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Johnson Matthey
Inspiring science, enhancing life

Enabling the transition to the hydrogen economy

18th September 2020

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Today’s presenters

Jo Godden,
Managing Director,
New Markets and Fuel Cells

Started as a graduate in ICI in 1995; joined JM in 2002 via acquisition

25 years’ experience in chemicals industry

Eugene McKenna,
Sector Business Development and Innovation Director

Joined JM in March 2017

30 years’ experience in the oil and chemicals industries in technology, strategy and business development

A world that's cleaner and healthier;

today and for future generations

The move to net zero is accelerating

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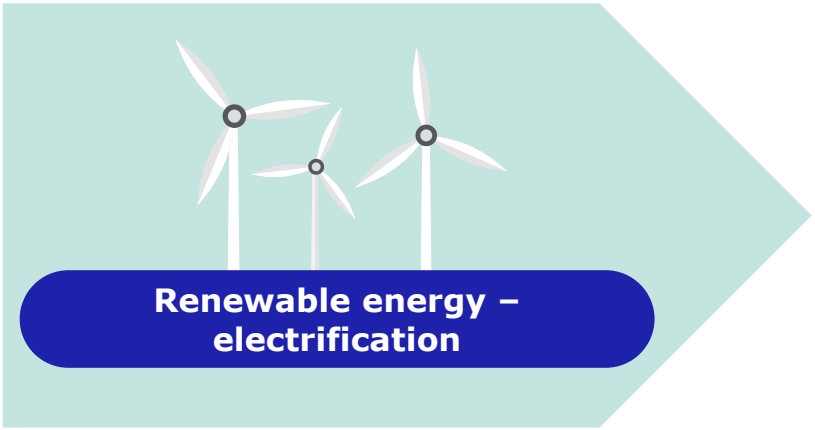
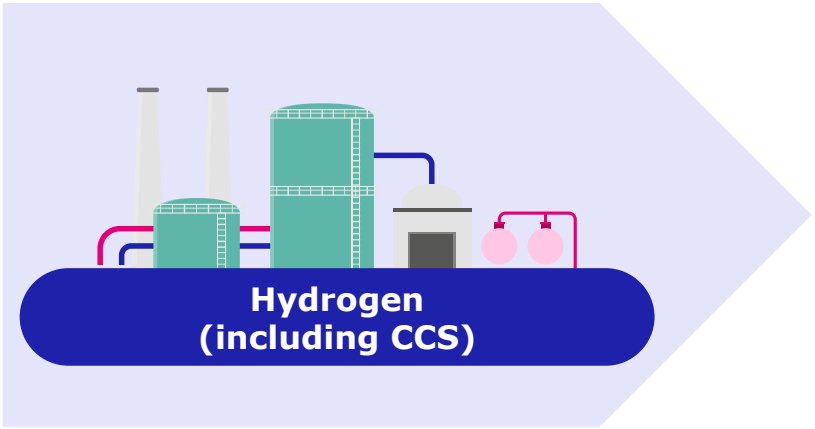
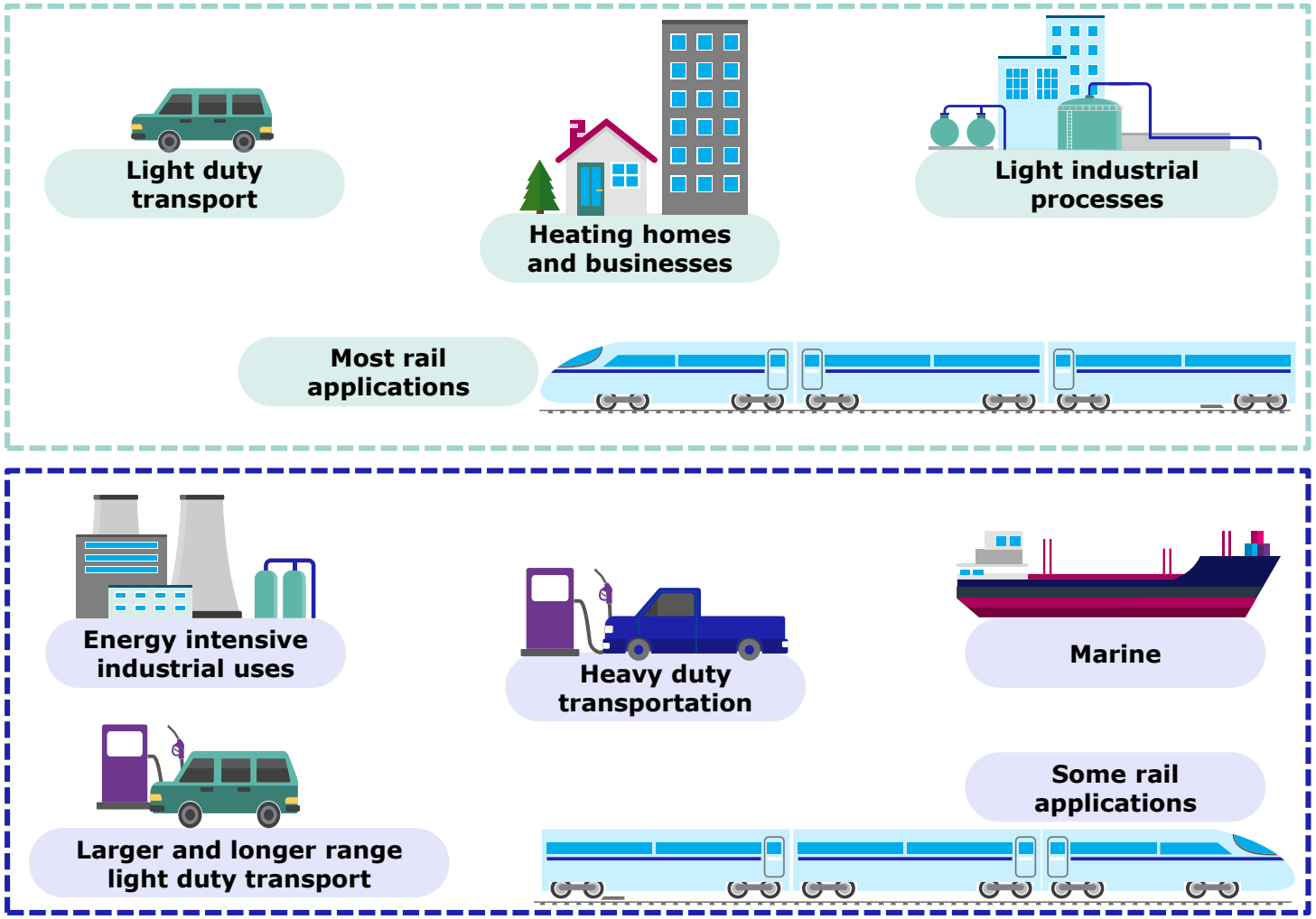
Source: Committee on Climate Change, Net Zero Report, May 2019; Energy and Climate Intelligence Unit, August 2020.

Hydrogen is an important part of decarbonisation







Note: CCS – carbon capture and storage.

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."

Germany 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"

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We are strongly positioned in hydrogen

- A significant opportunity in a fast growing market
- Integrated offering and leading technology
- Strong segment shares
- Highly complementary customer base
- Low capital intensity

Aligned to our vision for a cleaner, healthier world

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Seminar will focus on three areas of hydrogen use and production

01

Fuel cell
technologies

02

Blue
hydrogen production

03

Green
hydrogen production

Use of hydrogen

Hydrogen production technologies

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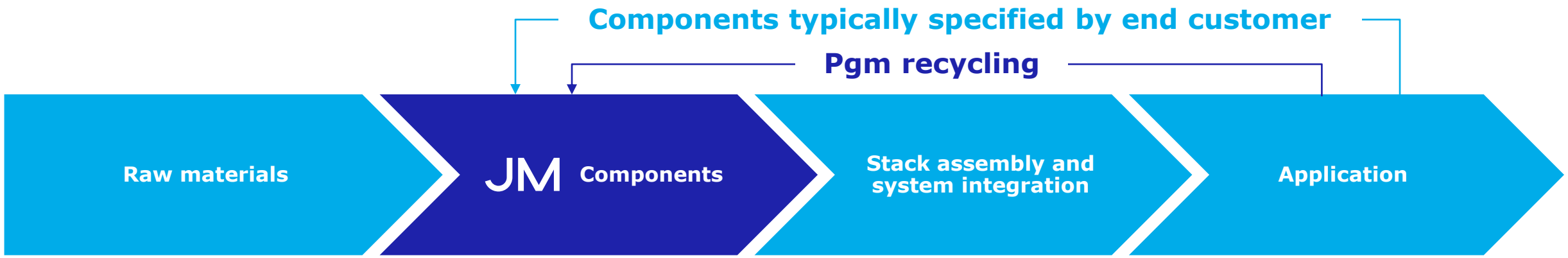
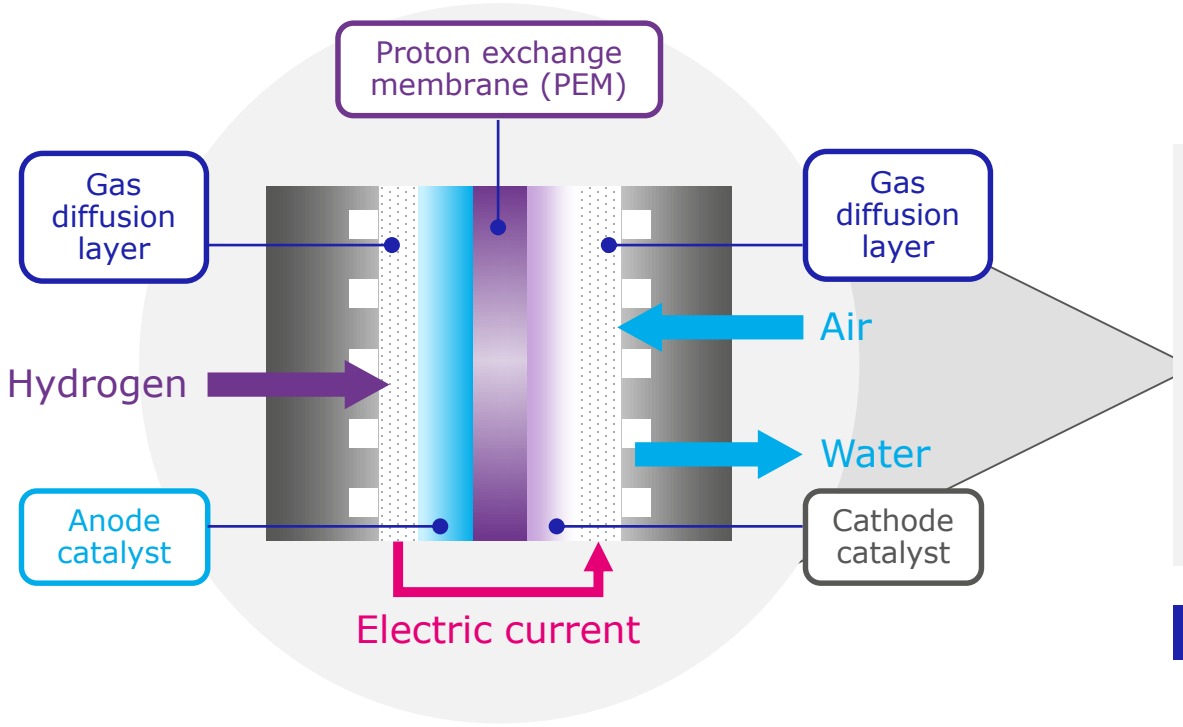
We operate in the complex part of the fuel cell value chain



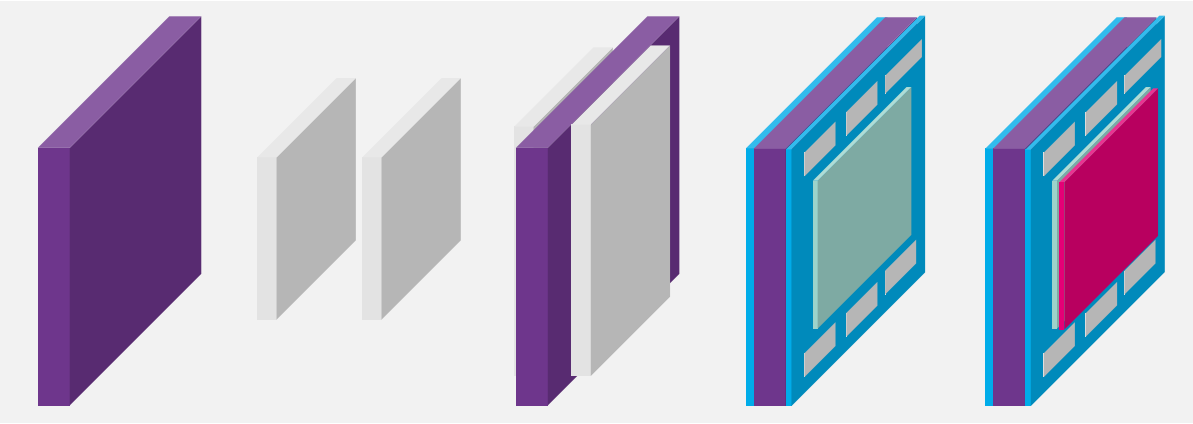
JM	Tier 1 players	Automotive OEMs (cars, trucks, vans, buses)
Ballard	Automotive OEMs	Non-automotive OEMs (forklift)
Gore	Non-automotive OEMs	Stationary (storage, power generation)
Greenerity	Stationary	
Umicore		

Differentiate on catalyst coated membrane – critical for performance

Fuel cells convert hydrogen and oxygen into electricity and water



Proton exchange membrane (PEM)	**Catalysts**	**Catalyst coated membrane (CCM)**	**Sealed CCM**	**Membrane electrode assembly (MEA)**
Membrane and associated supports	Anode and cathode layers	'3-layer system'	'5-layer system'	'7-layer system'



Components				
Ionomer ePTFE	Carbon Pgm / other metal Ionomer	Membrane Anode catalyst Cathode catalyst	CCM Seals	Sealed CCM Gas diffusion layer

Note: ePTFE – expanded polytetrafluoroethylene.

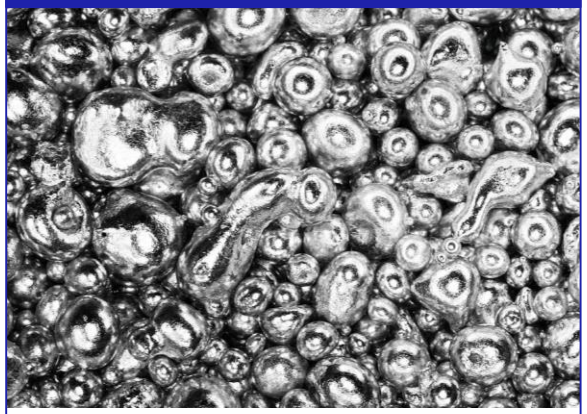
We have a strong competitive advantage

Science

Catalyst and membrane expertise

Optimisation for high performance

Pgm expertise



Potential closed loop offering

Lower carbon intensity

Ability to reduce cost

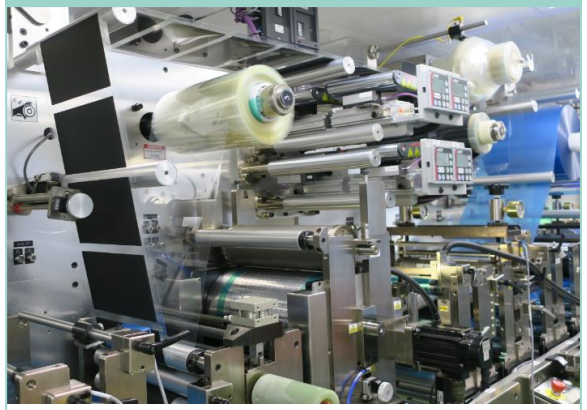
Trusted partner

Proven commercial product

Existing customers

Over 20 years' experience

Established manufacturing



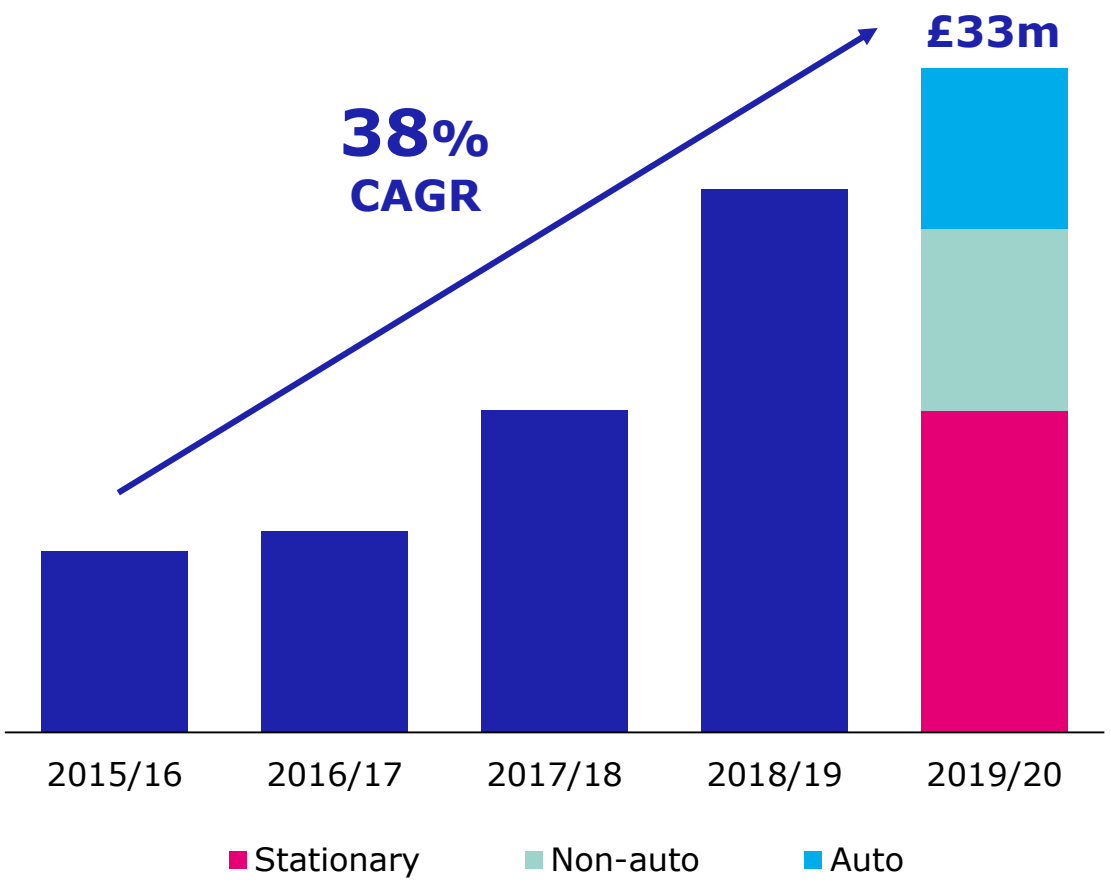
Well along experience curve

Efficient processes

Expanding capacity

Leader in fuel cells with an established, profitable business

Fuel cell sales (£m)



Customers include major global truck and auto OEMs

Supplying commercial vehicles and buses in China

c.25% auto sales (nil 18 months ago); working with a low double digit number of truck and auto OEMs

Doubling capacity by end of 2020/21

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Note: Sales excluding precious metals.

Trucks and buses: a major opportunity for fuel cells

Cost

Weight

Range

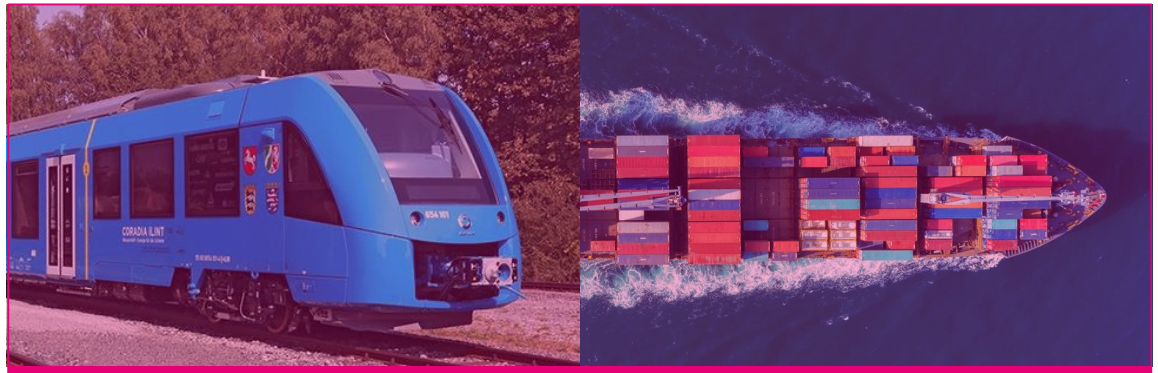
Charging time

Further opportunities in autos, rail and marine

Autos

Fuel cells likely to be in larger cars that require longer range

Enabled by declining hydrogen prices, lower fuel cell costs and more extensive hydrogen infrastructure



Rail and marine

Emerging segments

Rail developments in China, Germany and the Netherlands

We have a significant opportunity in fuel cells

Major opportunity in trucks and autos

Leading market shares today in emissions control and fuel cell technology

Fuel cell penetration of trucks in 2030[1]: c.5%

Estimated CCM value per truck in 2030[2]: c.£2,500

Addressable fuel cell market for trucks and autos estimated to be worth:

- c.£1bn p.a. in 2030[1,2]
- More than £10bn p.a. in 2040[2,3]

1. Based on LMC, KGP and Johnson Matthey assumptions which equate to i) c.0.4 million trucks.
2. Source: McKinsey cost estimations and OEM targets.
3. Based on LMC, KGP and Johnson Matthey assumptions which equate to i) c.3 million trucks and ii) c.14.5 million autos, of which c.60% is assumed to be non-captive in 2040. Estimated CCM value per auto vehicle is c.£800.

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Blue and green hydrogen production

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technologies

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Hydrogen production technologies

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We have a strong presence across different production technologies

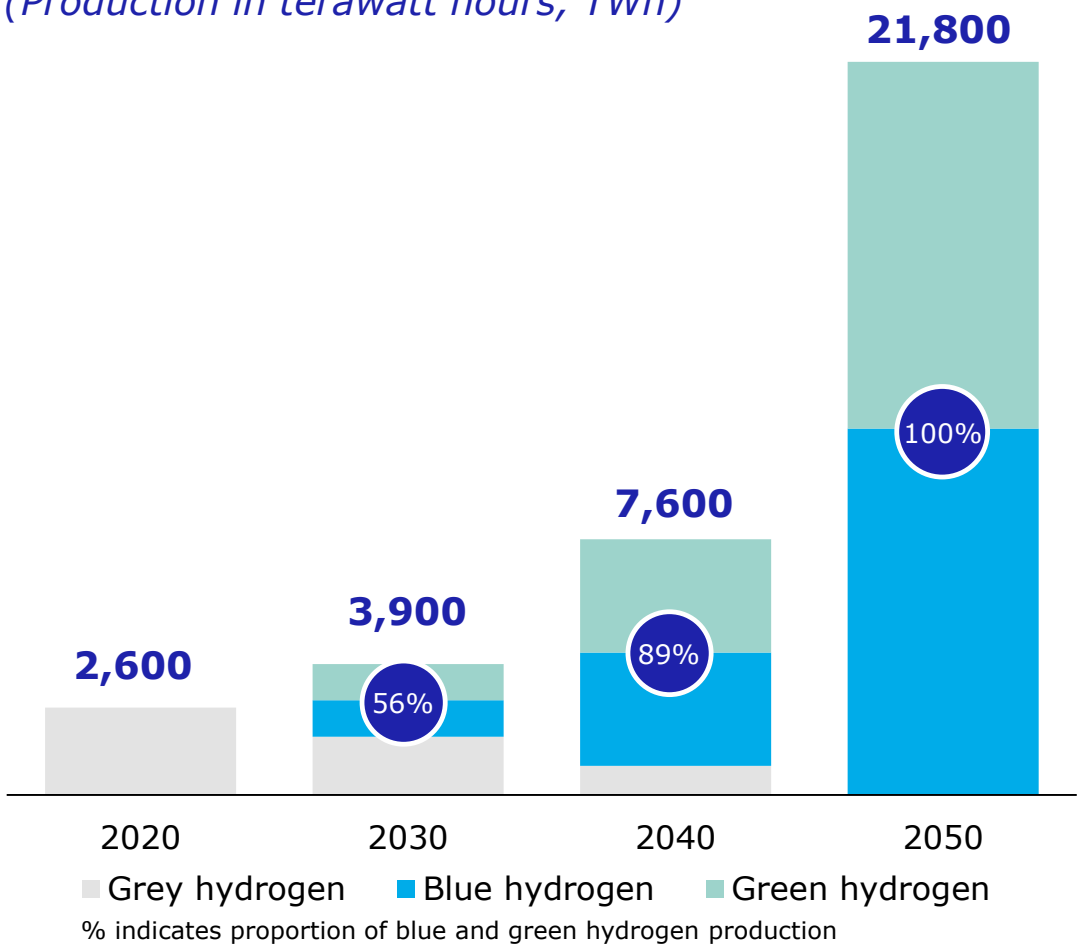
JM's technologies

Brown	Grey	Blue	Green
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.

Blue and green hydrogen are critical in the transition to net zero

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

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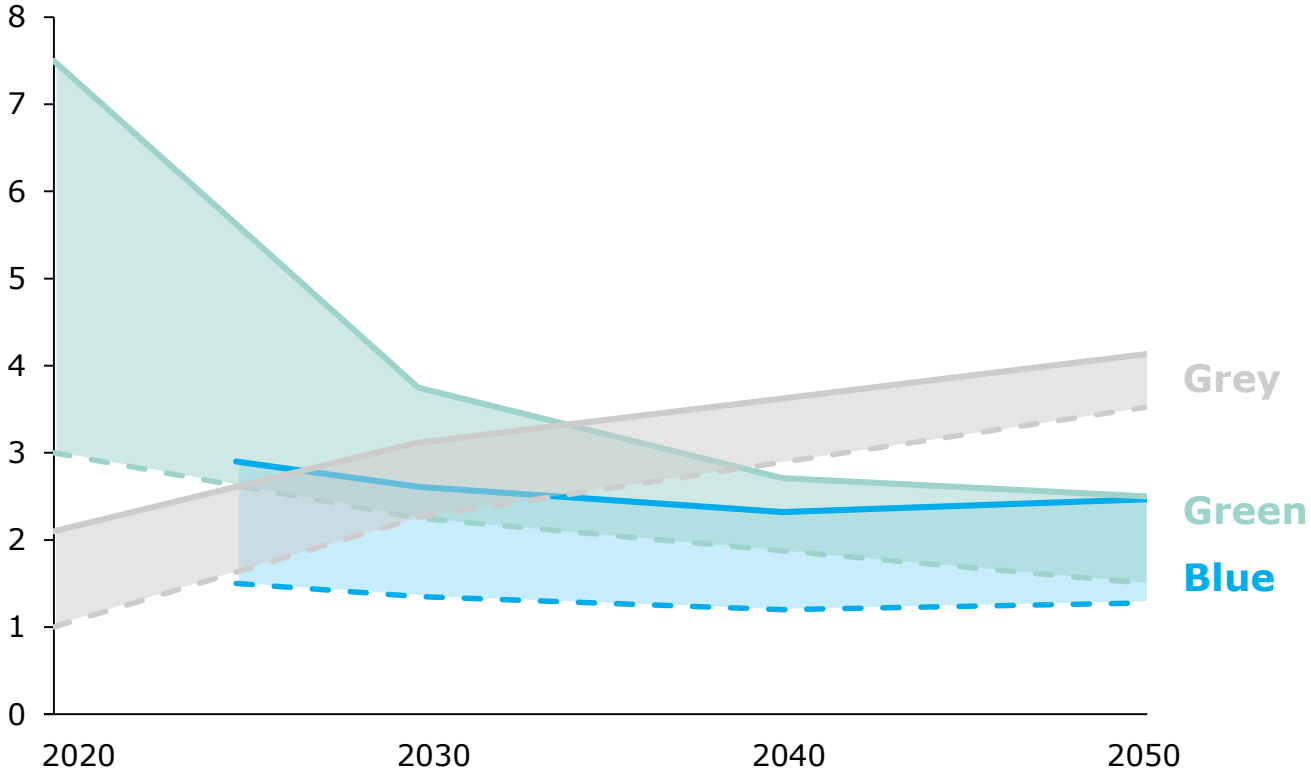
Source: Hydrogen Council, "Hydrogen, Scaling up" report, 2017, (total hydrogen demand); Johnson Matthey, IEA, BP (split of hydrogen production methods).

Green hydrogen becomes more competitive over the medium term

Estimated hydrogen cost
($ per kg H_2)



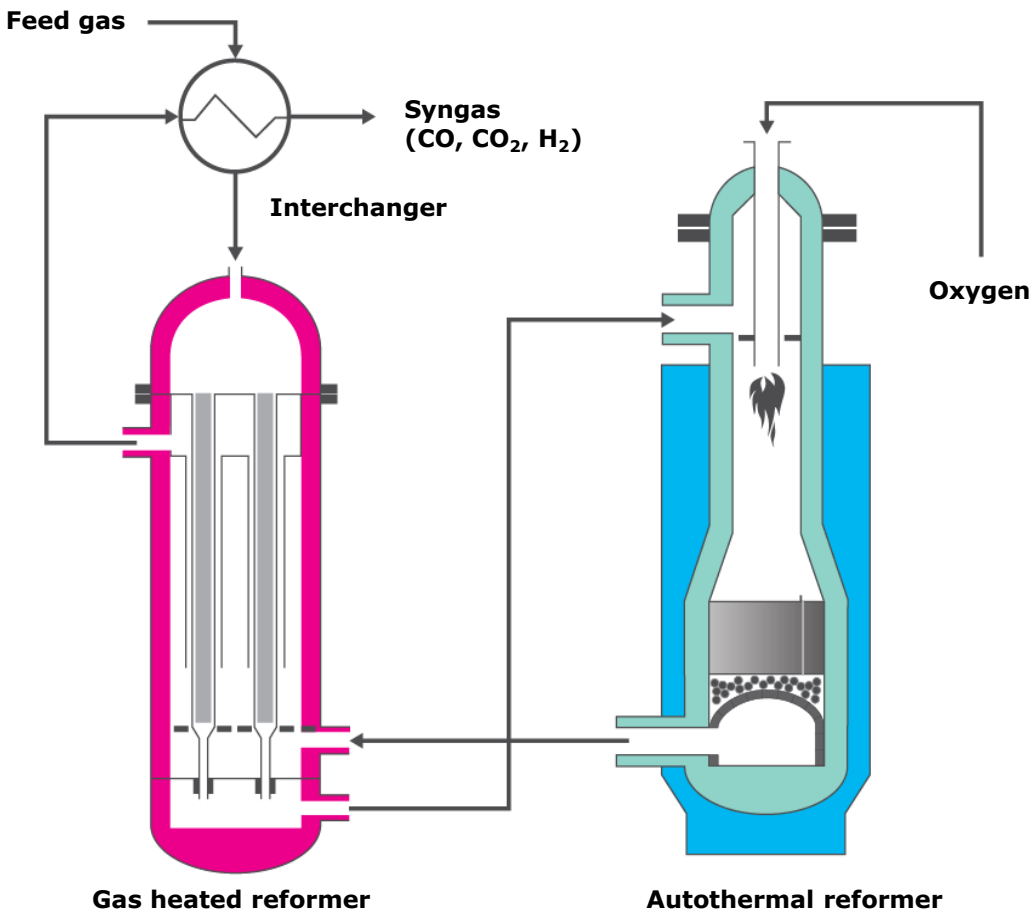
Blue hydrogen advantaged in certain regions and likely to be a long term solution in places with the right geology and infrastructure e.g. US and UK

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.

Blue hydrogen builds on our expertise in grey hydrogen and methanol

Johnson Matthey's blue hydrogen technology



Methane (CH_4) from natural gas is reacted with steam to produce **hydrogen** (H_2) and **carbon dioxide** (CO_2)

Most efficient process – 9% less natural gas usage[1]

Lowest capex – 40% lower capital cost[1]

>95% of produced CO_2 captured: **single stream** at **high pressure** and **purity** enabling easier transport or storage

1. Compared to conventional steam methane reforming technology with carbon capture and storage. *Johnson Matthey Technol. Rev.*, 2020, **64**, (3), 357–37. 9% efficiency saving based on a project equivalent to the size of HyNet Phase 1 (80kt p.a.) would give a saving of c.£6 million to 7 million p.a.
Note: Feed gas is methane from natural gas; syngas is predominantly carbon monoxide (CO), carbon dioxide (CO_2) and hydrogen (H_2).

Success in grey and methanol translates to success in blue

Grey hydrogen

- Supply catalyst
- Many years' experience
- c.£60m annual sales of catalysts for grey hydrogen
- Segment share of 40%[1]
- Over 400 customers including oil and gas, industrial gas companies

Blue hydrogen

- Supply catalysts, equipment, engineering expertise and license technology
- Hard to replicate our experience
- Builds on grey hydrogen technology and methanol process expertise
- Lowest opex and capex; expect leading segment share[2]
- Existing and new customers

Note: Sales excluding precious metals. Blue hydrogen technology builds on existing methanol process expertise (auto thermal reformer).
1. Based on Johnson Matthey data.
2. Main competitors include Air Liquide and Halder Topsoe.

Our blue hydrogen technology is being commercialised

HyNet Phase 1

North West England

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

Acorn Phase 1

North East Scotland

- North Sea natural gas reformed into clean hydrogen and CCS
- Phase 1: 55kt of hydrogen p.a.
- Used in transport and the gas grid to decarbonise heating

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Note: CCS – carbon capture and storage.

A significant opportunity in blue hydrogen

Estimated addressable market:
c.£1.5bn to c.£2bn p.a. in 2030[1,2]

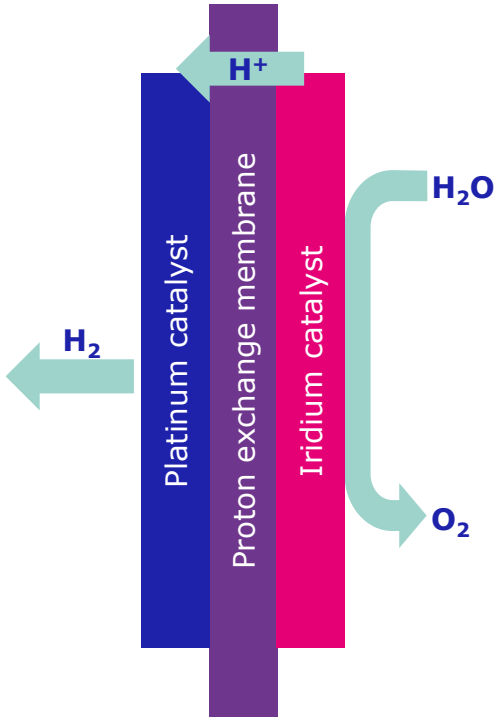
Average one-off fee for JM (including first fill catalyst, engineering and licence):
c.£50m to £60m per plant[1]

Average refill catalyst for JM (every 3-4 years):
c.£5m per plant[1]

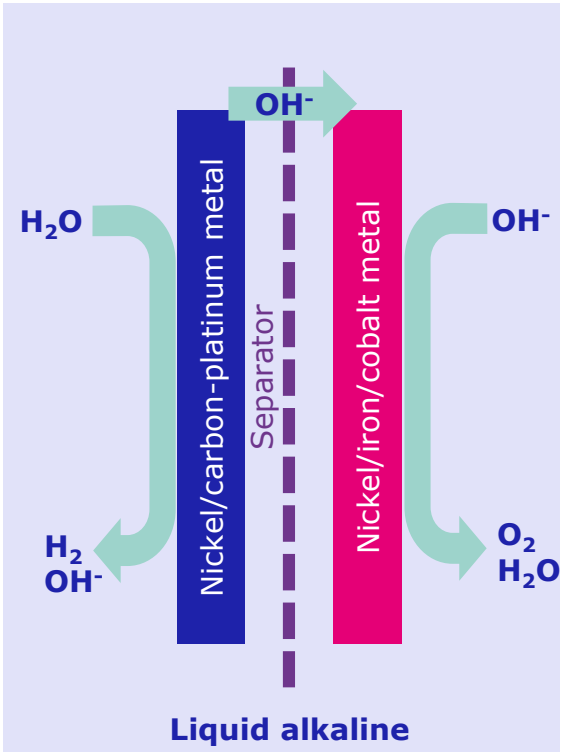
1. Based on total hydrogen demand (Hydrogen Council, "Hydrogen, Scaling up" report, 2017); average plant size of 160kt p.a. (equivalent to twice the size of HyNet project Phase 1).
2. Assumes c.30% of the market is blue hydrogen (Johnson Matthey, IEA, BP).

Green hydrogen: electrolysis of water to produce hydrogen using renewable energy

PEM



Alkaline



Proton exchange membrane (PEM): polymer electrolyte and pgm electrodes

- Compact or large systems
- Robust in non-continuous use applications
- Higher hydrogen purity
- Lowest cost option as technology develops

Alkaline: liquid alkaline electrolyte and base metal electrodes

- Large systems only
- Less suitable for non-continuous applications, e.g. some renewable energy
- More commoditised technology

PEM technology expected to play a major role

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Why we can be successful in green hydrogen

Comparable technology to fuel cells

- Builds on core competencies in fuel cells
- Strong competitive advantage in pgm catalysis
- Ability to scale quickly

Potential closed loop offering

- End of life options designed in from R&D stage
- Pgm recycling expertise

Experienced in enabling new technologies e.g. fuel cells and Fischer Tropsch (FT CANS™) technology for waste to aviation fuel

Estimated addressable PEM market of c.£2bn to £4bn p.a. in 2030[1]

Testing with leading electrolyser players

Note: PEM – proton exchange membrane.
1. Assumes c.30% of the market is green hydrogen, of which the PEM share is 30-60% (Johnson Matthey, IEA, BP).

JM is a leading player in the transition to the hydrogen economy

A significant opportunity in a fast growing market

Established and profitable hydrogen business with c.£100m sales today

Leading technology in fuel cells and hydrogen production

Hydrogen underpinned by our science expertise across the group

Delivering on our vision for a cleaner, healthier world

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Note: Sales in fuel cells and grey hydrogen production excluding precious metals.

Q&A

www.matthey.com/investors