UBS Mobility Conference

11th December 2020

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A world that’s cleaner and healthier; today and for future generations
The move to net zero is accelerating: “building back greener”

26 countries and regions have defined dates to become net zero

59% of global GDP with net zero targets by 2050; 16% a year ago

COVID-19 has not slowed this trend

Source: Committee on Climate Change, Net Zero Report, May 2019; Energy and Climate Intelligence Unit, August 2020.
Hydrogen is key to reaching “net zero”

Renewable energy – electrification

Hydrogen (including CCS)

Light duty transport

Light industrial processes

Most rail applications

Heating homes and businesses

Energy intensive industrial uses

Heavy duty transportation

Larger and longer range light duty transport

Marine

Some rail applications

Note: CCS – carbon capture and storage.
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

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Hydrogen production technologies

Use of hydrogen

**Note:** CCM – catalyst coated membrane, PEM - proton exchange membrane.
Fuel Cells: JM has 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**
- Stationary, auto and non-auto markets
- Existing customers
- Over 20 years’ experience

**Established manufacturing**
- Well along experience curve
- Doubling capacity 2020/2021
- Further expansion
...JM has an established, profitable and growing business

Fuel cell sales (£m)

- Stationary
- Non-auto
- Auto

38% CAGR

£33m


Customers include major global truck and auto OEMs

Estimated addressable truck market of c.£1bn p.a. in 2030\textsuperscript{1,2} >£10bn p.a. in 2040\textsuperscript{2,3}

Note: Sales excluding precious metals.
1. Based on LMC, KGP and JM assumptions which equate to i) c.0.4 million trucks.
3. Based on LMC, KGP and JM 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.
JM has a strong presence across hydrogen production technologies

### JM’s technologies

<table>
<thead>
<tr>
<th>Brown</th>
<th>Grey</th>
<th>Blue</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Natural gas</td>
<td>Natural gas</td>
<td>Renewable electricity</td>
</tr>
<tr>
<td>-</td>
<td>Leading catalyst supplier 40% segment share¹</td>
<td>Differentiated technology and catalyst supplier</td>
<td>Expect to supply catalyst coated membrane</td>
</tr>
<tr>
<td>Gasification No CCS</td>
<td>Steam methane reforming No CCS</td>
<td>Advanced gas reforming CCS</td>
<td>Electrolysis</td>
</tr>
<tr>
<td>Highest GHG emissions (19 tCO₂/tH₂)</td>
<td>High GHG emissions (11 tCO₂/tH₂)</td>
<td>Low GHG emissions (0.2 tCO₂/tH₂)</td>
<td>Potential for zero GHG emissions</td>
</tr>
<tr>
<td>$1.2 to $2.1 per kg H₂</td>
<td>$1 – $2.1 per kg H₂</td>
<td>$1.5 – $2.9 per kg H₂</td>
<td>$3 – $7.5 per kg H₂</td>
</tr>
</tbody>
</table>

Note: GHG – greenhouse gas; CCS – carbon capture and storage; tCO₂/tH₂ – tonne of carbon dioxide per tonne of hydrogen.

¹. Based on Johnson Matthey data.

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

JM’s award winning blue hydrogen technology builds on our expertise in grey hydrogen and methanol

Johnson Matthey’s blue hydrogen technology

Methane \((\text{CH}_4)\) from natural gas is reacted with steam to produce hydrogen \((\text{H}_2)\) and carbon dioxide \((\text{CO}_2)\)

Most efficient process – 9% less natural gas usage \(^1\)

Lowest capex – 40% lower capital cost \(^1\)

>95% of produced \(\text{CO}_2\) 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 \((\text{CO})\), carbon dioxide \((\text{CO}_2)\) and hydrogen \((\text{H}_2)\).
Our blue hydrogen technology is already 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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...and a pipeline of blue hydrogen projects globally

Estimated addressable market of c.£1.5bn to c.£2bn p.a. in 2030¹,²

Note: CCS – carbon capture and storage.

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

**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**
Why JM will be successful in green hydrogen

Comparable technology to fuel cells
- CCM is heart of system and key for performance and cost reduction
- Competitive advantage in pgm catalysis and thrifting
- Ability to scale quickly

Potential closed loop offering
- End of life options designed in from R&D stage
- Pgm recycling expertise

Experience in enabling new technologies
- Fuel cells
- Fischer Tropsch
- Technology for waste to aviation fuel

Estimated addressable PEM market of c.£2bn to £4bn p.a. in 2030¹

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 continues to support an integrated hydrogen economy...  
-from hydrogen to base chemical building blocks to specialty chemicals and fuels

**Research**
- R&D investment
- Sample and small series production
- Partnering for pilot scale demonstration

**Commercialisation**
- Accelerated growth
- Blue Hydrogen, commercial launch
- Appointment of MD in Green Hydrogen
- JM Hydrogen Council

**Strategy**
- Hydrogen and fuel cells sales already c.£100 million
- Fit with portfolio of small chemical building blocks
- JM is a Global Hydrogen Council Board member & on UK Govt Hydrogen Advisory Council
...and our stakeholders are recognising it

JM receives London Stock Exchange’s Green Economy Mark
January 2020

JM recognised as a constituent of the FTSE4Good Index Series
13th August 2020

JM’s leading Low Carbon Hydrogen technology scoops IChemE award
11th November 2020

Johnson Matthey recognised by Dow Jones Sustainability Index
24th November 2020
Turning green hydrogen into chemical building blocks: a vision

- **Industries emitting high concentration CO₂, etc.**
- **Carbon dioxide**
- **Gas conditioning**
- **rWGS unit**
- **Fischer Tropsch Synthesis**
- **Hydrogen**
- **Methanol**
- **Methane**
- **Fuels**
- **Chemicals**
- **Hydrocarbons**
- **Air separator**
- **Nitrogen**
- **Ammonia**
- **Fertiliser**
- **Crops**
- **Food**

**Water**

**Renewables, solar, wind power**

**Electrolyser**

**Oxygen**

**Electrons**

**Air**

**JM technology areas**

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.