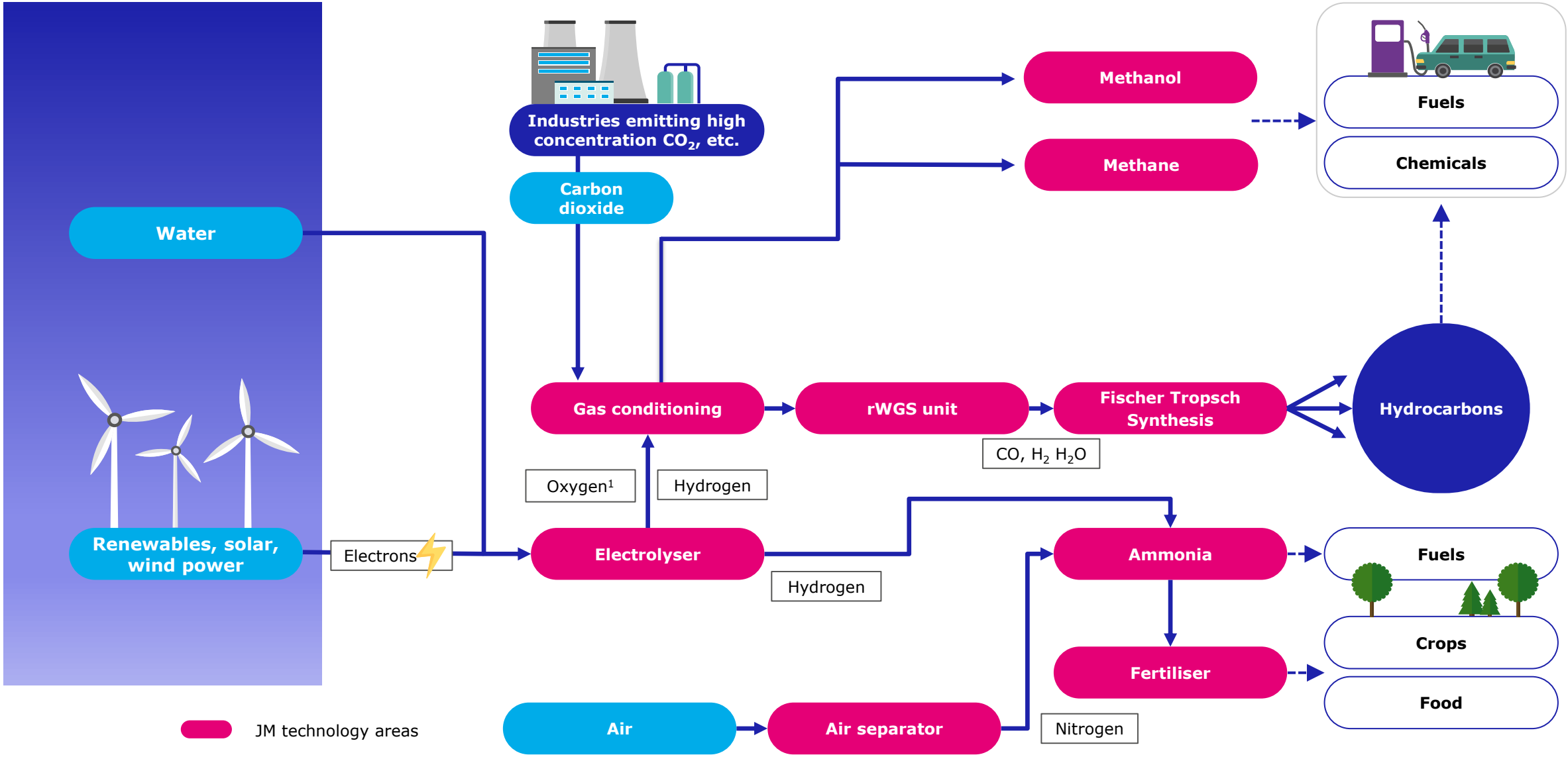




Note: CCS – carbon capture and storage.

Turning green hydrogen into chemical building blocks: a vision

Upgrading renewable feedstocks (eg biomass, CO_2) into the sustainable fuels & chemicals of the future



Note: rWGS – reverse water-gas shift reaction

1. Oxygen produced opens up new value streams for electrolyser operators as oxygen is another important chemical widely used by industry. This is not covered in this presentation.

JM has a strong presence across hydrogen production technologies

Brown	Grey	Blue	Green
	JM's technologies		
Coal	Natural gas	Natural gas	Renewable electricity
-	Leading catalyst supplier 40% segment share[1]	Differentiated technology and catalyst supplier	Expect to supply catalyst coated membrane
Gasification No CCS	Steam methane reforming No CCS	Advanced gas reforming CCS	Electrolysis
Highest GHG emissions (19 tCO_2/tH_2)	High GHG emissions (11 tCO_2/tH_2)	Low GHG emissions (0.2 tCO_2/tH_2)	Potential for zero GHG emissions
$1.2 to $2.1 per kg H_2	$1 – $2.1 per kg H_2	$1.5 – $2.9 per kg H_2	$3 – $7.5 per kg H_2

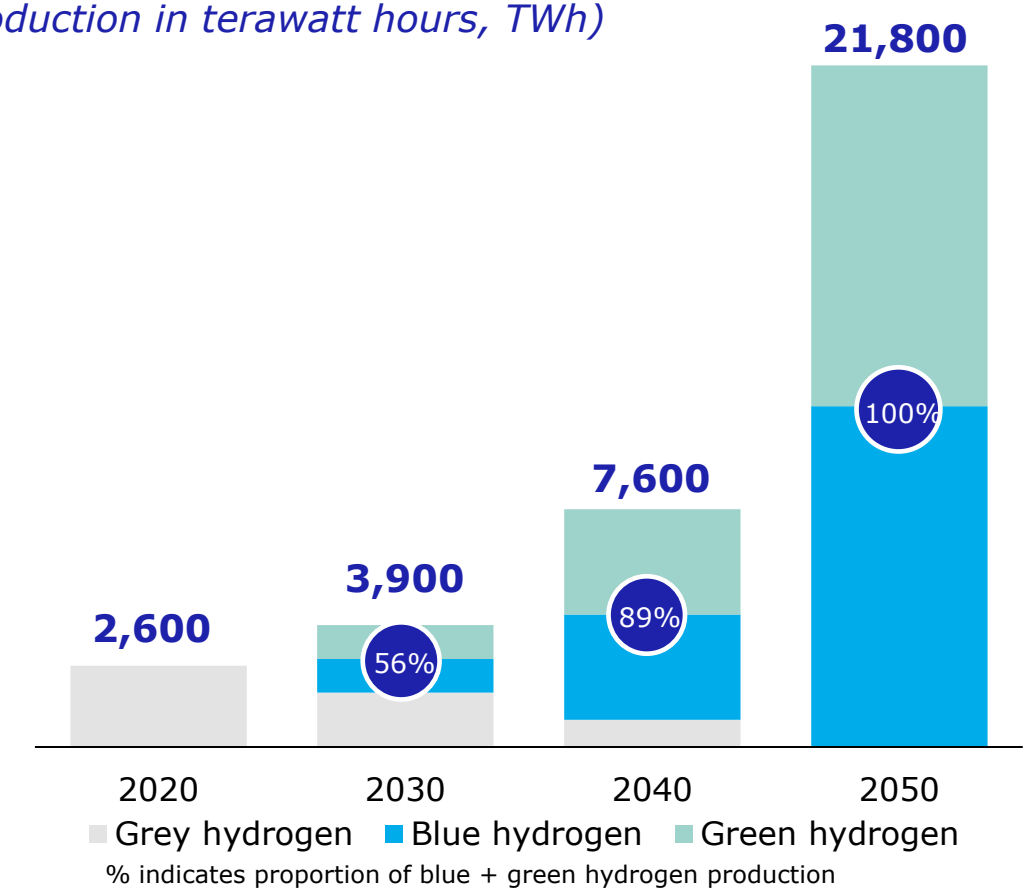
Note: GHG – greenhouse gas; CCS – carbon capture and storage; tCO_2/tH_2 – tonne of carbon dioxide per tonne of hydrogen.
Source: IEA, The Future of Hydrogen, Karuizawa, Japan, June 2019.
1. Based on Johnson Matthey data.

We are going to need a lot more H_2 in future – and it must be clean

Both Blue and Green H_2 will be used as enabling business models are introduced

Split of hydrogen production methods

(Production in terawatt hours, TWh)



Grey share declines with future carbon tax

Blue adoption driven by geology (carbon storage locations), infrastructure (pipelines) and high cost of alternative routes to low carbon hydrogen

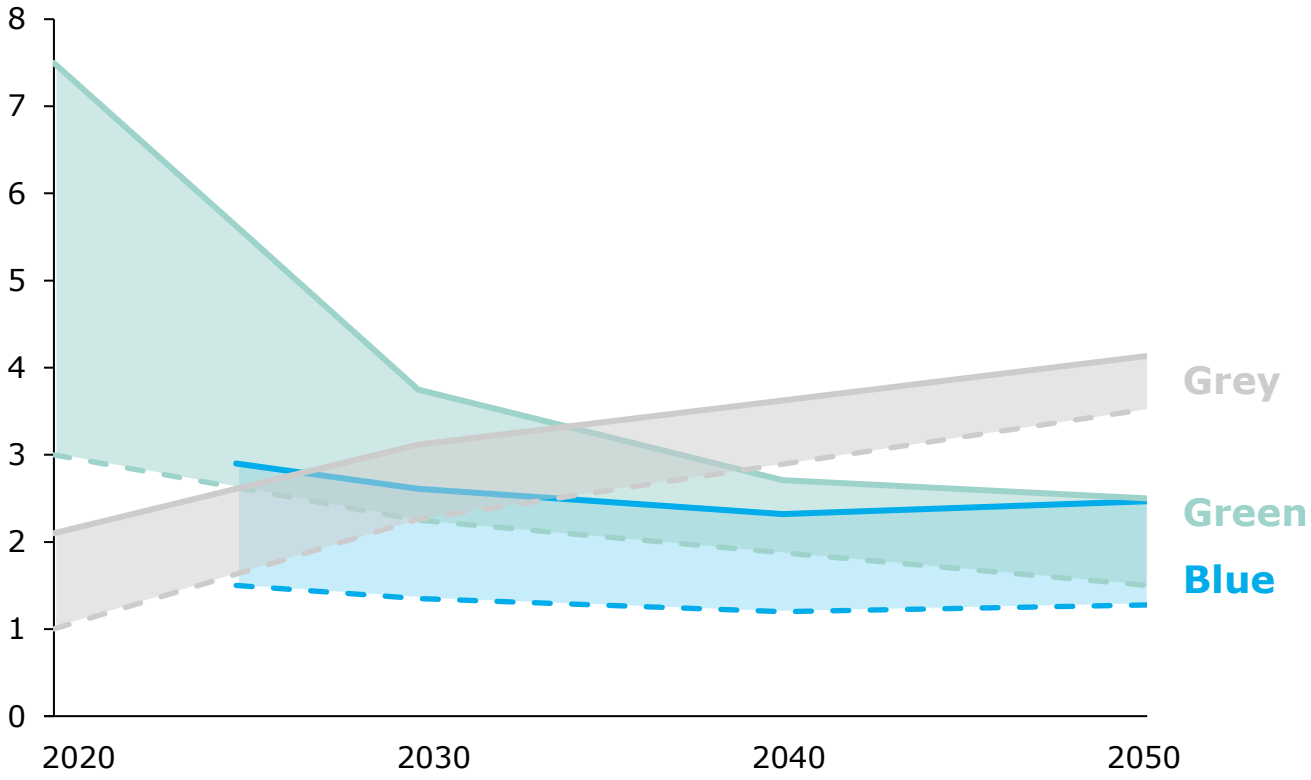
Green adoption driven by geography, declining cost of renewable energy and incentives

Sources: Hydrogen Council, "Hydrogen, Scaling up" report, 2017, (total hydrogen demand); Johnson Matthey, IEA, BP (split of hydrogen production methods).

JM

Green hydrogen becomes more competitive over the medium term

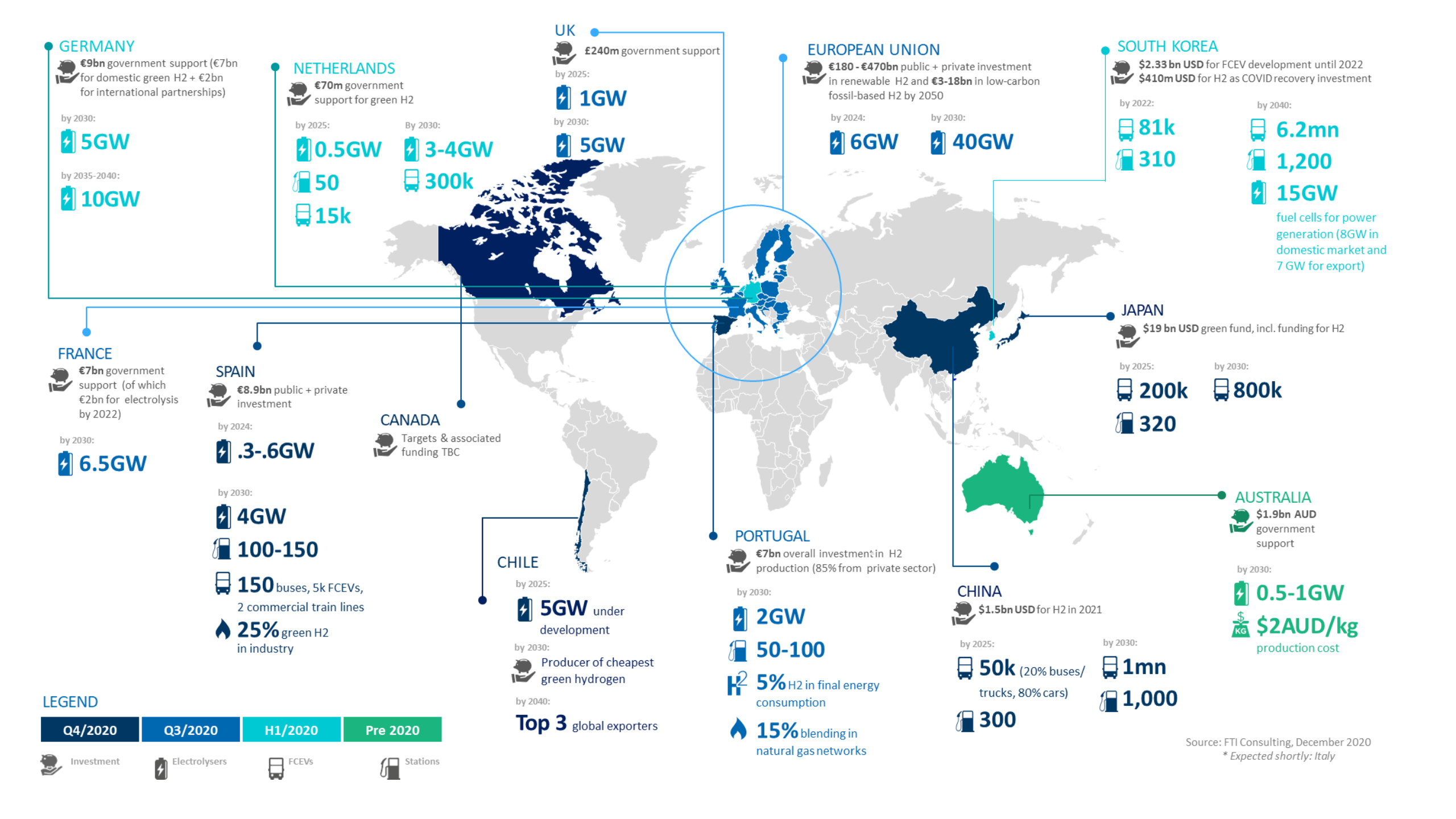
Estimated hydrogen cost
($ per kg H_2)



Blue hydrogen advantaged in certain regions and likely to be a long term solution in places with the right geology and infrastructure e.g. US and UK

Green hydrogen will be a solution in some regions as both renewable energy and capital costs decline

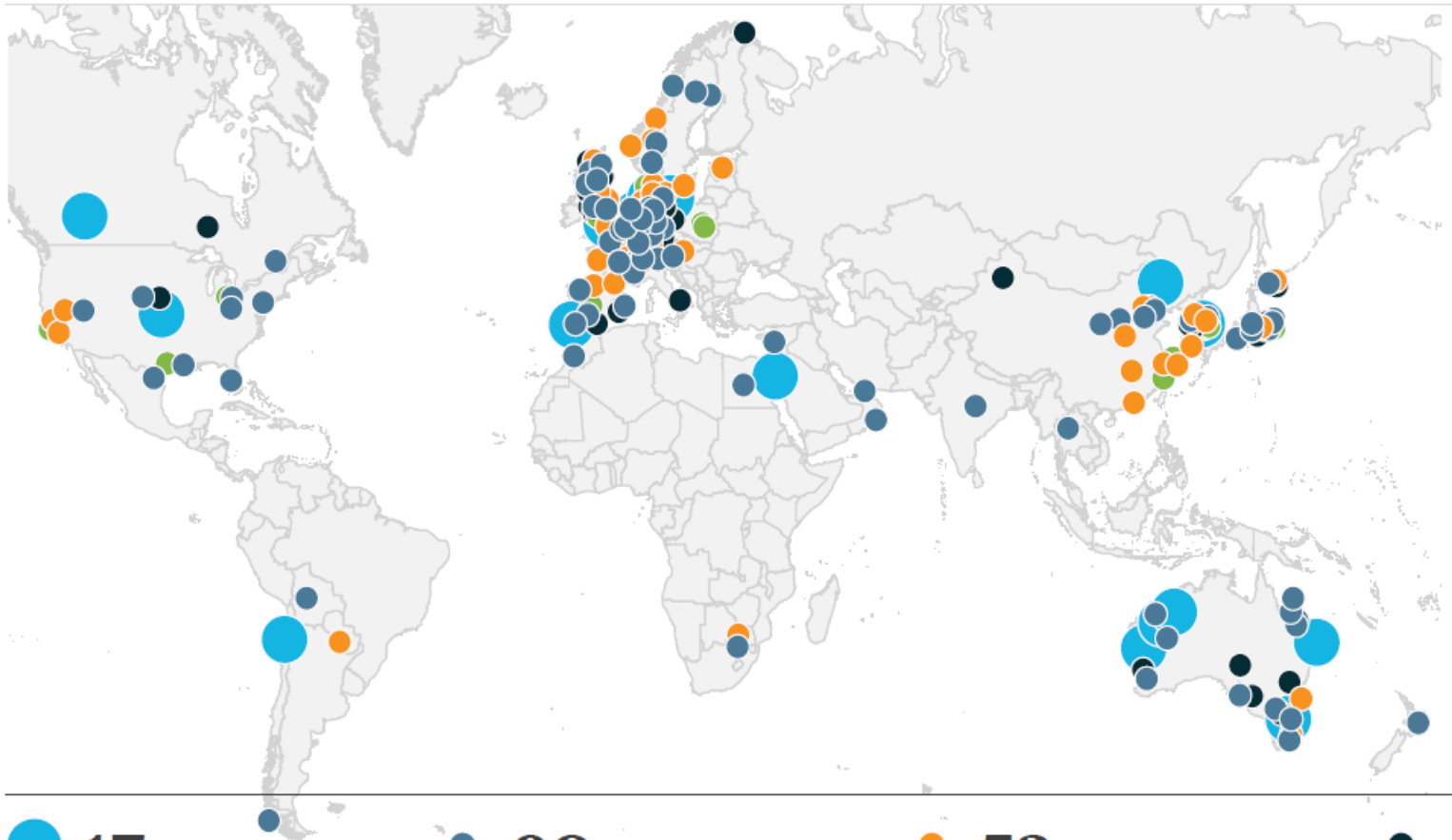
Source: IEA, The Future of Hydrogen, Karuizawa, Japan, June 2019; McKinsey; Johnson Matthey.



Source: FTI Consulting, December 2020

** Expected shortly: Italy*

Around the world hydrogen projects of unprecedented scale are being announced across the entire value chain, with 85% located in Europe, Asia and Australia



228 announced projects

- **126** Europe
- **46** Asia and China
- **24** Oceania
- **19** North America
- **8** Middle East and Africa
- **5** Latin America

17

Giga-scale production
Renewable H_2 projects >1GW and low-carbon H_2 projects >200 kt p.a.

90

Large-scale industrial usage
Refinery, ammonia, methanol, steel, and industry feedstock

53

Transport
Trains, ships, trucks, cars and other hydrogen mobility applications

45

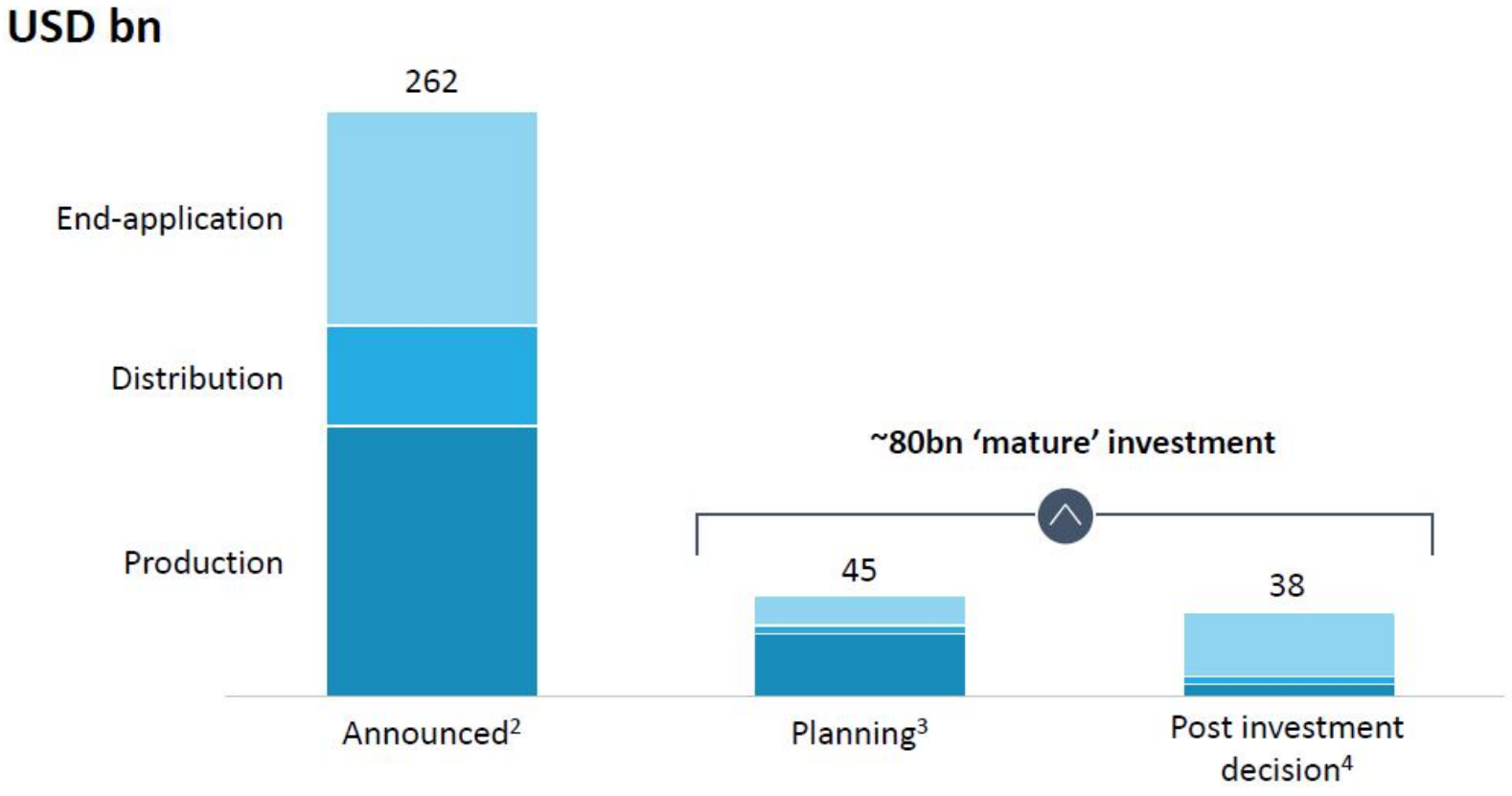
Integrated H_2 economy
cross-industry, and projects with different types of end-uses

23

Infrastructure projects
H_2 distribution, transportation, conversion, and storage

Hydrogen investments

Around 80bn of announced investments are considered mature, either in planning stages or post FID1



- **70bn of government funding** has been announced to support project and technology development
- **6X increase in private investment** until 2025 compared to 2019 spending. And x16 until 2030
- **80% of private investment allocated to capex,** while the remaining is into R&D and M&A

1. Final Investment Decision
2. Includes projects at preliminary studies or at press announced stage. It also includes required investment to reach national targets and governments funding
3. Includes projects that are at the feasibility study or front-end engineering and design stage
4. Includes projects where are a final investment decision (FID) has been taken, under construction, commissioned-and operational

The UK has some world-leading initiatives to demonstrate clean H_2 at scale

- Trialling decarbonised hydrogen as a fuel and feedstock
- Phase 1: 80kt (350MW) of hydrogen p.a. Equivalent to world scale hydrogen plant
- Used in industry, homes and transport

- Renewable hydrogen from electrolysis of water using off-shore wind
- 100 MW electrolyser linked to Hornsea Two offshore wind farm
- Potential to supply up to 30% of the Phillips 66 Humber Refinery hydrogen demand

Great opportunity for the UK to learn by doing and drive further innovation - but we need to act quickly or we will become followers

Global H_2 market estimated at $2.5tn in 2050[1]

UK targeting 5GW of clean H_2 (Green and Blue) by 2030

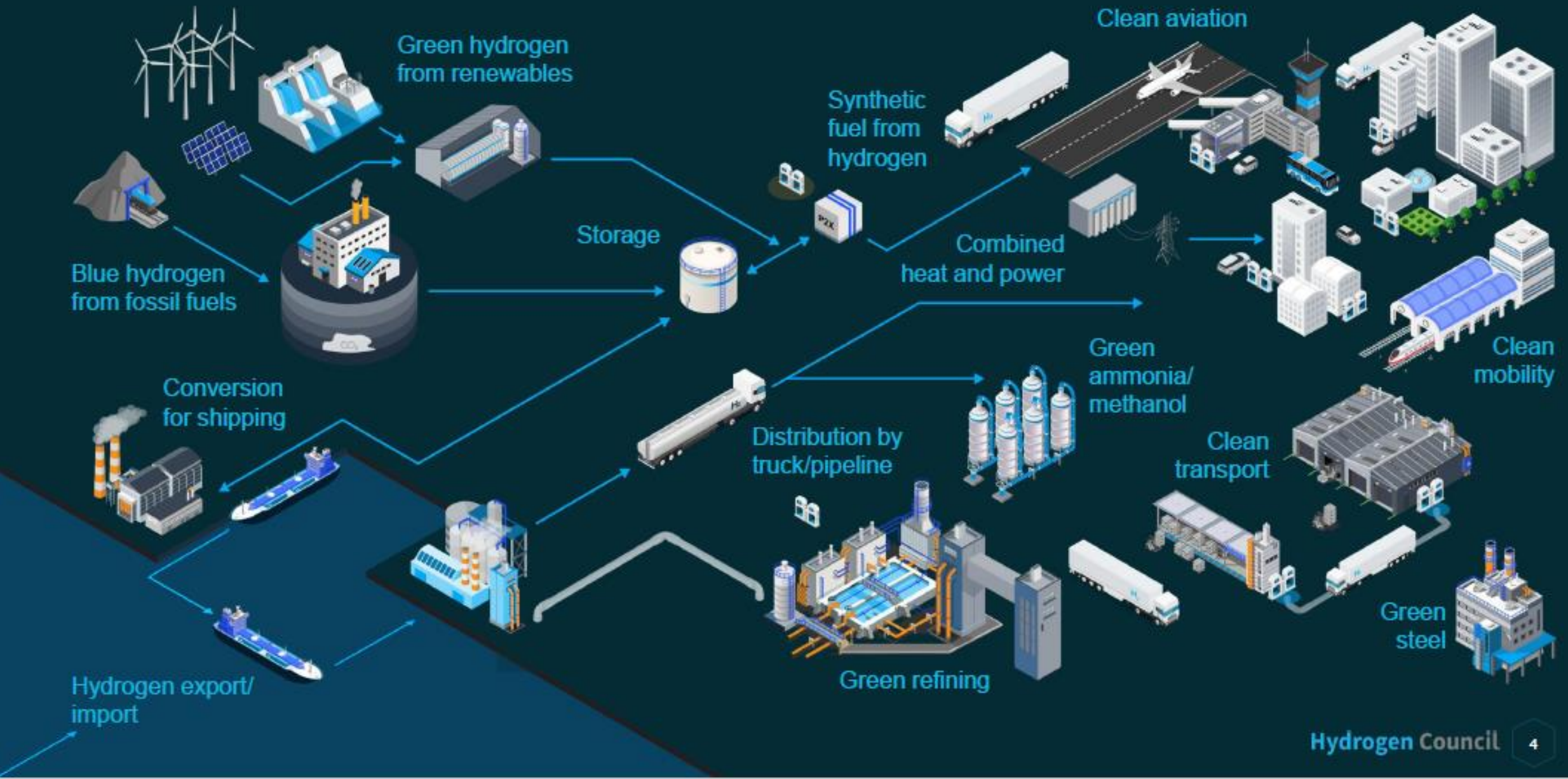
Strongly supports new skills development and levelling-up of UK communities

JM

Note: CCS – carbon capture and storage.

1. Hydrogen Council, "Hydrogen, Scaling up" report, 2017

The hydrogen economy spans across sectors



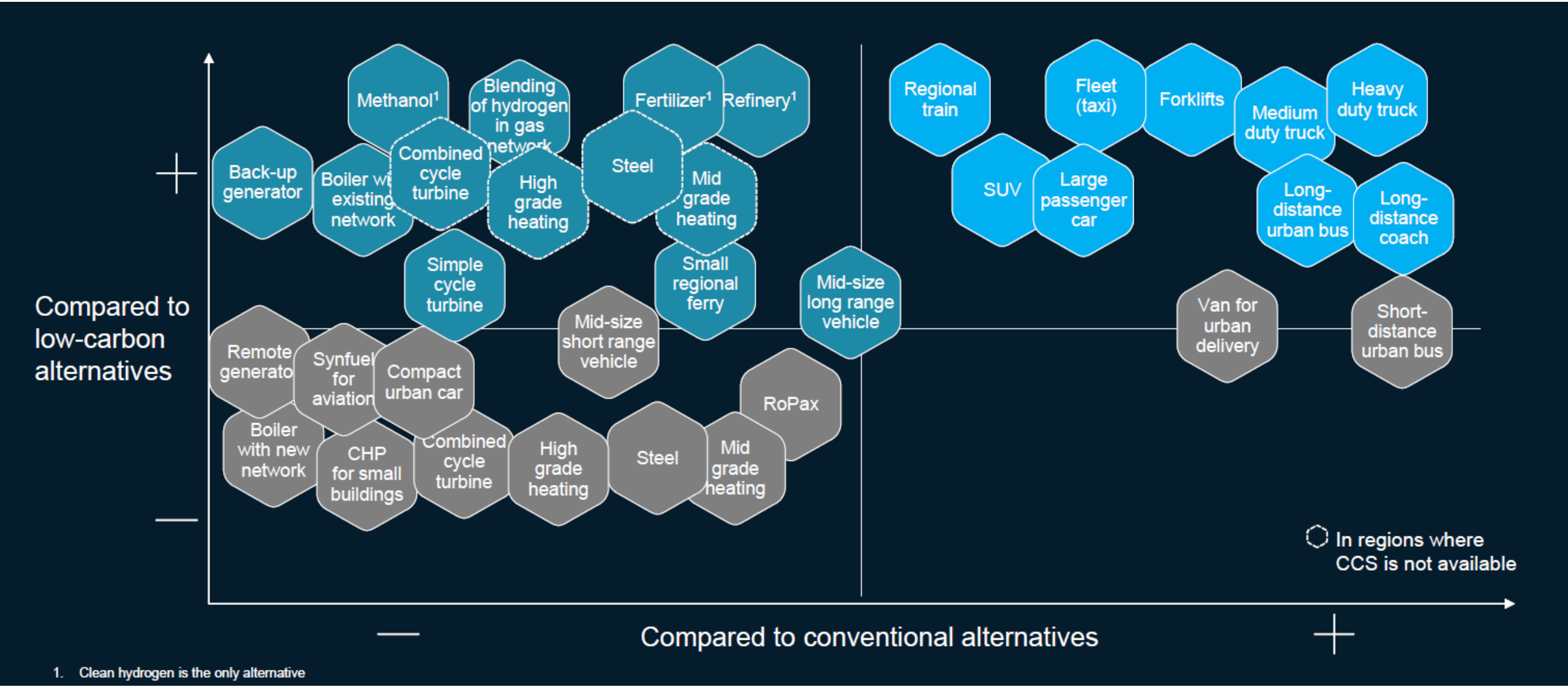
JM

Johnson Matthey

Inspiring science, enhancing life

Q&A

Competitiveness of hydrogen by 2030



1. Clean hydrogen is the only alternative

UK 10 Point Plan has a strong focus on hydrogen

2. **Hydrogen**: Aim to generate **5GW of low carbon hydrogen production** capacity by 2030 for industry, transport, power and homes, and aiming to develop the first town heated entirely by hydrogen by the end of the decade

- Up to £500m, including for trialling homes using hydrogen for heating and cooking, starting with a Hydrogen Neighbourhood in 2023, moving to a Hydrogen Village by 2025, with **an aim for a Hydrogen Town – equivalent to tens of thousands of homes – before the end of the decade**. £240m of this will go into new hydrogen production facilities.

6. Jet Zero and greener maritime: Supporting difficult-to-decarbonise industries to become greener through research projects for **zero-emission planes and ships**

8. **Carbon capture**: Becoming a world-leader in technology to capture and store harmful emissions away from the atmosphere, with a target to remove 10MT of carbon dioxide by 2030, equivalent to all emissions of the industrial Humber today

- "the UK will be at the global forefront of carbon capture, usage and storage technology, benefiting regions with industries that are particularly difficult to decarbonise. **£200m of new funding to create two carbon capture clusters by the mid-2020s, with another two set to be created by 2030**, which increases the total invested to £1 billion, helping to support 50,000 jobs, potentially in areas such as the Humber, Teesside, Merseyside, Grangemouth and Port Talbot"

JM

Commitments to hydrogen are gathering pace globally

Cummins CEO, August 2020:
"I'm very confident that hydrogen will be a bigger and bigger part of that portfolio over time and at some point in the future it will be the single largest part of what Cummins provides to customers."

EU Hydrogen Strategy, July 2020:
Hydrogen is "essential to support the EU's commitment to reach carbon neutrality by 2050 and for the global effort to implement the Paris Agreement while working towards zero pollution."

German Hydrogen Strategy, June 2020:
"The time has come for hydrogen and the technologies enabling its use. We must therefore harness the potential for economic output, employment, and the climate, and do this now."

Daimler Trucks Chairman, April 2020:
"For trucks to cope with heavy loads and long distances, fuel cells are one important answer… This joint initiative with the Volvo Group is a milestone in bringing fuel cell powered trucks and buses onto our roads."

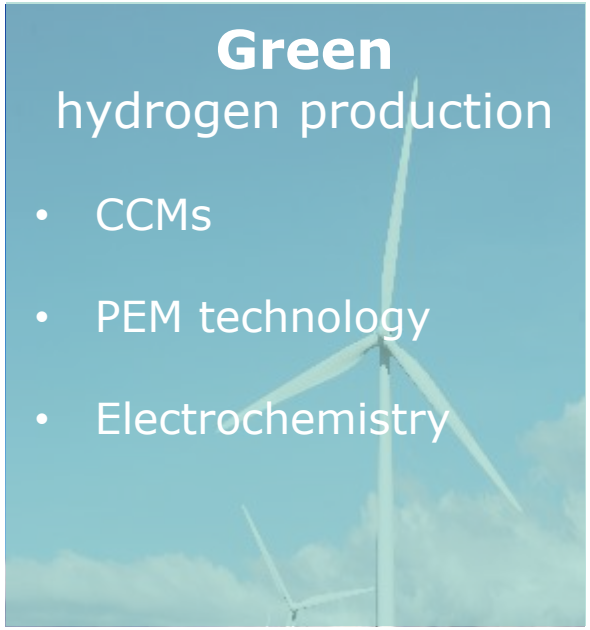
International Energy Agency, June 2019:
"The time is right to tap into hydrogen's potential to play a key role in a clean, secure and affordable energy future"

JM

Let’s look at some of JM’s technologies for the hydrogen transition

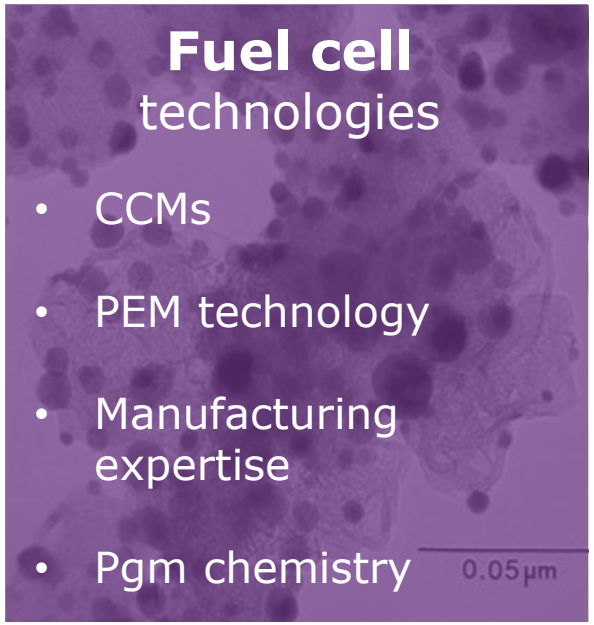
Blue
hydrogen production

- Leading technology
- Commercialisation
- Building on our expertise



Green
hydrogen production

- CCMs
- PEM technology
- Electrochemistry



Fuel cell
technologies

- CCMs
- PEM technology
- Manufacturing expertise
- Pgm chemistry

Chemical
building blocks

- Existing technology
- Syngas conversion, Fischer Tropsch
- Jet fuel, ammonia, methanol, formaldehyde

Hydrogen production technologies

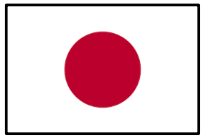
Use of hydrogen

Note: CCM – catalyst coated membrane, PEM - proton exchange membrane.

Fuel cell electric vehicle and hydrogen infrastructure development

- >1m FCEVs in 2030
- >1,000 hydrogen refuelling stations (HRS) by 2030

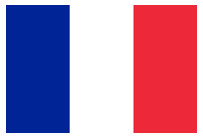
- >1.8m FCEVs in 2030
- >500 HRS in 2030
- $2.2bn investment by 2022



- Strong drive towards hydrogen economy
- 800k FCEVs by 2030
- 900 HRS by 2030

- Zero emission vehicle mandate
- 50k FCEVs by 2025
- 200 HRS by 2025

FCEV/HRS deployment by 2030 from European National Hydrogen Strategies






		Bavaria	North-Rhine Westphalia				
LCV	20-50k (2028)	80k	6k	15k (2025) 300k (2030)		5% of road transport powered by H_2	5-7.5k
HCV	0.8-2k (2028)	3k	15k	3k (2025)	2k		
HRS	400-1,000 (2028)	400	200	50 (2025)	150	50-100	100-150

Note: FCEV – fuel cell electric vehicle; HRS – hydrogen refuelling station