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Johnson Matthey
Inspiring science, enhancing life

PGM Circularity in Hydrogen Technologies

Ross Gordon, 26 MAY 2022

DOE Manufacturing Automation and Recycling for Clean Hydrogen Technologies

Agenda

01	Introduction
02	Hydrogen Technologies
03	PGM Services
04	PGM Circularity in Hydrogen Technologies

01 JM Overview

Strong Credentials

Strong brand
200+ year history

Technology leadership
#1 or 2
in chosen markets

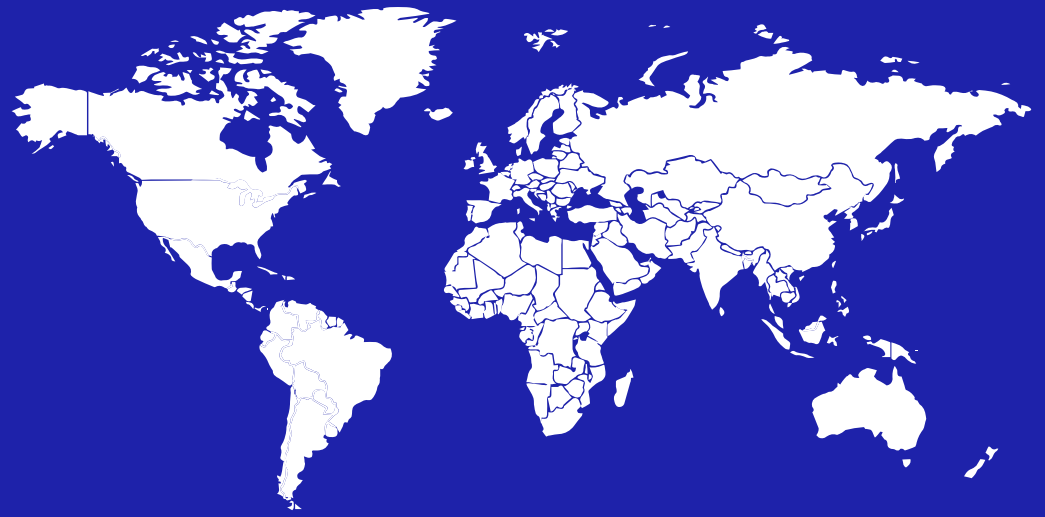
Annual sales*
£3.9 billion

Operating profit
£504 million

R&D investment
£194 million
per annum

*Sales excluding precious metals

A global footprint



14,580
employees worldwide

North America

11 major manufacturing facilities
27% of Group sales*
19% of employees

Europe

15 major manufacturing facilities
41% of Group sales*
59% of employees

Rest of World

4 major manufacturing facilities7
7% of Group sales*
5% of employees

China

6 major manufacturing facilities
13% of Group sales*
8% of employees

Rest of Asia

4 major manufacturing facilities
12% of Group sales*
9% of employees

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*Sales excluding precious metals

Making the world cleaner and healthier

1 in 3

new cars caries one of our emission control catalysts

2.5 million tonnes

of harmful air pollutants removed by catalysts

211,000 tonnes

CO_2 equivalent avoided by our battery materials and fuel cell technology

£804 million

sales of products designed for in-use resource efficiency

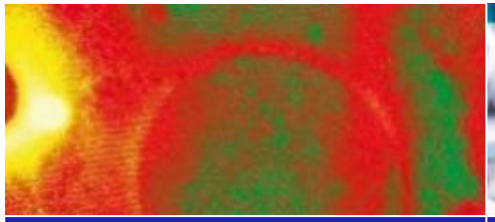
84.7% of sales align to UN Sustainability Development Goals

JM

Note: Performance in 2020/21

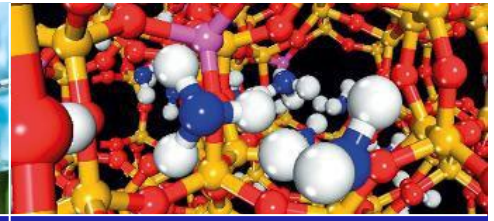
World class science and technology expertise

Our core capabilities

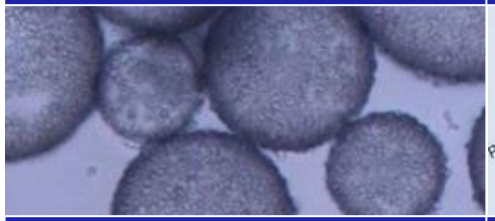


Characterisation and modelling

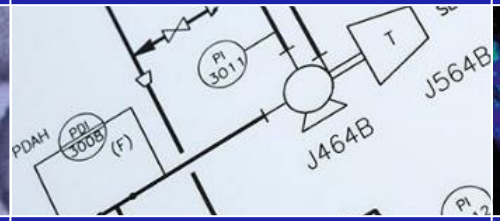
Chemical synthesis



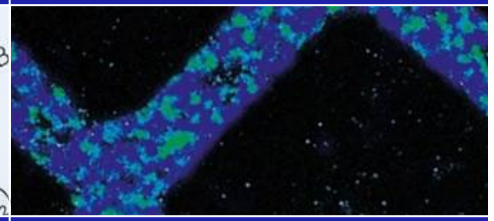
Material design and engineering



Product formulation



Process optimisation



Surface chemistry and coatings

PGM chemistry and metallurgy

Catalysis and advanced materials

Electrochemistry

Delivering value

Customised solutions

New and next generation products

Scale up of complex manufacturing

02 JM Hydrogen Technologies

JM’s technologies for the hydrogen economy

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**

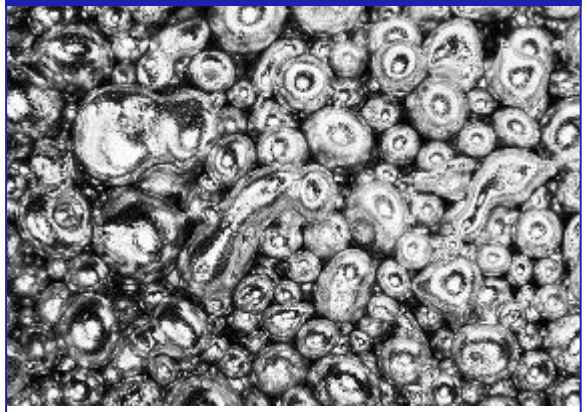
JM is well positioned for hydrogen technologies

Science

Catalyst and membrane expertise

Optimisation for high performance

PGM expertise



Ability to reduce PGM costs

Secondary refiner: Potential closed loop offering

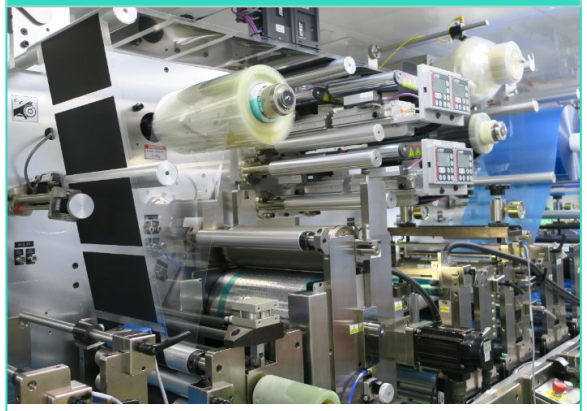
Trusted partner in fuel cells

Proven commercial product

Existing customers

Over 20 years' experience

Experienced in CCM manufacturing



Reduction in manufacturing cost

Efficient processes

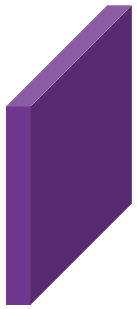
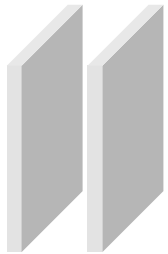
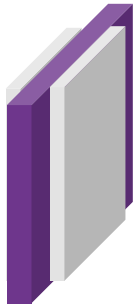
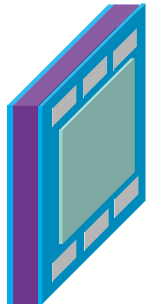
Leverage knowledge for electrolyser CCMs

Proton exchange membrane (PEM) offer

JM experience in electrochemical value chain is comprehensive

precious metal recycling

Raw Materials → Components → Stack assembly and systems integration → Application

Proton exchange membrane (PEM)	Catalysts	Catalyst coated membrane (CCM)	Sealed CCM	Membrane electrode assembly (MEA)
membrane and associated supports	anode and cathode catalyst layers	"3-layer system"	"5-layer system"	"7-layer system"
				
ionomer ePTFE	carbon metal ionomer	membrane anode catalyst cathode catalyst	CCM seals	sealed CCM gas diffusion layer

Recent proof points in public domain

Announced that 170 heavy duty FCEVs have hit China's roads during the past 6 months powered by JM and REFIRE fuel cell technology. Over the coming months this number is expected to reach **280 vehicles**.

JM joins new European consortium to develop advanced fuel cell technology for heavy duty trucks. Aims to develop higher performance fuel cell components for heavy duty trucks with a predicted lifetime of at least **30,000 hours**.

JM, as part of leading European consortium GAIA, has helped deliver a fuel cell power density of **1.8 W/cm² @ 0.6V**. This represents a twenty per cent increase versus state-of-the-art technology.

JM and Plug Power Inc. sign MoU to develop a roadmap to accelerate the joint development of high-performance **electrolyser technology** with improved durability, increased performance, and greater energy efficiency than systems available today.

JM joins UN development agency, International Hydrogen Energy Centre (IHEC), to help **support the successful transition to the hydrogen economy**.

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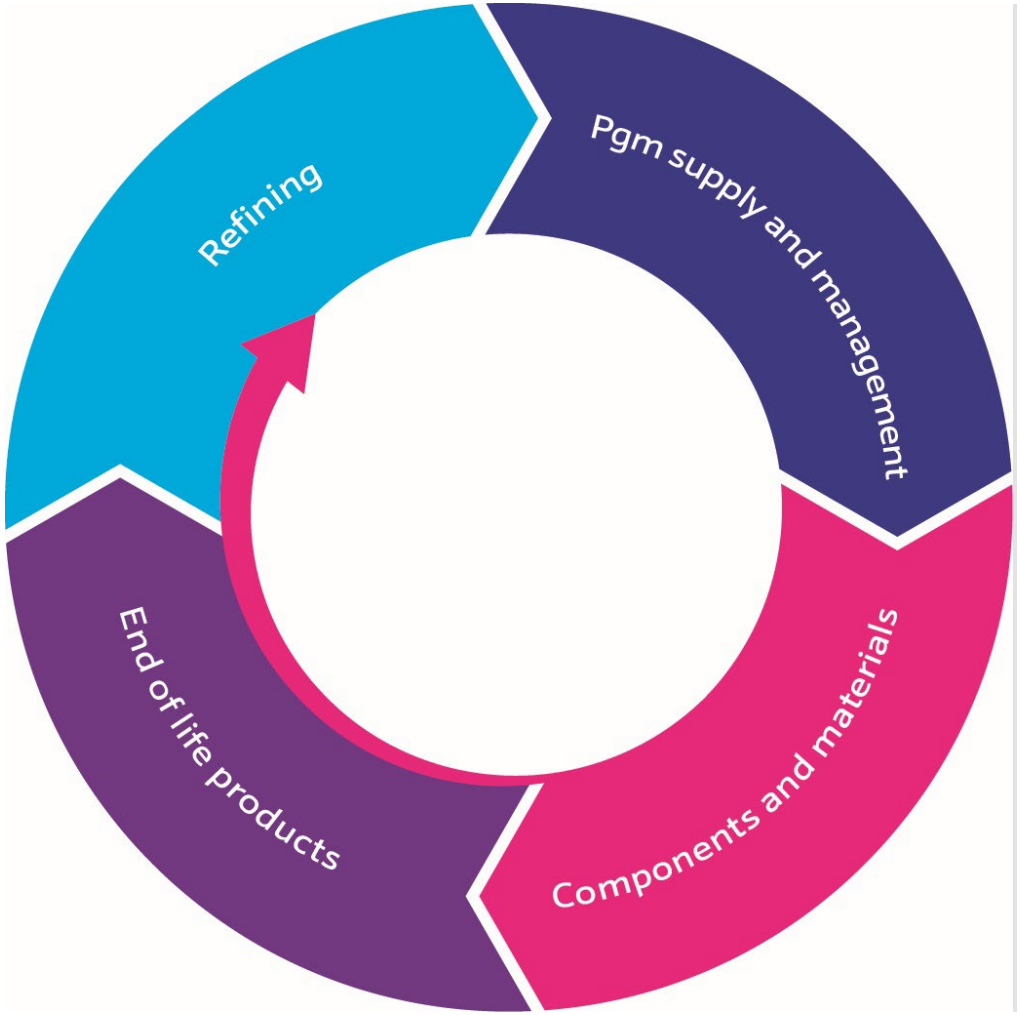
03 PGM Services

Refining and Recycling

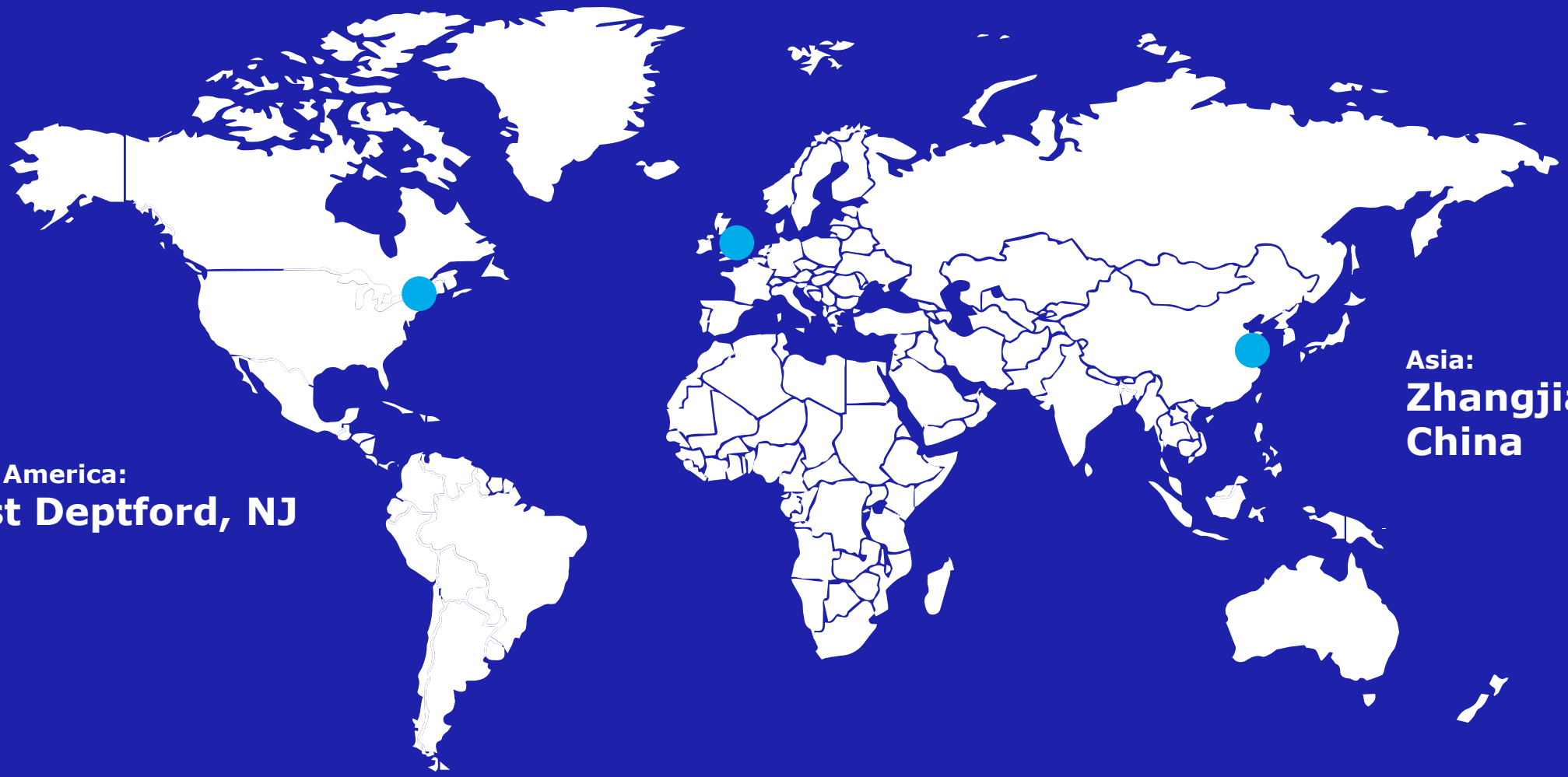
As the largest secondary PGM refiner in the world, we make the most efficient use of these critical materials, conserving and recycling them to enable their circular use. We work with our customers to offer:

- Highly advanced processes for extracting and separating PGMs from complex products, with a purity of up to 99.95%.
- A seven metal separation, helping to recover platinum, palladium, rhodium, iridium, ruthenium, gold and silver.
- Recovery of PGMs from spent catalysts and alloys from manufacturing processes.
- Refining of primary PGMs from mining operations and refineries.
- A full refining supply cycle with metal management options and ongoing technical support.



Our refining sites

Europe:
Royston, UK
Brimsdown, UK



North America:
West Deptford, NJ

Asia:
Zhangjiagang, China

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The refining process

Evaluation

- Critical stage
- PGM content determined
- Refining lead-time agreed
- Material uniquely barcoded

Smelting

- Material combined
- Pyrometallurgical process
- Non-PGM removed
- Two bullion feeds produced

Chemical leaching

- Bullion leached
- Further concentration
- Gold separated
- Silver extracted

Chemical separation

- Highly complex process
- PGMs separated out
- Pure PGM salts produced
- Upgraded to pure PGM sponge

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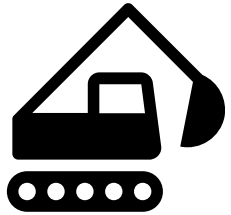
JM PGM refining process: https://youtu.be/Ix9xfF3QgRw

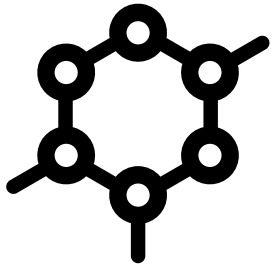
04 PGM Circularity in Hydrogen Technologies

Key factors for the effective utilisation of PGM in HT

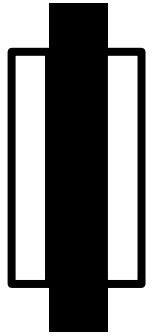
Increasing metal utilisation is key to success



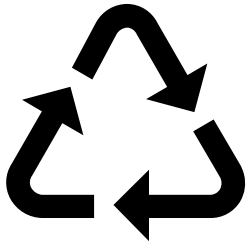
Understanding the supply of PGM



Catalyst innovation to reduce the amount required



Optimisation of the rest of the CCM and stack



Efficient recycling processes

Spent PGM returned from the field needs to be reprocessed efficiently and re-used at lower levels.

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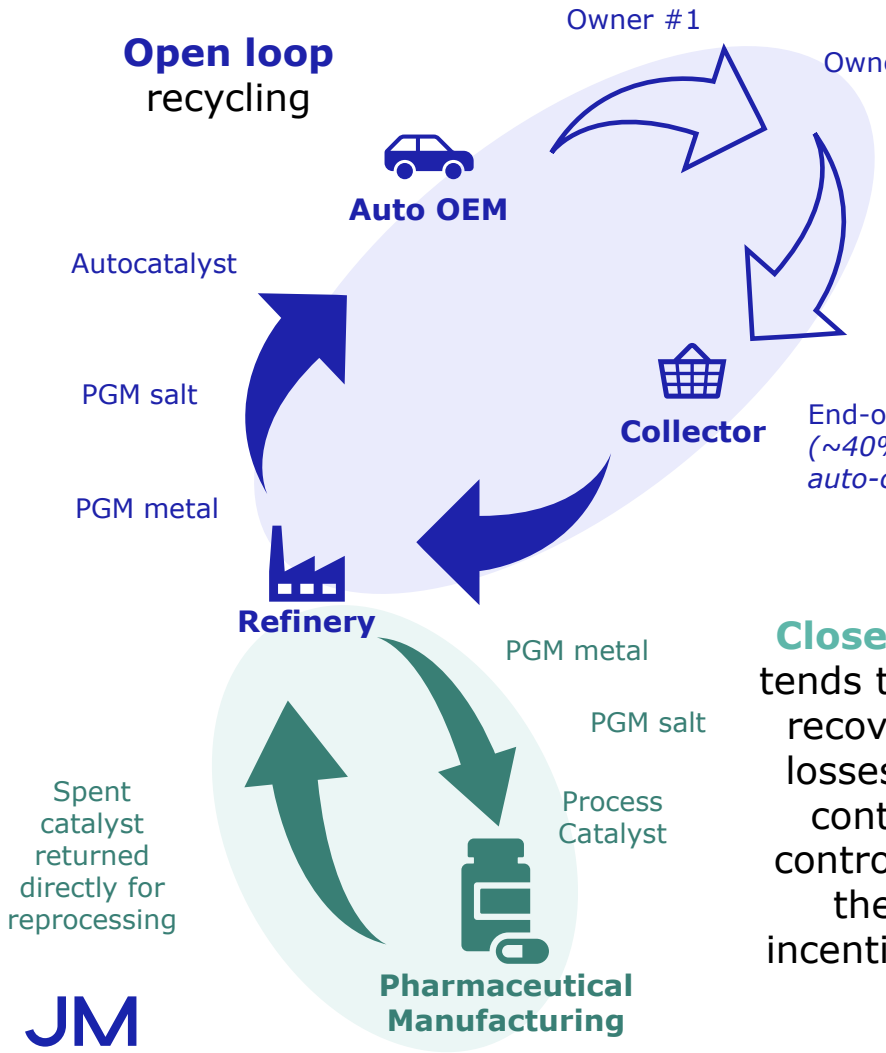
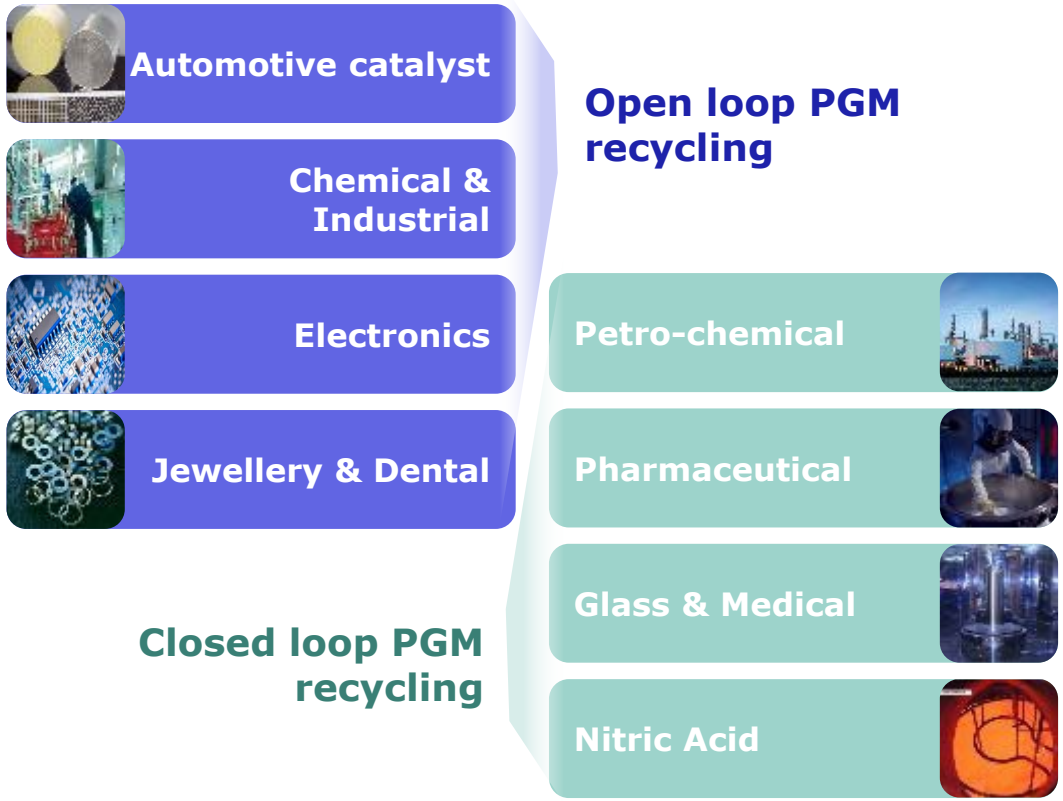
JM enabling open and closed loop recycling

Effective management of PGM will be key in the success of Hydrogen Technologies



Closed loop recycling tends to result in higher recovery rates, lower losses, more efficient contracting, better control of metal within the system, and incentive to design-for-recycle

Today JM enables circularity in a broad range of industries



A net zero world requires circularity of scarce critical materials

Enabling circularity

World leader in recycling of scarce pgms

Twice the size of next largest player

Deep metals expertise

Supply of scarce critical materials for pgm based technologies, e.g. fuel cells

Growth driven by the needs of tomorrow

Expertise in designing new materials

Design to recycle solutions

Applying expertise to new materials

Examples:

- Fuel cells recycling
- Lithium, nickel and cobalt for battery materials recycling

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The Design to Recycle Challenge

Value chain integration: as we thrift our critical materials and achieve more with less, can we still recycle them?

Restore and refurbish: can we avoid having to break things back to their elements before re-using – direct recycle?

Materials selection: alternatives that are easier to handle and less hazardous both in production and recycling processes

Sustainable processes: minimise hazardous waste streams and repurpose them where possible

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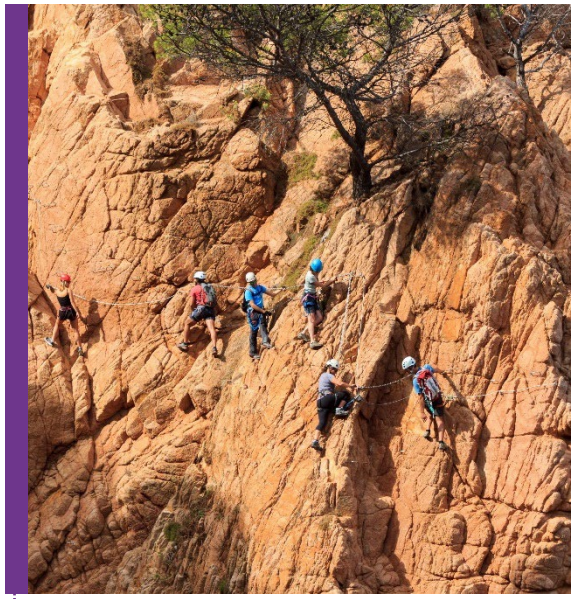
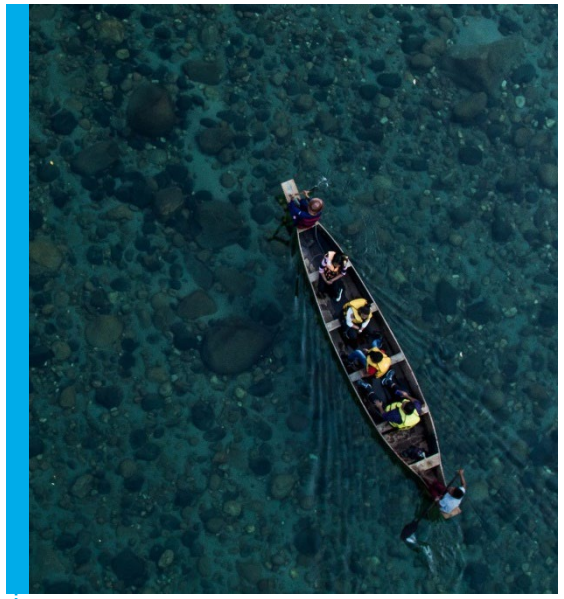
We work in collaboration

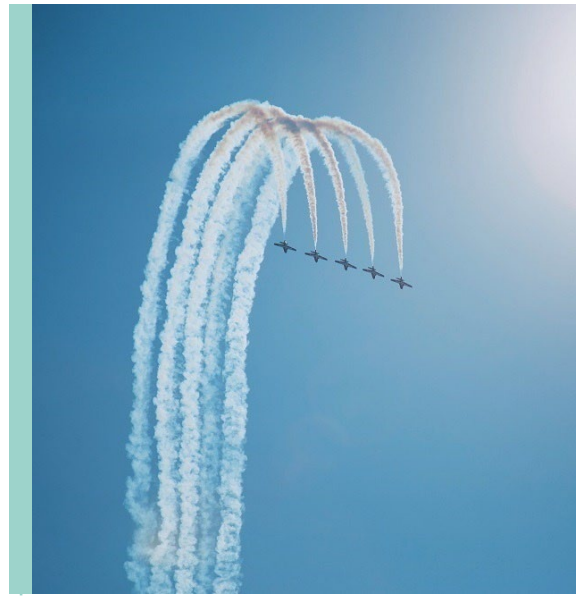
Long term relationships



Risk sharing



Understanding our customers' needs



Collaboration

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