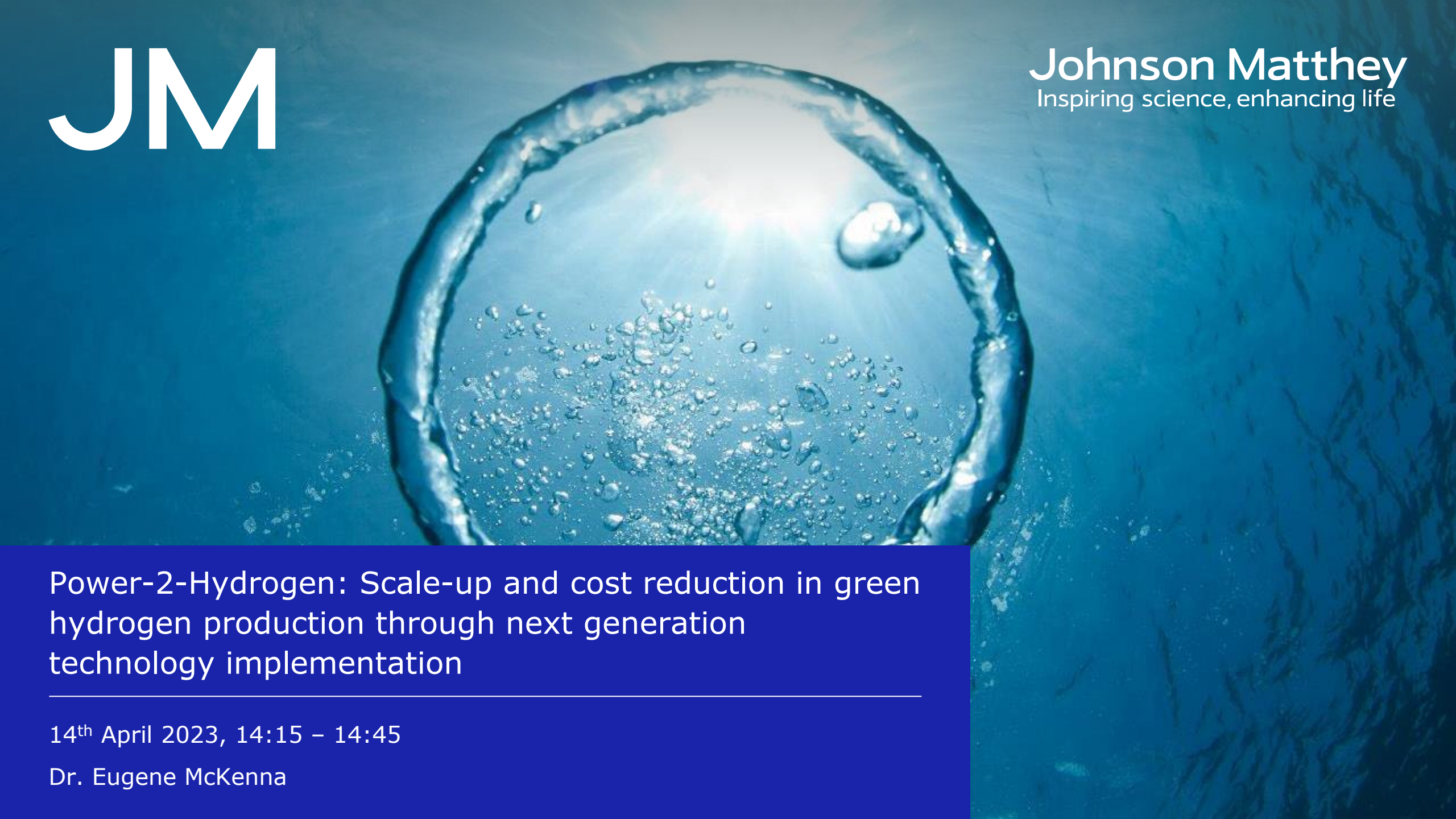


Johnson Matthey
Inspiring science, enhancing life

Power-2-Hydrogen: Scale-up and cost reduction in green hydrogen production through next generation technology implementation

14th April 2023, 14:15 – 14:45

Dr. Eugene McKenna

Agenda

01 **Who is Johnson Matthey and why hydrogen?**

02 **Planning for product generations**

03 **Building robust supply chains and partnerships**

Strong credentials supporting our strategy and vision for a cleaner and healthier world

Strong brand
205 year history

Technology leadership
#1 or 2
in chosen markets

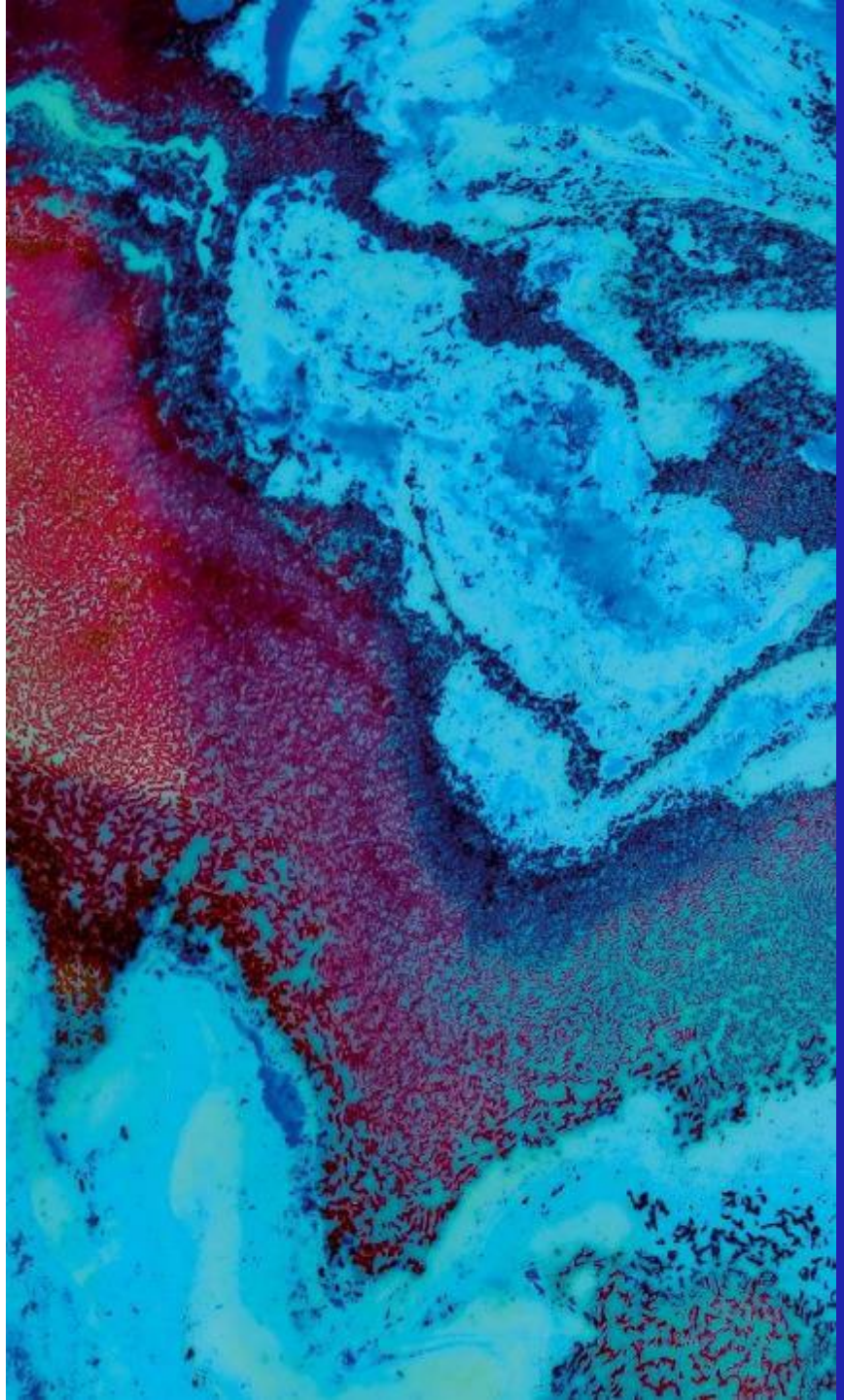
2021/22 sales[1]
£3.8 billion

13,400 employees
worldwide[2]

[1]Sales excluding precious metals [2] As at 31st March 2022

Science and metal expertise at the heart of the group

- Leaders in complex metal chemistry
- Developed over decades; hard to replicate
- Synergies across the group
- Key to many technologies tackling climate change



c.£200m
R&D spend (5% sales)

>1,600
R&D employees

87%
Gross R&D spend contributing to 4 UN SDGs

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Note: 2020/21 figures. UN SDGs – United Nations Sustainable Development Goals

Our markets

Emission control systems

Components for fuel cells

Sustainable methanol and ammonia technology

Sustainable formaldehyde technology

Low carbon solutions

Sustainable fuels technology

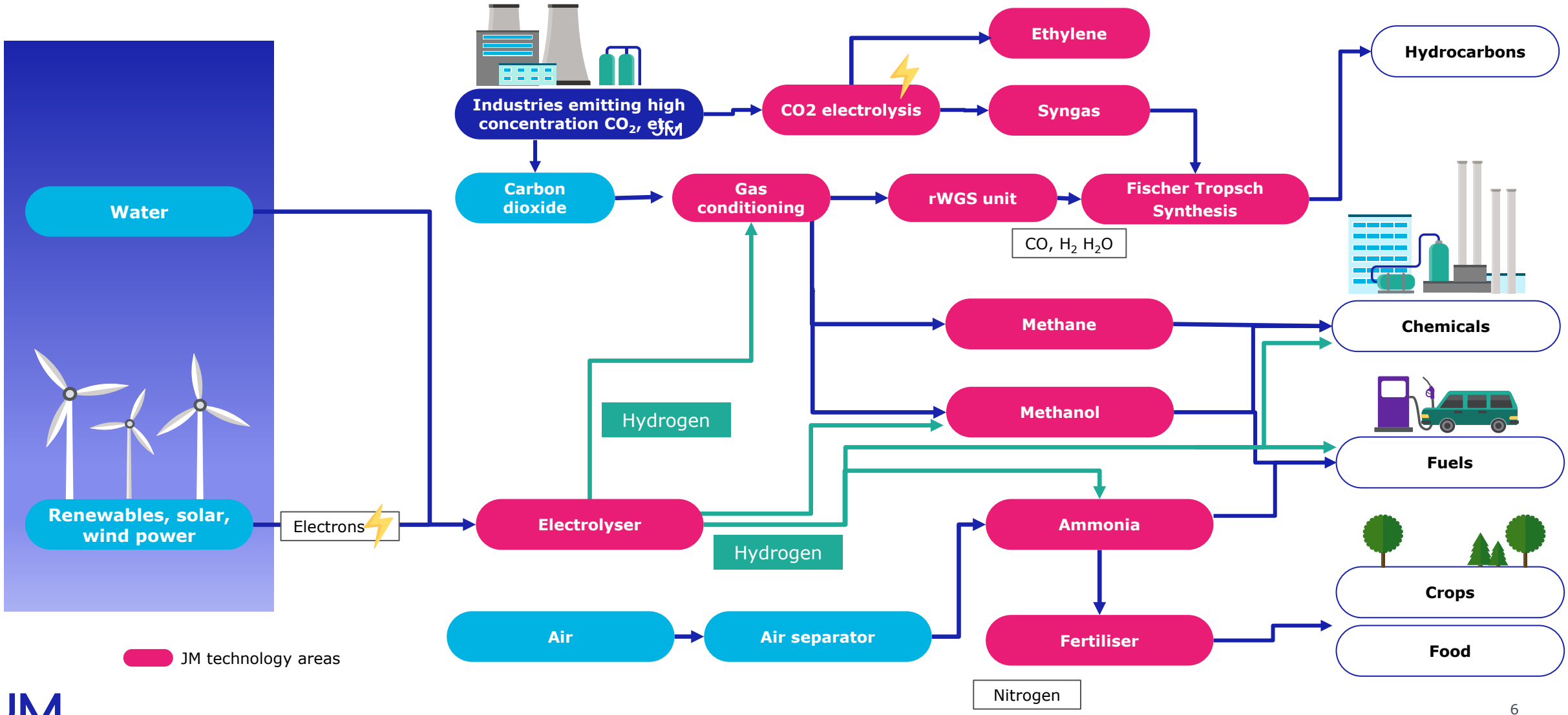
Sustainable methanol and ammonia technology

CCS-enabled (blue) hydrogen technology

Components for electrolysers to make electrolytic (green) hydrogen

Turning green hydrogen into chemical building blocks: a vision

Upgrading renewable feedstocks into the sustainable fuels and chemicals of the future

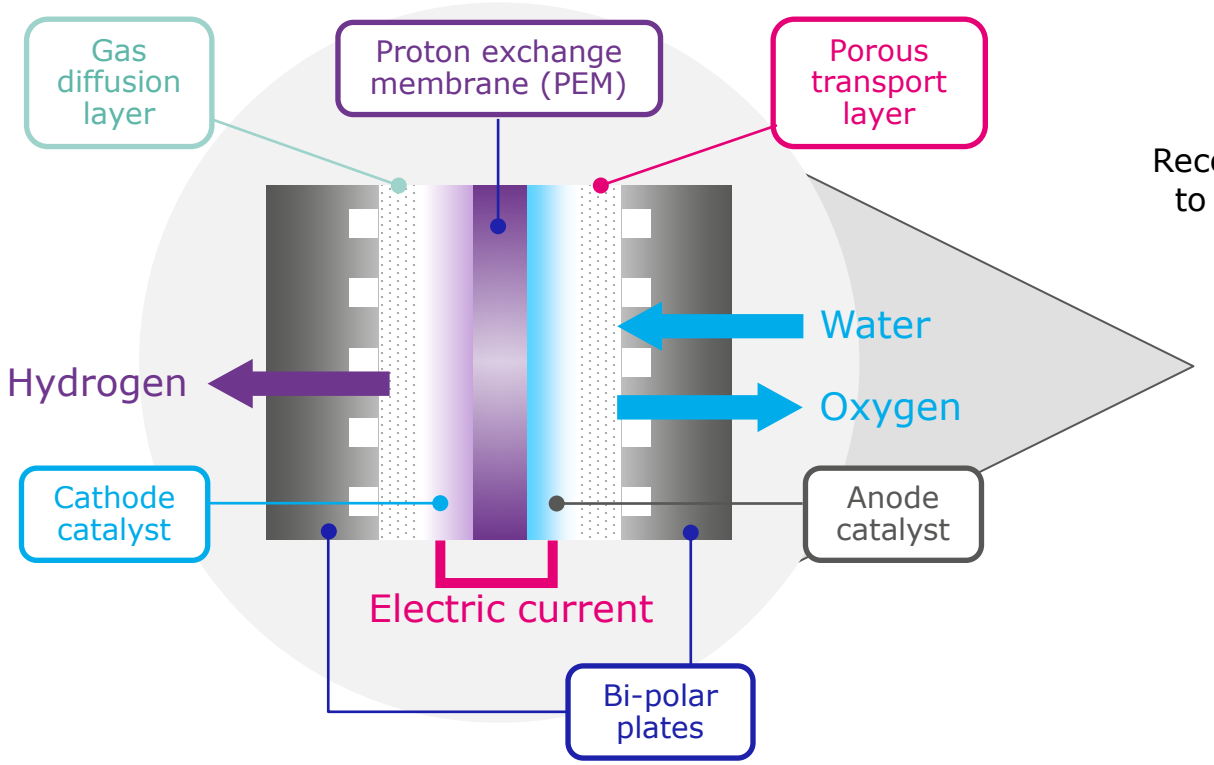


Note: rWGS – reverse water-gas shift reaction

Electrolysis – CCM overview

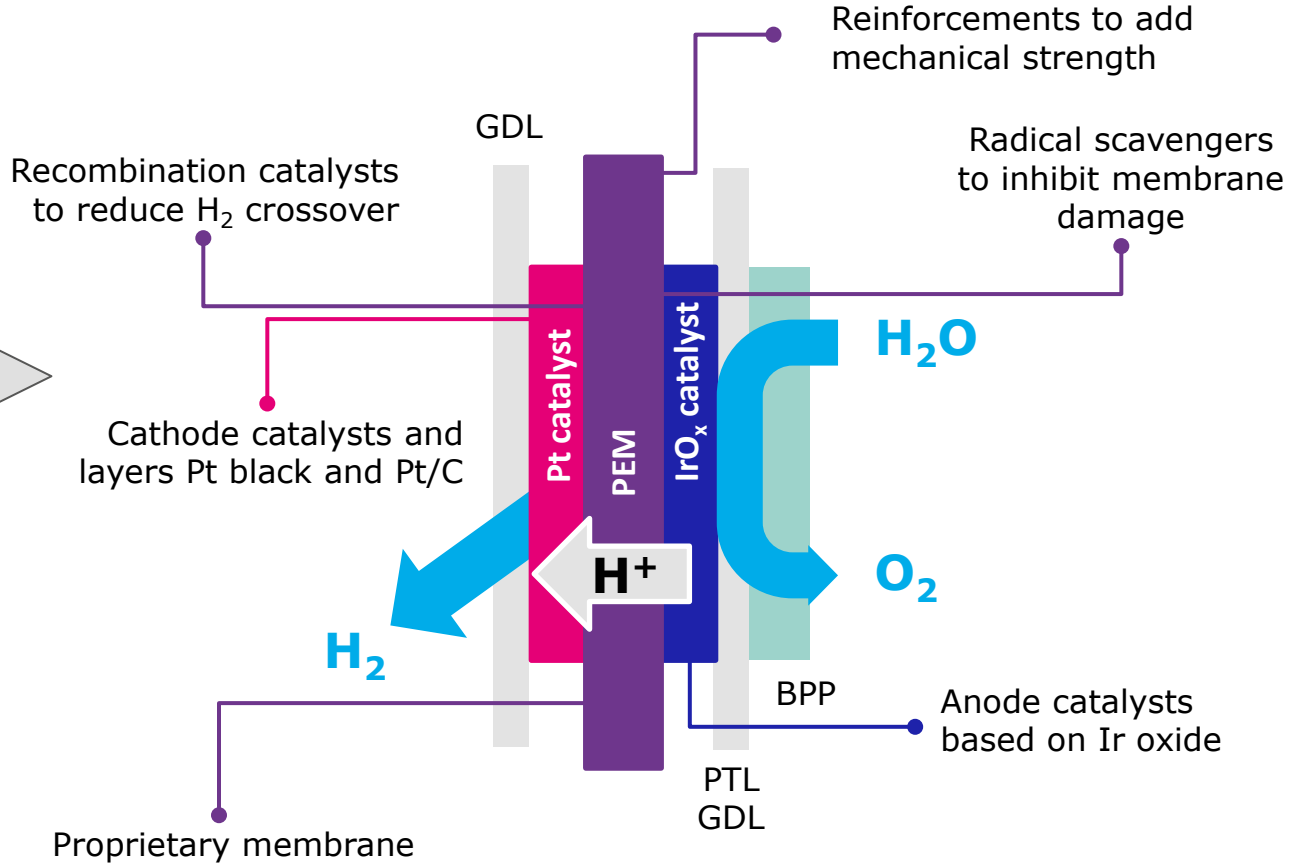
Catalyst coated membranes are key to electrolytic hydrogen production

Electrolysers convert water into hydrogen and oxygen



Electrolysis example

JM optimises technical levers to meet customer specification



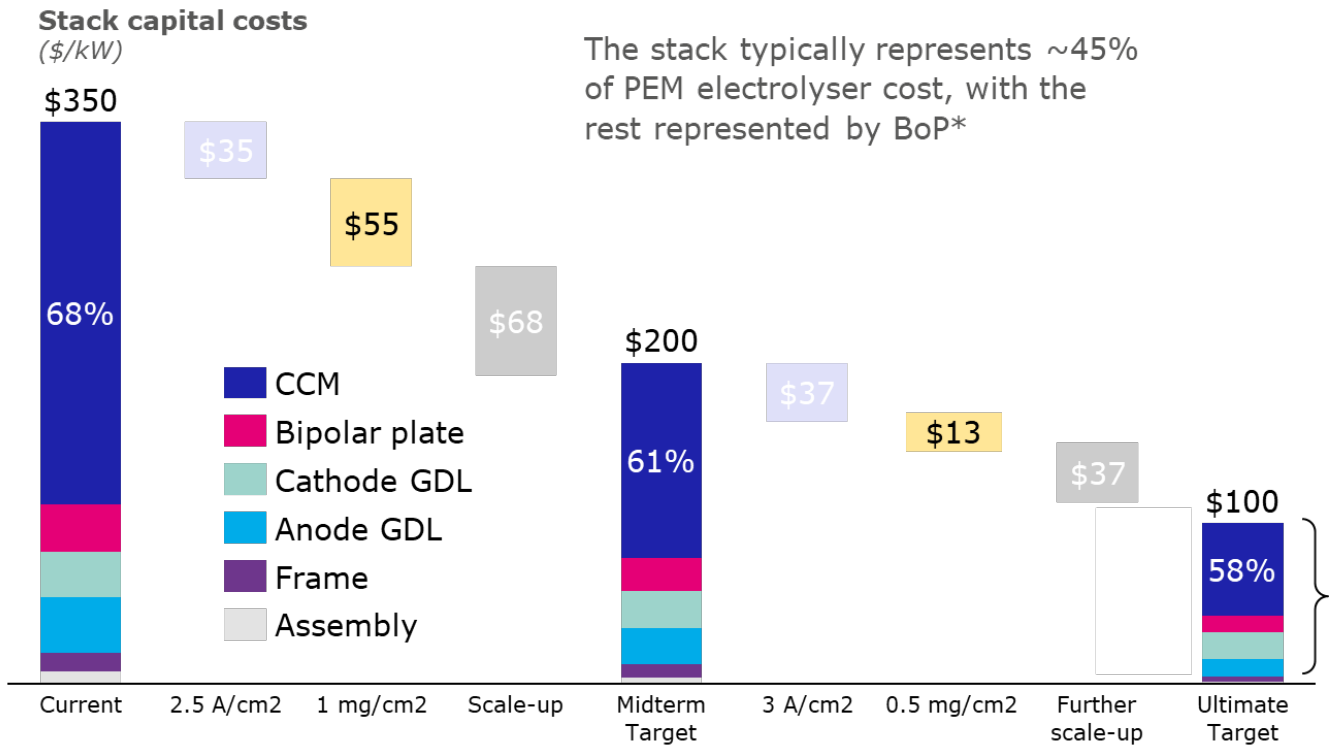
+ layer formation and adhesion must be optimised

Note: ePTFE – expanded polytetrafluoroethylene.

Green hydrogen PEM electrolyser goals

Innovation key to drive down cost and address recyclability of key materials

H_2New/US DoE targets



Efficiency and durability

- Lower power consumption
- Increased H_2 production
- Systems with long lifetime

Cost reduction

- Economies of scale
- Increased automation
- Improved component availability

Thrifting and Recyclability

- Transitioning to net-zero without depleting resources, using less to achieve more
- Supporting iridium optimisation (e.g. recycling compared to primary metal)

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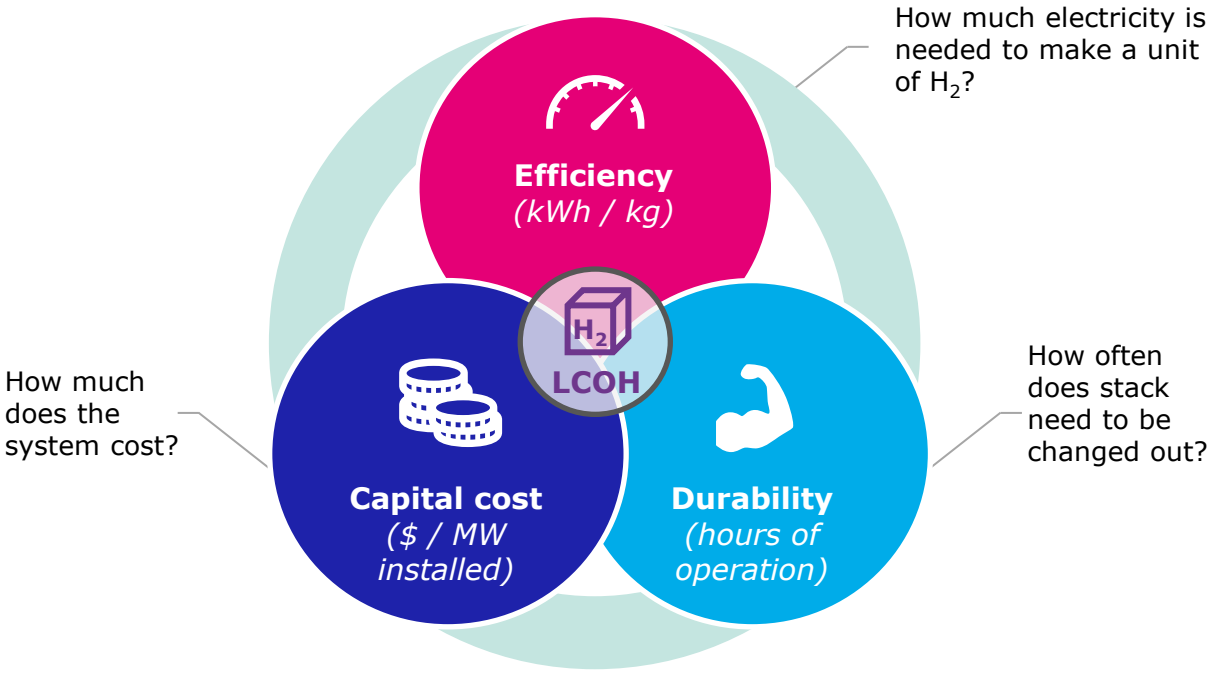
Graph source: *H2NEW: Hydrogen (H2) from Next-generation Electrolyzers of Water Overview*, 2021
*IRENA Green Hydrogen Cost Reduction 2020 – 55% of PEM electrolyser cost is BoP

Optimisation of CCMs key to achieving electrolyser goals

CCM design – like overall systems – has to balance multiple goals depending on application

Reducing the Levelised Cost of Hydrogen is a priority for system manufacturers and end users…



…and **ensuring availability of key materials** and **designing for recycling** is of fundamental strategic importance!

Multiple trade-offs must be managed as PEM technology develops to meet market needs

- Thinner membranes are more efficient but this can affect durability

- Thicker membrane or higher catalyst loading can increase lifetime, but increase cost

- Can reduce capital cost with low-cost components, but likely to compromise efficiency

…and **significant expertise** is needed to optimise these trade-offs

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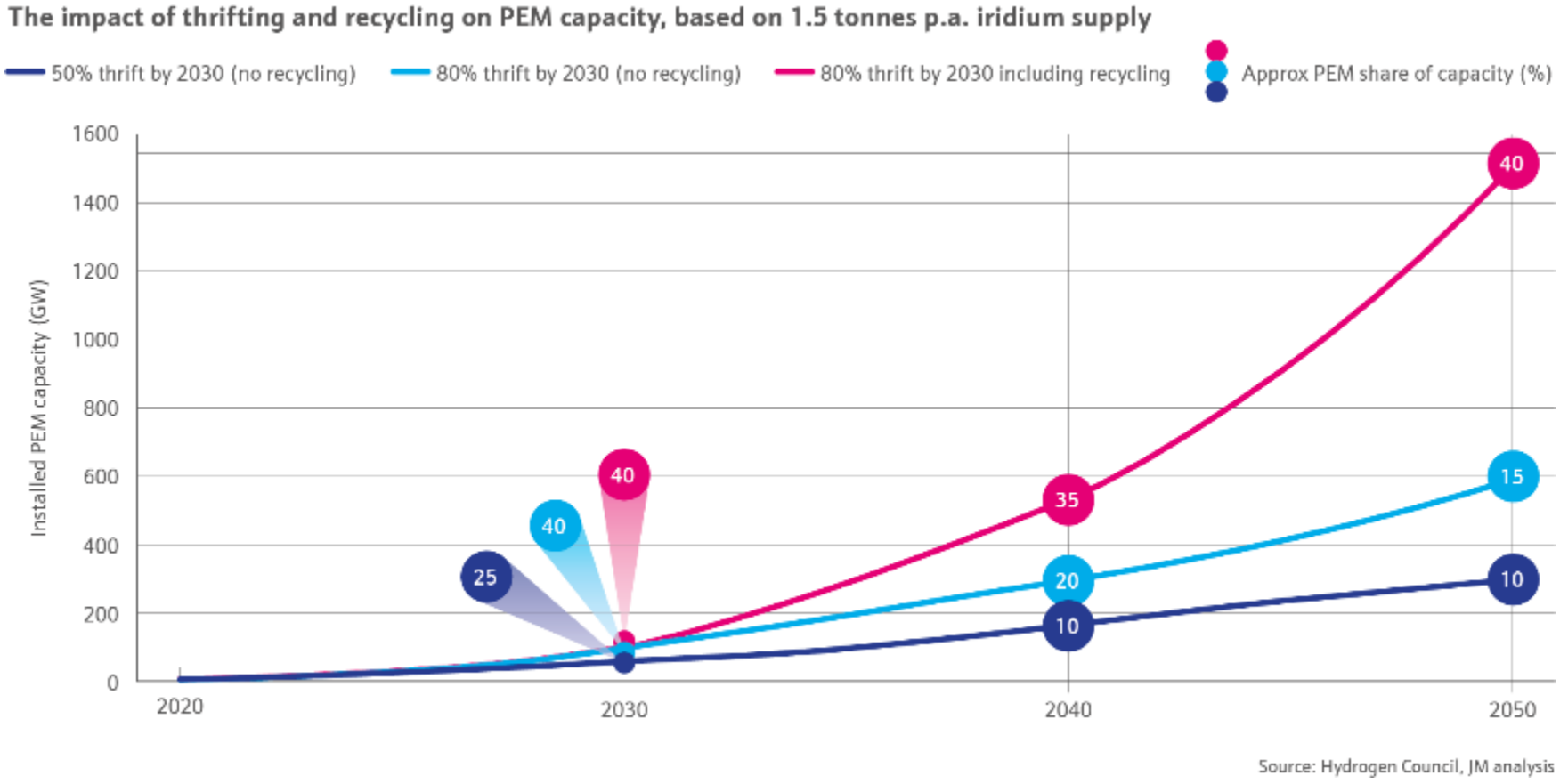
Impact of thrifting and recycling

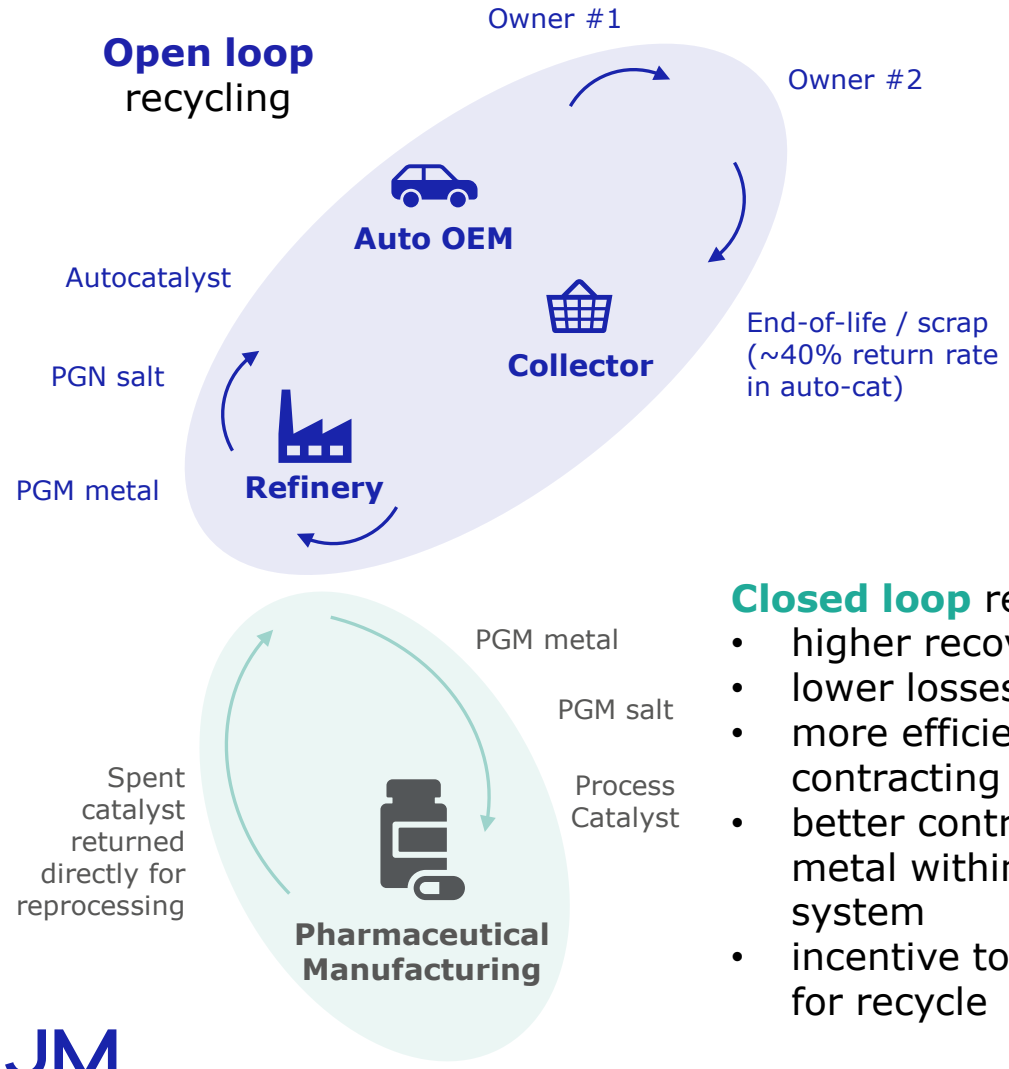
In an Iridium-constrained world, thrifting and circularity are critical enablers



- **Reducing Iridium per GW by 80% by 2030 will allow PEM to take ~40%** of the electrolysis market in 2030 (compared to a ~25% share if loadings were only reduced by 50%)
- In the longer term, **PEM potential** will be **limited** if entirely **dependent on primary metal**
- **Recycled iridium** will have a **lower carbon footprint** than primary PGMs
- **Not recycling would create an issue** similar to that seen in photovoltaics, where systems reach end-of-life contain a significant quantity of precious metal which is difficult to recycle and extract value from

JM enables open and closed loop recycling

Effective management of PGMs will be key in the success of PEM electrolysis



Closed loop recycling

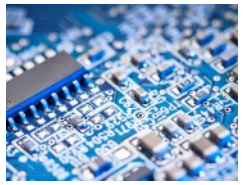
- higher recovery rates
- lower losses
- more efficient contracting
- better control of metal within the system
- incentive to design for recycle

Today JM enables circularity in a broad range of industries

Open loop PGM recycling


Automotive catalyst


Chemical & Industrial


Electronics

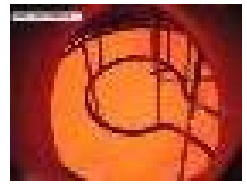

Jewellery & Dental

Closed loop PGM recycling


Petro-chemical


Pharmaceutical


Glass & Medical


Nitric Acid

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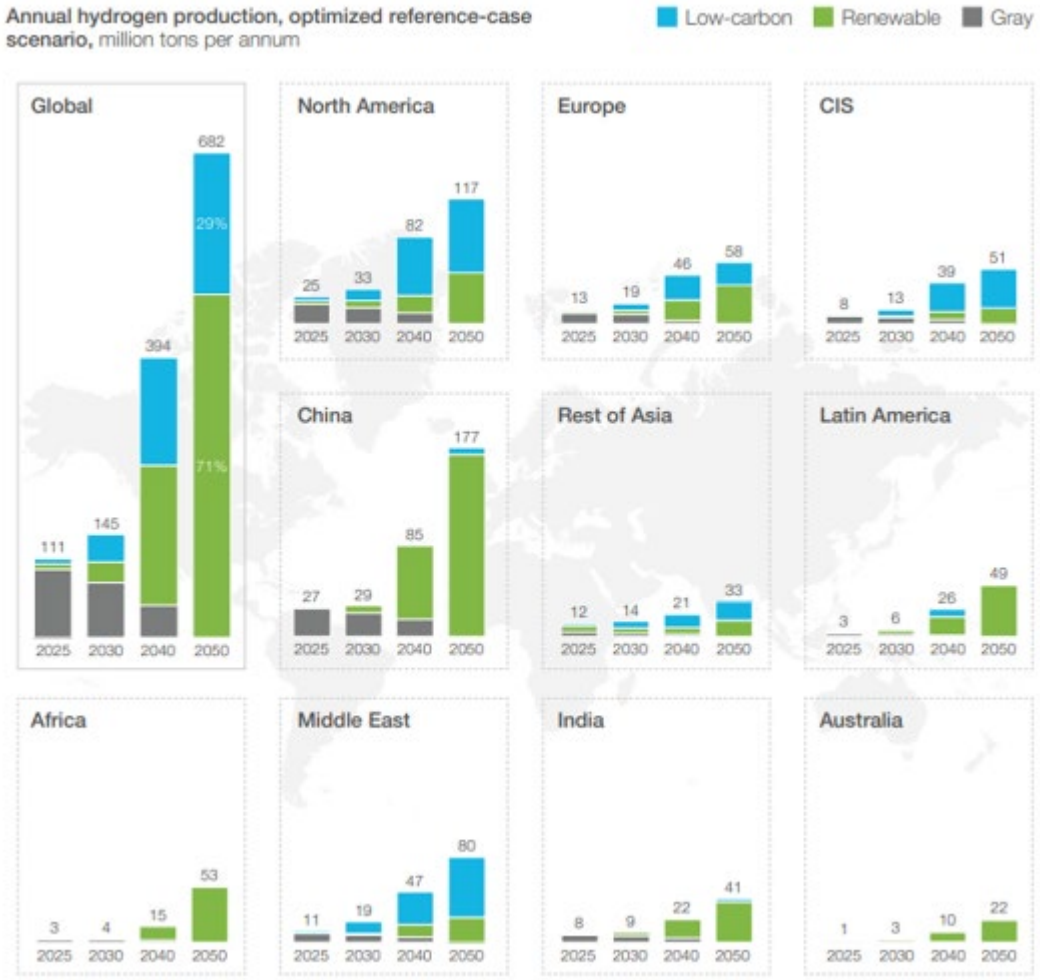
70% of hydrogen is expected to come from renewables by 2050

To achieve the forecasted growth - supply chains partnerships are critical



Gray hydrogen	Grey share declines with future carbon tax
Low-carbon	CCS (blue) adoption driven by geology (carbon storage locations), infrastructure (pipelines) and high cost of alternative routes to low carbon hydrogen
Renewable	Renewable (green) adoption driven by geography, declining cost of renewable energy and incentives

Figure taken from Hydrogen Council – Global Hydrogen Flows Report – October 2022

Building strong collaborative partnerships for success

Fuel Cell Funded Programmes

Since 2005

- Participated in **46** programmes
- Invested **>£35 million**
- Secured **~£17 million** in funding
- Supported by **>20 academic institutions**
- Collaborated with **>100 partners**
- Best **innovation** & **success stories** 2019/20

Recent Partners

BMW, sgl carbon, DANA, IVECO, BOSCH Invented for life, Technische Universität München, elringklinger, 3M

Recent Success Stories

VOLUMETRIQ[1]
Stack volumetric power density[2] of 5.4 kW/L

GAIA[1]
20% increase in power density to 1.8W/cm^2 at 0.6V

Announced Customer Partnerships

Fuel Cells

EKPO FUEL CELL TECHNOLOGIES
REFIRE
DOOSAN
plug

Green hydrogen

Enapter
plug
HOELLER THE STACK COMPANY
hystar

JM

[1] Passenger car focused fuel cell programmes. [2] Stack volumetric power density including end plate. 6.6 kW/L was achieved on the cell block.

PGM based raw materials

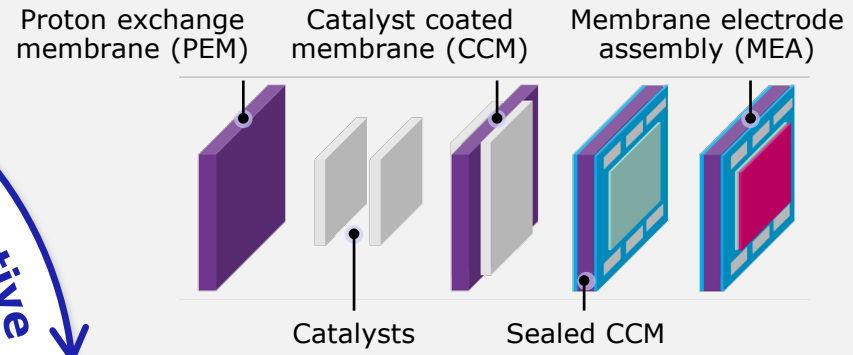
#1 global refined PGM supplier and secondary recycler

PGM recycling – closed loop objective

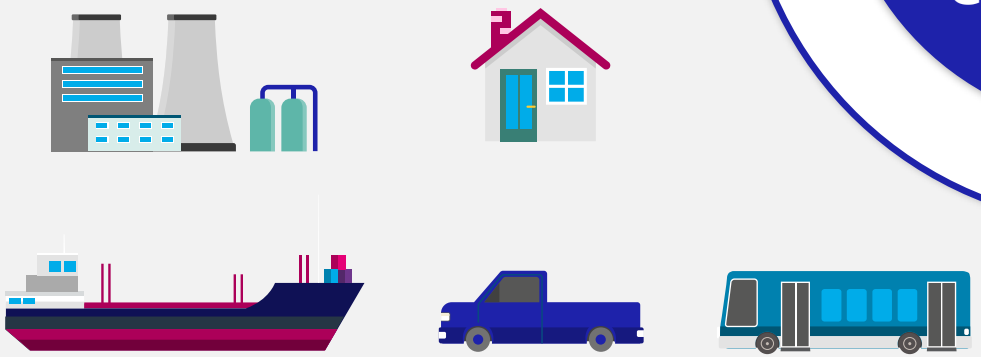
JM and Plug partnership accelerates deployment of fuel cells and electrolysers

Components

CCMs drive performance in the fuel cell and electrolyser

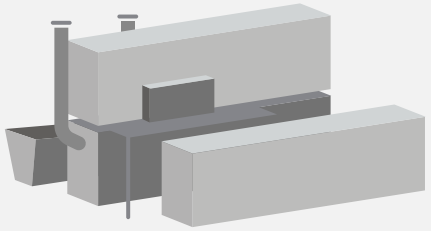


Applications



Stack assembly

to make fuel cells and electrolysers



Electrolyser

Stack

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www.matthey.com/hydrogen